



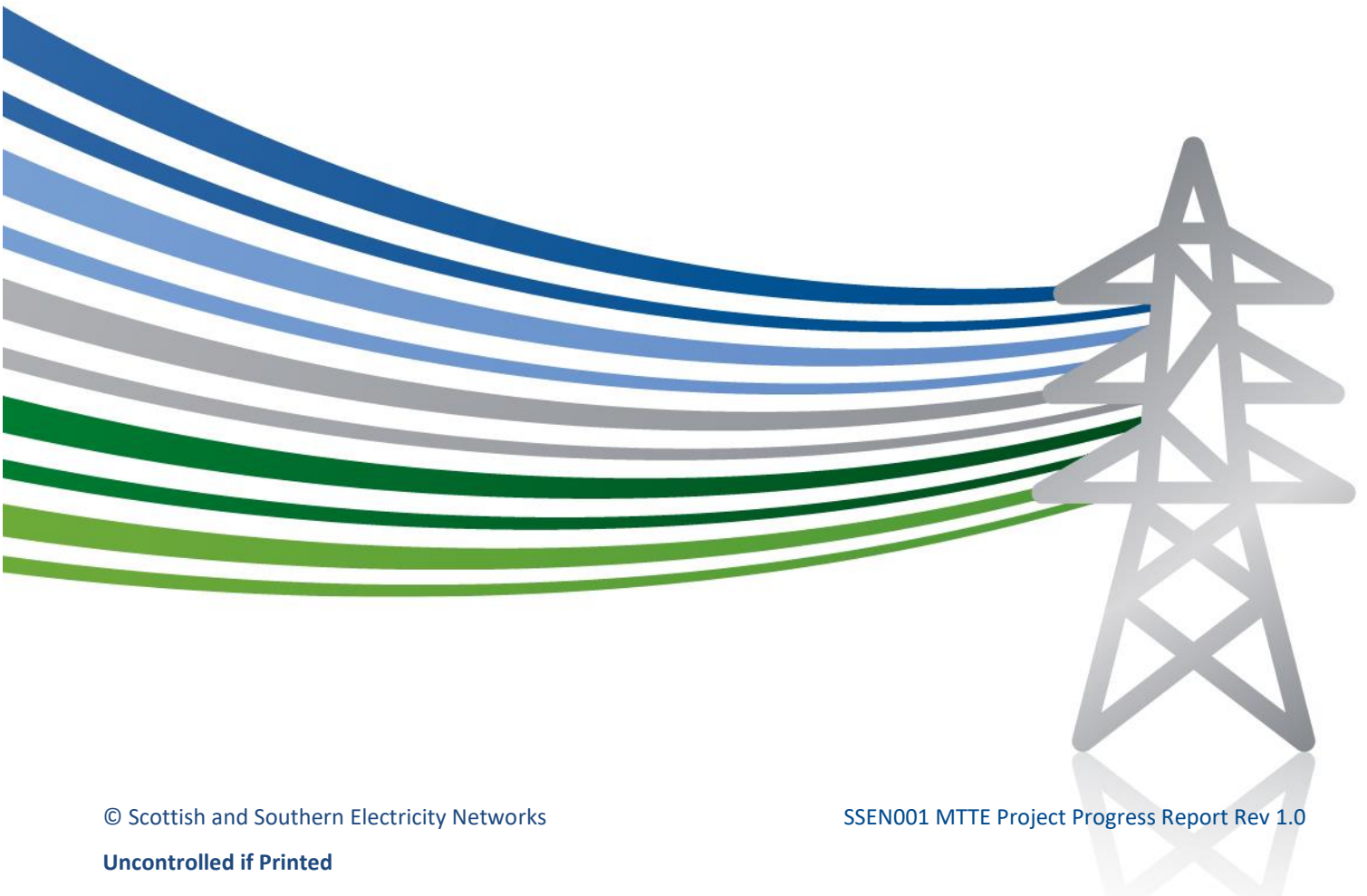
Scottish & Southern
Electricity Networks

SHE Transmission

Multi-Terminal Test Environment for HVDC Systems (SSEN001)

Project Progress Report (for reporting period June 2020 to May 2021)

June 2021



1) Executive Summary

Overview of MTTE

The Multi-Terminal Test Environment for HVDC (MTTE) Project, established 'The National HVDC Centre', which formally opened on 26 April 2017.

The National HVDC Centre is Great Britain's (GB's) simulation and training facility for HVDC; supporting the integration and successful operation of all HVDC schemes connecting to the GB Network.

The Centre is also the National hub for HVDC knowledge exchange, expertise and innovation.

The Centre uses state-of-the-art simulators to model and resolve potential issues in real-time before they impact on the delivery (or operation) of HVDC projects, to ensure the integrity and security of the GB Network.

Success of the HVDC Centre

The Centre has developed into a critical component of Great Britain's (GB's) electricity infrastructure, enabling the delivery and integration of HVDC schemes onto the GB network.

On 3 July 2020, Ofgem published its determination on the future of The National HVDC Centre, based on the future business plan that the Centre submitted.

Ofgem's determination can be found here:

www.ofgem.gov.uk/publications-and-updates/decision-future-operation-hvdc-centre-following-end-nic-funding-period

This determination provides certainty and direction for the Centre's activities across the RIIO-T2 period and an endorsement from Ofgem of the importance of these activities in supporting GB's net zero targets.

The HVDC Centre has become a world-leading Centre of HVDC expertise and is providing critical support to projects in GB and the security of the GB network; directly benefiting GB's electricity consumers.

Successful Delivery Reward Criteria (SDRCs)

All nine of the Project SDRCs have been successfully completed.

During this period, the project successfully completed SDRC 9.9, securing the next set of Replicas, for which the evidence was submitted to Ofgem on 31 March 2021.

2) Project Manager's Report

This is the last Annual Progress Report for the MTTE project.

It has been a successful year of the Centre, meeting all of the project SDRCs, delivering a number of high profile projects, and securing the future of the Centre through Ofgem's determination. Though Covid-19 has impacted on our suppliers delaying a number of our activities.

Future Business Model

On 7 February 2020, the Centre submitted its 'Future Business Model' to Ofgem, which describes the HVDC Centre's plans for 2021-2026 (aligning with the RIIO-T2 period) to provide critical support to HVDC projects in GB and support the security of the GB network:

www.ofgem.gov.uk/system/files/docs/2020/07/hvdc_centre_future_business_model_public.pdf

On 3 July 2020, following a consultation process, Ofgem published its determination, which approved the continued ownership and operation of the facility during RIIO-T2:

www.ofgem.gov.uk/system/files/docs/2020/07/hvdc_facility_decision_for_continued_ownership_0.pdf

Project Delivery

This section highlights the technical projects that the Centre has delivered.

NSL Protection Study (Phase 1)

Commissioned by Scottish Power Transmission (SPT) and National Grid Electricity Transmission (NGET), this project tested the coordination of protection for the connection of the North Sea Link (NSL).

NSL is a new HVDC interconnector connecting Blyth in the north east of England, to Kvitlidal in Norway. To be confident that the AC protection operates correctly, the HVDC Centre tested the AC protection relays (using the actual protection hardware) in a Real-Time (Hardware-in-the-Loop) simulation environment.

Moyle Support

The National HVDC Centre has agreed to host the replicas of the control and protection system of the Moyle HVDC Interconnector (refurbishment project) from 2022 onwards.

Integrated Offshore Design

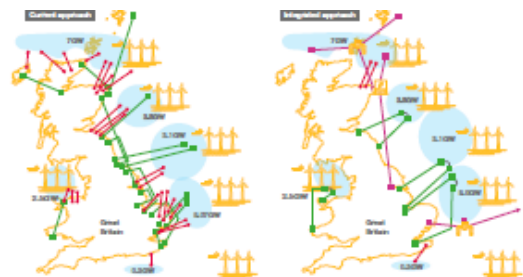
Commissioned by the Offshore Wind Industry Council (OWIC), the Centre has developed and delivered a report on the design of integrated offshore connections.

Building on established technologies, the Centre developed a toolkit of flexible integrated solutions for the connection of offshore wind, at the scales required within the future offshore development zones.

Offshore Coordination (Phase 1)

The Centre (in a consortium with DNV-GL and EPNC) supported the National Grid Electricity System Operators' (ESOs') Offshore Co-ordination project; for which the Centre led the technical and conceptual network designs. This culminated with our delivery of the 'Holistic Approach to Offshore Transmission Planning' report together with the DNV-GL led CBA report on 30 September 2020.

The Centre also supported the ESO across a range of stakeholder engagement workshops.



www.nationalgrideso.com/future-energy/projects/offshore-coordination-project

2) Project Manager's Report

Offshore Coordination (Phase 2)

The ESO has engaged the Centre to deliver three activities as part of the 2nd phase of the offshore coordination project:

- Early Opportunities: Analysing what can be delivered within existing arrangements;
- Offshore design tool review: Reviewing a University developed tool to enable fast initial options evaluation; and
- Technical Advisor: Providing technical project support & review.

Distributed ReStart (NIC)

The Centre is supporting Scottish Power Energy Networks, TNEI and National Grid ESO with the Distributed ReStart project; which involves the construction of a real time model of the distribution system being restored and the associated resources available to Black Start, allowing work already underway within the project to be complemented by the more detailed view of resource control and protection that our real time environment provides; this allows traditional and non-traditional sources of Black Start resource performance to be compared.

www.spenergynetworks.co.uk/pages/distributed_restart.aspx

HVDC Phasor Based Monitoring (NIA)

The National HVDC Centre is working with SHE Transmission and GE Intelligent Systems, to investigate the potential to use a variety of PMUs (and other devices) to inform wide area control as key metrics of local system strength change within the onshore transmission system.

The National HVDC Centre has undertaken comparative evaluations of devices, with these and a new Phasor Controller platform being used for detailed RTDS-HiL evaluation of the proposed system and device responses to it.

www.smarternetworks.org/project/nia_shet_0029

Eastern HVDC Support

Commissioned by the SPT, NGET and SHE Transmission, the Centre is providing ongoing technical expertise and support to the Eastern HVDC project teams.

Caithness-Moray Operational Support

The Centre continues to provide operational support for the Caithness-Moray HVDC scheme.

Shetland Multi-Terminal Extension

Commissioned by SHE Transmission, the Centre is providing technical support for the multi-terminal extension of the Caithness-Moray HVDC Scheme to Shetland.

The multi-terminal extension of the Caithness-Moray link to Shetland will require testing against the detailed model of the Shetland network (and utilising the Shetland Replica controls that the Centre hosts) to avoid adverse effects on the AC and DC networks.

SCADA Installation

SSEN Transmission's real-time systems team, are in the process of installing GE PowerOn (SCADA system) at the Centre (which interfaces with the Caithness, Moray and Shetland Replicas).

HVDC R&D Strategy and Supply Chain Review (Coordinated Offshore)

BEIS and Ofgem requested that the Centre deliver two reports to inform the 2050 net zero targets:

- An HVDC R&D strategy to enable the delivery of a coordinated approach to offshore connections to meet 2050 net zero targets; and
- A technical report describing the components, and other technology, that will be required to deliver a coordinated approach to offshore connections to meet 2050 net zero targets, and an overview of the associated supply chains.

2) Project Manager's Report

Innovation Projects

PROMOTioN

On 21 September 2020, the PROMOTioN project (one of Europe's largest energy research projects) completed its final close out event. After 4.5 years, €43 million and with 34 organisations involved in collaborative research to advance the readiness of meshed DC grids.

The goal of the PROMOTioN project was to progress the use of meshed offshore HVDC grids for connecting offshore wind farms to onshore and interconnectors. The objective of WP9 (Work Package 9), led by The National HVDC Centre, was to demonstrate DC grid protection solutions developed in the project using hardware-in-the-loop testing on a real-time platform.

www.hvdccentre.com/our-projects/promotion-testing-the-feasibility-of-meshed-dc-grids-protection/

Protection Performance Overview and Validation in Low Strength Areas

This project is investigating the impact of the low short circuit levels on the performance of existing protection relays; to identify if generator, transformer and line protection will be impacted due to system changes and identify necessary mitigation measures.

The National HVDC Centre is collaborating with a team of experts from Manitoba Hydro International (MHI) to deliver this project.

www.hvdccentre.com/protection-overview/

Evaluation of HVDC with Synchronous Condenser impact on AC Protection

This project is developing representative detailed models to enable the comprehensive testing of the impact of HVDC system on AC protection performance.

www.hvdccentre.com/innovation/dc_with_ac_protection/

Adaptive Damping of Power Oscillations using HVDC

This project is designing adaptive POD controllers via HVDC links and/or FACTS devices using a novel measurement-driven approach to mitigate low frequency inter-area oscillations and local sub synchronous oscillations.

www.hvdccentre.com/pod_project/

Transmission Operator Tools for EMT Modelling (TOTEM)

All Transmission Operators, together with National Grid ESO, are taking forward an NIA project to explore construction of a whole GB simulation environment within PSCAD. The Centre is advising on hardware and software support needs within the project is expected to host the Scottish TOs model, the Centre will also support verification of models being used.

www.smarternetworks.org/project/nia_shet_0032

Stability Assessment and Mitigation of Converter Interactions (Phase 2)

This project builds on the previous work done by the University of Strathclyde for the HVDC Centre on the development of small-signal impedance model of MMC converter and its use for assessing multi-converter interactions. The project focuses on developing further converter models for stability analysis of complex networks with significant converter presence. The development of analytical impedance model can provide further insight into the impact of circuit and control structure / parameters on system impedance.

www.hvdccentre.com/stability-phase-2/

2) Project Manager's Report

COMPOSITE Testing of HVDC-connected Offshore Wind Farms

This project developed new approaches to defining the key tests & simulations and the associated data and other requirements needed across the process of designing, testing, commissioning and operating complex, multi-device connection solutions.

www.hvdccentre.com/composite/

Impact of Covid-19

Based on Government advice the Centre closed during the first lock-down and has been operating with a reduced occupancy since re-opening.

The MTTE project was due to be completed on 31 March 2021; however due to the impacts of Covid-19, the project is now expected to be fully completed by 30 September 2021.

This is due to a number of sub-projects being delayed (as a result of Covid-19 impacts on the suppliers):

- Protection Performance Overview and Validation in Low Strength Areas (undertaken by Manitoba Hydro International);
- Evaluation of HVDC with Synchronous Condenser impact on AC Protection (undertake by the University of Strathclyde);
- Adaptive Damping of Power Oscillations using HVDC (undertaken by EPRI);
- Stability Assessment and Mitigation of Converter Interactions - Phase 2 (undertaken by the University of Strathclyde); and
- Extension of the HVDC Centre Building (undertaken by VQ).

We continue to work with the suppliers to ensure that the outputs are delivered to the appropriate quality and within acceptable timescales.

3) Business Case Update

Business Case

The Future Business Model (7 February 2020), provides details of the future business case for the Centre.

4) Progress Against Plan

Summary of Progress This Reporting Period

During this reporting period, The National HVDC Centre has delivered the following programme of work:

- NSL Protection Study (Phase 1);
- Moyle Support;
- Integrated Offshore Design;
- Offshore Coordination (Phase 1);
- Offshore Coordination (Phase 2);
- Distributed ReStart (NIC);
- HVDC Phasor Based Monitoring (NIA);
- Eastern HVDC Support;
- Caithness-Moray Operational Support;
- Shetland Multi-Terminal Extension;
- SCADA Installation;
- HVDC R&D Strategy and Supply Chain Review (Coordinated Offshore);
- Innovation Projects; and
- Dissemination Programme.

Key Activities Next Reporting Period

This is the last annual progress report for the MTTE project.

Following this report the activities to close the project are:

- Complete the MTTE project by September 2021;
- Submit the project close-down report by December 2021; and
- Submit the SDR application by 1 May 2022.

Risks

Refer to Appendix III for an extract of the project risk Register.

There is currently one 'high' risk highlighted below:

- **R030 Covid-19 may impact on the Centre's ability to deliver on its commitments:** Covid-19 has impacted on a number of our actives, causing significant delays.

Since the last report, the following risks have been closed: R004, R005, R006, R015, R023 and R024.

5) Progress Against Budget

The table below details the spend (& revenue) to date against the Project budget for each cost category.

Cost Category ⁽³⁾	Total Budget	Spend to Date ⁽¹⁾	Comment
Labour			
Project team resource costs	£2,181.68k	£1,713.03k	21% below budget
MTTE resource costs	£2,032.13k	£1,347.24k	34% below budget
Contractors			
Project team resource costs	£288.44k	£253.32k	12% below budget
IT			
IT Infrastructure (incl RTS and Replica Panels)	£3,828.21k	£4,020.03k	5% above budget
Annual Running Costs of the MTTE	£304.37k	£178.84k	41% below budget
Travel & Expenses			
Travel & Expenses	£197.40k	£66.83k	66% below budget (refer to Note 2)
Other			
Academic Support	£827.07k	£973.95k	18% above budget
Learning & Dissemination	£165.41k	£46.67k	72% below budget
MTTE Building Facility	£2,916.20k	£3,214.74k	10% above budget
Annual Running Costs of the MTTE	£515.09k	£204.82k	60% below budget
Recruitment & Training	£137.90k	£16.42k	88% below budget
Total	£13,393.91k	£12,035.92k	10% below budget
Revenue		Revenue to Date	Comment
Revenue Generated		£385.65k	
Net Total		£11,650.27k	(refer to Note 10)

5) Progress Against Budget

Notes:

- 1) Project Spend as extracted from the finance system (Harmony) on 31 May 2021.
- 2) Travel and expenses spend is being kept to a minimum, and is further lower due to the impact of Covid-19.
- 3) There is no Project budget or Project spend under the Cost Categories: Equipment, IPR Costs, Payments to Users, Contingency and Decommissioning.

6) Bank Account

A copy of the current project bank account statement is provided in Appendix II.

7) SDRCs

An update on the Project's SDRCs is provided below.

The MTTE identified eight Successful Delivery Reward Criteria (SDRC) which span both the objectives and the lifecycle of the Project. Furthermore, Ofgem's decision letter (27 March 2015) added an additional criteria (SDRC 9.9).


The following table lists each SDRC in chronological order and details the Project's progress towards their achievement.


SDRC	Due	Description	Evidence	Status
9.1	31/8/2014	Formal Agreement with Project Partners. The success of this Project will be crucially dependent on the involvement of the Project partners & stakeholders. Therefore, an early indication of success of the Project is the establishment of formal agreements with the Project partners (National Grid, Scottish Power and NETSO) and HVDC expert support.	Signed agreements with Project partners (National Grid, Scottish Power and the NETSO) (note, agreement will include IP security requirements) and HVDC expert support.	Completed (SDRC met) Formal agreements with Scottish Power and National Grid were signed and concluded on 29 August 2014. Parsons Brinkerhoff was engaged as external HVDC expert support in February 2014.
9.2	31/10/2014	OFTOs and Renewable Developers Event Given the anticipated number of HVDC schemes in GB for connection of offshore renewable, the engagement of OFTOs and Renewable Generators is important to ensure the benefits of the MTTE are maximised, therefore the MTTE Project will hold an event to inform and encourage their participation.	Holding an event to which all OFTOs and Renewable Generators are invited, to inform and encourage their participation in the MTTE.	Completed (SDRC met) The OFTOs and Renewable Generators Event was held in Glasgow on 11 September 2014. In addition, the Project presented to the ENA's OFTO Forum on 20 August 2014.
9.3	31/12/2014	Engagement with 1st HVDC Project The purchase of the 1st set of replica control panels for the MTTE will be key to its success, and the panels will be purchased through an HVDC Project. Therefore the formal engagement of the initial HVDC Project is an important early milestone.	Formal agreement between the MTTE Project and an HVDC Project, which includes the intention to purchase/supply replica control panels through the HVDC Project's procurement process.	Completed (SDRC met) A memorandum of understanding has been signed, between the MTTE Project and the Caithness-Moray Project, confirming the arrangement for the provision and use of replica control panels.
9.4	31/5/2015	Complete Design of MTTE Facility The completed design of the MTTE facility, both technical design and physical design, and the agreement of this design with the Project stakeholders (including vendors), is a key milestone for the Project. The detailed design will be consolidated within the Design Development Document, and will adhere to the requirements defined in the requirements specification.	Design development document and requirements specification for the MTTE facility endorsed by participating vendors and signed-off by SHE Transmission, NGET, NETSO and SPT.	Completed (SDRC met) The Design Development Document and Functional Specification were reviewed at the Design Workshop on 23rd April 2015, following which each stakeholder provided written confirmation of their endorsement.
9.5	31/10/2015	Establishing HVDC Operators' Forum and Website A key component of our knowledge and dissemination strategy is the establishment of	The establishment of the HVDC Operators' Forum (including holding the 1 st event), together with the publishing of the MTTE	Completed (SDRC met) The first HVDC Operators' Forum event was held on 8

7) SDRCs

SDRC	Due	Description	Evidence	Status
		the HVDC Operators' Forum (to which all Network Licensees, including OFTOs will be invited), the associated members' Website (which provides a secure area to share the MTTE outputs with Transmission Licensees), and the public Website.	Websites.	October 2015, the second on 27 April 2017. The website (hvdccentre.com) was launched in April 2015.
9.6	31/5/2017	<p>Commence Operation of the MTTE</p> <p>The criteria consolidates the:</p> <ul style="list-style-type: none"> o Completion of the building/upgrade of the MTTE facility; o Commissioning of the IT/RTS infrastructure; o MTTE Resourcing; o Management structure in place; o Processes and procedures agreed; o Data sets of the AC network received (from NETSO); and o Plan of studies and tests agreed. <p>When all of these are in place, the MTTE will be able to commence operations, therefore this is a key milestone and measure of success of the Project.</p>	Commencement of MTTE Operations.	Completed (SDRC met) The facility was formally opened on 26 April 2017. The building, IT infrastructure, resourcing, governance, processes, data/models and work plan were all in place to enable operation to commence.
9.7	31/3/2018	<p>Publishing Studies & Test results</p> <p>The key outputs from the MTTE are the reports on specific scenarios which are completed within the MTTE, which will be disseminated to transmission licensees. Therefore, a key success criterion is the publishing of studies or test reports on the MTTE members' Website.</p>	Publishing the first set of reports on a specific Transmission Licensee led Project, on the MTTE members' Website.	Completed (SDRC met) The first set of four reports was published on the Centre's Website on 30 March 2018.
9.8	31/3/2020	<p>Future Business Model</p> <p>At least 12 months prior to the end of the funded operation of the MTTE (i.e. by end of March 2020), the MTTE management team will submit a proposal for the future operation and funding of the MTTE (post NIC funding), to Ofgem.</p>	Submission of proposal regarding MTTE ongoing operation and funding to Ofgem.	Completed (SDRC met) The Future Business Model report was submitted to Ofgem on 7 February 2020.
9.9	31/3/2021	<p>Second Replicas</p> <p>Use reasonable endeavours to secure the provision and testing of a second set of replica control panels for the MTTE from a second vendor. The panels would be provided by an HVDC Project, a transmission Licensee or a second vendor.</p>	Submission of evidence of the use of reasonable endeavours for the provision and testing of the second vendor's replica control panels at the MTTE facility; by the end of March 2021.	Completed (SDRC met) Evidence of the successful completion was submitted to Ofgem on 31 March 2021.

 Completed (SDRC met)

 On target

 Emerging issue, remains on target

 Unresolved issue, off target

 SDRC completed late

 Not completed and late

8) Learning Objectives

Learning during this reporting period

During this reporting period, the HVDC Centre has held a significant number of events, produced a significant number of reports and participated in a number of industry working groups, to share the project learnings.

Technical Events (Webinars, Conferences & Training Courses)

The National HVDC Centre delivered the following to industry stakeholders.

June 2020

- Offshore Co-ordination Project Conceptual design & unit cost for technology. Hosted by National Grid ESO. Slides available at: www.nationalgrideso.com/document/172396/download

July 2020

- Considerations for Development and Integration of HVDC in GB. Hosted by Cigre UK. Slides available at: https://drive.google.com/file/d/1TMwiFPlr5W-5KAYz_R4EjaFIUeOwAgI3/view

August 2020

- At the IEEE PES 2020 General Meeting virtual conference (3-6 August 2020), the Centre presented on real-time testing environments for utilities.
- At the CIGRE 2020 e-session, the Centre presented a paper on the key considerations for multi-vendor extension and testing of HVDC schemes.
- Held the kick-off meeting for our innovation project on Adaptive Damping of Power Oscillation with EPRI, with representation from all the TOs and the ESO.
- Hosted the control room team and supported their training on the operation of the CM link using Replicas.

September 2020

- CIGRE: The Centre has participated in the B4.81 CIGRE session on network integration.
- PROMOTioN: This month saw the culmination of this large European project, with the broadcast of our final demonstration event. We have now published all of our deliverables. We also participated at the final conference (chairing a session);
 - All the final conference and associated build up videos are here: www.promotion-offshore.net/news_events/final_conference_2020/
 - The link to the breakout chaired by the Centre (and the associated videos) can be found here: www.promotion-offshore.net/news_events/final_conference_2020/breakout_session_2_hvdc_technology_qualification/
- Converter Interaction and Network Stability: The Centre kicked-off phase 2 of the Converter Interaction and Network Stability project with the University of Strathclyde (attended by all TOs and the ESO).

October 2020

- Webinar with RTDS: The Centre presented at RTDS's international Spotlight webinar on 'De-Risking the Deployment of HVDC Projects at The National HVDC Centre'; slides and recording available at: www.rtds.com/events/uss-week-2/
- The Centre presented a keynote speech to ICRERA 2020 conference on Renewable energy research; materials available at: www.icrera.org/
- The Centre presented to New York operators NYSERA/DSP conference on renewables integration; materials available at: www.nyserda.ny.gov/ober

8) Learning Objectives

November 2020

- The Future of Offshore Grids: The Centre co-presented at the SSE Group Engineered Lunch webcast.
- RUK Cables 2020 Conference: The Centre presented the COMPOSITE project and cable modelling approaches:
<https://events.renewableuk.com/cables20-programme>

December 2020

- Introduction to HVDC training course: The Centre delivered a half-day virtual training course to the project team working on the Shetland extension.
- Sharing learnings with NYPA's AGILE: The Centre met with the 'New York Power Authority', to share knowledge on establishing a real-time test environment.
- Newfoundland Environmental Industry Association Webinar: The Centre presented at the Newfoundland Environmental Industry Association Webinar, on the work of the Centre, and on HVDC in GB.
- OWIC meeting: The Centre participated in the OWIC review of the ESO Offshore Coordination project.
- Offshore Transmission Network Reform: The Centre supported the Q&A session of the Ofgem, BEIS and ESO consultation on Offshore Coordination.
- NERC modelling guidelines: The Centre participated in the Q&A discussions at the NERC modelling guidelines webinar.

January 2021

- Prospero Offshore Transmission and HVDC Conference – The Centre presented Holistic planning of Integrated Offshore Networks to over 20 cross industry stakeholders
- Prospero Offshore Transmission and HVDC Conference – The Centre presented Multi-terminal

Extension of HVDC Schemes to over 20 cross-industry stakeholders.

- Offshore Grid Interoperability and master control – The Centre provided technical insights on a potential service being developed by DNV-GL for off-shore grid operation and control.

February 2021

- Introduction to HVDC training course - Half day virtual training giving intro on HVDC.
- CIGRE B4.81 Specialist Technical Working Group: Contributed technical insights on converter interactions.

March 2021

- COMPOSITE Testing Webcast, with RTEi (over 230 attendees).
- Introduction to HVDC Training Course: External training course.
- CIGRE Chili tutorial: HVDC technology and its integration: Presentation and Expert Panel.

April 2021

- Webinar: Evaluation of HVDC with Synchronous Condenser impact on AC Protection.
- Webinar: Composite testing of HVDC connected offshore wind farms using EMT simulation tools.

May 2021

- The Centre presented at a variety of events including: Panel session for EPRIs expert group, World HVDC Week, EPRI RT-HiL Interest group, CIGRE B4.81 (Ch4) kick-off meeting, ERIGRID 2.1, and IEEE SGSMA Panel session.
- As part of the Centre's series of TOs/ESO 'Roadshows' the Centre held separate virtual events with SSEN Transmission, National Grid Electricity Transmission and the ESO.

8) Learning Objectives

Technical Publications

June 2020

- Offshore Wind Integration: The Offshore Wind Industry Council (OWIC) transmission group sought guidance from the Centre on options for de-risking integrated offshore transmission approaches in GB. The Centre, in consultation with industry stakeholders, led the publication of a report, which identifies that: Integrated offshore transmission is technically feasible for projects at design stage; Solutions can be built in stages to meet offshore wind growth and benefit the onshore grid; and Bipole HVDC with return cable option appear to offer greater flexibility and less export cables. The full report was published on 25 June; and is available at: www.hvdccentre.com/wp-content/uploads/2020/06/De-risking-Integrated-Offshore-Networks_v2.0_25June2020.pdf

July 2020

- Stability Assessment and Mitigation of Converter Interactions (Phase 1): The University of Strathclyde developed frequency domain network/converter models for small signal stability analyses and time-domain validations of stability assessments when obtaining frequency domain HVDC converter models. The key outcomes of the project are recommendations for specifications and operation requirements of converter models and advice to HVDC projects connecting to the GB network on stability issues. Project associated reports are available at: www.hvdccentre.com/hvdc-stability-assessment/
- Coordination of AC network protection during HVDC energisation: EPRI investigated how relay/protection types impacts AC network protection during HVDC energisation, especially when the network short circuit strength is low. In this project, a case study on the Scottish transmission system is considered to study the implications for protection devices operating in the unique scenario where the network is restored from a HVDC scheme. All reports are

available at: www.hvdccentre.com/ac-protection-dc-energisation/

- Improving Grid Code for HVDC schemes: Cardiff University studied and tested improved specifications and requirements for the operation and integration of HVDC schemes on the GB network. The outcomes of the project provide guidelines for the recommended operational regions for a safe and stable HVDC interconnection without jeopardising the power system security and reliability. All reports are available at: www.hvdccentre.com/hvdc-grid-code-compliance/

August 2020

- Submitted 'Consolidated Technical Report' on integrated offshore designs, to the ESO.
- Submitted 'HVDC Challenges and Barriers' report to the ESO (for the Integrated Offshore project).

September 2020

- Integrated Offshore: The Centre finalised the Technology Report for the ESO, which describes the future integration of offshore infrastructure. The overarching report can be found here: www.nationalgrideso.com/document/177296/download and the detailed report can be found here: www.nationalgrideso.com/document/177221/download
- PROMOTioN: This month saw the culmination of this large European project. We have now published all of our deliverables. All the final conference and associated build up videos are here: www.promotion-offshore.net/news_events/final_conference_2020/ The link to the breakout chaired by the Centre (and the associated videos) can be found here: www.promotion-offshore.net/news_events/final_conference_2020/breakout_session_2_hvdc_technology_qualification/
- MVDC (Medium Voltage Direct Current): Completed a report on MVDC to inform SSEN's transmission and distribution development.

8) Learning Objectives

October 2020

- Journal Paper Published: Key research outcomes from the “Stability Assessment and Mitigation of Converter Interactions (Phase I)” project with the University of Strathclyde, have been published in the journal paper:
www.hvdccentre.com/library/stability-assessment/
- Protection Testing Briefing Paper: Based on work undertaken at the Centre, we have published a briefing paper on the: ‘Evolution of Protection Testing in Low-Strength and Converter-rich areas within the GB Grid’.
www.hvdccentre.com/library/evolution-of-protection-testing/

November 2020

- Sensitivity study on the effect of change in the starting date of offshore grid coordination for the ESO.
- Cost-Benefit Analysis of Offshore Transmission Network Designs (with DNV-GL) for the ESO.
- Proposals for EMT modelling, simulation and validation (for CIGRE B4.83 committee).

December 2020

- Multi-terminal Extension of Existing VSC-HVDC schemes: Assessment of performance testing approaches for multi-vendor VSC-HVDC systems. Full Paper accepted for presentation at CIGRE2021 Centennial Session Paris.
- Wider Impacts of Interconnectors: HVDC Centre response to Ofgem on technical risks with references to be considered in WS3 interconnector policy review.

February 2021

- IET RPG Journal Special Issue - Upscaling electricity innovations to deliver net zero targets.
- OWIC response to BEIS call for ideas as part of OTNR - Technical changes required for coordinated offshore electricity connection
- Recommendations to BEIS on progressing Coordinated Offshore - Provided BEIS with recommendation on progressing the Coordinated Offshore project.

March 2021

- COMPOSITE Testing of HVDC-connected offshore wind farms: Technical report on guidelines, tools and processes for compliance testing of HVDC-connected offshore wind connections
- Demonstration of Multi-vendor Protection Systems for Multiterminal VSC-HVDC Networks: IEEE PES conference paper
- VSC-HVDC Newsletter article on Composite Project: Summary of Composite Project Outputs.
- Composite Testing of HVDC-connected Offshore Wind Farms: RTEi in collaboration with the Centre and ESO will undertake analytical studies to illustrate EMT phenomena, identify composite interactions between wind farms and HVDC system and provide a methodology to conduct EMT studies over the lifetime of a project. Details available at: www.hvdccentre.com/composite/
- Stability Assessment and Mitigation of Converter Interactions (Phase 2): The University of Strathclyde will assess stability of classic HVDC converters and variable speed wind turbines, using the impedance modelling methods and tools developed across the 2019 Phase1 project. Details available at: www.hvdccentre.com/stability-phase-2/

8) Learning Objectives

April

- The Centre submitted 4 abstracts to CIGRE 2022.
 - Modelling and Stability Assessment of Integrated Offshore HVDC Networks;
 - Lessons Learnt from the Composite Project;
 - Real Time Simulation and Demonstration of Black Start on Transmission Networks using Distributed Energy Resources (DER); and
 - Protection Testing Approaches for Low Fault Level Areas Dominated by Power Electronic Converters.

Industry Working Groups

The Centre is actively participating in the following Working Groups:

- **Offshore Wind Industry Council (OWIC):** The Centre has supported the OWIC Future transmission group as Chair of the Technical solutions workstream, contributing to policy papers submitted to BEIS and Ofgem, to inform the Offshore Coordination project and ongoing OTNR.
- **CIGRE B4.81:** Covering tools, techniques and simulation process associated with de-risking convertor rich environments; aiming to release a technical brochure in 2022. The Centre is providing drafting for the Chapters on: small signal techniques, COMPOSITE testing techniques, validation and verification aligning with GC proposals, and review and input into processes for SSCI simulation and network reduction guidance.
- **Grid Code Working Group:** Representative across workgroups GC0137, GC0138, and GC0141 covering respectively virtual synchronous machine convertor control, convertor testing and compliance testing, EMT data exchange / simulation and verification and increasing robustness following 9 August 2019. All are now approaching external consultation with the Centre part of expert group supporting eventual implementation.

- **IET RPG Journal industrial panel:** The Centre has supported the IET Renewable Power & Generation (RPG) with a Special Issue intended to attract more industry papers with focus on energy solutions to deliver net zero targets.
- **IET ACDC Organising Committee:** The Centre is supporting the organisation of the annual prestigious ACDC international conference, event format & organisation, paper review and approval, conference presence, key note speech & paper generation. This year's conference will be hybrid virtual event in November 2021.
- **Global-PST consortia:** The Centre (with the TAB and EPRI) has supported R&D direction of the above, exchanged updates on the small signal analysis approaches it has developed with partners AEMO and NERC, and supported its model validation and verification workstream.
- **CIGRE WG C4/C2.62/IEEE:** Participating in this working group to review advancements in Synchrophasor Measurement Applications.

Learning Objectives

These events, publications and working group participation; support the project learning objectives of:

- Support Transmission Planning of HVDC schemes;
- Improve Requirement Specification of HVDC schemes;
- Facilitate Multi-Terminal HVDC solutions;
- Facilitate Competition and Multi-Vendor HVDC schemes;
- De-risk Control interactions between co-located and electrically connected converters, and with other active controlled equipment;
- Train Transmission Planning and Operational Engineers;
- Undertake Post commissioning scenario planning and operational optimisation; and
- Model New HVDC Technologies.

9) IPR

IPR

No relevant IPR has been generated or registered during this reporting period.

10) Risk Management

Risk Management Plan

The Project has a Project Risk Management Plan that describes how Project risks are managed throughout the Project.

The Project risk register is regularly reviewed by the Project team and the key Project risks are highlighted and discussed at the Governing Board meetings, where mitigating actions are agreed.

Risk Register

An extract of the current Project Risk Register is provided in Appendix III.

11) Accuracy Assurance Statement

PPR Preparation Steps

To ensure that the information contained in this report is accurate and completed, the following steps have been taken, the report has been:

- Prepared by the Centre Manager;
- Peer Reviewed;
- Reviewed by the Head of HVDC; and
- Approved by Regulation and Data Assurance representatives.

Sign-off

As the senior manager responsible for the MTTE Project, I confirm that the processes in place and steps taken to prepare this PPR are sufficiently robust and that the information provided is accurate and complete.



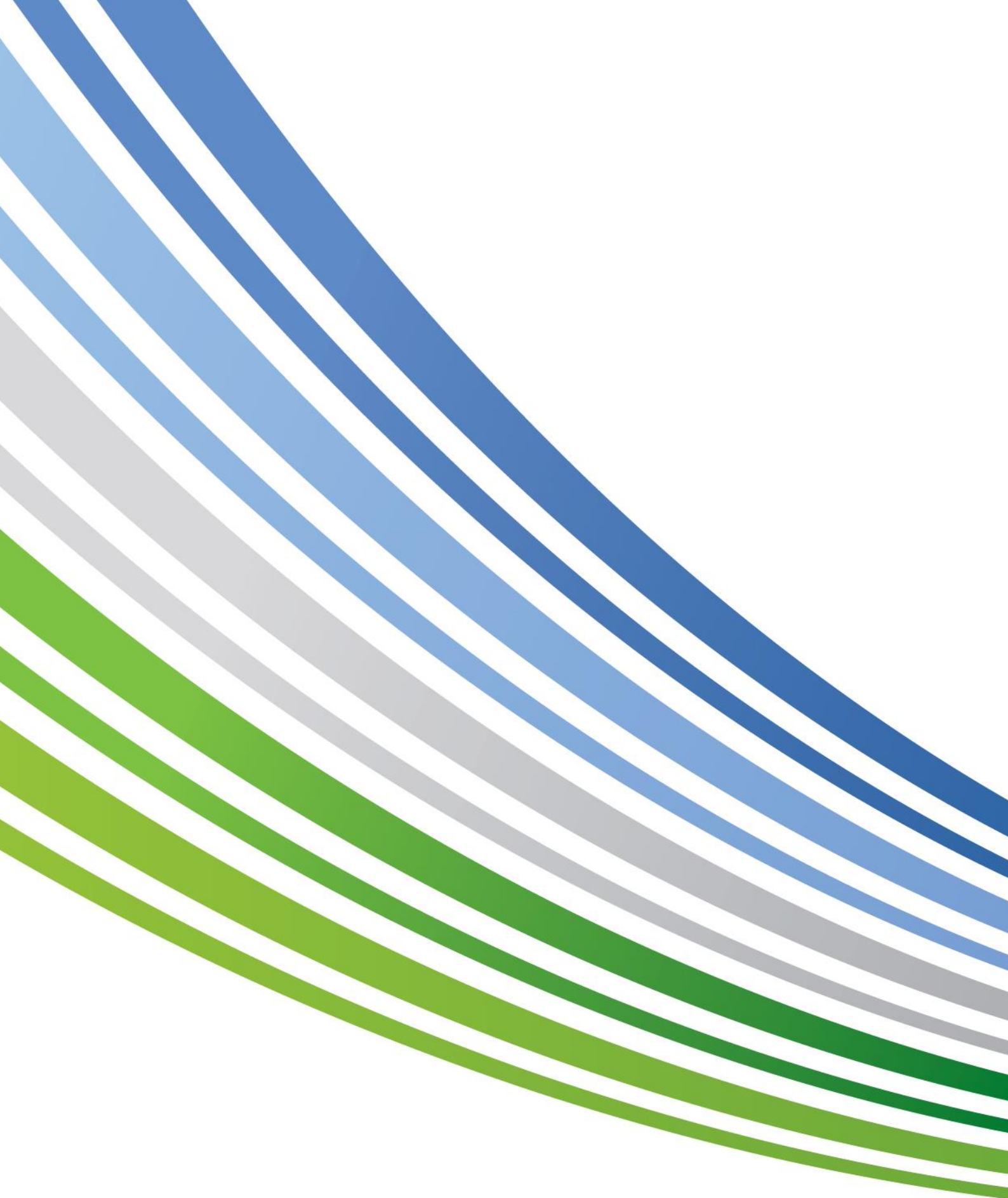
Richard Hanson
Head of HVDC
SSEN Transmission

8th June 2020

Date Date

12) Appendices

Appendix I	Newsletters
Appendix II	Project Bank Account Statement
Appendix III	Project Risk Register



MTTE Project Progress Report – June 2021

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