배전시스템에서의 저항형 초전도 한류기 파라미터 산정방법

Application Analysis of a Resistive type SFCL for Distribution Systems

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Abstract: Since the discovery of the high-temperature superconductors, many researches have been performed for the practical applications of superconductivity technologies in various fields. As results, significant progress has been achieved. Especially, Superconducting Fault Current Limiter (SFCL) offers an attractive means to limit fault current in power systems. In order to verify the effectiveness of the SFCL, in this paper, the analysis of fault current and voltage stability assessment in a distribution system are performed by the PSCAD/EMTDC-based simulation method in which a component for resistive type of SFCL is presented. Through the simulation, the advantage of SFCL application is shown, and the effective parameters of the SFCL are also recommended.

Key Words: Superconducting Fault Current Limiter, PSCAD/EMTDC simulation

1. Introduction

Recently, increases in the installed capacity and the interconnection of the transmission networks lead to very high short-circuit currents. It is very important to protect electric power systemsfrom high short-circuit current. The present techniques use circuit breakers. However, since their principle is to cut the current at its zero crossing, all the components beyond the fault point have to withstand the destructive effects of the high short-circuit currents for a period of at least 3 ~ 5 cycles. An attractive device is a current limiter that clips the fault current and reduces the electromechanical stress on the network. In addition, the reduction of the fault duration provided by the limiter could increase the power transmission capability and improve the dynamic stability as well [1, 2].

Conventional copper-based current limiters can cause voltage instability in the electrical system by adding reactance to the system. This forces the utility to add capacitance to the system to counter-balance the reactive element. One of well-known limiters is current limiting reactor.

The SFCLs, in contrast to current limiting reactors or high impedance transformers, are capable of limiting short circuit currents without adding considerable voltage-drop and energy-loss to power systems during normal operation. Under fault conditions, a resistance is automatically inserted into the power grid to limit the peak short-circuit current by transition from the superconducting state to the normal state, the quench. Further advantages, like fail safe operation and quick recovery, make SFCL very attractive, especially for rapidly growing power systems with higher short-circuit capacities.

It is expected that the resistive type of SFCL will be commercialized near the future for both transmission and distribution system [5, 6]. The resistive type SFCL consists of a low inductance superconducting coil which is inserted in series in the line. In case of resistive type SFCL, the characteristic of the resistances from quench to recovery is very important for the real system applications [7-9]. It is, however, very difficult to analyze the characteristics of the SFCL under various real world system conditions due to the limited access to the physical SFCL and real power systems.

For the purpose of verifying the effectiveness of the SFCL for a practical distribution system, a simulation-based analysis of fault current and voltage stability in a simplified distribution system were performed using PSCAD/EMTDC. A component for a resistive type of SFCL is adopted in the analysis.

The simulation results demonstrate the effectiveness of the proposed simulation and parameter assessment techniques.

2. Characteristics of the SFCL

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Fig. 1 depicts the PSCAD/EMTDC component of resistive type SFCL, for which the characteristic equation of limiting resistance (1) is used.

$$R(t) = R_{sc}\left\{1 - \exp\left(-\frac{t-t_0}{\tau}\right)\right\} \qquad (1)$$

where, Rsc represents the maximum resistance of superconductor, and thelimiting resistance R(t) will be increased exponentially up to Rsc(0~10 Ω) with the time constant τ after the quench-onset (t=to).

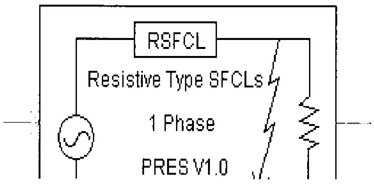

Fig. 1. EMTDC component of resistive type SFCL.

Fig. 2(a) shows the characteristic curve of SFCL and the limiting features of fault current are given in Fig. 2(b). If fault current exceeds the critical point of the SFCL, the limiting resistance of SFCL is activated during to<t<t1 (t1: time at clear of fault), and thus suppresses the fault current as shown in (b).

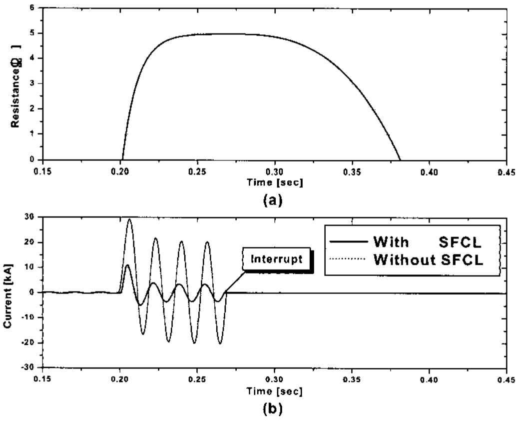

Fig. 2. Characteristic curves of SFCL and current limiting effects.

3. Configuration of a model system

Fig. 3 shows a simplified practical distribution system associated with a SFCL. The model system consists of a 154 kV system bus, three banks of 154/22.9 kV 60[MVA] conventional transformers and the SFCLs. Detailed parameters of the system are given in Table 1.

Ten loads are supplied through the three transformers, 3.5[MW] and 7.3[MW] of loads are attached to D/L(A) and D/L(B), and the possible application points of SFCL are represented by CASE1, CASE2 and CASE3, respectively. Among those three cases, the CASE3 is the most effective position from the suppressing rate of fault current and system voltage drop point of view. Thus, the CASE3is chosen for the study case in this work. A single-line to ground fault is assumed to occur at the sending end of the 22.9 kV system.

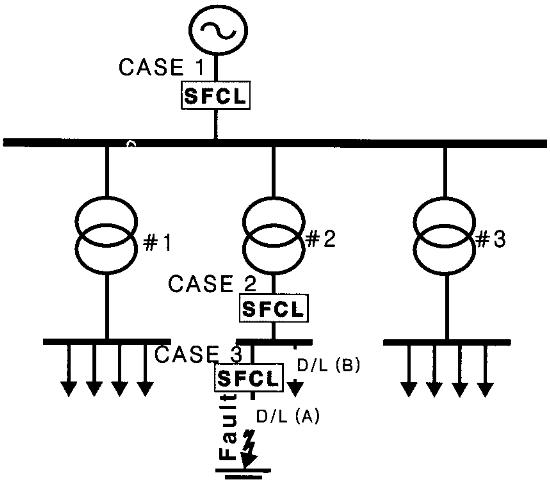

Fig. 3. Simplified practical distribution system.

The fault inception point and duration times are 0.2[sec], 0.3[sec], respectively.

Table 1. Parameter of the model system

Source Voltage	154[kV]/23[kV]	
Transformer	(20x3)60[MVA](Y-Y-Δ)	
%Z of D/L (A)	Z_0	5.705+j1.860
	Z_1	1.533+j2.509
%Z of D/L (B)	Z_0	15.247+j34.175
	Z_1	5.932+j11.365
Load of D/L (A)	3500[kW]	
Load of D/L (B)	7300[kW]	

4. Simulation Result

4.1 Single-line to ground fault at D/L(A)

Fig. 4 represents the results for the prospective fault current of D/L(A) and the voltage shape of D/L(B) without SFCL. The peak of fault current reaches 29.22[kA], and the voltage drop of D/L(B) is 87[%].

The resistance curve, fault current of D/L(A) and the voltage shape of D/L(B) with 1[Ω] of maximum SFCL resistance are given in Fig. 5.

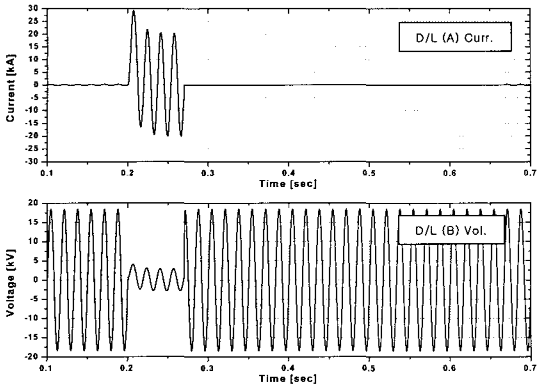

Fig. 4. Fault current and voltage without a SFCL

The peak of fault current reaches 21.0[kA], and the voltage drop of D/L(B) is 49[%] in this case.

Fig. 6 shows the simulation results with 5[Ω] of maximum SFCL resistance. The peak of prospective fault current is suppressed to 11.0[kA], which is 40[%] of the fault current without a SFCL, and the voltage drop of D/L(B) is only 4[%] in this case.

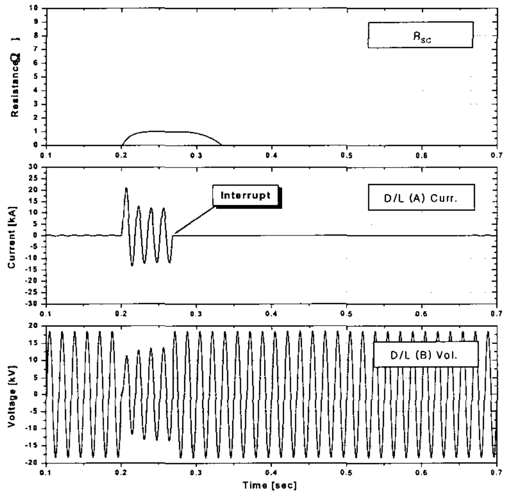

Fig. 5. Fault current and voltage with a SFCL (1Ω).

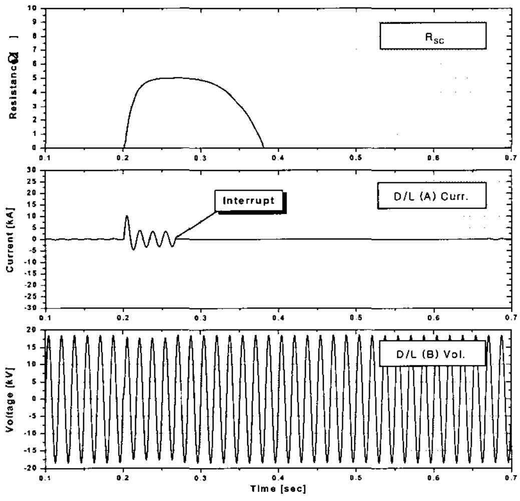

Fig. 6. Fault current and voltage with a SFCL (5Ω).

4.2 Single-line to ground fault at D/L(B)

As in Section 4.1, the same process of simulation is conducted for the D/L(B). Fig.7 represents the results for the fault current of D/L(B) and the voltage shape of D/L(A) without a SFCL. The peak of prospective fault current reaches 23.95[kA], and the voltage drop of D/L(A) is 76[%].

The resistance curve, fault current of D/L(B) and the voltage shape of D/L(A) with 1[Ω] of maximum SFCL resistance are given in Fig. 8. The peak of fault current reaches 18.2[kA], and the voltage drop of the D/L(A) is 41[%] in this case.

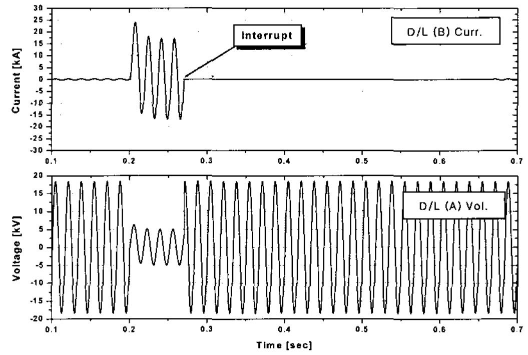

Fig. 7. Fault current and voltage without a SFCL.

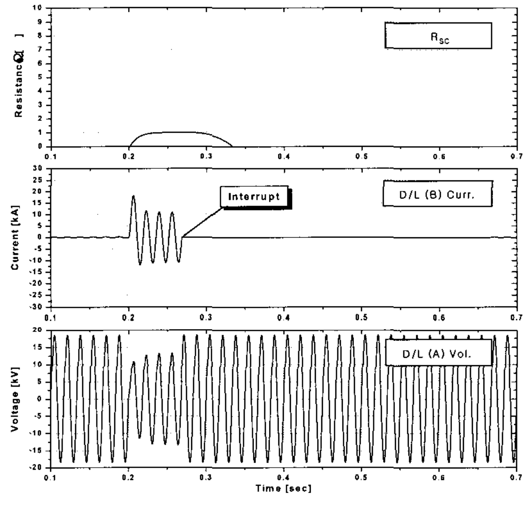

Fig. 8. Fault current and voltage with a SFCL (1Ω).

Fig. 9 shows the simulation results with 5[Ω] of maximum SFCL resistance. The peak of prospective fault current is suppressed to 10.24[kA], which is 40[%] of the fault current without a SFCL, and the voltage drop of D/L(A) is only 5[%] in this case.

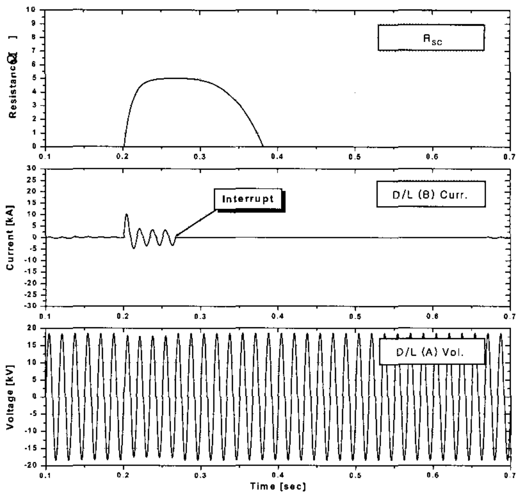

Fig. 9. Fault current and voltage with a SFCL (5Ω).

Fig. 10 and Fig. 11 depict the relationship between fault current, voltage drop and resistance of SFCL for the two different cases (A & B), respectively.

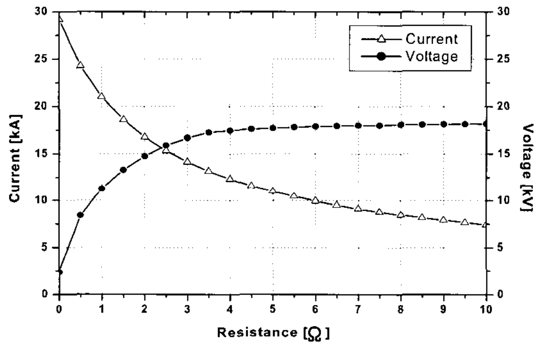

Fig. 10. Fault current and voltage vs. resistance for D/L(A).

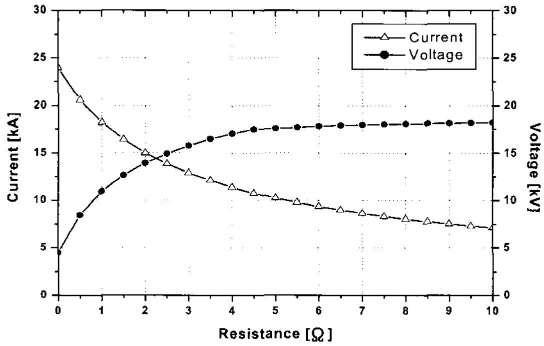

Fig. 11. Fault current and voltage vs. resistance for D/L(B).

As shown in the above figures, the prospective fault current and voltage drop rate are decreased with the resistance of SFCL. The impact obtained by the SFCL application is saturated at around 5[Ω] in this study case, which means that the parameter assessment of SFCL is very important and necessary for the proper operation of power systems. Furthermore, the subsequent fault current can be reduced into the load current level with higher values of the SFCL resistance. However, the recovery time of superconductor may exceeds the reclosing time of the protective system and can causes serious voltage stability problems consequently.

5. Conclusions

In order to verify the effectiveness of the SFCL for a practical distribution system, simulation-based analysis of fault current and voltage stability in a simplified distribution system are performed using PSCAD/EMTDC. In the analysis, a component for a resistive type of SFCL is adopted. Through the simulation, the advantage of SFCL application is shown, and effective parameters of the SFCL are also recommended.

The prospective fault current and voltage drop rate decrease with the resistance of SFCL. However, the impact by the SFCL is saturated at a certain point, which means that the parameter assessment of SFCL is very important and necessary for the secure operation of power systems. Furthermore, proper coordination between the SFCL resistance and the recovery time should be considered in order not to cause voltage instability problem of the system.

감사의 글

본 연구는 21세기 프론티어 연구개발 사업인 차세대 초전도 응용기술 개발 사업단의 연구비 지원에 의해 수행되었음.

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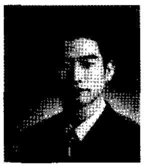
저자소개



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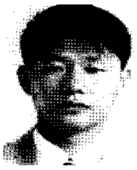

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