27 September 2019

Hardware in the Loop setup
Testing DCCB controller performances in an HVDC grid

Workshop on DC Circuit Breakers and DC Grid Protection

Friday, 27 September 2019
09:00 – 17:00

Groundfloor Meeting Room
ENTSO-E
Avenue de Cortenbergh 100, Brussels

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

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Introduction

Introduction

Context

- DCCBs are seen as important lever for HVDC grid
- HVDC grid are considered to connect renewable energy

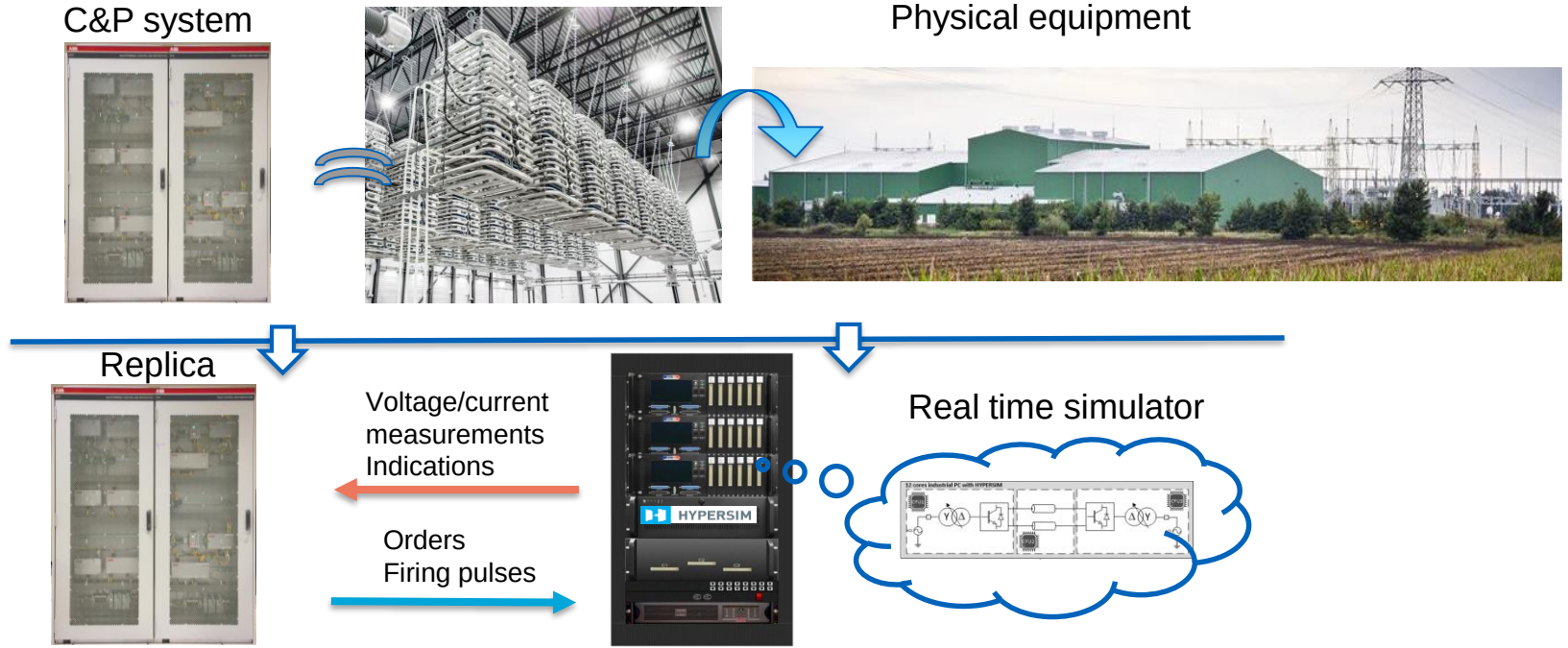
Scope of work

- Test the effectiveness of DC protection algorithms (selective fault clearing)
- Show the capability of HVDC grid to survive to DC fault
- Integration of DCCB in multivendor HVDC grid scheme
- Provide a proof of DCCB controller performances on
    - Control of switches, DC chopper,
    - Signal processing

Introduction

Real-time simulation with physical hardware in the loop

- A replica is an exact copy of the actual control and protection system installed on site

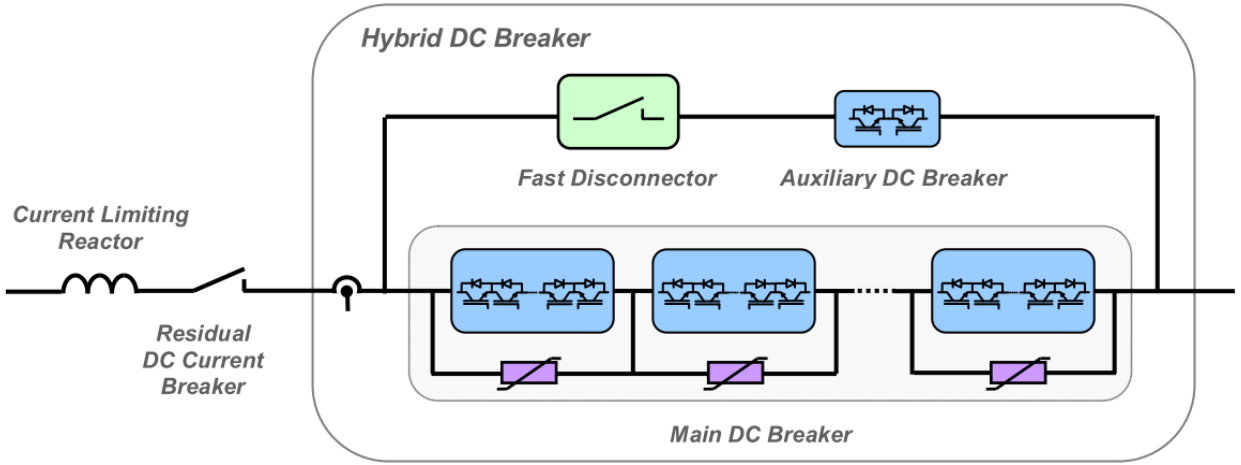


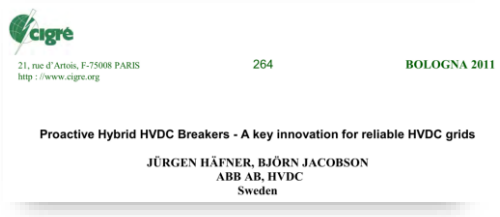
02

Hybrid DCCB modeling for RT

Hybrid DCCB modeling for RT

Hybrid DCCB description

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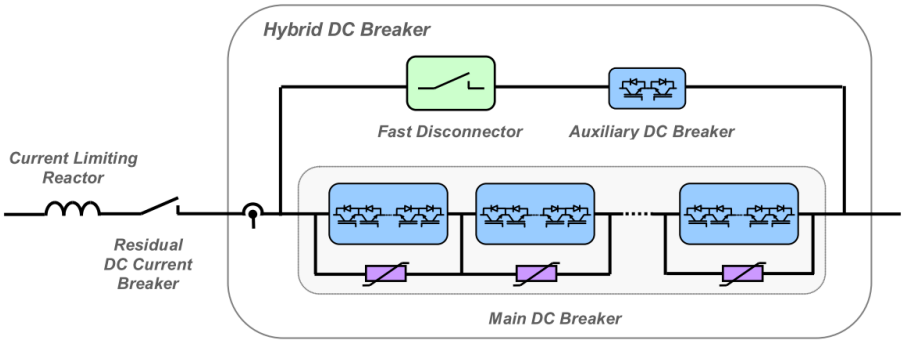
BOLOGNA 2011

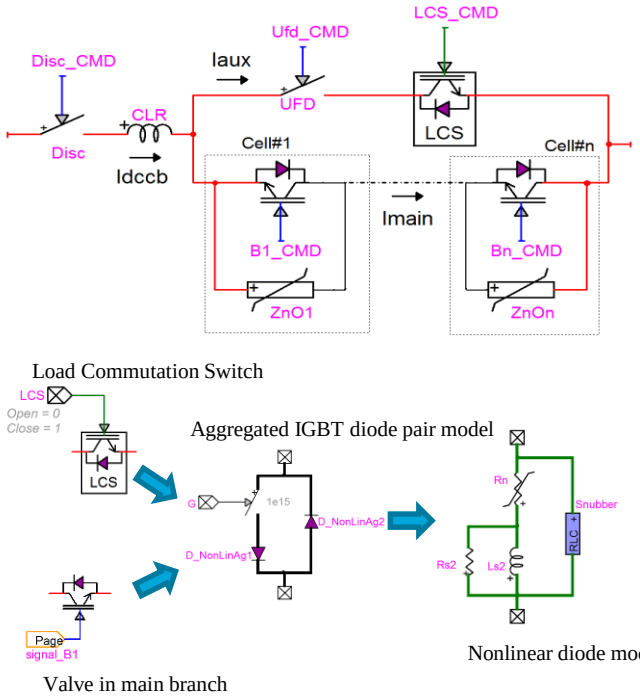
Proactive Hybrid HVDC Breakers - A key innovation for reliable HVDC grids

JÜRGEN HÄFNER, BJÖRN JACOBSON
ABB AB, HVDC
Sweden

Hybrid DCCB modeling for RT

Hybrid DCCB offline modeling

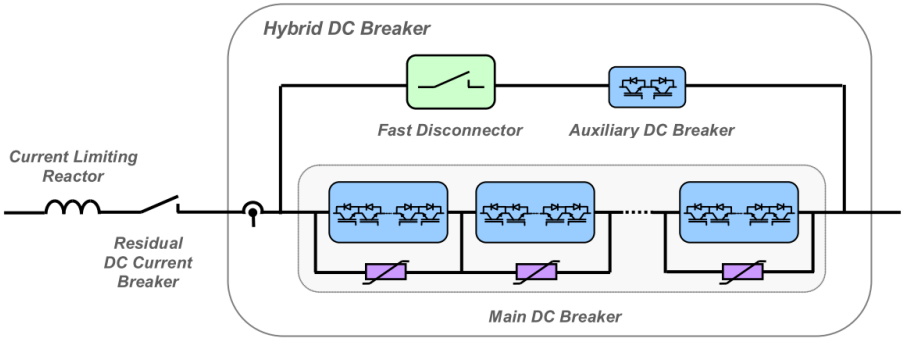


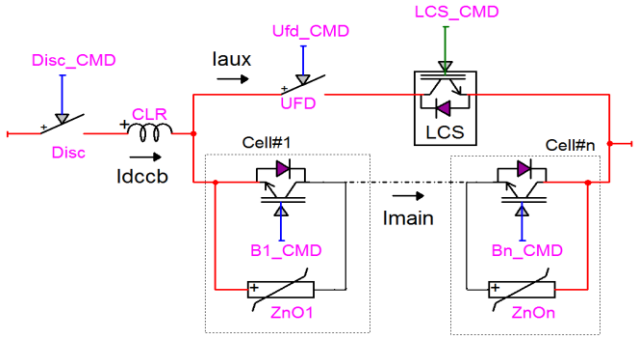


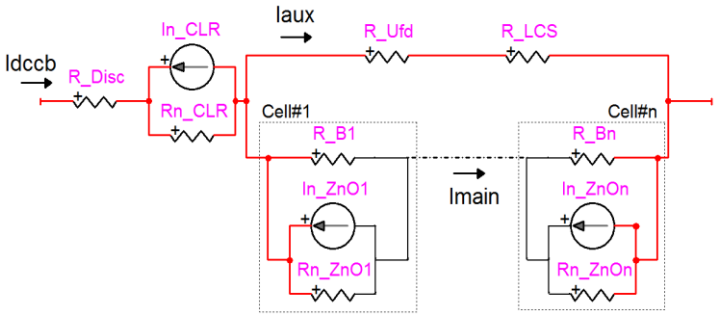
[1] W. Lin, D. Jovcic, S. Nguefeu and H. Saad, “Modelling of High Power Hybrid DC Circuit Breaker for Grid Level Studies,” IET Power Electronics, special issue on DC grids, Feb 2016

Hybrid DCCB modeling for RT

Hybrid DCCB RT modeling



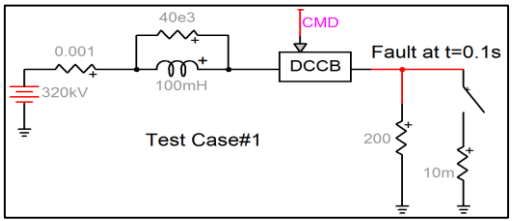


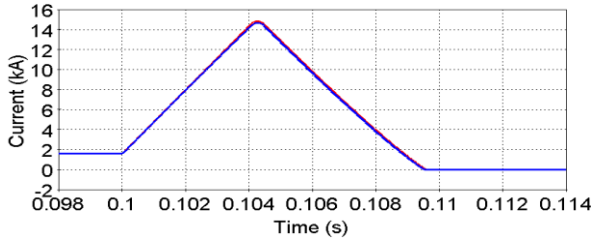


Hybrid DCCB modeling for RT

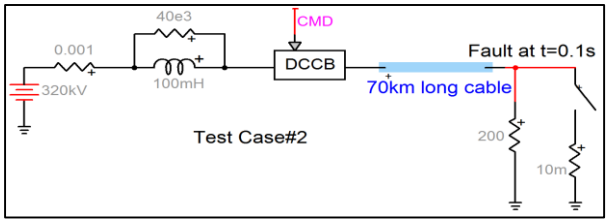
Hybrid DCCB RT model validation

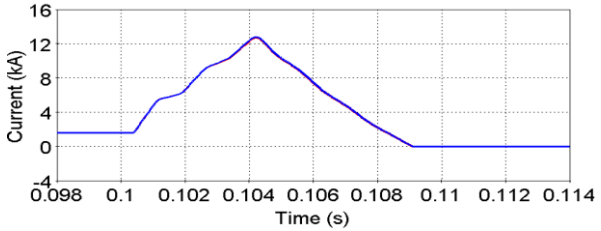
Test case#1





Test case#2





03

Hardware-in-the-loop SET-UP

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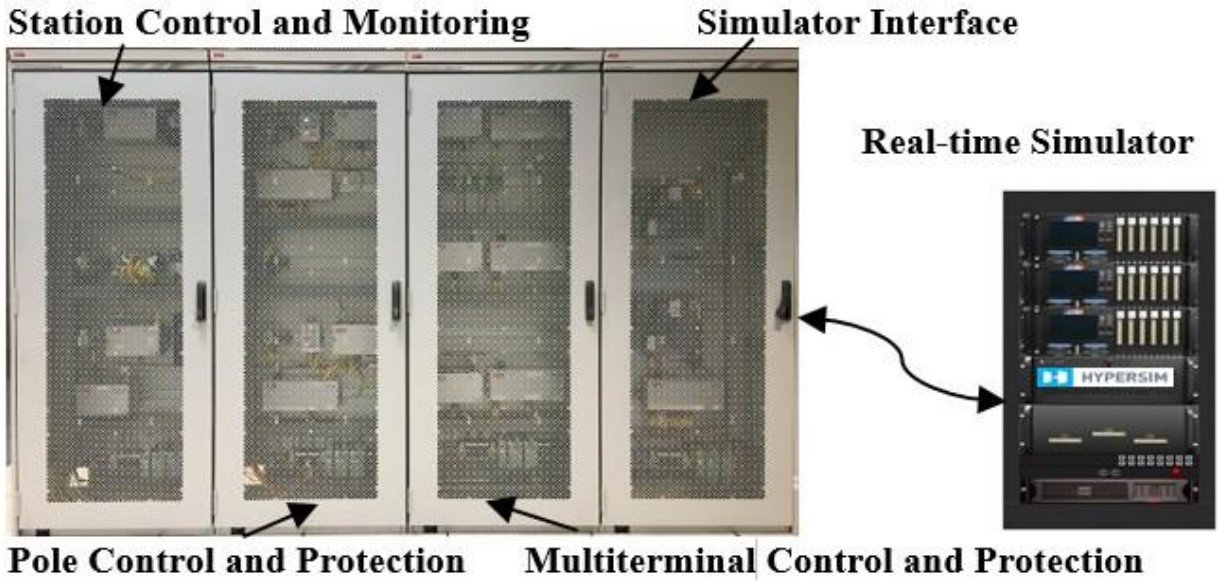
Control cubicles & Real time simulator

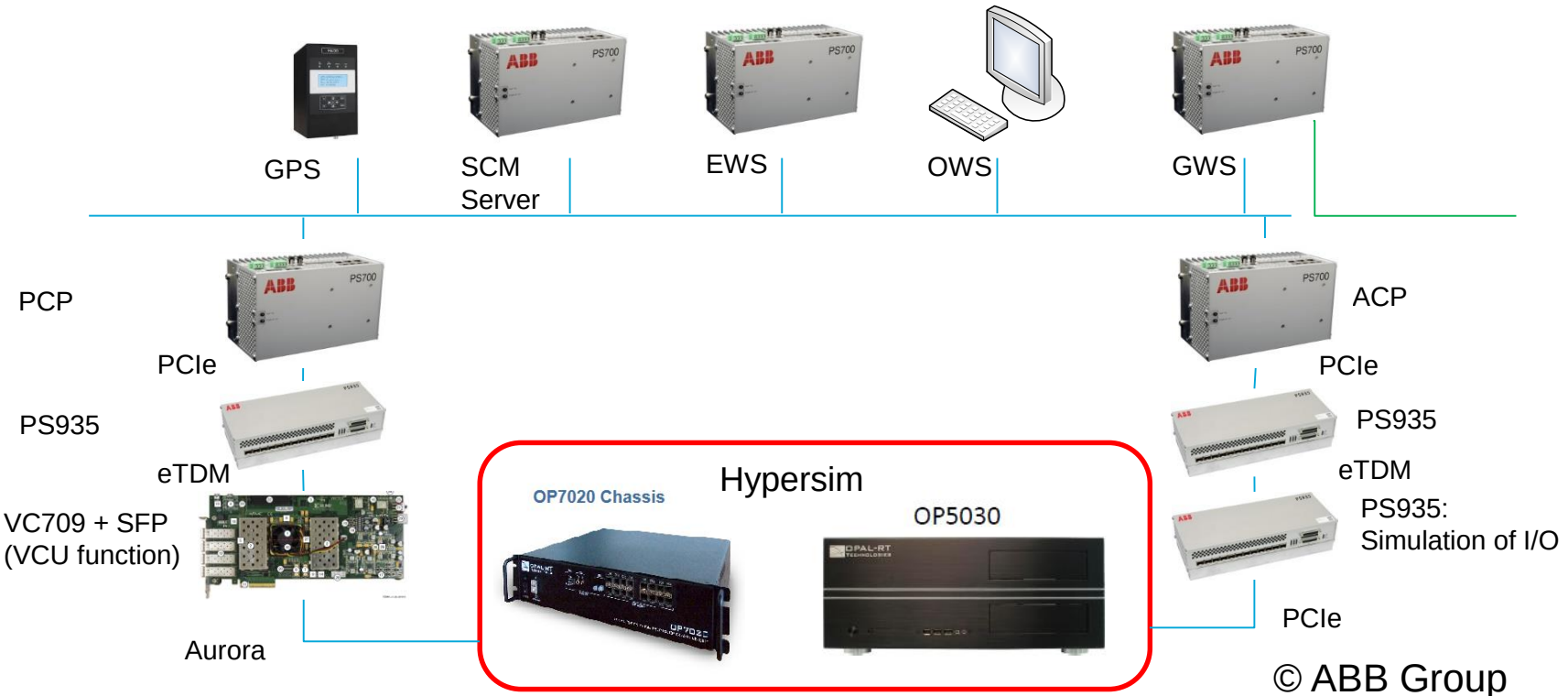
Hardware-in-the-loop SET-UP

Control cubicles & Real time simulator



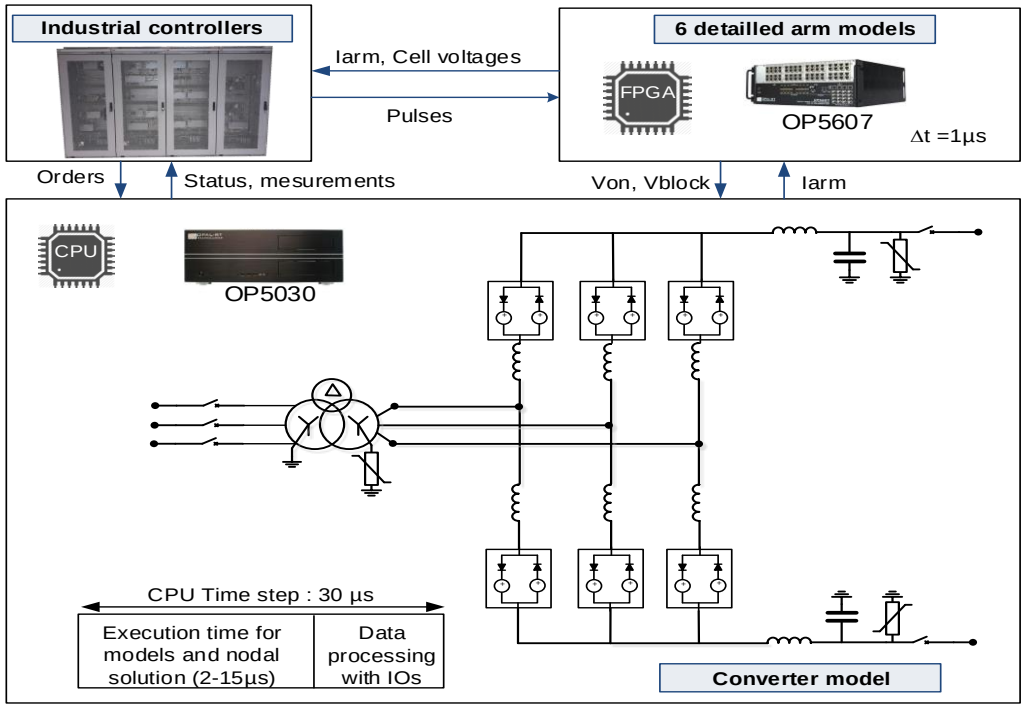
Hardware-in-the-loop SET-UP

Control cubicles



Hardware-in-the-loop SET-UP

Hardware setup for the HIL simulation



Hardware-in-the-loop SET-UP

DC network modelling

Frequency dependent cable model

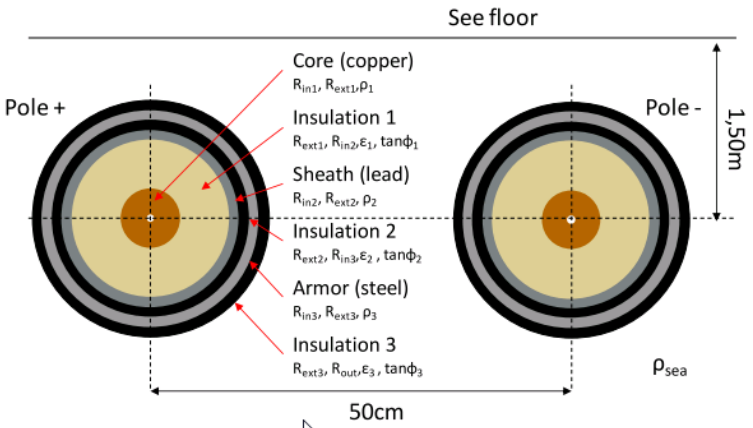
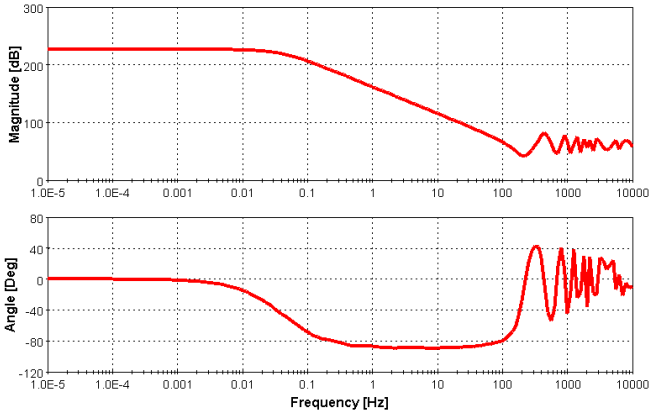
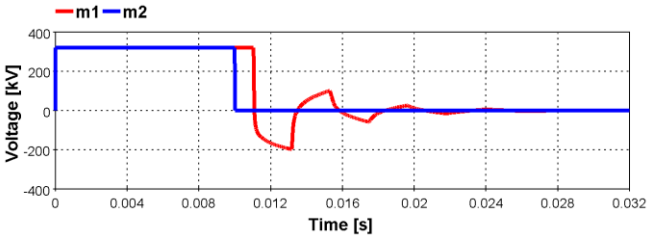


Figure II.7: DC underwater cable layout

Frequency scan



Time domain



04

DCCB embedded functions

DCCB embedded functions

Hybrid DCCB control

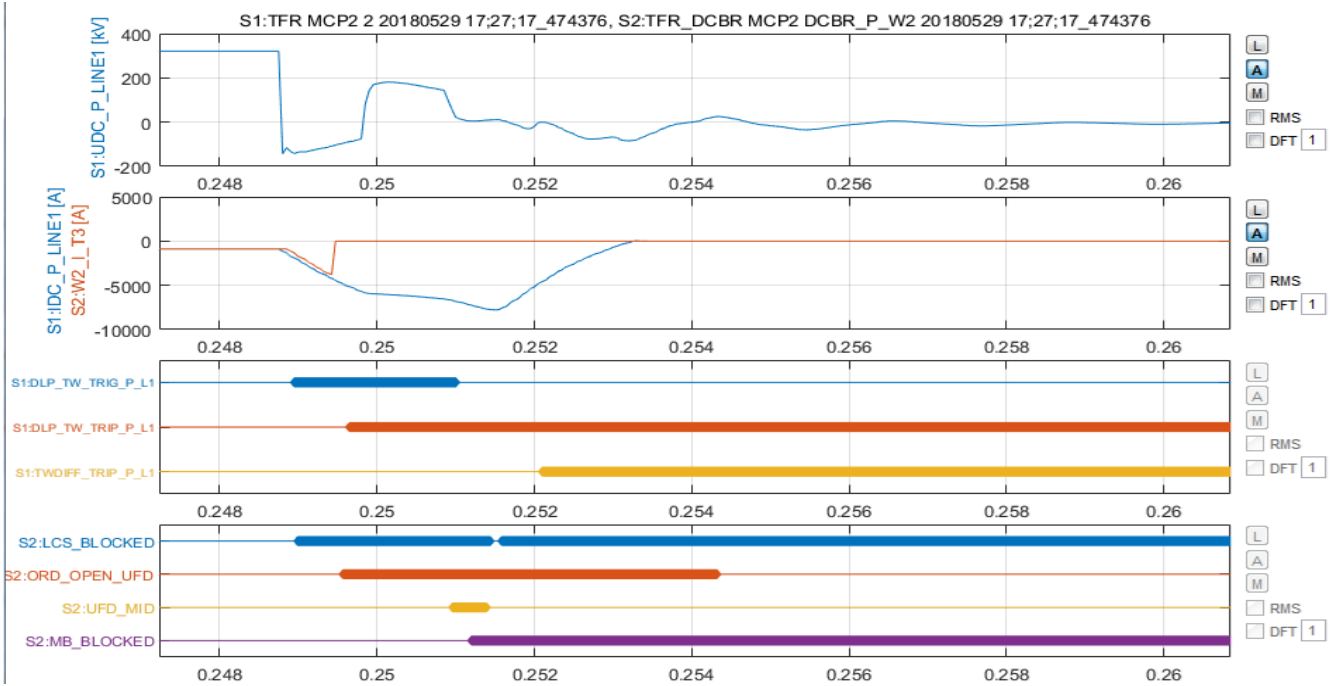
- Block/deblock the LCS
- Open/close UFD, RCDCB
- Block/deblock individually main branch cell
- Control & balance the varistor energy

Functions

- Soft start
- Current limiting functionality
- DC chopper controls
- HVDC grid protection algorithm:
  - locally based: measure & compare the steepness of the incident wave
  - telecommunication based: traveling wave differential protection

DCCB embedded functions

Example of DCCB of fault clearing

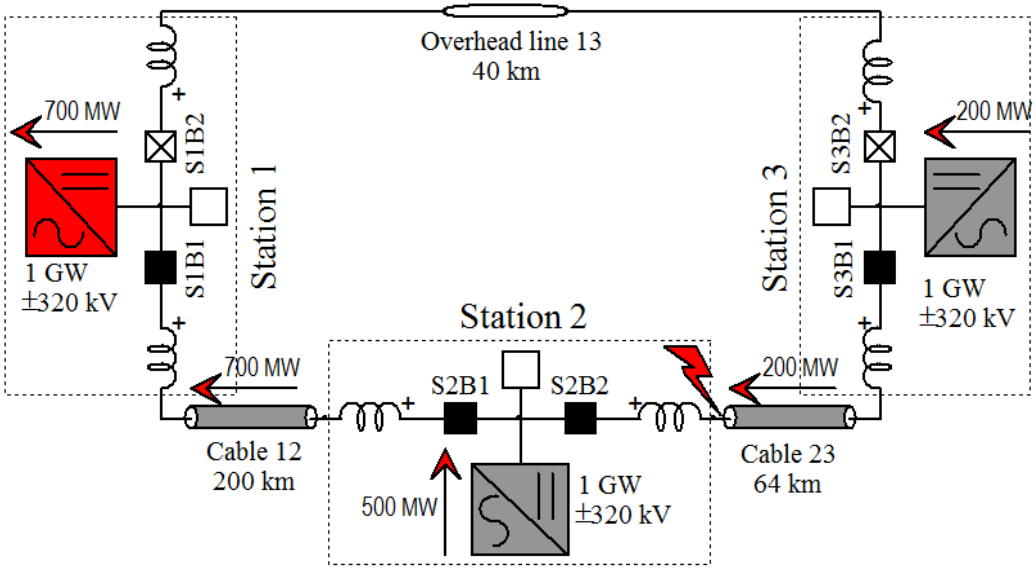


05

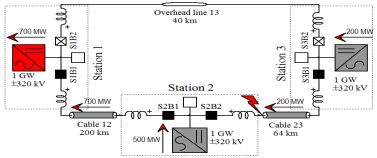
Example of Test Results

Example of Test Results

Scenario considered for the DC fault test case

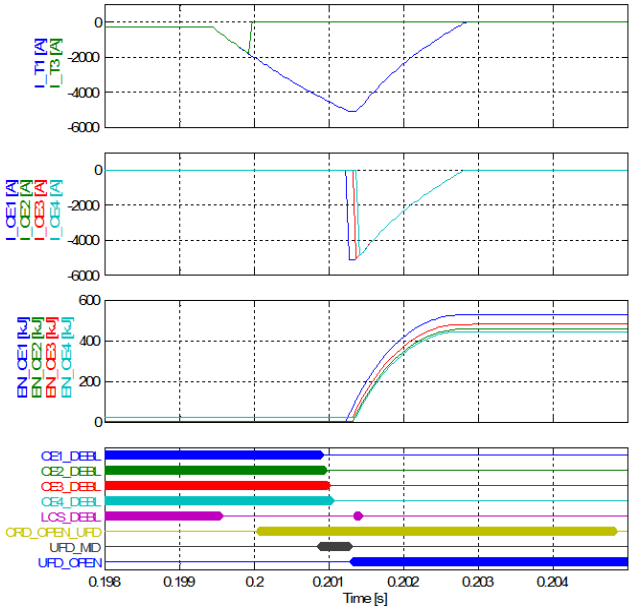


Example of Test Results

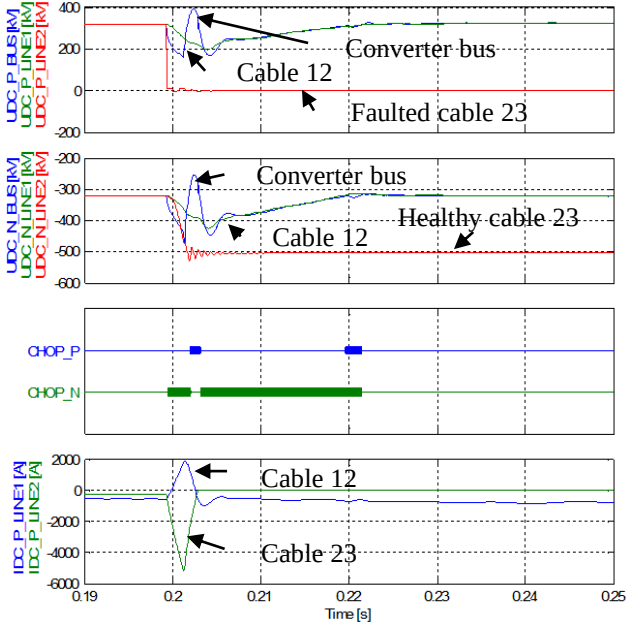


Scenario considered for the DC fault test case

DCCB internal variables



Currents & voltages at station 2



Conclusion

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Summary

- Hardware in the loop set-up built-up for testing DC breakers
- Connect several physical industrial controllers corresponding to latest technology
- Modeling and set-up validation was proven over several representative examples

R&D facility

- Available for preforming future R&D activities around DC grid protections
- Can be extended to other vendor equipment

DCCB HIL set-up contribution

- Demonstrate the effective operation of DC breaker controllers
- Provide more confidence for installation of DC breakers for future DC grid development

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Thank you for your attention.

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[1] P. Rault, M. Yazdani, S. Dennetière, C. Wikstrom, H. Saad, N. Johannesson, “Real-time simulation with an industrial DCCB controller in a HVDC grid” International Conference on Power Systems Transients (IPST'19) in Perpignan, France, June 16-20, 2019

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