PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP11 – Harmonization and standards

DC switchgear

Technical inputs from WP5, WP6, WP10 and WP15

HVDC circuit breaker standardization

- Experimental HVDC breakers used to quantify stresses on subcomponents
- Test program agreed among manufacturers
- Feasibility demonstrated in public demo's
- Brought forward to CIGRE WG B4A3-80
- Merge with GB/T 38328-2019 (China)
- Produce new IEC document to prepare IEC TS 62771-313

HVDC circuit breaker technologies tested

Name	Current	Breaking test	#
TC10+	10% of rated continuous current	2 tests in positive current direction	2
TC10-	10% of rated continuous current	2 tests in negative current direction	2
TC100+	100% of rated continuous current	2 tests in positive current direction	2
TC100-	100% of rated continuous current	2 tests in negative current direction	2
TF100+	100% of peak fault current	2 test at specified energy absorption, positive current direction	2
TF100-	100% of peak fault current	2 test at specified energy absorption, negative current direction	2
TDT+	TBD	2 test at rated fault current suppression time, positive current direction	2
TDT-	TBD	2 test at rated fault current suppression time, negative current direction	2

Test program defined

HVDC gas insulated systems standardization

- Specification of HVDC GIS, prototype installation test defined and the test was performed for the first time worldwide
- HVDC GIS demonstrates the technology is well suitable for commercial HVDC station application
- Brought forward to CIGRE JWG D1/B3.57 and CIGRE JWG B1/B3/D1.79
- Input for new IEC document IEC TC 17 WG 6 and IEC TC 17C WG 42
- Monitoring and diagnostics of HVDC GIS
- Measurement and behavior of partial discharge for SF_6 substitute gases

HVDC gas insulated switchgear long-term tested

Pre-tests
Thermal cycle
LI / SI
DC/AC PD
SIM LI/SI
Polarity reversal
(120-2-120-2-45 min)

ZL + HL 6 x 60 days
1 x Zero Load: – U_T
1 x High Load: – U_T
1 x Zero Load: + U_T
1 x High Load: + U_T
1 x High Load: – U_T
1 x High Load: + U_T

LC 2 x 15 days
1 x Load Cycle: + U_T
1 x Load Cycle: – U_T

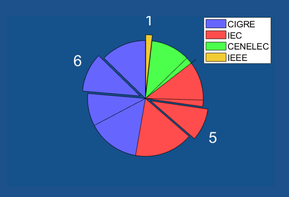
Sub-sequent tests
DC PD
LI / SI
AC PD

Superimposed impulse (SIM) voltage test: U_r ± LI/SI
Mechanical operation: 10 CO
AC PD (partial discharge) measurement

Prototype installation test program defined

HVDC System Protection

Technical inputs from WP4, WP6 and WP9

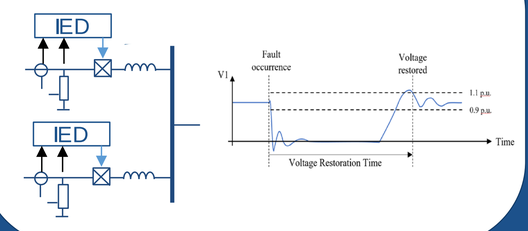


Design of Protection for HVDC Systems

PROMOTioN work has examined a wide range of protection system design challenges, the outcome of which is expected to be useful when working towards future harmonisation in system design.

Contributions to **Cigré B4/A380** and **B4/B1/C4.73**, planned contribution to **IEC TC95**.

Design and Evaluation of Protection Systems

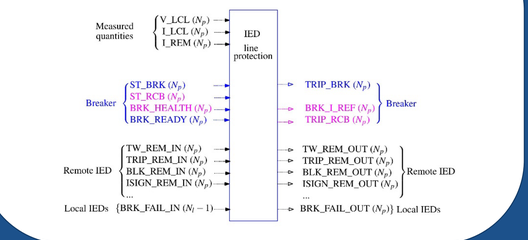


Application and Specification of HVDC Circuit Breakers

Differing protection strategies and system configurations can result in diverse requirements on the DC circuit breaker. In this work, circuit breaker requirements are discussed and three generalised types are developed.

Contribution to **Cigré B4/A380**.

HVDC Circuit Breakers: Application and Interfaces

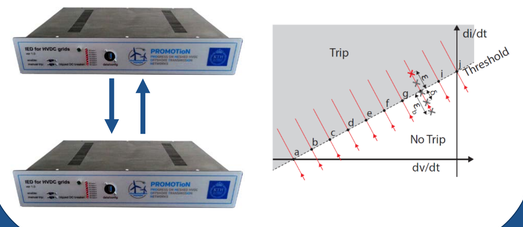


Substation Communication Protocols for MTDC Protection

Although communication protocols are already used in power system protection, they are not all fast enough for all HVDC protection functions. Summary of the possible protocols and possible applications in an HVDC substation is included.

Planned contributions to **Cigré B5** and **IEC TC57**.

Protection IEDs: Communications and Testing



Performance Evaluation of HVDC Protection Systems

In order to accurately compare different protection solutions, the metrics by which different systems are measured should be harmonised. KPIs proposed in this work allow for the systematic comparison of different protection system implementations.

Planned contribution to **IEC/TC115/WG15**.

Communication Interfaces Between HVDC Circuit Breakers and HVDC Protection IEDs

HVDC circuit breakers and HVDC protection IEDs are expected to be commonplace, however, there is no definition of a standard interface and of which information should be communicated. Interface requirements are introduced and discussed.

Planned contributions to **Cigré B5** and **IEC TC95**.

Specification and Functional Testing of HVDC Protection IEDs

Although HVDC protection IEDs are near commercialisation, there are no harmonised requirements or specifications. Proposals for functional requirements and dynamic test procedures to determine the functional performance have been introduced.

Contribution to **IEEE SA P2004** and **IEC TC95**. Planned contribution to **Cigré B5**.

More information on each protection topic and the specific contributions can be found in Deliverable 11.2

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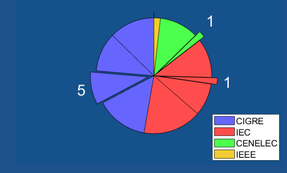
PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

WP11 – Harmonization and standards

Interoperability and Control of HVDC Systems

Technical inputs from WP2 and WP16

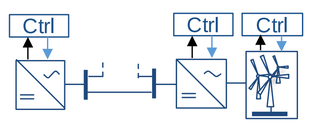


Terminology and Functional HVDC System Specification

As HVDC systems are still under development a lot of different technological options are available to realise these systems. To facilitate the development of HVDC grids functional system specifications have been discussed, extended and complemented.

Contributions to **IEC TC1** and **CENELEC TC8X WG06**.

Control Specification & Demonstration



(Power)- Hardware-in-the-Loop Demonstration of Controls

Within PROMOTioN, a (Power)-Hardware-in-the-loop (PHIL) system has been set-up and suitable interface definitions have been identified to test developed controls and the interaction between different converters and control concepts.

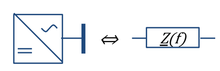
The system will be used for demonstration in **Cigré B4.85**.

Converter and HVDC Grid Modelling for EMT Studies

The existing Cigré converter model from B4.57 has been restructured to allow for a more modular set-up and has been extended with further converter and control concepts, e.g. for fault-blocking converters.

Contribution to **Cigré B4.69** and **Cigré B4.71.**

Modelling of MMCs



MMC Impedance Derivation

To analyse and limit resonances between converters and power systems, stability analyses in the frequency domain are recommended. Methods & test circuits are proposed and tested to derive frequency-dependent impedances.

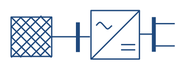
Contribution to **Cigré C4.49**.

Interaction between converter controls and AC line protection

The interaction between different possible MMC controls and HVAC line protection, especially with regard to the dynamics and limitations, has been identified as a gap in existing standardisation.

Working group proposal submitted to Strategic Advisory group of **Cigré B5**.

System behavior at the points of connection



Recommendations towards HVDC grid codes

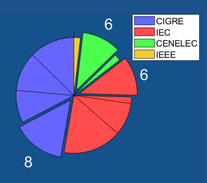
Existing national grid codes on HVDC systems have been analysed and potential for harmonisation has been identified. Moreover, first analysis for DC side requirements have been carried out.

Discussion of insights with TSOs.

More information on each topic and the specific contributions can be found in Deliverables 11.2 & 11.4

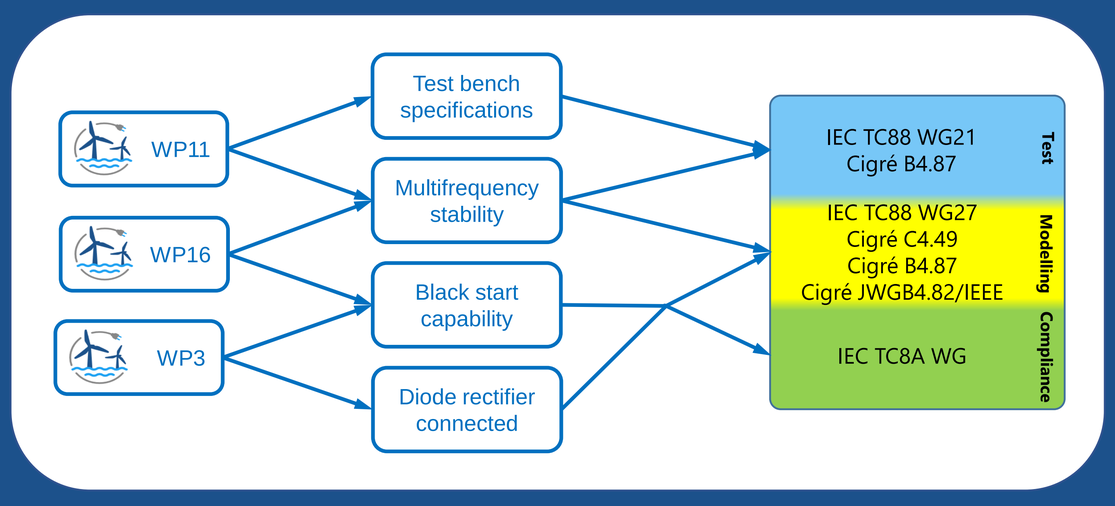
Grid Forming and DC connected offshore wind power

Technical inputs from WP3 and WP16



Specifications for wind turbine nacelle test benches

Test institutes are today using test benches for wind turbine nacelles before the complete wind turbine prototype is tested. PROMOTioN has Benchmarked specifications for existing test benches.



Multi-frequency modelling and test of WTs

The multi-frequency behaviour of wind turbines (WTs) is important for stable interoperability with high shares of converter based generation. PROMOTioN has demonstrated test of harmonic impedance of a wind turbine inverter and applied EMT simulations to study multi-frequency behaviour of a wind turbine.

DRU connected WPPs

A diode rectifier unit (DRU) is a passive one-directional AC/DC converter without grid forming capability. DRU connected wind power plants (WPPs) therefore have to form the grid using the wind turbine converters. Present grid codes and standards consider only grid following WPPs. PROMOTioN has defined functional requirements and proposed cases and procedures for simulation based compliance evaluation of DRU connected WPPs.

Black start from WPPs

Black start operation based on WPPs is not present in existing standards. PROMOTioN has proposed functional requirements and procedures for simulation based compliance evaluation of black start capability from WPPs, and also proposed test procedure for black start capability of wind turbine converter.

More information on each topic and the specific contributions can be found in Deliverable 11.3

Summary of Harmonisation Contributions regarding HVDC System Control:

6 topics, with 8 **completed contributions** and 1 **planned contributions** to **Cigré**, **IEC** and **CENELEC** technical activities.

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