MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019
Wed-Mo-Po3.09-06 [68]

Analysis of R-SFCL with Parallel Shunt Resistor in MMC-HVDC System

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***Abstract*— R-SFCL has a board application prospect in MMC-HVDC system. However, the R-SFCL will quench due to fault current, which results in temperature rise and may damage superconducting coils. A shunt resistor in parallel can protect the superconducting coils, but the influence has not been quantitatively calculated. This work proposed a novel *R-Q* curve method to calculate quenching resistance of R-SFCL. Using this method, the influence of shunt resistor to R-SFCL is analyzed in terms of current-limiting effect and maximum temperature. Performance of R-SFCL with different shunt resistance is compared, and the optimal shunt resistance value is obtained.**

Basic structure of R-SFCL

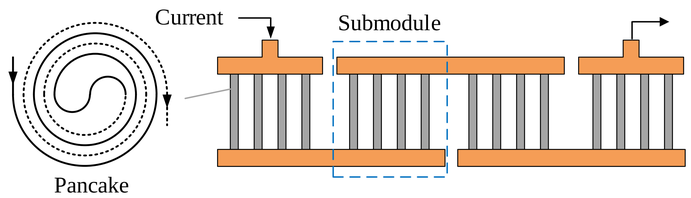


Fig. Configuration of non-inductive pancake and R-SFCL

Tab. Parameters of R-SFCL

Parameter	Value
Rated voltage	160kV
Critical current	2kA
No. of turns	24
No. of pancakes	16

R-Q curve method to calculate quenching resistance

Experiments show that there is a corresponding relation between quenching resistance *R* and the accumulated joule heat *Q*.

An *R-Q* method to calculate quenching resistance is proposed. Result is well fitted with finite element method (FEM) and experiments.

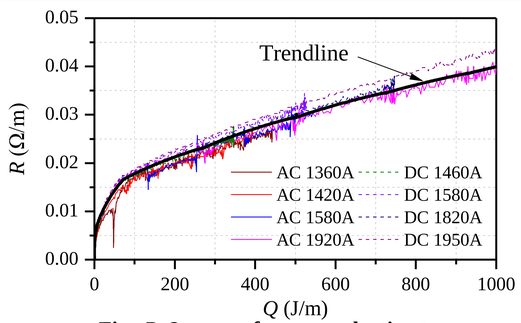


Fig. *R-Q* curve of superconducting tapes.

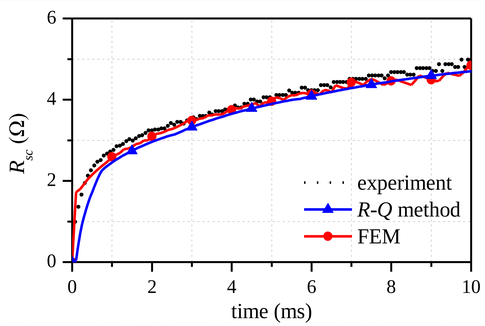


Fig. Calculation result of *R-Q* method compared with experiment and FEM.

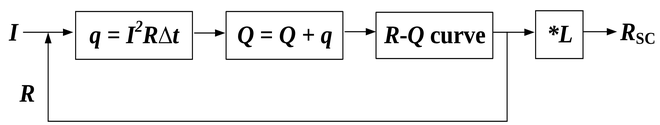


Fig. Calculation process of *R-Q* curve method

The *R-Q* method is coupled with system simulation to calculation quenching resistance. And FEM is used to calculate magnetic file and temperature.

Analysis of R-SFCL with shunt resistor

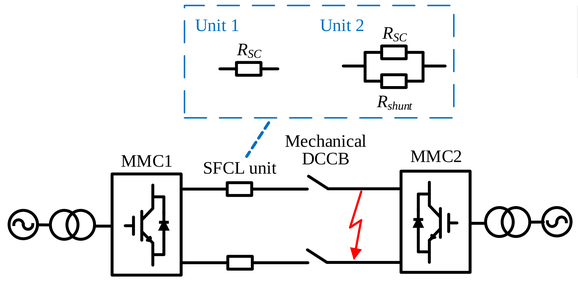


Fig. Structure of MMC-HVDC system with SFCL unit

Four types of SFCL units with different shunt resistance and tape length are chosen for analysis.

Tab. Parameters of SFCL units

No.	R_{shunt}	Turns	Tape length
1	without R_{shunt}	24	2.64 km
2	15 Ω	28	3.53 km
3	12 Ω	30	3.89 km
4	10 Ω	36	4.49 km

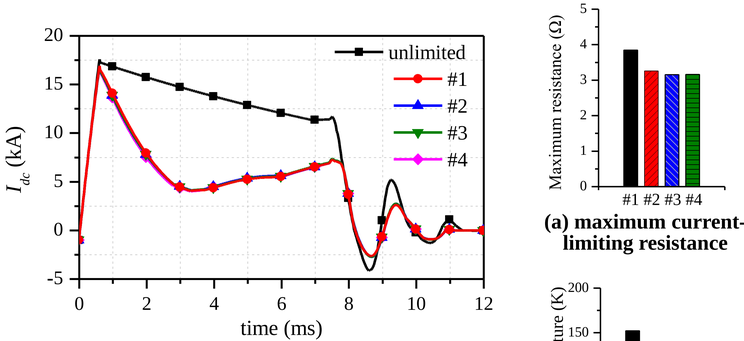


Fig. Fault current during DC pole-to-pole fault

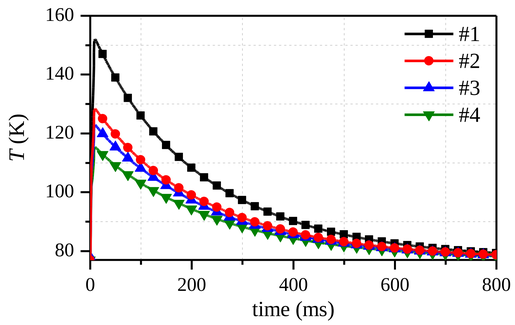
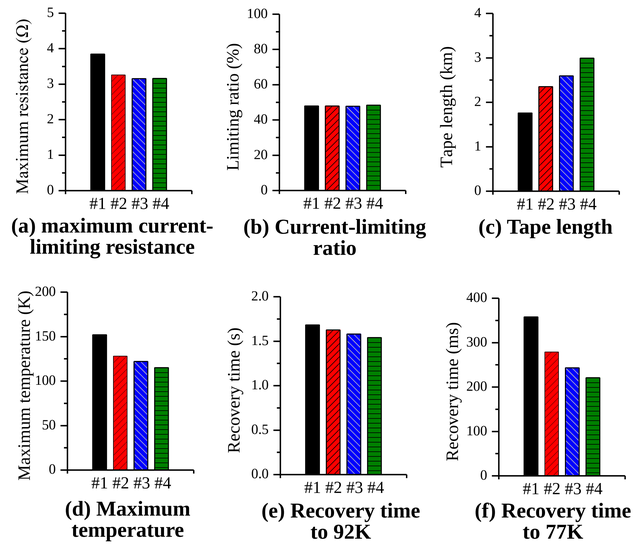


Fig. Temperature of superconducting coils



(a) maximum current-limiting resistance
(b) Current-limiting ratio
(c) Tape length
(d) Maximum temperature
(e) Recovery time to 92K
(f) Recovery time to 77K

Fig. Comparison of SFCL units

All SFCL units have the same current-limiting ratio. The temperature is reduced by shunt resistor. Considering the temperature and tape length, No.3 is the most economical scheme.

This paper studies the performance of R-SFCL with a fixed-value shunt resistor using *R-Q* method and FEM. Conclusions are as follows:

- **The *R-Q* method is highly fitted with FEM and experiment. Combing the *R-Q* method and FEM, system simulation and finite element analysis are separated. The calculation speed is greatly improved.**
- **The shunt resistor can reduce the temperature and recovery time, but more tapes are consumed. When shunt resistance is 12Ω, the maximum temperature is reduced by 30K, which is the most economical.**