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Detailed Modelling of MMC-HVDC Links

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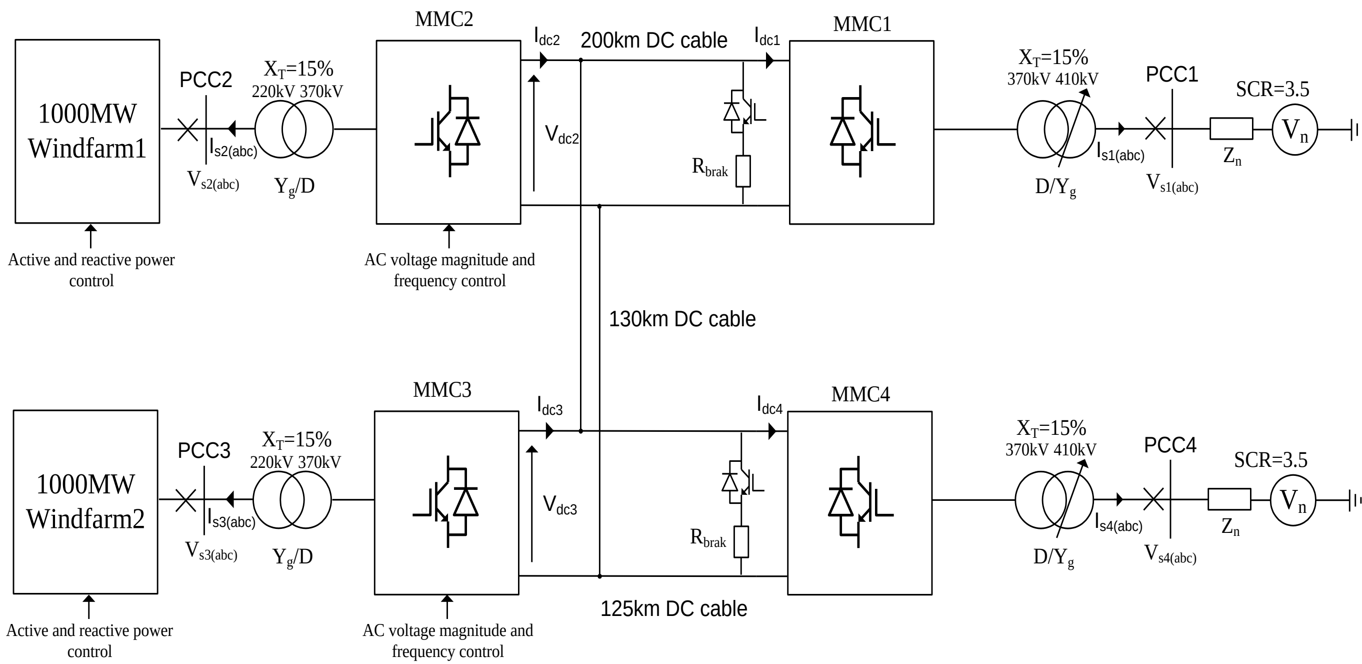
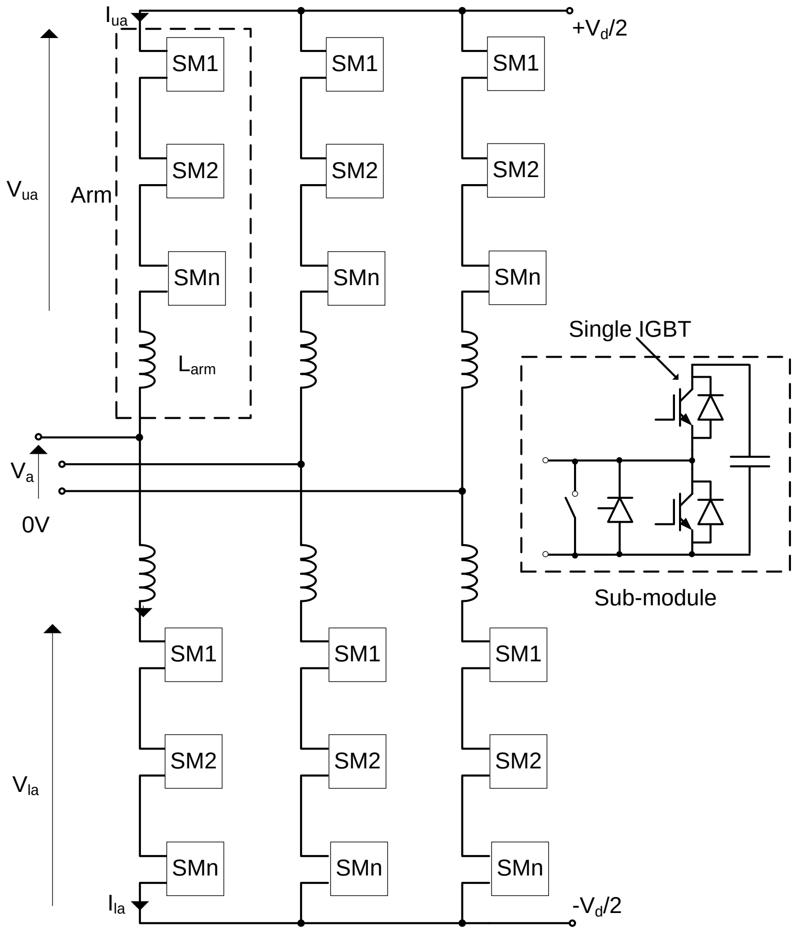
VSC-HVDC

- Demand for VSC-HVDC systems is growing worldwide.
- Modular Multi-level Converters (MMC) is the VSC topology of choice.
- Focus is on the DC components

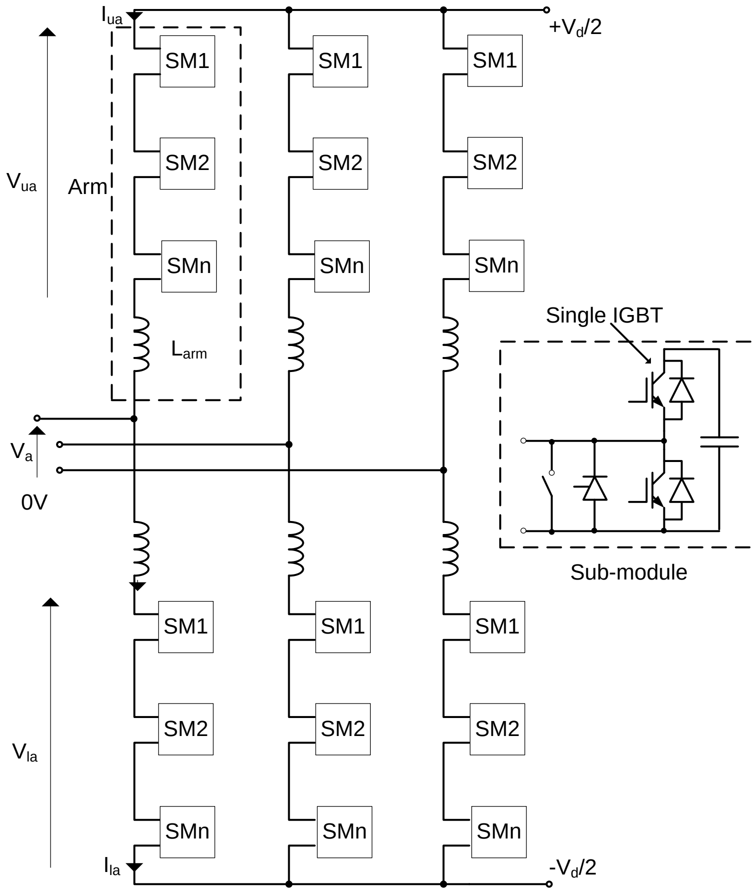


MMC



- Types of MMC
  - Half-bridge
  - Full-bridge
  - Alternate arm converter
- Selecting MMC Parameters
  - Number of voltage levels
  - SM capacitance
  - Arm reactance

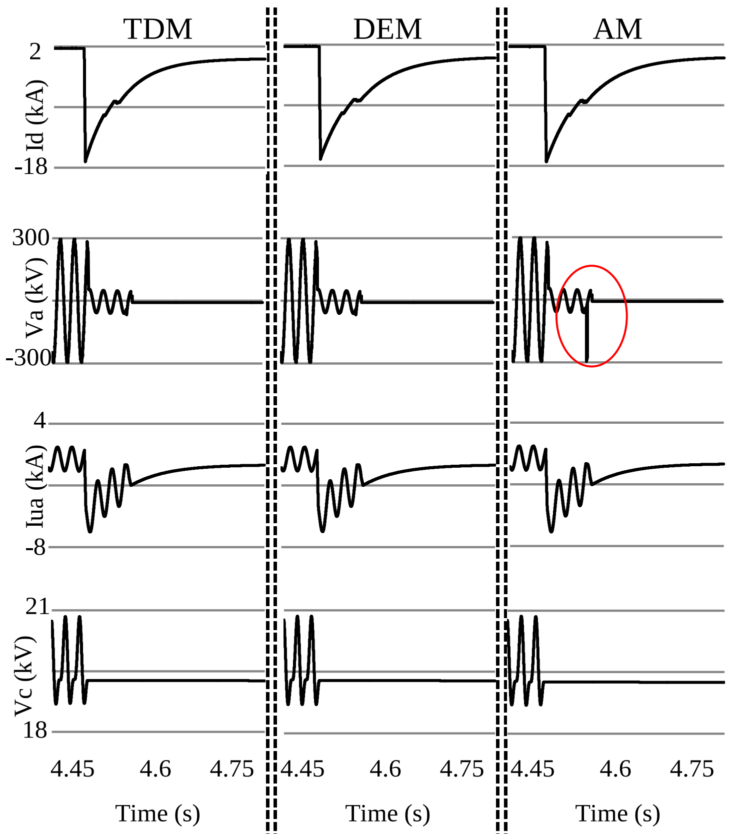
MMC Modelling Techniques



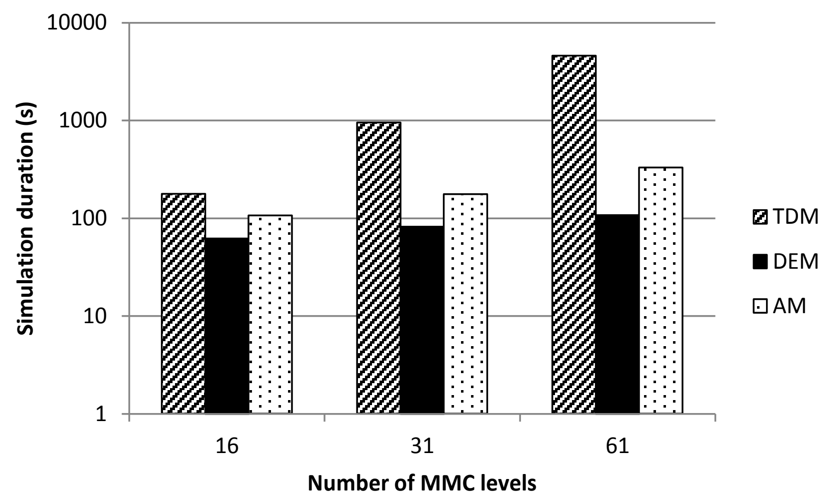
- Type 1 – Full physics based model
- Type 2 – Full detailed model
- Type 3 – Traditional detailed model (TDM)
- Type 3.5 – Accelerated model (AM)
- Type 4 – Detailed equivalent model (DEM)
- Type 5/6 – Average value model (AVM)
- Type 7 – Phasor domain model
- Type 8 – Power flow model

Comparison of TDM(3), AM(3.5) and DEM(4)

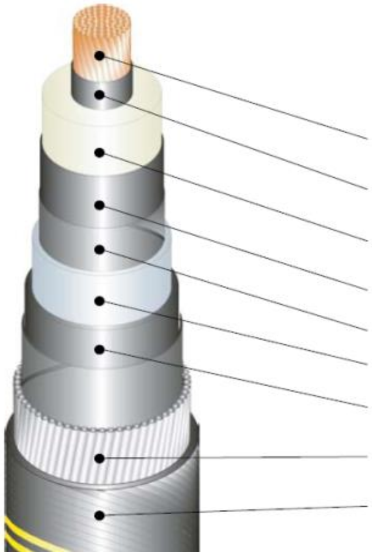
DC line-to-line Fault



DC Fault		
Signal	DEM error (%)	AM error (%)
I_d	0.41	2.29
V_a	0.22	1.12
I_{ua}	0.51	1.83
V_c	0.07	0.07



HVDC Cable Modelling



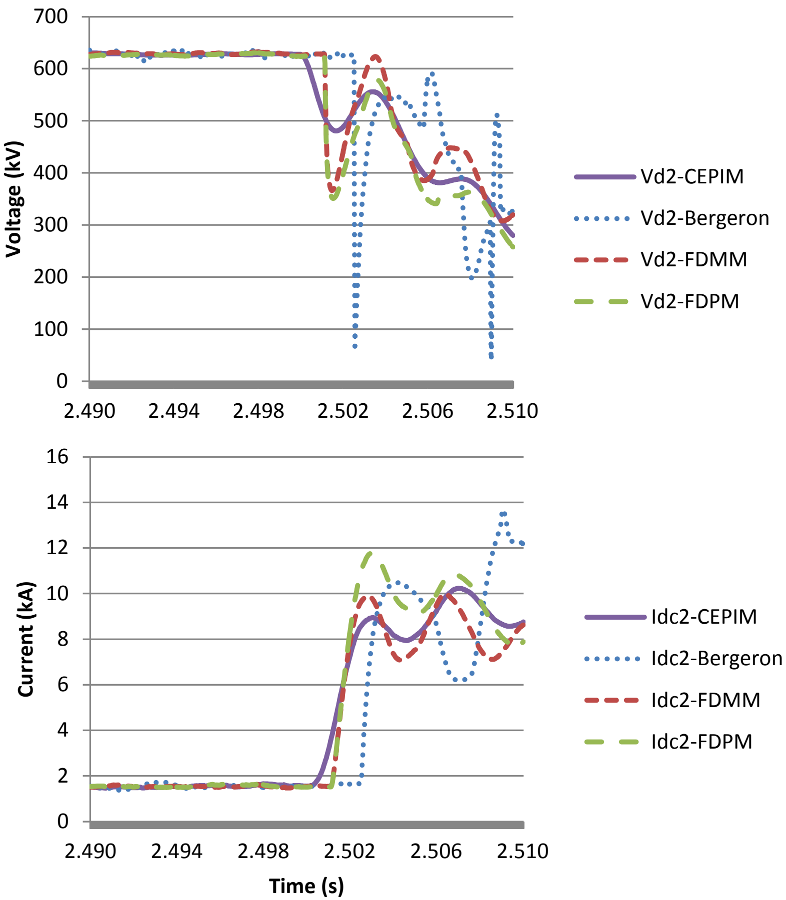
Types of HVDC Cable Model:-

- Lumped Parameter Model
- Bergeron Model
- Frequency Dependent Mode Model (FDMM)
- Frequency Dependent Phase Model (FDPM)

Layer	Material	Radial Thickness (mm)	Resistivity (Ω/m)	Relative Permittivity	Relative Permeability
Conductor	Stranded Copper	24.9	2.2×10^{-8}*	1	1
Conductor screen	Semi-conductive polymer	1	-	-	-
Insulation	XLPE	18	-	2.5	1
Insulator screen	Semi-conductive polymer	1	-	-	-
Sheath	Lead	3	2.2×10^{-7}	1	1
Inner Jacket	Polyethylene	5	-	2.3	1
Armour	Steel	5	1.8×10^{-7}	1	10
Outer cover	Polypropylene	4	-	1.5	1
Sea-return	Sea water/air	-	1	-	-

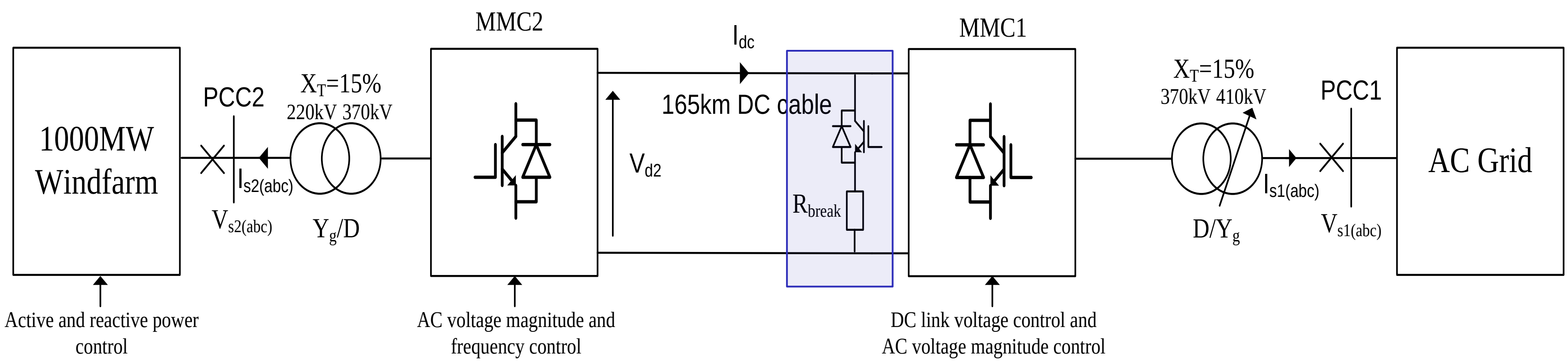
*Copper resistivity is typically given as 1.68×10^{-8}Ω/m. It has been increased for the cable model in PSCAD due to the stranded nature of the cable which cannot be taken into account directly in PSCAD.

Comparison of Cable Models



- The choice of cable model can have a significant impact on the simulation results.
- Computational efficiency is approximately the same for the travelling wave models.
- The CEPIM was found to be the least computationally efficient model.
- FDPM is therefore the default model of choice for typical VSC-HVDC studies in this work.

Dynamic Braking System



- Typically employed for HVDC windfarm connections
- Normally located onshore
- Common models:
  - Voltage dependent current source
  - Power electronic switch with resistor
  - Control – Two level switching, PWM etc.

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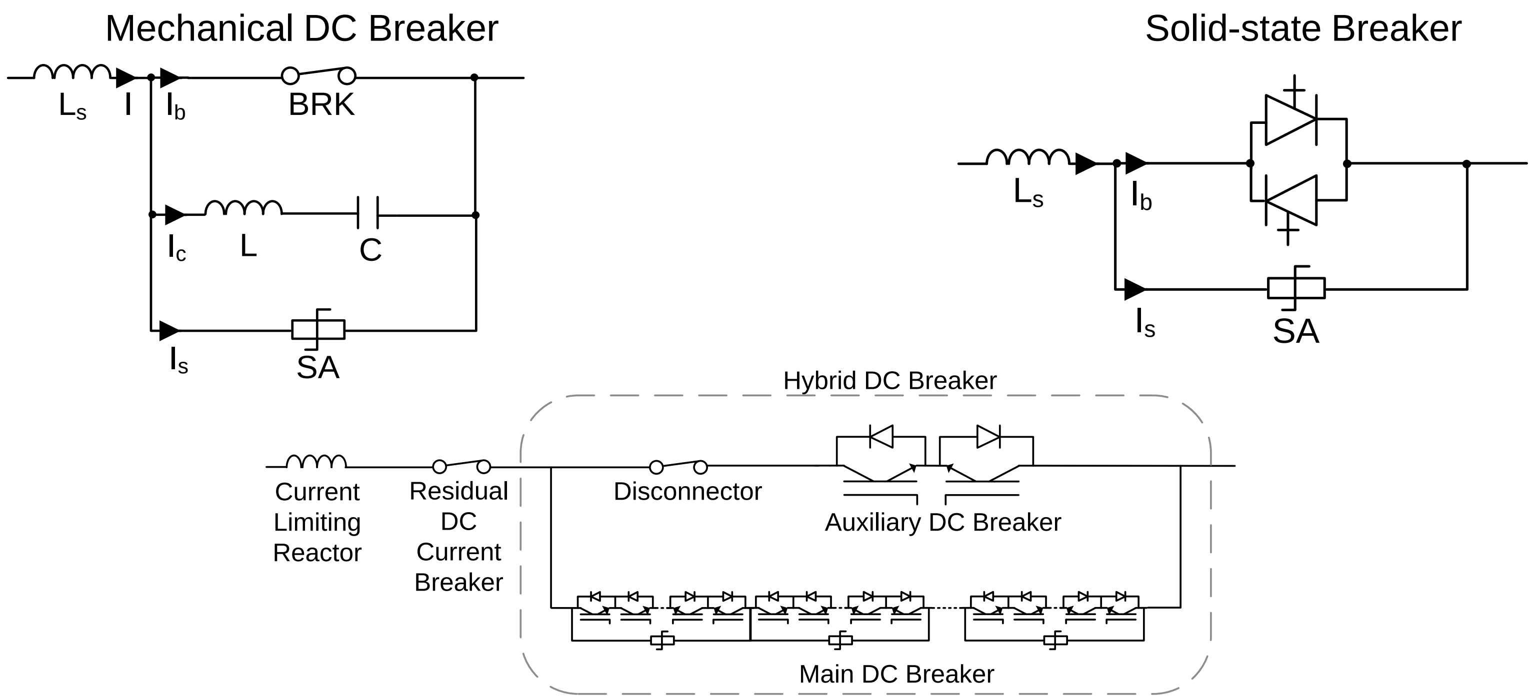
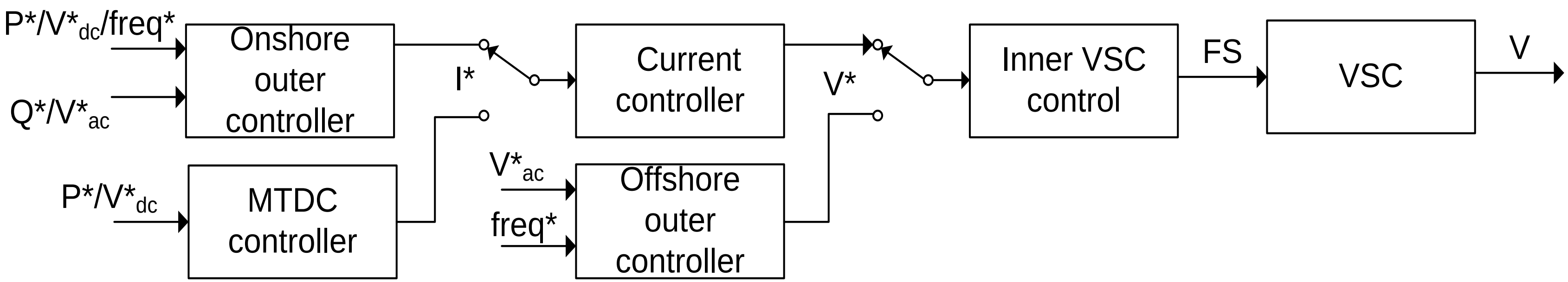
HVDC Circuit Breaker

SUPERGEN WIND



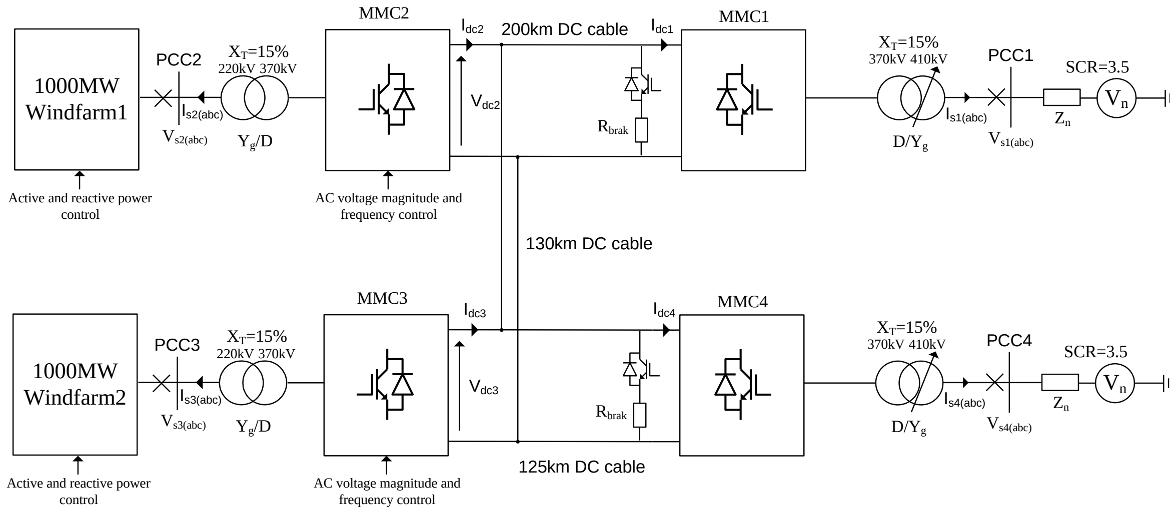
- Required for large HVDC grids
- Hybrid DC breakers are currently the preferred topology
- Modelling options – Cigre WG B4-57 technical brochure

Control



- MMC Control
  - Modulation - Nearest level control (NLC), selective harmonic elimination etc.
  - Capacitor balancing controller (CBC)
  - Circulating current suppressing controller (CCSC),
  - Outer controllers similar to traditional VSCs. i.e. not specific to valve topology

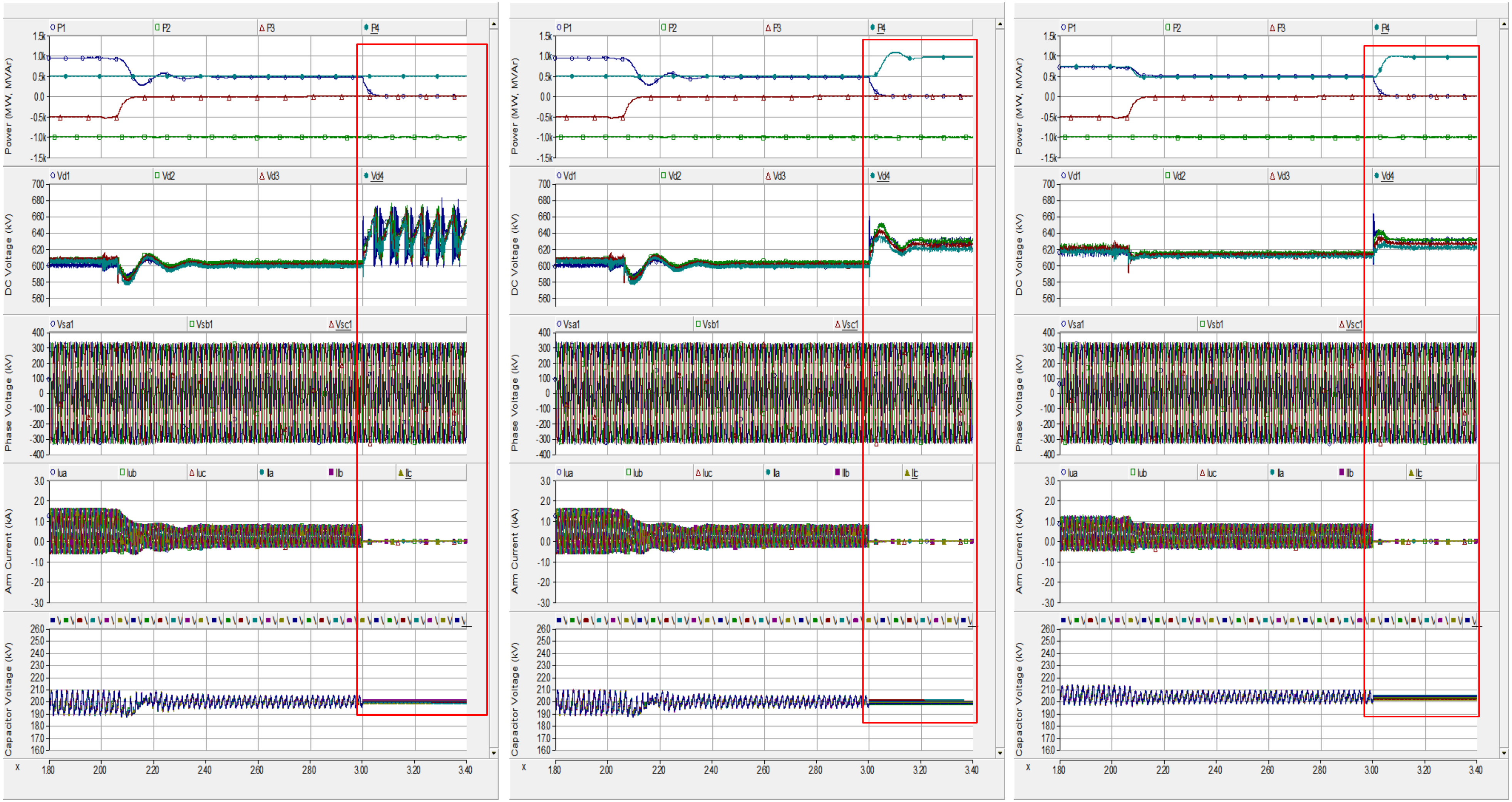
MTDC Control Strategies



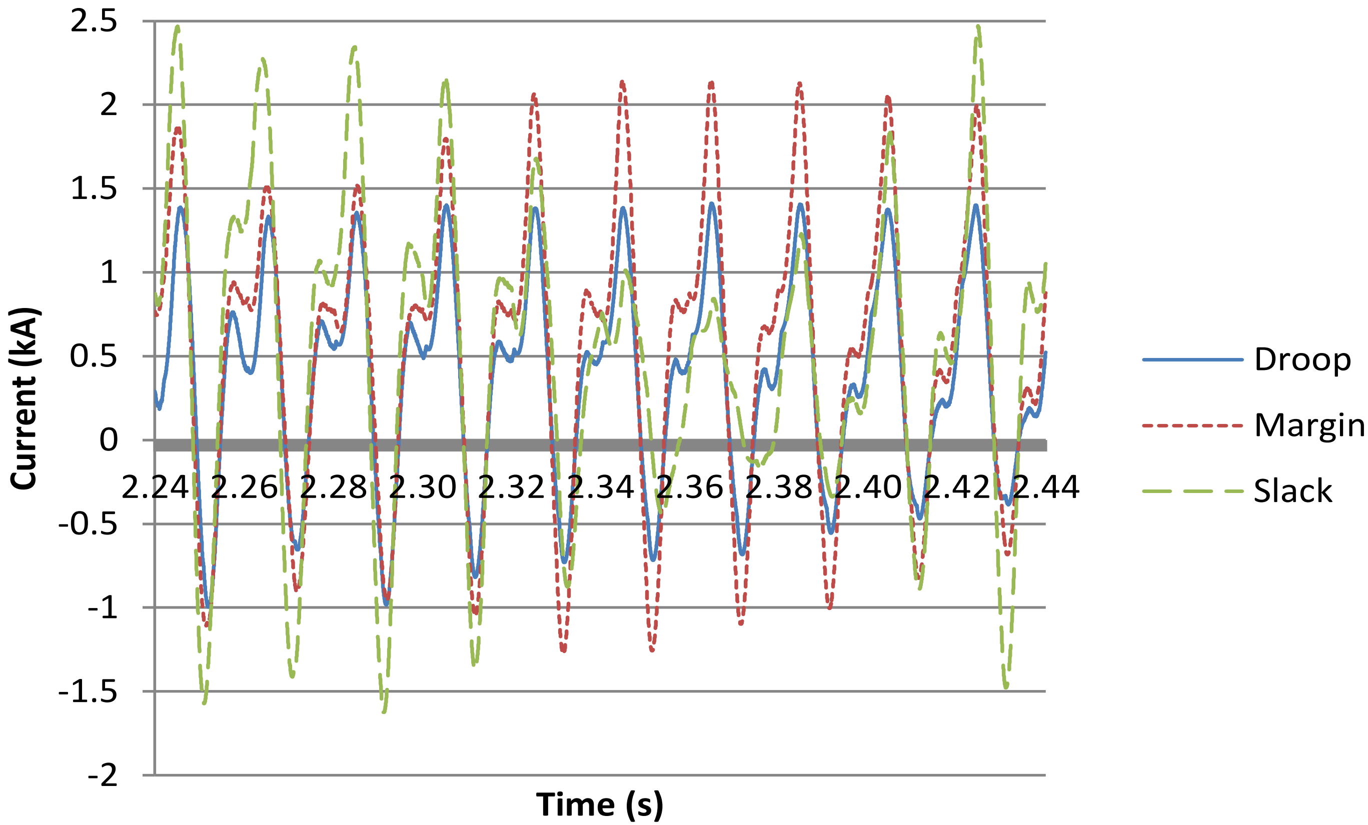
Control Method	MMC1 control mode	MMC4 control mode	Comments
Centralised DC slack bus	DC voltage & AC voltage magnitude	Active power & reactive power	P*=500MW
Voltage margin control	DC voltage & AC voltage magnitude	Voltage margin & reactive power	Vd-High=620kV, Vd-Low=580kV
Droop control	Standard droop & AC voltage magnitude	Standard droop & reactive power	Droop gain =- 0.1

Example Simulation Results – MMC disconnection

Centralised DC slack bus | **Margin Control** | **Droop control**



Example Simulation Results – MMC1 AC fault



Thank you!

References

- Slide 1 – Picture courtesy of: Danish Energy Authority (left) CleanTechnica (right)
- Slide 6 - Picture courtesy of ABB