

Characterisation of DC Circuit Breakers

June 2018

Dragan Jovcic, University of Aberdeen

PROgress on Meshed HVDC Offshore Transmission Networks



CONTENT

- ↗ Motivation for DC CB characterisation,
- ↗ Overview of WP6 (DC CB characterisation),
- ↗ Common test system and model verification plan,
- ↗ Hybrid DC CB characterisation,
- ↗ Mechanical DC CB characterisation,
- ↗ VARC DC CB characterisation,
- ↗ Hardware DC CB demonstration,



1) Motivation for Characterisation of DC CBs

- DC CBs are new components, not used in power systems previously,
- DC CB technology is much different, and more complex compared with AC CBs,
- There are multiple substantially different DC CB technologies,
- DC CB models are required for DC Grid system studies (protection , power flow, stability, ...),
- It is essential to study component failure modes to understand impact on DC grids,
- Low-power prototypes enable flexibility in hardware-based studies,
- Roadmap for technology development is important for dc grid planners,
- Common platform and verification program for DC CB models,



2) Characterisation of DC CBs, WP overview

	Tasks	Lead	partners	timeframe
6.1	Develop system-level model for hybrid DC CB	UAbdn	ABB, SGI, DNV-GL	M1-M11
6.2	Develop system-level model for mechanical DC CB	DELFT	MEU, DNV-GL	M1-M11
6.3	Develop component-level and real-time model for hybrid DC CB	UAbdn	DELFT, ABB, DNV-GL	M18-M30
6.4	Develop component-level and real-time model for mechanical DC CB	DELFT	MEU, DNV-GL, UAbdn	M18-M30
6.5	Develop kW-size hardware prototypes for hybrid and mechanical DC CBs	UAbdn	ABB, DELFT, DNV-GL	M1-M30
6.6	Demonstrate DC CB failure modes on kw-size hardware prototypes	UAbdn	DELFT	M31-M48
6.7	Analyse hybrid DC CB integration into EHV DC grid	UAbdn	DELFT, TenneT	M31-M48
6.8	Develop roadmap for VARC DC CB scaling to EHV DC voltage	DELFT	SciBreak, TenneT	M31-M48
6.9	Develop standard DC CB verification plan and RTDS models	UAbdn	ABB, DELFT, MEU, DNV-GL, SGI, SciBreak	M12-M24
6.10	Develop roadmap for mechanical DC CB scaling to EHV DC voltage	MEU	DNV-GL, TenneT, UAbdn	M31-M48



3) Common test system and model verification plan

1. General DC CB model verification plan (including self protection),
2. Verification of IGBT-based Hybrid DC CB model,
3. Verification of Thyristor-based Hybrid DC CB model,
4. Verification of Mechanical DC CB model,
5. Verification of VSC assisted (VARC) mechanical DC CB model,
6. RTDS (Real Time digital Simulation) modelling and verification of IGBT based hybrid DC CB,
7. RTDS modelling and verification of mechanical DC CB,



3) Common test system and model verification plan

General DC CB model verification plan,

1. Test circuit

- Agreed with all participants,
- Realistic 320kV case with DC cable,
- Representing difficult case,

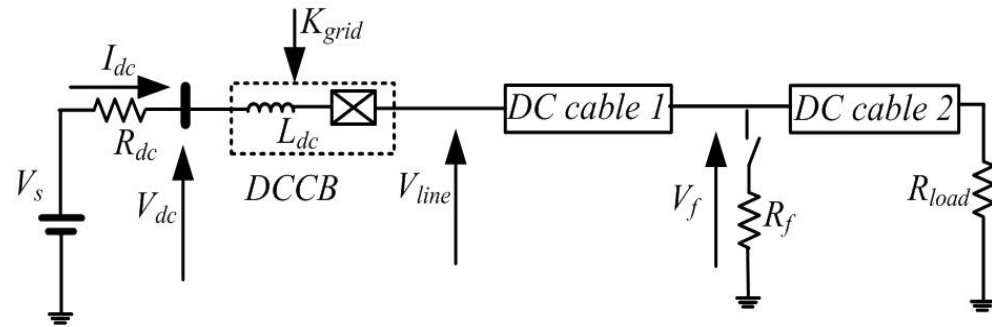


Figure 1. Test circuit for DC CB model verification.

2. Model testing with external trip signal

- Opening on rated interrupting current,
- Opening on low load current (0.01kA-0.2kA),
- Closing on load current,
- Repeated open-close (Reclosing in fault)
- Reverse current direction (all the above),

3. Model testing with no external trip signal (self protection)

- Low impedance fault,
- High-impedance fault,

4. Model testing with different parameters

- Different L_{dc} ,
- Different cable parameters,

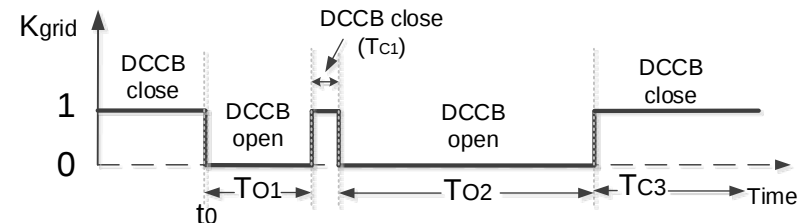


Figure 2. Open-close sequence for DC CB model verification.



4) Hybrid DC CB characterisation

Hybrid DC CB model:

1. 320kV, 16kA test system,

2. Detailed model:

- Load Commutation switch,
- Ultrafast disconnecter,
- Main valve,
- Energy absorber,

3. DC CB Controller

- Opening sequence,
- Closing sequence,
- Self protection,

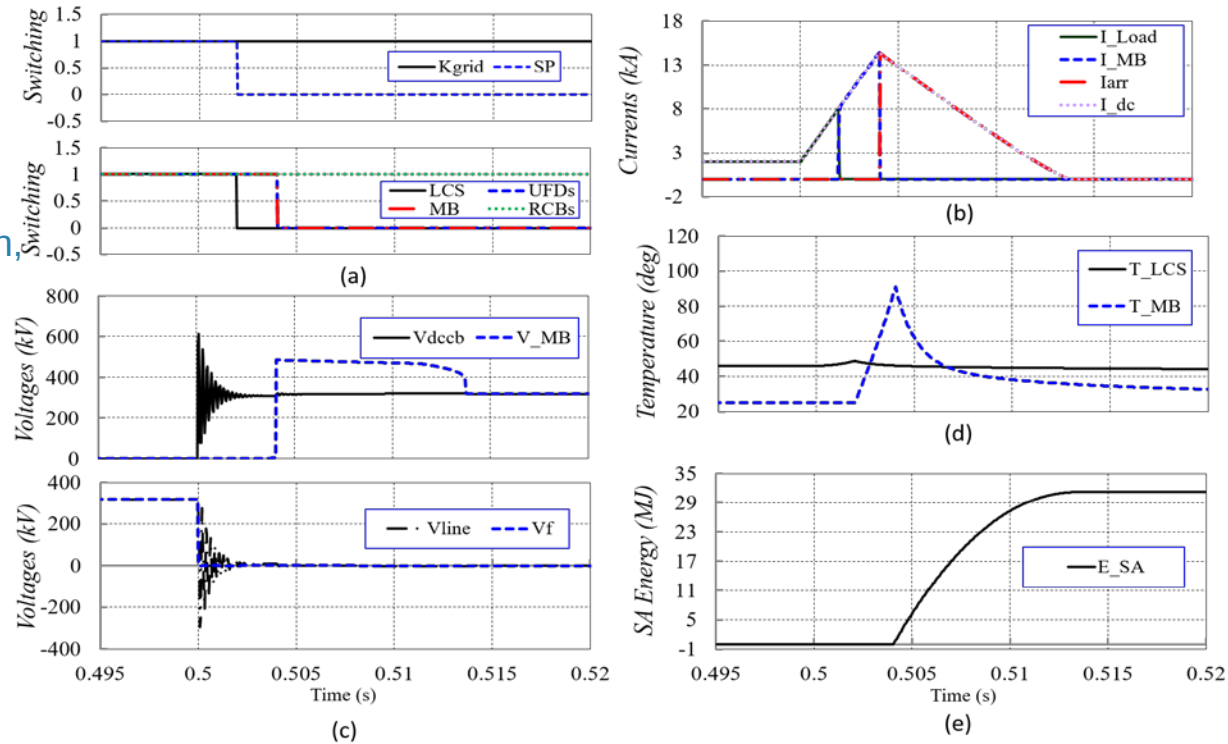


Figure 4. Hybrid DC CB operating under self-protection.

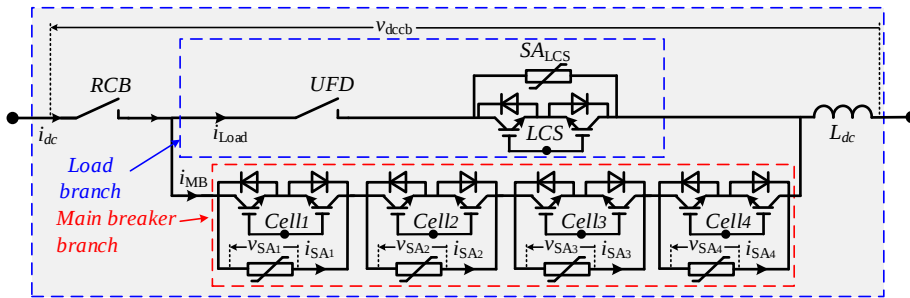


Figure 3. Hybrid DC CB.



4) Hybrid DC CB characterisation

Fault current limiting:

1. Enables control of fault current for a limited time period,
2. Can be used for connecting circuits (starting resistors),

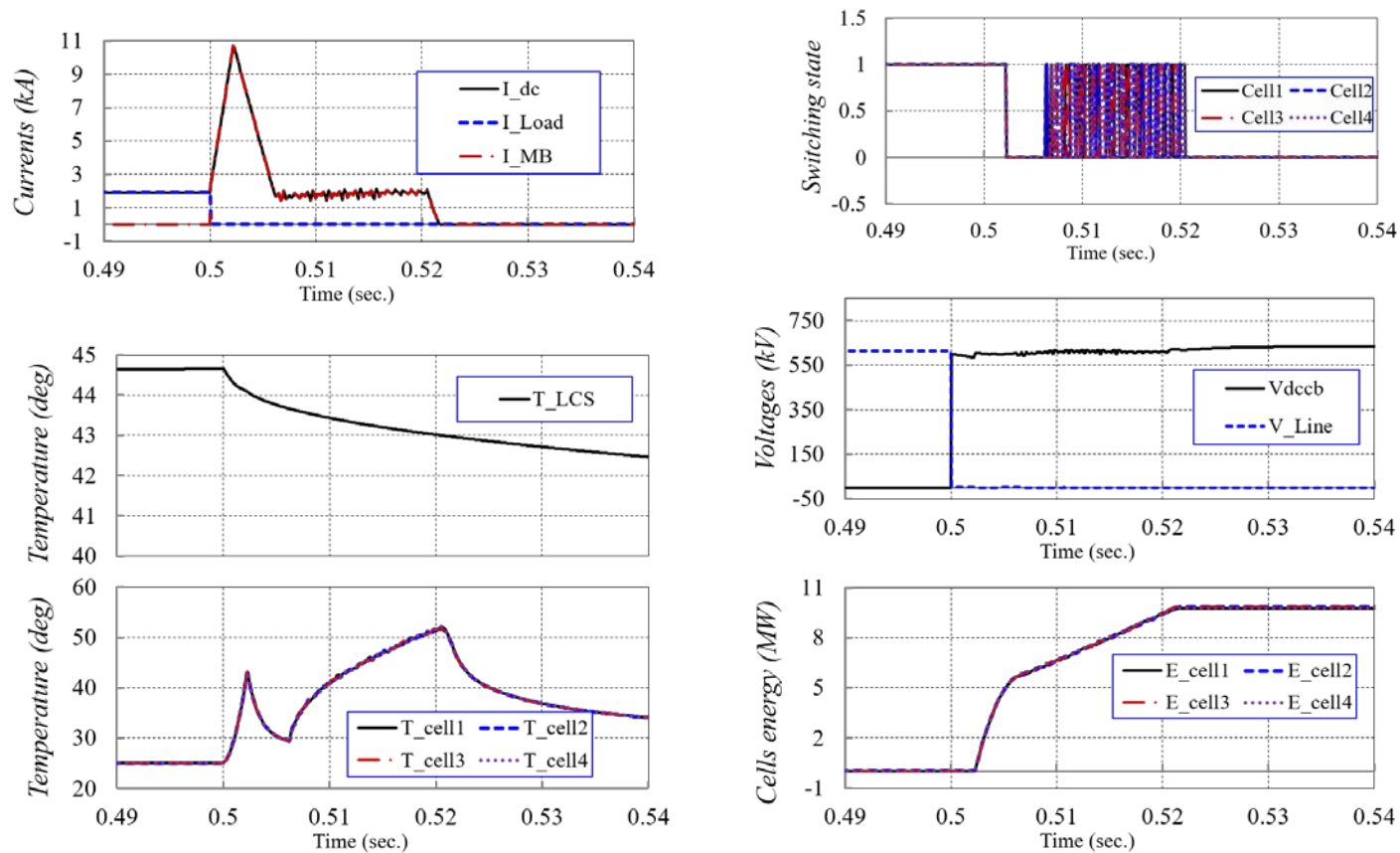


Figure 5. Fault current limiting with hybrid DC CB.



5) VARC DC CB characterisation

VARC DC CB (from Scibreak) model

1. Main interrupter,
2. Resonant circuit,
3. VSC converter,
4. Energy absorber,
5. Residual breaker,

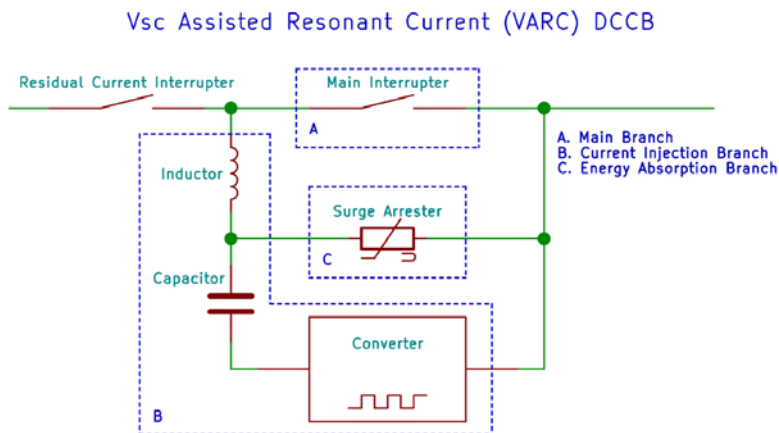


Figure 8. VARC DC CB.

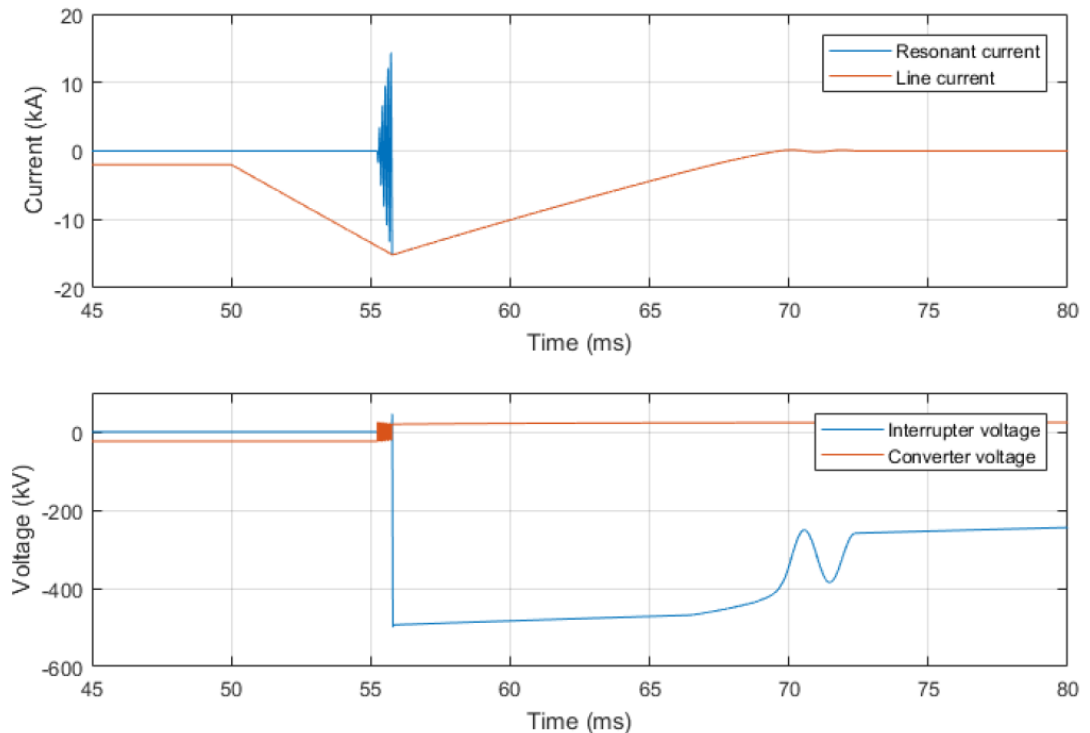


Figure 9. VARC DC CB opening on rated fault current.



6) Hardware DC CB demonstration

Purpose of hardware DC CB demonstration

1. Demonstrate hardware DC CB on reasonable power levels,
2. Same (as close as possible) topology as high-power DC CBs
3. Provide flexibility for testing:
 1. failure modes,
 2. new topologies,
 3. new controls,

Hardware includes:

1. Test circuit 900V, 500A,
2. Hybrid DC CB 900V, 500A, 1kJ,
3. Mechanical DC CB 900V, 500A, 2kJ,

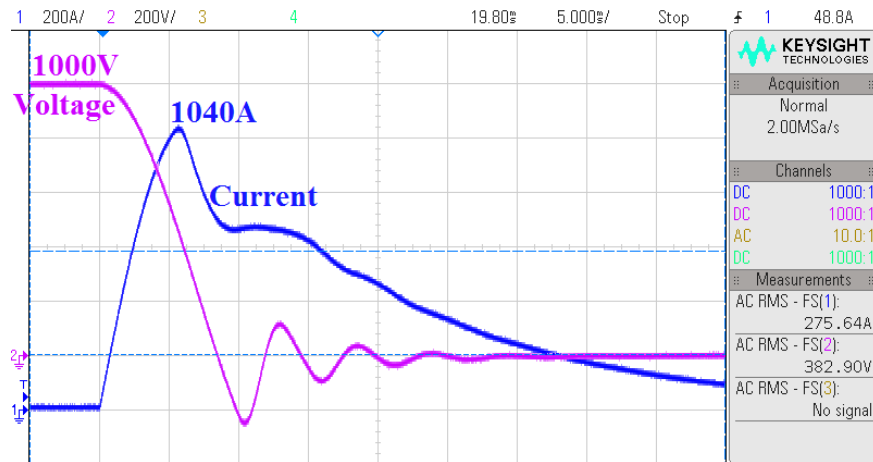


Figure 10. Testing DC CB test circuit.



Figure 11. DC CB test circuit and hybrid DC CB.



6) Hardware DC CB demonstration

Hybrid DC CB demonstration:

1. Ultrafast disconnecter, 2ms, 3mm (9kV).
2. 900V, 500A, 2ms, 1kJ.
3. Fault current limiting,

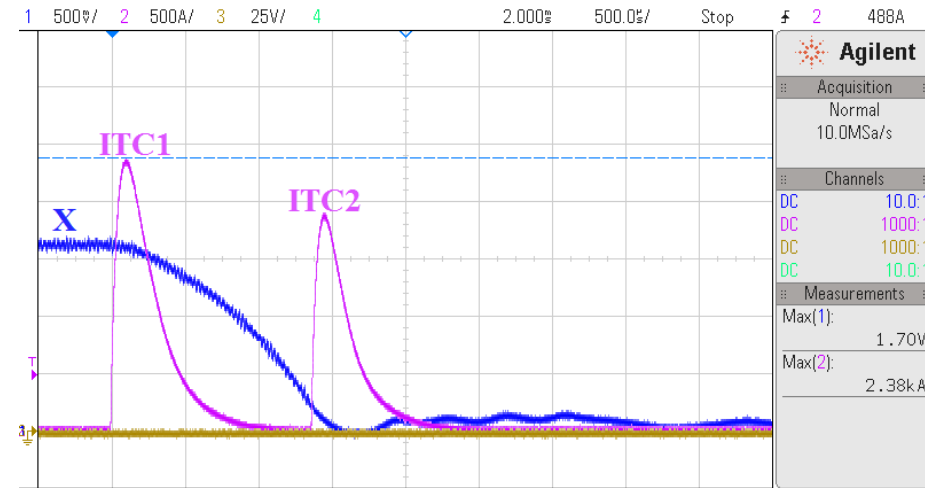
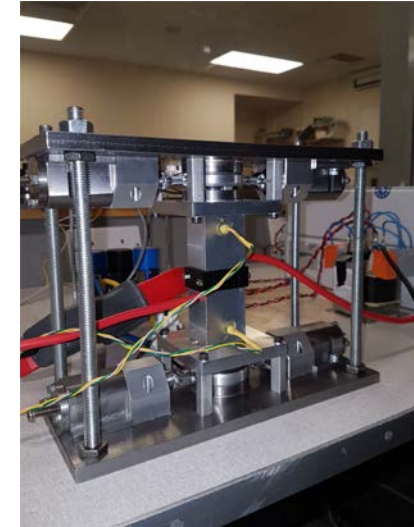
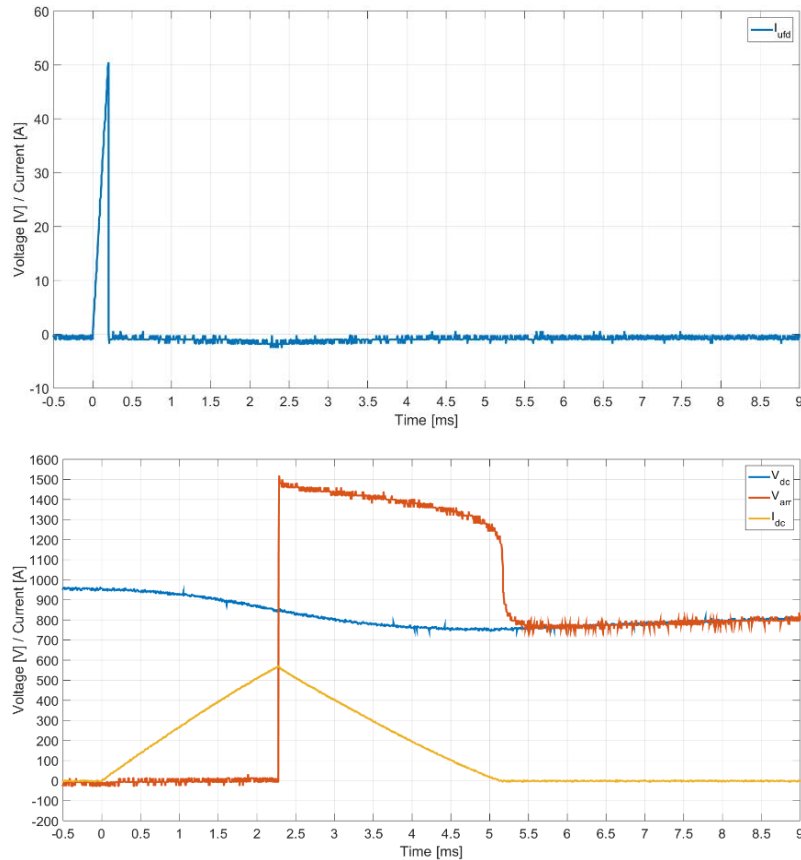


Figure 12. Hardware hybrid DC CB interrupting 500A

Figure 13. Ultrafast disconnecter with magnetic braking .



6) Hardware DC CB demonstration

New control method is studied: (Voltage control of ultrafast disconnecter)

1. Enables faster operation of hybrid DC CB,
2. Peak current is lower,
3. Energy dissipation is lower,
4. Demonstrated on model and on hardware,

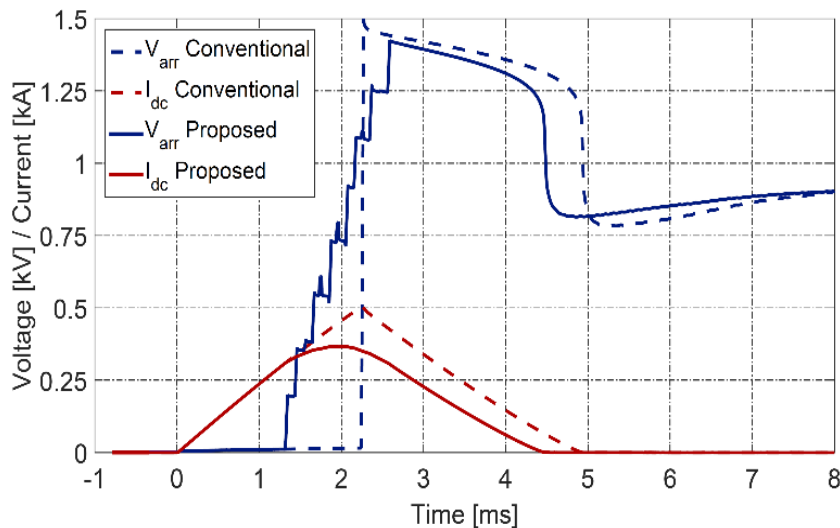


Figure 14. Voltage and current with UFD voltage control.

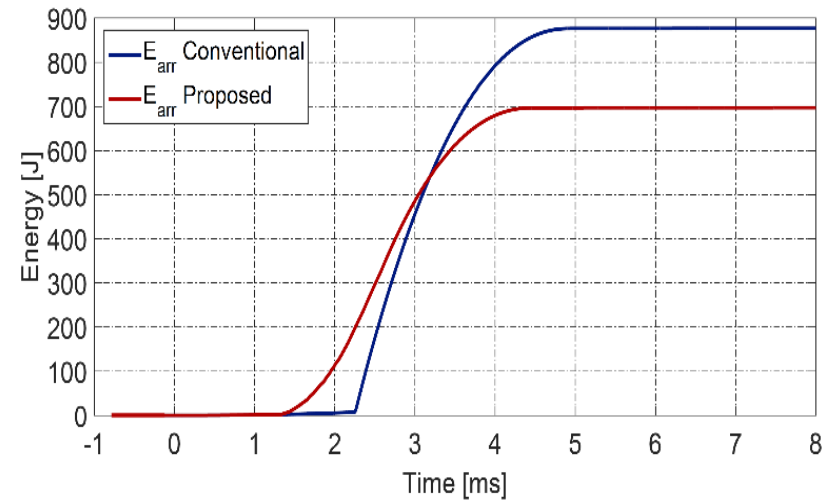


Figure 15. Energy with UFD voltage control.



6) Hardware DC CB demonstration

Mechanical DC CB :

1. 3 x 900V vacuum interrupters,
2. LC resonant circuit,
3. Energy absorber,
4. Opening time is 5ms,

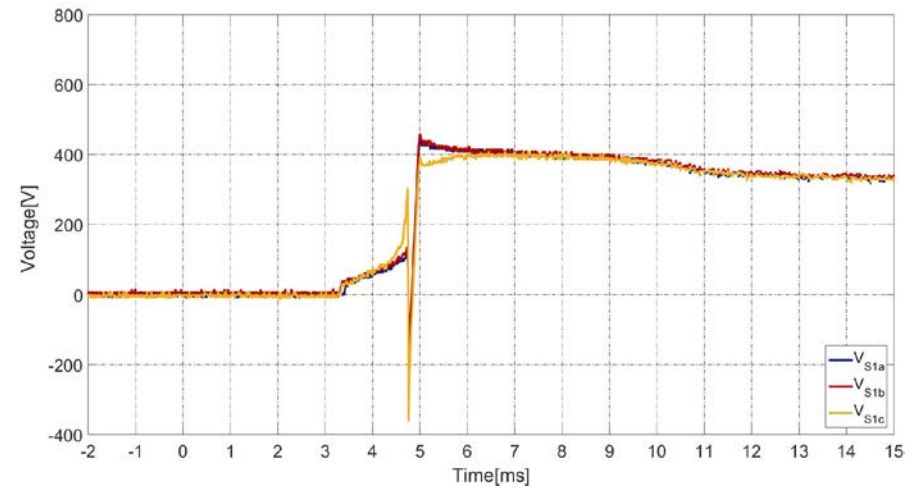
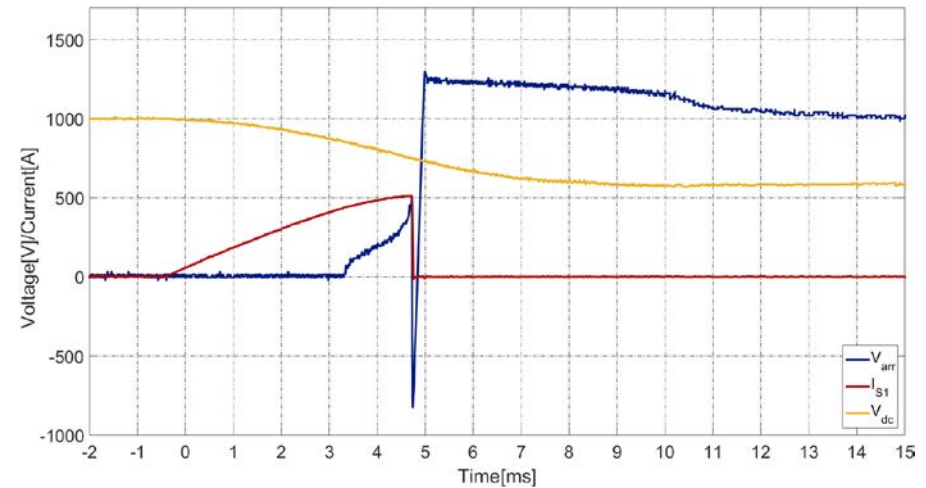
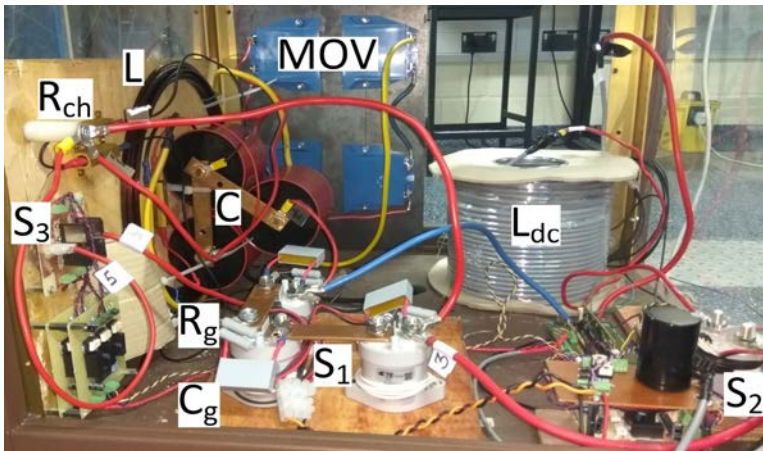


Figure 16. Hardware mechanical DC CB.

Figure 17. Opening on 500A with mechanical DCCB .



Conclusions

1. DC CB Models completed,
 - a. Hybrid DC CB,
 - b. Mechanical DC,
 - c. Thyristor-based hybrid DC CB,
 - d. VARC DC CB,
2. RTDS models completed,
3. Hardware demonstrators completed,
 - a. Hybrid DC CB,
 - b. Mechanical DC CB,
4. On going work on new DC CB topologie and control,
5. On going work on new DC CB failure mode analysis,
6. Forthcoming work:
 - a. Roadmap development for all 3 topologies,
 - b. Failure mode study,

