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Analysis of the Recovery Characteristics of Superconducting coupled DC Circuit Breakers during Reclosing Operation

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Abstract

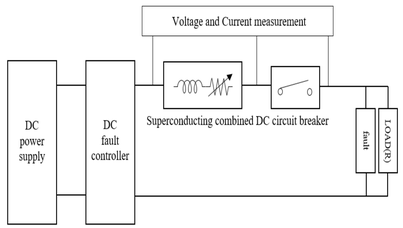
- The circuit breaker is a protective device that conducts current without loss in a steady state, and that automatically reduces the fault current in the event of a fault, using a mechanical circuit breaker. For the superconducting DC circuit breaker, the fault-current-limiting rate and the power burden of the superconducting wire are determined by the inductance of the superconducting wire.
- As such, in this study, the previously proposed superconducting DC circuit breaker was actually implemented, and experiments were performed using a fault simulation device. Moreover, the fault-current-limiting and blocking characteristics were analyzed according to the inductance of the superconducting wire.

Introduction

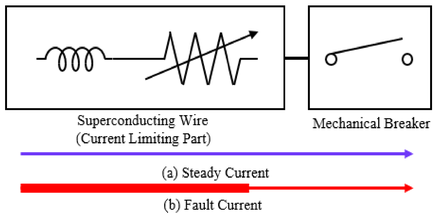
- This study's research team previously proposed a superconducting DC circuit breaker by combining a superconducting wire (resistance type) that can automatically detect and reduce fault current and a mechanical circuit breaker with a simple shape. In addition, the basic blocking characteristics of the circuit breaker were analyzed through simulation.
- For the superconducting DC circuit breaker, the maximum value of the fault current, the current-limiting rate, the operation of the circuit breaker, and the blocking time are determined by the inductance of the superconducting wire.
- If the inductance of the superconducting wire is significantly large, it will interfere with the quench characteristics of the superconducting wire. If a superconducting wire with a suitable inductance is applied, on the other hand, it is possible to minimize the burden of the superconducting wire due to the fault current while reducing the magnitude of the maximum fault current.
- , the limiting of the fault current and the blocking characteristics of the mechanical circuit breaker according to the inductance of the superconducting wire were investigated.

Current-limiting DC circuit DC breaker structure

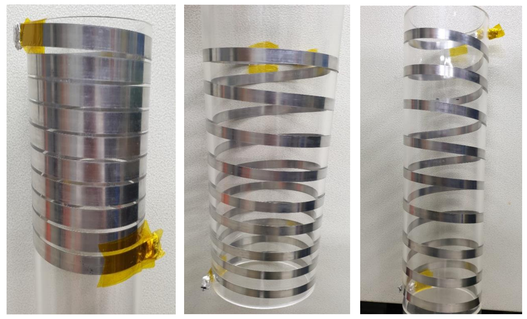
1) Operation mechanism of the superconducting DC circuit breaker



< Circuit Modeling of Superconducting DC Circuit Breakers >



< Simulation model of Arc-induction type DC circuit breaker >



< CASE 1 >

< CASE 2 >

< CASE 3 >

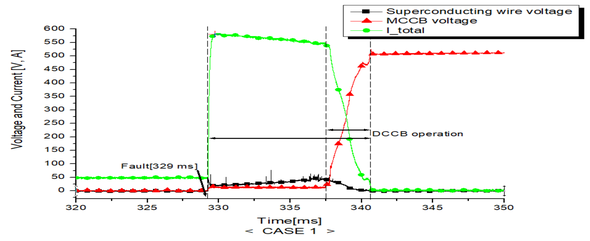
Parameter	CASE 1	CASE 2	CASE 3
Diameter [mm]	100	100	100
Length [mm]	3000	3000	3000
Turn	10.5	9.5	9.3
Height [mm]	150	300	400
Inductance [uH]	5.65	2.61	1.94

< Parameter value of coil according to CASE >

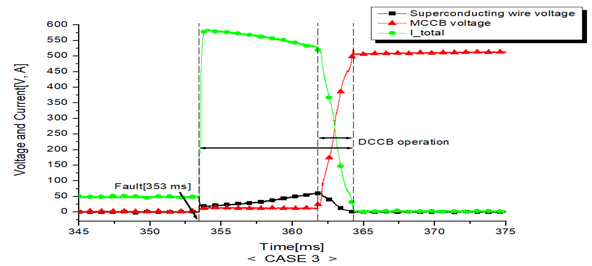
Superconductor theory

$$R_{SW} = \left[\frac{0}{R_m \sqrt{1 - \exp(-t/T_{SC})}} \begin{matrix} t < t_{fault} \\ t > t_{fault} \end{matrix} \right] \qquad emf = -\frac{di}{dt}$$

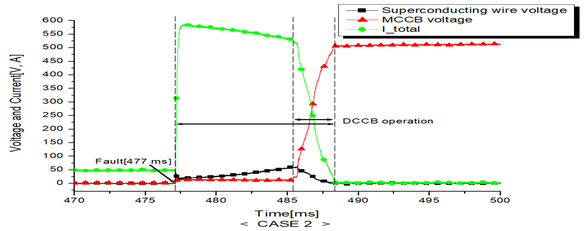
Experiments



< Superconducting DC Breaker Characteristics of CASE 1 >



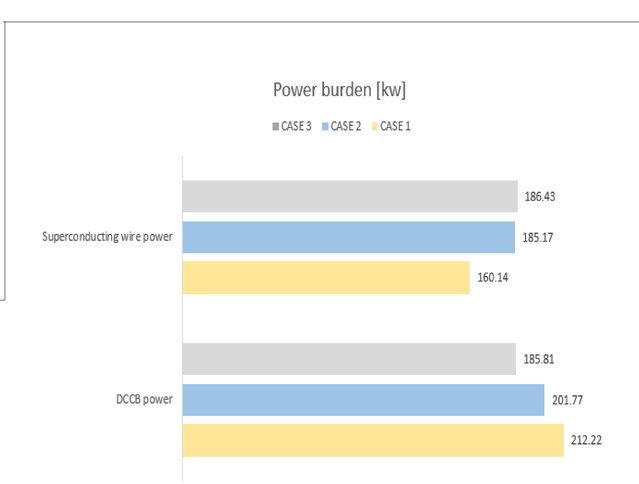
< Superconducting DC Breaker Characteristics of CASE 3 >



< Superconducting DC Breaker Characteristics of CASE 2 >

Power Burden

$$Power\ Burden = \int VIdt = \int I^2 Rdt$$



< Superconducting Wire and Mechanical breaker Power Burden according to inductance >

Conclusion

- In this study, the previously proposed superconducting direct current (DC) circuit breaker was actually fabricated, and its blocking characteristics were investigated. In addition, to analyze the effect of the inductance of the superconducting wire on the superconducting DC circuit breaker, different kinds of superconducting coils were fabricated, and their current-limiting and blocking characteristics were analyzed. Finally, the power burdens of the superconducting coil and the mechanical circuit breaker were analyzed by case.
- The analysis results showed that an increase in the inductance of the superconducting coil reduced the power burden of the superconducting coil but lowered the fault-current-limiting rate. It also increased the power burden of the circuit breaker, and decreased the blocking speed. On the other hand, it was shown that a decrease in the inductance of the superconducting coil could reduce the power burden of the circuit breaker and achieve faster blocking even though it increased the power burden of the superconducting coil. As such, the blocking speed of the circuit breaker can be adjusted, and the power burden of the circuit breaker can be shared, due to the inductance. This will help extend the service life of the circuit breaker.

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