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Analysis of fault current limiting performance of resistive-type hybrid SFCL for parallel operation of distribution transformers

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Recently, the increasing domestic power demand has led to an expansion of power facilities, resulting in a decrease in system impedance and subsequently causing an increase in fault currents. These fault currents surpass the interrupting capacity of conventional circuit breakers, leading to significant economic losses due to equipment malfunctions and damages. Although solutions like circuit breakers and power fuses exist, circuit breakers take 0.1 seconds to interrupt fault currents, while power fuses, though faster, have significantly lower fault current interrupting capacities. To address this issue, research and development efforts are underway for superconducting fault current limiters (SFCLs), capable of swiftly reducing large fault currents.

This paper analyzes the quench characteristics and operational principles of a hybrid superconducting fault current limiter developed by LS ELECTRIC. The SFCL in this study operates at a rated voltage of 22.9[kV] and a rated breaking current of 2000[A], featuring a configuration with a Fast-Switch(FS) connected in series with the High-Temperature Superconductor(HTS), complemented by a parallel Current-Limiting Resistor(CLR). Using Power System CAD (PSCAD), the SFCL and the power system are simulated to confirm the effectiveness of SFCL application in power systems.

Under normal current conditions, the SFCL maintains a superconducting state until a fault occurs, at which point the fault current exceeds a threshold, leading to the appearance of a superconductor quench resistance before half a cycle. This paper mathematically models and simulates these characteristics using PSCAD. Furthermore, the resistive hybrid SFCL initially relies on the superconductor to handle most faults until the Fast-switch operates at the current zero-crossing point. Subsequently, the current-limiting resistor intervenes to restrict fault currents, a principle modeled and applied to a case study of parallel operation of distribution transformers in PSCAD.

The parallel operation of distribution transformers, aimed at equitably distributing load to reduce underutilization and enhancing reliability by supplying power from parallel circuits during distribution line faults, is considered by power companies to improve energy supply efficiency. However, parallel operation of transformers decreases system impedance, accompanying a critical drawback of increased fault currents. SFCLs offer significant advantages in transformer parallel operation due to their minimal impedance under normal conditions and rapid fault current reduction capabilities during faults.

Through simulation, this paper verifies the operational effectiveness of SFCLs by connecting them to the secondary side of distribution transformers and assessing fault current magnitudes during both isolated and interconnected transformer operations. It examines various fault scenarios, including voltage phase angle differences and fault locations, to ascertain the applicability of SFCLs in power systems.

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