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Application of Flux-Coupling-Type Superconducting Fault Current Limiter on Shipboard MVDC Integrated Power System

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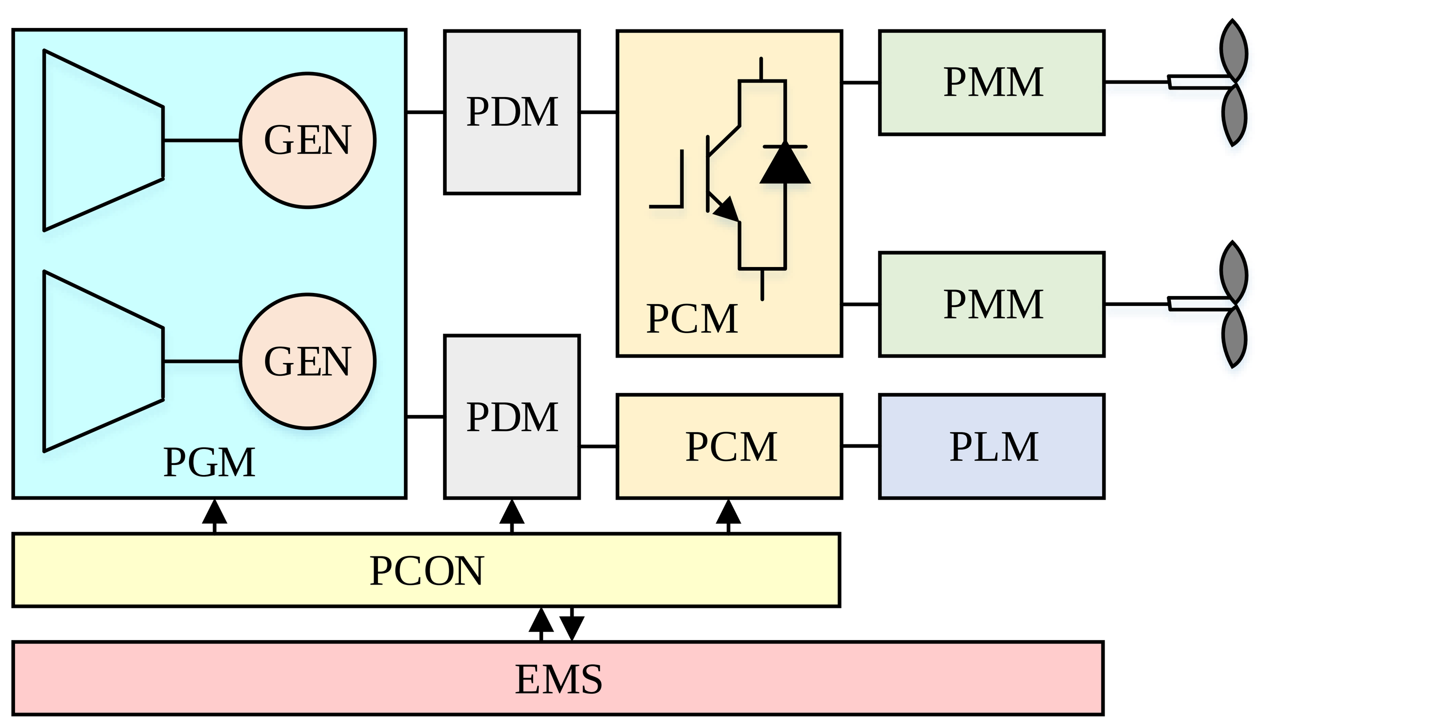
Abstract**——**With the rapid development of the integrated power system on shipboard, the medium voltage DC power distribution system has received extensive attention. At present, one of the bottlenecks restricting the development of medium voltage DC power distribution systems for ships is the occurrence of short circuit faults. Short-circuit faults not only cause extensive damage to the line hardware, but also cause a lot of losses. Therefore, how to break the large-capacity DC short-circuit fault current has become a hot research topic. In order to ensure that the medium voltage DC power distribution system of the ship can still operate safely in the event of a typical fault, a hybrid current limiter is applied to the ship medium voltage DC power distribution system under two typical short circuit faults. In this paper, the working principle and mathematical model of the hybrid superconducting current limiter are analyzed. Two typical short-circuit fault conditions are selected in the ship medium voltage DC power distribution system, and the hybrid current limiter is installed at different positions. The optimal installation position of the current limiter is found by SIMULINK. Finally, the validity and feasibility of the hybrid current limiter applied to the medium voltage DC power distribution system of the ship are verified by the prototype experiment. The verification results show that the hybrid superconducting current limiter has fast response speed and good current limiting effect in the medium voltage DC power distribution system of the ship.

1. Topology structure of shipboard MVDC IPS



– Power Generation Module (PGM) – Propulsion Motor Module (PMM)
– Power Distribution Module (PDM) – Power Conversion Module (PCM)
– Power Control (PCON) – Energy Storage Module (ESM) – Load (PLM)

Fig.1. Schematic diagram of the periodic strain test apparatus.

2. Topology structure and principle of SFCL

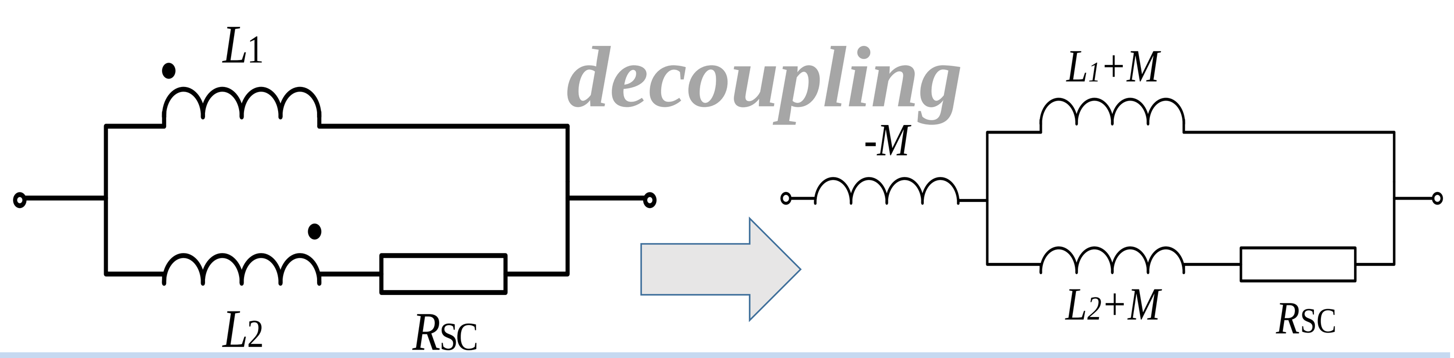


Fig.2. Schematic diagram of the periodic strain test apparatus.

4. Electromagnetic design of SFCL

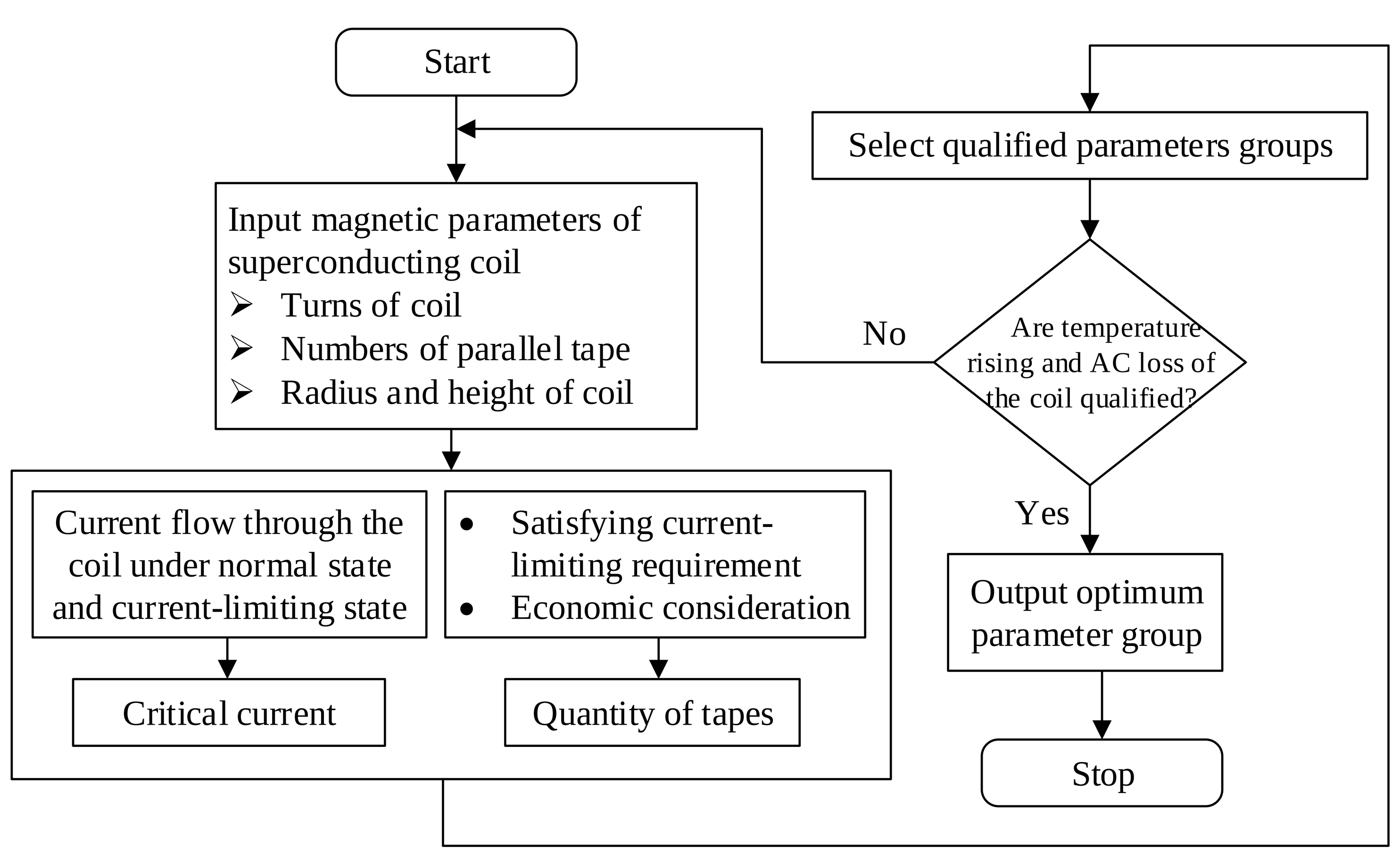


Fig.7. The flow chart of design on the superconducting coil

3. Performance of SFCL Applying on Two Typical Faults

I. DC side pole-to-pole short circuit fault

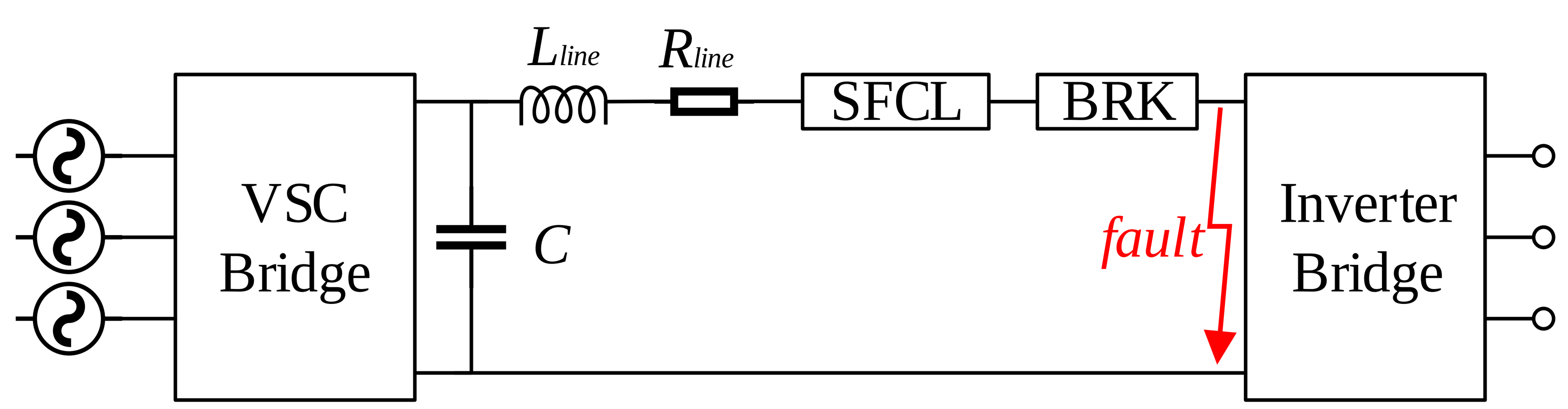


Fig.3. Schematic diagram of SFCL in DC side pole-to-pole short circuit fault

II. The three-phase grounding short circuit fault on the outlet side of synchronous generator

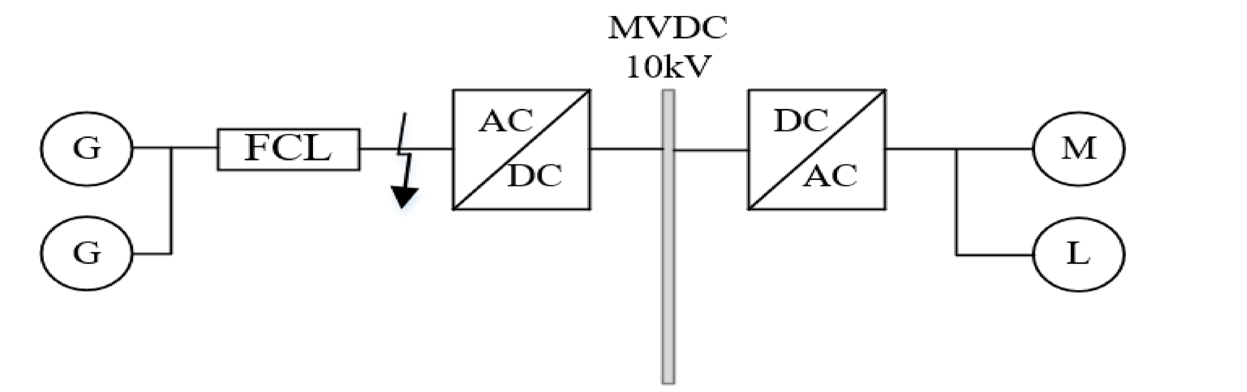


Fig.4. The simulation schematic diagram of SFCL in short circuit fault on the outlet side of synchronous generator

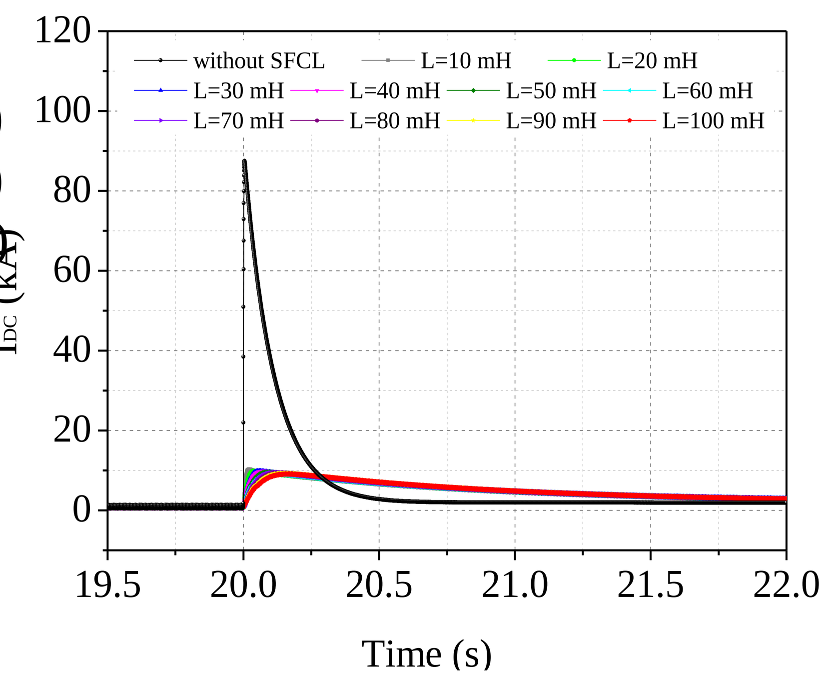


Fig.5. Effects of SFCL on I_{DC}

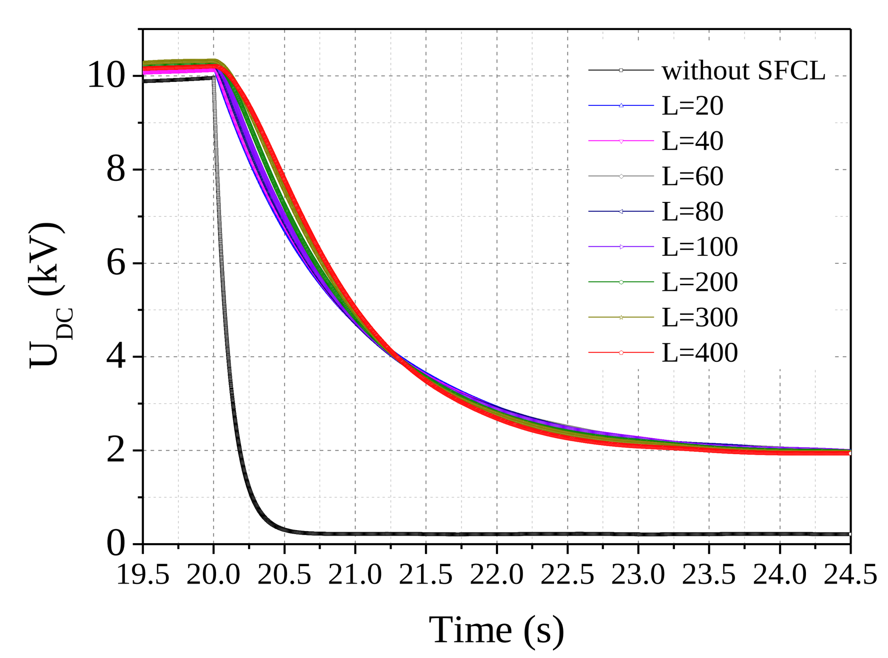


Fig.6. Effects of SFCL on U_{DC}

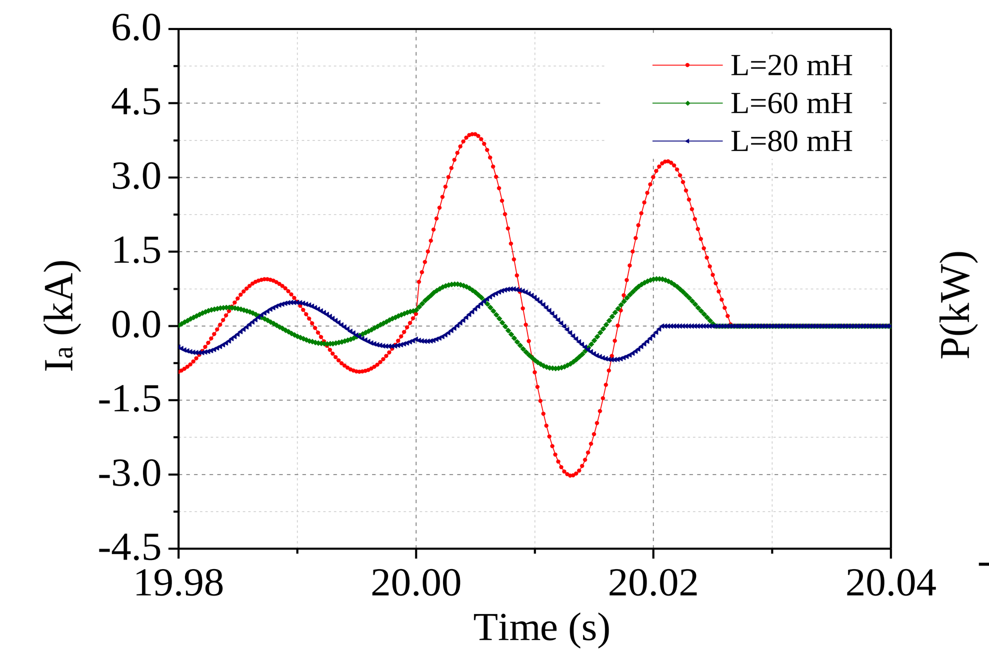


Fig.7. Effects of SFCL on output current

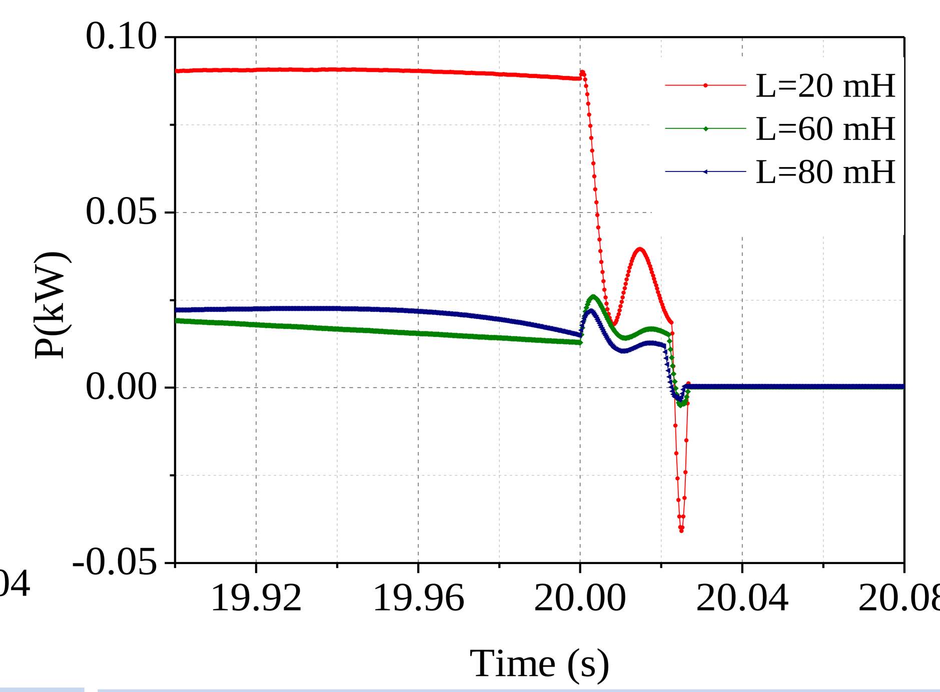


Fig.8. Effects of SFCL on active power

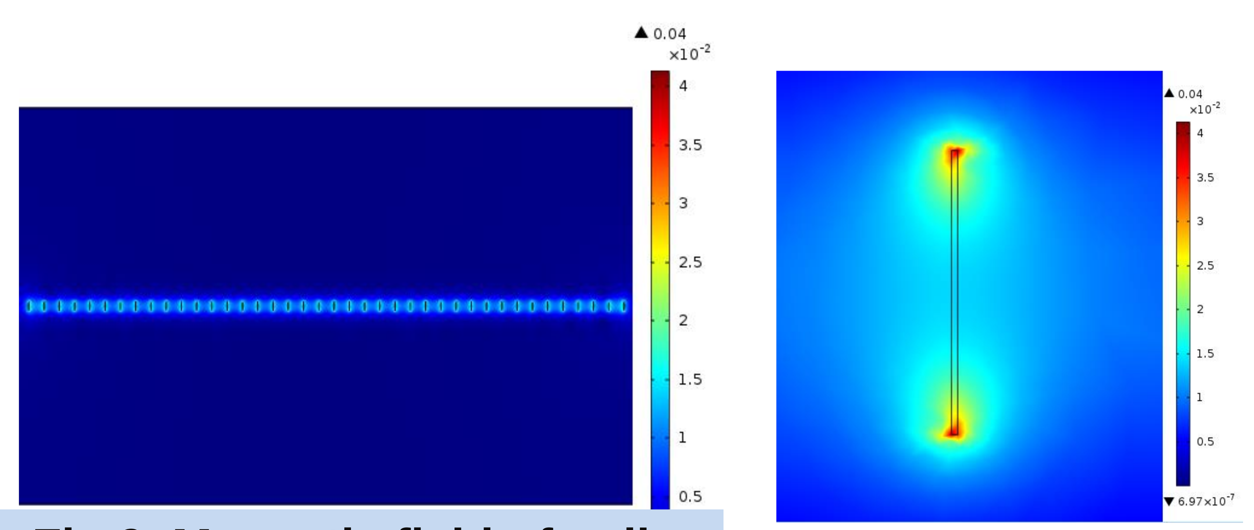


Fig.9. Magnetic field of coil

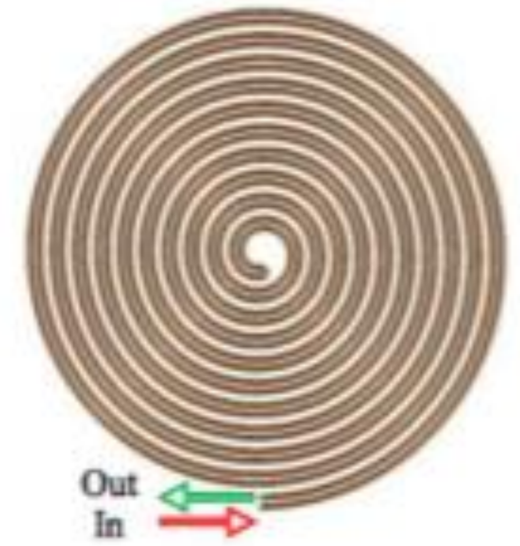


Fig.10. Structure of coil

Table I PARAMETERS OF HTS TAPE PARAMETERS.

HTS TAPE PARAMETERS	
Critical current	200A at 77K
Tape width	12 mm
SC resistance	4.5 ohm
Number of coil units	1
Tape thickness	0.275 mm
Tape length	218.09 m

5. Conclusion

1) The SFCL has extraordinary performance in current limiting under both faults conditions.
2) The SFCL has effectively avoided large and violent fluctuations of active power in three-phase short fault. And it also obstructs voltage dropping at DC side.
3) The inductor in the SFCL has greater influence on the performance of current-limiting on both typical faults.

Table II PARAMETERS OF SIMULATION OF SFCL PERFOMANCE.

Parameter	Value
Rated RMS line-to-neutral voltage of generator	2.7 kV
Rated RMS line current of generator	40 kA
Number of synchronous generators	2
Filter capacitor	1 F
Line inductance	0.1 mH
Line resistance	1 ohm
Rated power of motor	0.373 MVA
Rated line-to-line voltage of motor	2 kV
Inductor in the SFCL	50 mH
Quenching resistance in the SFCL	1 ohm
Time of the short fault happens	20 s
Time of the SFCL takes effect	20 s
Time of the circuit breaker takes effect	20.02 s
Duration of the short fault	15 s