PROMOTioN

PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP9 – Protection System Demonstration *Partially and Fully Selective Schemes*

Non-Selective: No protection zones or entire DC grid as one zone

Partially Selective: DC grid is split into several protection zones or sub-grids

Fully Selective: Protection zones are defied to individually protect each line and bus

Introduction

The **objective** of **W**ork **P**ackage **9** was to **demonstrate** the operation of the **DC grid protection** systems developed.
This was achieved through**:**

- use of hardware in-the-loop real-time testing
- integration of DC protection systems and relays from WP 4 and DCCB models from WP6
- development of DC grid benchmark models and test procedures
- assessment of primary and back-up DC Grid protection operation
- investigation of equipment interoperability

The Test Objects (Developed in WP4)

Intelligent Electronic Devices (IEDs) for **HVDC protection**:

- Execute algorithms
- *Fault detection and discrimination*
- *Breaker failure backup protection*
- High speed operation required (e.g. <1ms)
- Desire for robustness, security, dependability…

Mitsubishi Electric Corp. (MELCO) IED

- Redundant architecture: duplicate systems
- Industrial-grade equipment - builds on HVDC/FACTS technology
- Speed: Multiple, high-speed DCCB trip-outputs
- Flexibility:
- *Software programmable to utilise a variety of algorithms*
- *Can be used in a variety of system configurations*

PROMOTioN IED

- Platform to perform research
- Low-cost
- Open-source hardware and software
- Save time and cost for building lab setup
- Easy adaptation to different purposes
- Algorithms: dv/dt, travelling wave, overcurrent, undervoltage, busbar

Test Environment

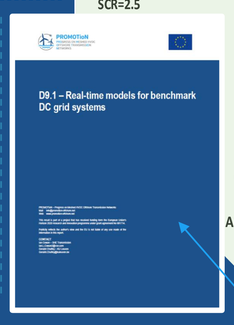
Base 3 terminal network **based on real** CMS (Caithness-Moray-Shetland) HVDC **system**

DCCBs

- Developed by WP6 in collaboration with industrial partners
- 3 types: hybrid; mechanical; and VARC

Converters

- Open-source
- Average HB-MMC
- Includes high and low level control



Model details available in D9.1

HVDC Cables

- Parameters from real project
- Travelling wave frequency-dependent phase model used giving accurate v, i response

Real time operation lets us **connect physical devices** in a **closed-loop** with the simulated environment

- Shows dynamic response of the system as test continues after action of the device.
- Test multiple devices simultaneously
- More detailed system representation than open-loop test provides

Testing

For different combinations of DCCB type and IED(s) for each model phase:

- faults every 5 km
- pole-to-pole and pole-to-ground faults
- three repetitions of each fault at each location
- all KPIs recorded

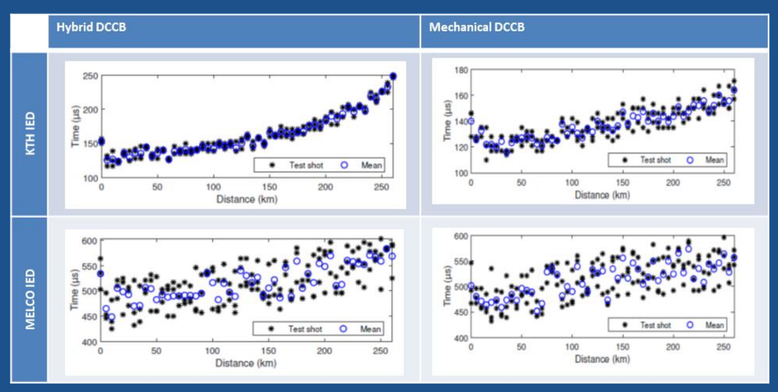
DC grid protection testing procedures and guidelines available in D9.2

Results

Single Vendor Protection System Tests

Testing of IED performance in three terminal Caithness Moray Shetland system. Testing has been performed showing various single vendor cases (PROMOTioN IED or Mitsubishi IED) in both partially and fully selective protection strategies.

Partially Selective Results



Results demonstrated successful operation of protection IEDs in both partially and fully selective protection schemes

Successful Demonstration in WP9

Successful IED operation in:

- Partially selective 3T radial system
- Fully selective 3T radial system
- Protection system consisting of **multivendor IEDs**

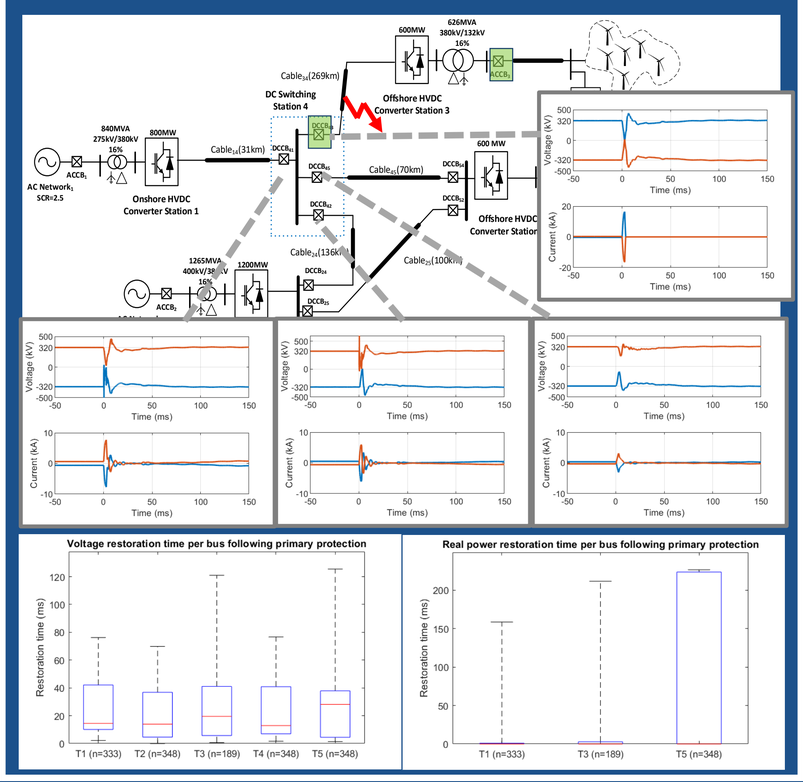
Demonstration indicates success on the most realistic test case possible without installation on real power system!

IED performance expected to be sufficient for possible future HVDC grids.

Control Replica	Protection IED	DC CB	Successful operation
ABB	MITSUBISHI ELECTRIC	SCiBreak	✓
ABB	MITSUBISHI ELECTRIC	ABB	✓
ABB	MITSUBISHI ELECTRIC	MITSUBISHI ELECTRIC	✓
ABB	PROMOTioN	SCiBreak	✓
ABB	PROMOTioN	ABB	✓
ABB	PROMOTioN	MITSUBISHI ELECTRIC	✓

Multi-Vendor Multi-Terminal Tests

Primary Protection



Publications and Further Reading

PROMOTioN Deliverable 9.1: Real-time models for benchmark DC grid systems. Available on the PROMOTioN website.

W. Leterme et al., "Designing for High-Voltage dc Grid Protection: Fault Clearing Strategies and Protection Algorithms," in IEEE Power and Energy Magazine, 2019.

I. Jahn et al., "An Open-Source Protection IED for Research and Education in Multiterminal HVDC Grids," *IEEE Trans. Pow. Sys*. Early Access, Jan. 2020.

G. Chaffey et al., "Requirements for functional testing of HVDC protection IEDs," in *Proc. CIGRE Colloq.*, Johannesburg, 1-4 Oct. 2019.

I. Cowan et al., "Demonstration of Partially Selective HVDC Grid Protection System with Hardware-in-the-loop HVDC Protection IEDs," in *Proc. IET DPSP*, Liverpool, 9-12 Mar. 2020.

M. Wang et al., "Multi-vendor interoperability tests of IEDs for HVDC grid protection," in *Proc. IET DPSP*, Liverpool, 9-12 Mar. 2020.

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