Study Committee B4

DC SYSTEMS & POWER ELECTRONICS

899

Severity adapted fault clearing strategy for MTDC grids including cables and overhead lines

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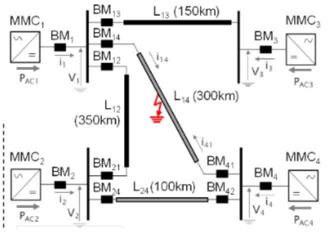
Motivation

- A cost effective solution is to convert existing AC Overhead Line (OHL) corridors into DC lines or to build new DC OHL, rather than installing new cables
- New challenges for MTDC protection design
  - Higher fault probability (12 times higher compared to cables)
  - Different transient characteristics (OHLs have a higher lineic inductance than cables and fault resistances of several tens of Ohms)
- Impact on non-selective fault clearing strategies
  - A fault event leads to a lower voltage drop and lower fault current contribution which may entail fault detection failures at distant substations
  - Increasing frequency of temporary shutdown of the entire MTDC grid due to higher fault probability

Conductor characteristics comparison

Characteristics		Cable	Overhead line
Conductor	Surge impedance	27Ω	360Ω
	Lineic inductance	0.12 mH/km	1.5 mH/km
	Lineic capacitance	241 nF/km	8,3 nF/km
	Mutual coupling	Negligible	High
Fault	Fault probability	0.07f/100km*y	0.83f/100km*y
	Fault resistance	0-1Ω	0-500Ω



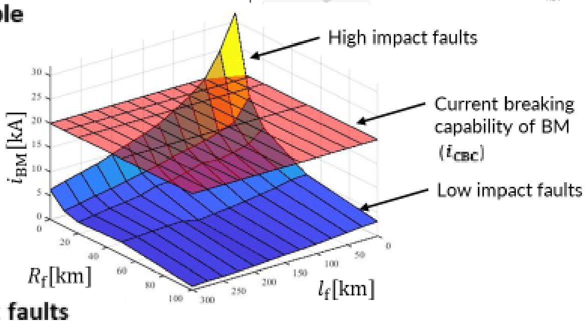
Severity adapted fault clearing principle

Fault impact zone classification:

Low impact faults: $i_{BM}(R_f, l_f, T_{op}) < i_{CBC}$

High impact faults: $i_{BM}(R_f, l_f, T_{op}) > i_{CBC}$

BM: Breaking module



Selective fault clearing for low impact faults

Fault detection → Faulty line isolation

Adjacent breaker opening for high impact faults

Fault detection → Fault current suppression by adj. BMs → Faulty line isolation → Reclosing of adj. BMs

Cable faults: Adjacent breaker opening at both busbars

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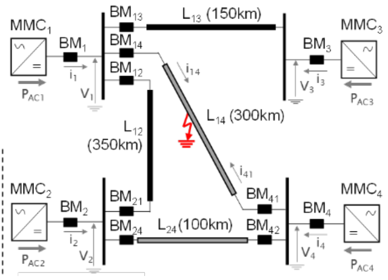
Benchmark grid

- Bipolar configuration with DMR
- Hybrid topology with cables and overhead lines
- DCCBs (T_{op}=10ms) at line ends & MMC output
- Optimized DC reactor design (<35mH)
- Extensive testing (136 fault scenarios)

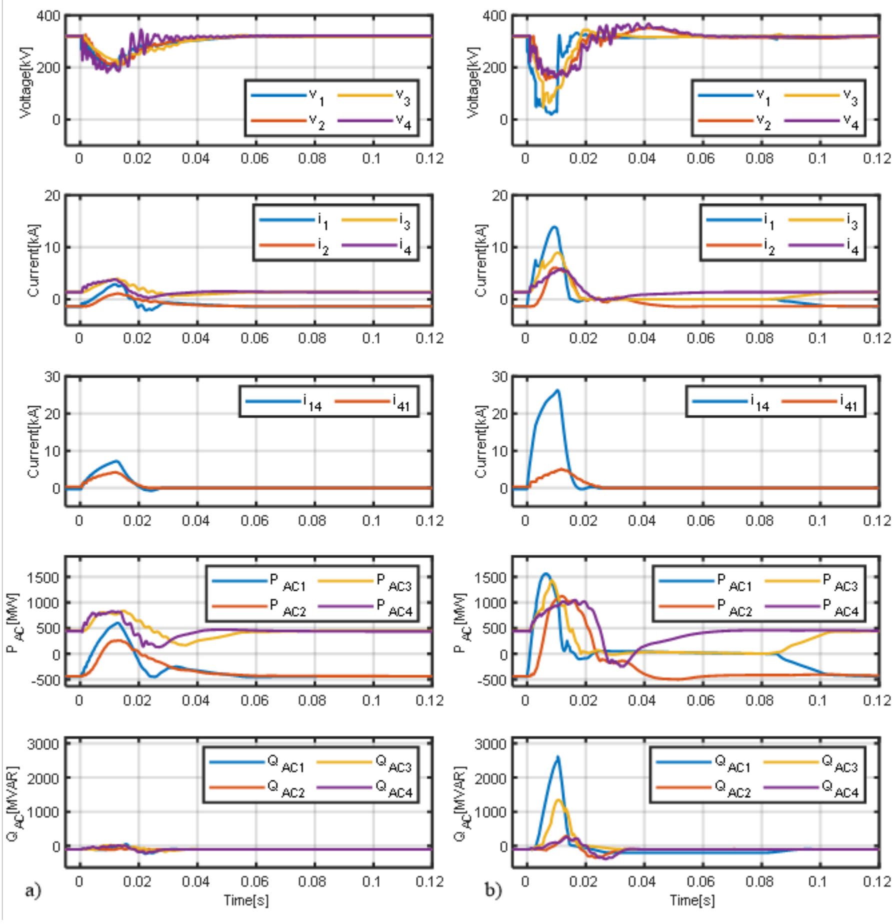


Low impact fault clearing

(Fault at 33% of L14, Rf=10Ω)

High impact fault clearing

(Fault at 0% of L14, Rf=0Ω)



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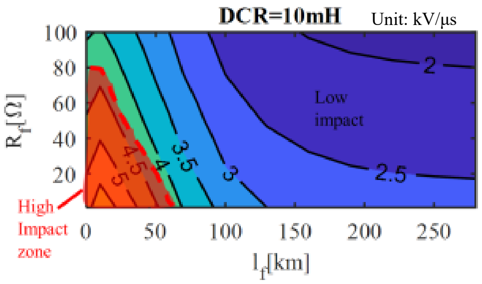
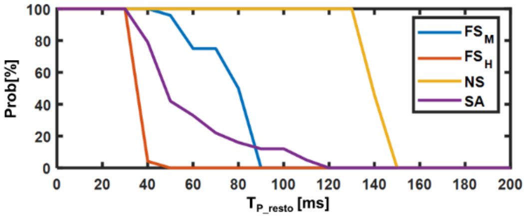
Fault severity discrimination algorithms

- Rate Of Change Of Voltage (ROCOV)
- Model based algorithms
- Wavelet transformation algorithm



Comparison with existing protection strategies

	Severity-adapted	Non-selective	Fully-selective $T_{op,DCCB}$=10ms	Fully-selective $T_{op,DCCB}$=2ms
Sum of DCR [mH]	223	40	2288	880
Sum of energy absorption [MJ]	187	108	311	97
CAPEX per pole [M€]	55	53	70	88
Comparison of CAPEX	63%	60%	80%	100%



Conclusions

- Novel severity-adapted protection strategy for MTDC grids consisting of cables & overhead lines
- Improvement of power restoration time compared to non-selective protection strategies
- Significant reduction of CAPEX compared to protection equipment required for fully-selective fault clearing strategies

Compared to non-selective protection strategies

- Significant power restoration performance improvement compared to non-selective strategies
- Faster power restoration
- Higher grid availability

Compared to fully-selective protection strategies

- Significant reduction of DC reactor requirements
- The proposed protection strategy uses cost effective mechanical DC breakers instead of ultra-fast hybrid DC breakers and lower value of DC reactors which further reduces the cost and the risk of DC voltage dynamic instabilities.
- The proposed strategy is able to selectively eliminate the fault for most of the OHL faults with a power restoration time close to full-selective strategies