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재폐로 동작시 1선 지락사고에 따른 고속도 초전도 한류기의 특성 분석

Analysis of Characteristics on the High-speed SFCL According to Single Line-ground-fault in the Reclosing Operation

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(In-Sung Jeong · Byung-Ik Jung · Hyo-Sang Choi)

Abstract – This paper proposed an high-speed superconducting fault current limiter (H-SFCL). The proposed H-SFCL functioned the initial fault current could be covered by the SFCL and the continued fault current after the one-cycle from fault occurrence could be controlled current-limiting-element of the normal conduction. To investigate the operation characteristics of the H-SFCL, a simulation power system was constructed, and a single line-to-ground fault was occurred. As a result, the H-SFCL limited the fault current by more than about 70%, and it was confirmed that the electric power burden was reduced compared to the SFCL that consisted only of superconductors.

Key Words : SFCL, H-SFCL, Line-to-ground fault, Superconductor

1. Introduction

The power demand is currently rapidly rising due to economic growth, industry development, abnormal climate events, etc. To respond to the continuously increasing power demand, more power facilities have been constructed. To improve the supply reliability of the power system, the power system was structured in the network system. The mass storage of power equipment, facilities and the network structure of the power system reduced the impedance of the entire power system. For this reason, the fault current increased considerably when faults occurred. The value of the increased fault current threatens the protection capacity of the existing protective equipment. To address such problem, this paper proposed an SFCL using the zero resistance characteristics of superconductors. The SFCL supplies power without any loss while maintaining the superconducting state during normal state. When a fault occurs, however, the superconductor quickly quenches and limits the fault current[1-7]. As a result of the studies conducted by many research teams worldwide, the SFCL has been proven to have stable fault current limitation[1-4]. However, as the superconductor is expensive, it is important to minimize the power burden of superconductor by its use. Therefore, this paper proposed an High-speed Superconducting Fault Current Limiter (H-SFCL) that combines the superconductor with the High-Speed Current Limiter(H-FCL).

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2. Maintain

2.1 Experiment circuit diagram and operation mechanism of H-SFCL

The HFCL is a new fault current limitation technologies proposed in this paper. It consists of a high-speed interrupter and a normal-conduction current-limiting element. The high-speed interrupter is a device that combines a vacuum interrupter with solenoid valves. The normal-conduction current-limiting element that was applied to the experiment, which used 10Ω/2kW resistance[4-5]. The H-SFCL was structured as a HFCL, which a superconductor was applied. Fig. 1.(a),(b),(c) shows the experiment circuit diagram and operation mechanism of the H-SFCL. The CT(current transformer) of the Fig.1.(a) detects fault currents, the interrupter control system, and a high-speed interrupter for driving solenoids were applied to the power line. The superconductor was connected to the fault line in the simulation system, and limited the initial fault current. The H-SFCL follows the current through the b-contact of the high-speed interrupter at the normal state. Here, as the superconductor acts without impedance, the steady-state current is supplied to the power line without any loss. If a fault occurs, however, the SFCL that was applied to the power line quenches, produces impedances, and limits the initial fault current. The fault line opens due to the switching operation of the high-speed interrupter, and a bypass circuit is constructed by the normal-conduction fault current limiting part. The fault current flown into the bypass line is finally limited by the normal-conduction fault-current-limiting part. The SFCL simultaneously recovers its superconducting state upon the switching operations being activated by the high-speed interrupter.

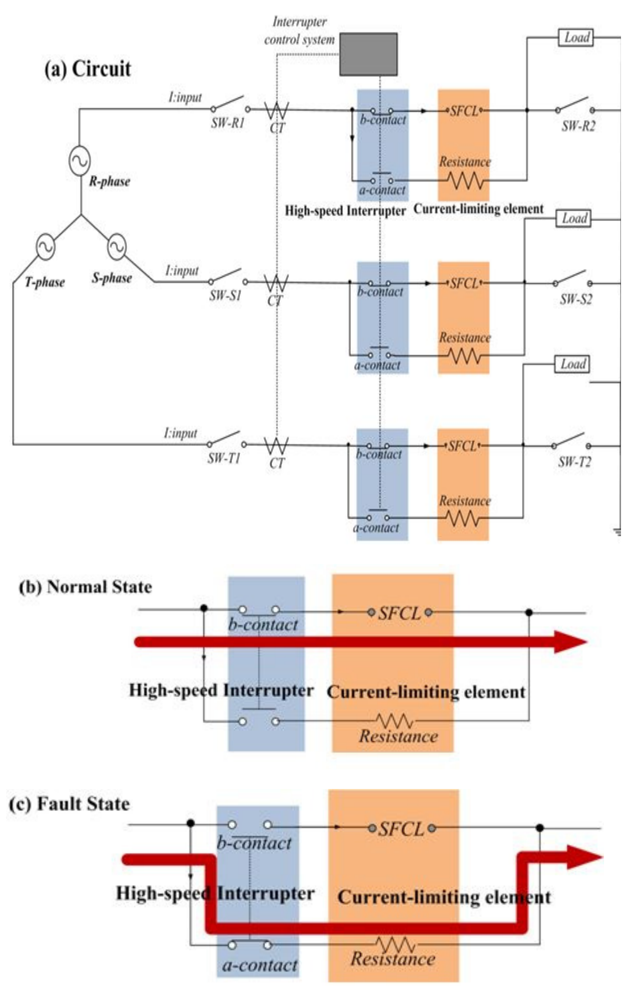

Fig. 1 (a) Experimental circuit diagram of H-SFCL; (b) Operational mechanism of H-SFCL at normal state; (c) Operational mechanism of H-SFCL at fault state

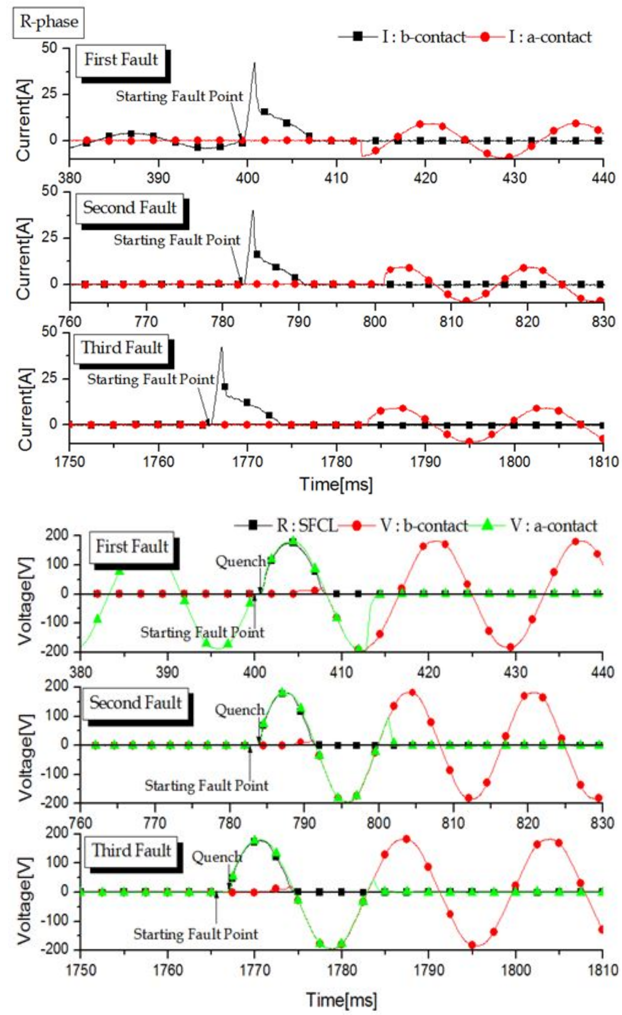

Fig. 2 Fault voltage and current curve when a single line-to-ground occurs (R-phase)

2.2 Operation characteristics analysis of H-SFCL when a single line-to-ground fault occurs

To secure the operation reliability of the H-SFCL, the reclosing operation cycles (5-18-10-50-5) were established, and three consecutive single line-to-ground faults were simulated. The experiment used a 240V applied voltage. Fig. 2. shows the value of the fault voltage and current generated when a single line-to-ground fault occurred. It was confirmed that the line had a steady-state current flow after power is applied, but the current of the power line was approximately 42A after the occurrence of a fault. The SFCL connected to the fault line quenched due to the increased fault current, and the CT and interrupter control system detected and determined the fault current and applied a signal to the high-speed interrupter. The quenched SFCL limited the value of the initial fault current to 42.56, 40.16, and 41.16A, respectively. The switching operation of the high-speed interrupter occurred from when 8.13, 10.71, and 9.46msec respectively lapsed after the fault occurrence. The values of the fault current that were finally limited by the normal-conduction current-limiting part after the activation of the switching operation by the high-speed interrupter appeared to be about 9.01, 10.09, and 9.46A. Fig. 3. shows the voltage and current characteristic curves at the normal phases, S- and T-phase. The H-SFCL was manufactured as a three-phase simultaneous-operation type, and it was confirmed that the switching operation were activated in the normal state.

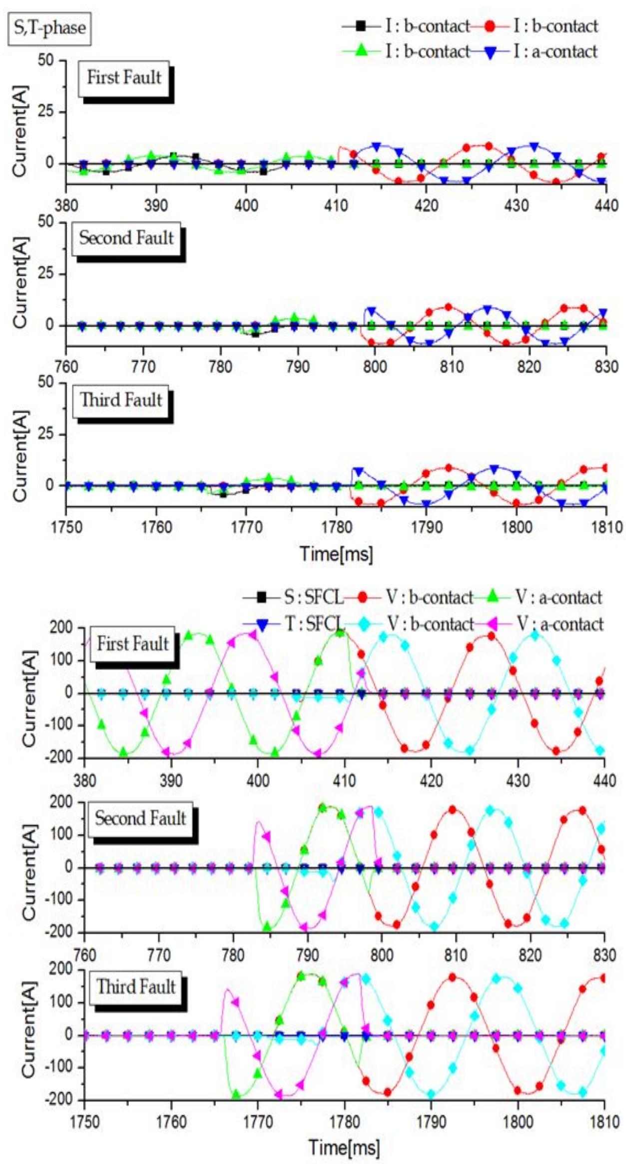

Fig. 3 Fault voltage and current curve when a single line-to-ground occurs (S, T-phase)

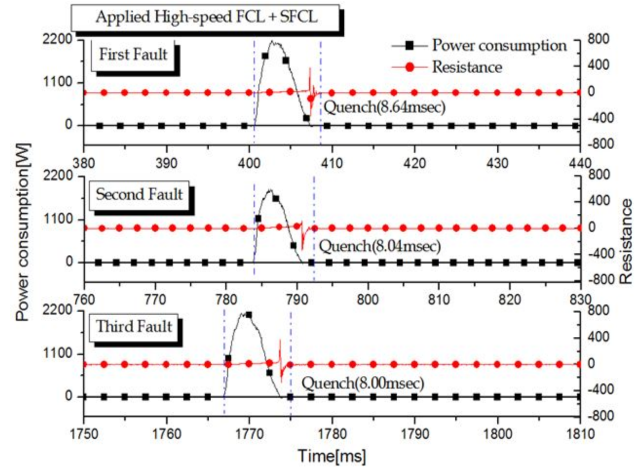

Fig. 4 Resistance and power consumption curves of the H-SFCL

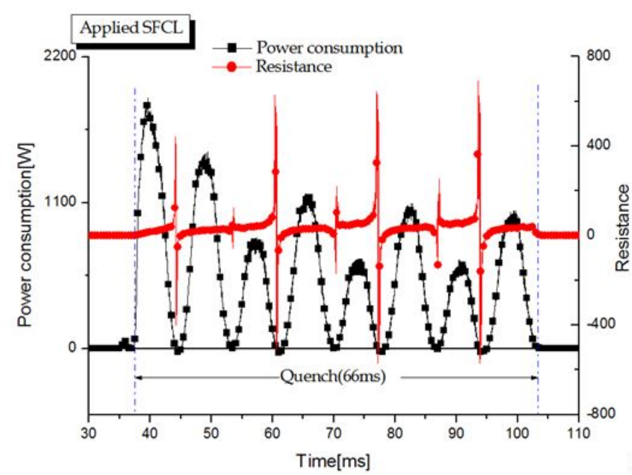

Fig. 5 Power consumption curve of an SFCL consisted of superconductors

2.3 Characteristics of the superconductor burden of H-SFCL

In this paper, the H-SFCL was designed so that the SFCL can share the fault power burden for a short time at the beginning of the fault and the normal-conduction current-limiting part can take the remaining burden of the continuous fault current in order to minimize the burdens to the SFCL. Fig. 4. shows the resistance and power consumption curves applied to the experiment performed in this study, through which the burdens to the SFCL can be confirmed. The SFCL that quenched due to the fault occurrence showed that 379.68, 331.25, and 385.93Ω resistance were generated for 8.36, 8.04, and 8.00msec. Also, Power consumption was about 2198, 2092, 2196W. Fig. 5.

shows the power consumption curve of the SFCL consisted of superconductors. power consumption was maximum 1812, and minimum 590 W. which confirms that the burden of the H-SFCL was much reduced maximum 74% than that of the existing SFCL consisted of superconductors[3,7].

3. conclusion

In this paper, a fusion HFCL structure was proposed to minimize the burden to the SFCL. The SFCL was connected to the fault line, and the normal-conduction current-limiting part was applied to the bypass line of the high-speed interrupter. In the normal state, the SFCL operations without impedance, and power is supplied without any loss. If a fault occurs, the SFCL quenches and limits the initial fault current. It recovers its superconductivity when the high-speed interrupter conducts switching operations; the fault current detours to the line connected to the normal-conduction current-limiting part, and is finally limited. Result of experiment, the H-SFCL stably limited the fault currents in all the three consecutive fault experiments, and the electric power burdens to the SFCL were reduced to a certain extent compared to the conventional structure as it covered the power burden for only a cycle of the fault occurrence. Based on the analysis results of this study, the application of the SFCL to the HFCL will likely stably limit the fault current, reduce the burdens to the SFCL, and extend its lifespan.

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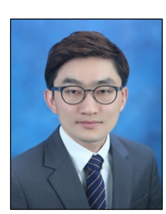

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