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상용변압기와 결합된 초전도체 및 상전도체 한류기의 고장전류 및 보호기기 동작특성

Characteristics of the Fault Current and the Protection for Superconducting and Normal Conducting Limiter combined with a Transformer

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Abstract - With increasing demand of power, the equipment of power system is enlarging and the absolute capacity is going up. As a result, when a fault occurs, the fault current is consistently increasing. Therefore, I suggested some solution for limiting the fault current more efficiently. This study shows the characteristics of superconducting limiting elements and normal conducting elements combined with a transformer. We performed a short-circuit test about the fault current by using SCR switching control system operated from a CT. When short circuit accidents happened in the secondary side of a transformer, fault currents flowed and a SCR switching control system was operated. It resulted in a decrease of the fault current in the limited elements of third winding connected in parallel. For this test, we used YBCO thin films and normal conducting elements as the limited elements. Within a cycle, a superconducting fault current limiter with YBCO thin films reduced more than 90% of fault current because the resistance of superconducting elements sustainedly grew. On the other hand, the limiter with normal conductors limited as much as a set value because its resistance characteristic was linear. Consequently, in case of the limiter with superconductor, limiting range of the circuit was wide but the range of protective detection was undefined. In contrast, as for the limiter with normal conductors, limiting range and protection duty were appropriate.

Key Words : Current transformer (CT), Normal conducting fault current limiter, Superconducting fault current limiter (SFCL), Silicon controlled rectifier(SCR)

1. Introduction

As industrialization has been performed rapidly, domestic power generation facilities have been increased gradually by being linked each other. So, impedance of the power system is decreased and fault currents have been increased gradually in case of fault. What is problem in this point is that fault currents are increased day by day, but protection equipment that controls them is not getting out of the existing methods largely. If the fault current increases continuously, it becomes to exceed the capacity of protection equipments having been installed for preparing for accidents. That is, breaking work of the protection equipment is not done well, and thus the faultis expanded to peripherals and its scale and influence become enlarged. Current 345KV power system within the country have exceeded breaking strength a long time ago owing to continuous increases of fault currents, and it was replaced to upper breakers of 60kA from 31.5kA. Replacement toward the upper breaker can be an alternative for carrying fault currents. However, replacing the breaker according to the size of fault currents will face limitations from every aspect such as expenses and time etc in addition to breaking performance. Thus, domestic powered system is in the situation of rapidly decreasing in stability of equipment together with reliability of power supply while the fault current excesses breaking performance of the circuit breaker [1-3]. Alternatives that are more systematic, economic, and reliable than existing protection equipment are necessary acutely. For making such alternatives, researches of limiting the fault current have been actively done at home and abroad nowadays by using critical properties of superconductor. The superconductor supplies electric power to load without losses in case of normal situations, but it easy influences to equipment by rapidly restricting the fault current after impedance happens from fault. Though superconducting element has economic problems such as composing heat and cooling systems yet, it seems to be developed through steady researches[4-6]. Therefore, this study proposed SFCL as

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a new alternative for reducing fault currents. For securing work reliability in case of applying it to the distribution system, the study compared and analyzed work characteristics with normal conducting fault current limiter when an fault happened in single line-to-ground.

2. Maintain

2.1 Simulated Distribution System Modeling and Test Methods

This study did modeling on simulated distribution system in order to access the system having been operated now. Fig. 1 is the single-phase electric circuits of the simulated distribution system. In the primary coil of the transformer, the study installed a breaker for 15A distribution, and CT detecting the fault current at the secondary coil. Also, the study set up SCR control system that makces the track of fault currents changed by executing switching work in case of fault. And the fault current element that limits the fault current was installed in the third coil. In order to get correct results by fault current elements, this study applied 240V to each experiment. After setting up the coil rate of single-phase transformer like NR : NS : NT = 3 : 2 : 3, and generated a single line-to-ground fault during 100 cycles. At this time, load resistance in the normal time was set up to 50Ω Also, the study manufactured SCR control system that changed fault generator and the track of

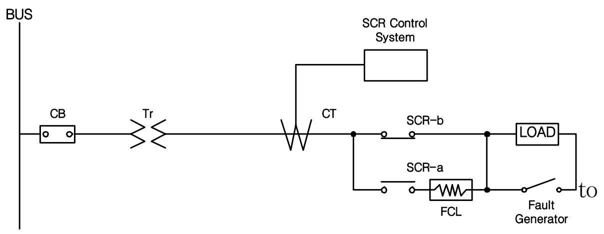

Fig. 1 Simulated single-phase power distribution system

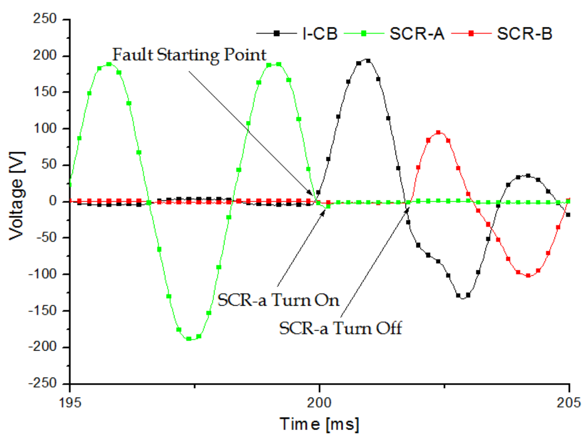

Fig. 2 SCR Operating characteristics

fault current so as to generate simulated accidents to small-size distribution system have been modeled. Fig. 2 shows work characteristics in case of fault, and Table 1 specifications of SCR control system. If an accident occurs to the system, SCR-a becomes turn-on simultaneously with the fault, and it shows work characteristics of limiting the fault currents by being turn-off. Table 2 shows specifications of molded case circuit breaker applied to the experiment, and Table 3 specifications of superconducting element that is one of fault current elements. Table 4 is setting value of components in small-scale simulated distribution system. (a) of Fig. 3 shows flow chart of currents that are supplied in normal situations. Currents are supplied to the secandary coil owing to induced currents. At this time, SCR is not switched because the current has value under

Table 1 SCR Control System specifications

Input	AC 220V
Phase	3Φ 60Hz
Current	Max 100A
Devices	SCR 1600V/150A
ON/OFF Time	Max 1/2 Cycle (8.3ms)

Table 2 Breaker specifications

Impulse Withstand Voltage	6KV
UI	AC 220V
Icu	1.5KA
Ics	50% Icu
Frequency	60Hz

Table 3 Superconducting element specifications

Parameter	Value	Unit
Element diameter	2	inch
Strip width	2	mm
Length	540	mm
YBCO Thickness	0.3	μm

Table 4 Set value of the simulated distribution system components

Parameter	Set value
Input	230V
Transformer turns ratio	3:2:3
Line impedance	1Ω
Load resistance	50Ω
Fault Cycle	100 Cycle

CT sensitivity current. (b) of Fig. 3 displays flow chart of the current in case of fault. When the system has fault, SCR switching work is made if CT detects the increased fault current, and the fault current becomes to be flowed the third coil after making a detour then. That is, if making fault to the simulated distribution system by fault current elements, the fault current flows up to the primarycoil, and then SCR Control system is generated if CT detects it. By work of SCR Control system, SCR-b, a carry out turn-off, on. Thus, the fault current that flowed to the secondary coil flows to the third coil, and the fault current is restricted by the fault current elements having been connected respectively.

2.2 Work Characteristics According to the Fault Current Element

For the fault current element, this study used normal conducting element and superconducting element. Fig. 4 is

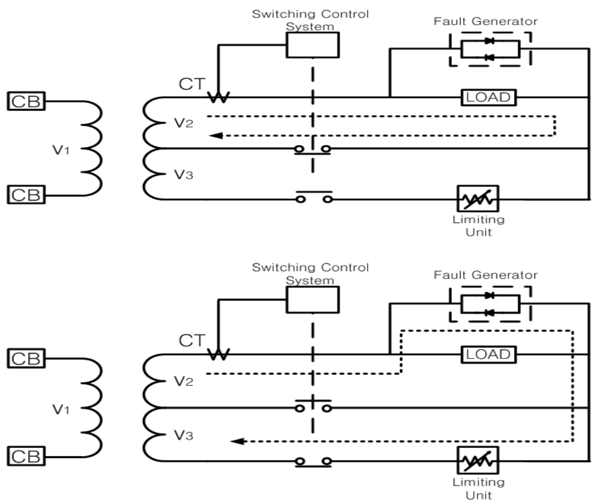

Fig. 3 Current flowchart
(a) steady-state current (b) fault current

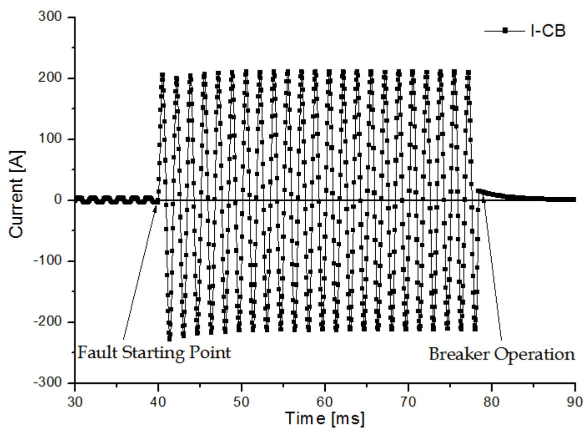

Fig. 4 Operating characteristics of breaker in the event of an fault

related to work characteristics of the breaker in case of not installing the fault current limiter. At this time, the study set up occurrence cycle of the fault current as 100Cycle. And this study simulated single line-to-ground fault by applying power and using fault generator in normal situations. In case fault happened, fault current of 213A flowed to the breaker, and breaking work of the breaker was made after 23 cycles. As a result, the fault current was breaked after flowing for 1/5 of the fault cycle having set up at the first stage. In this experiment, the breaker that was installed for protecting the distribution system in case of not having fault current limiter breaked the track after 23 cycles. Fig. 5 indicates the case of installing normal conducting fault current limiter so as to reduce burdened influences to the breaker in case of fault. For the normal conducting element, the study connected 2 resistance of 20Ω and capacity of 1KW in parallel, and then set up 10Ω 2KW. Same as uninstalling the fault current limiter, the currents increased rapidly to 196 when simulating single line-to-ground fault with the fault generator. If CT detects the fault current, SCR control System becomes to play roles of changing the track by SCR switching work within one cycle. The SCR-b point of contact connected to the neutral line becomes turn-off, and SCR-a point of contact of the third coil changed into turn-on. Thus, the track of fault current was changed and the current is flowed to the fault current limiter connected to the third coil of a transformer. At this time, the fault current was limited to 49A. Fig. 6 displays installation case of SFCLso as to reduce burdened influences to the breaker when accidents happen. Same as normal conducting fault current limiter, the current increased to 196A if simulating single line-to-ground fault by using fault generator in normal situations. CT detected the occurred fault current, and SCR control system carried out switching work. SCR-b point of contact connected to the neutral line became turn-Off, and SCR-a point of contact linked to the third coil changes into turn-On. By the

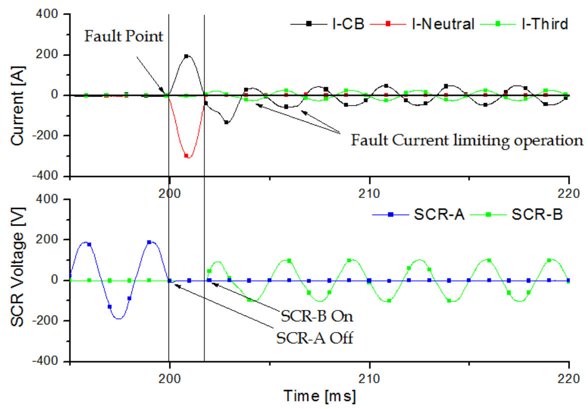

Fig. 5 Normal conducting fault current limiter

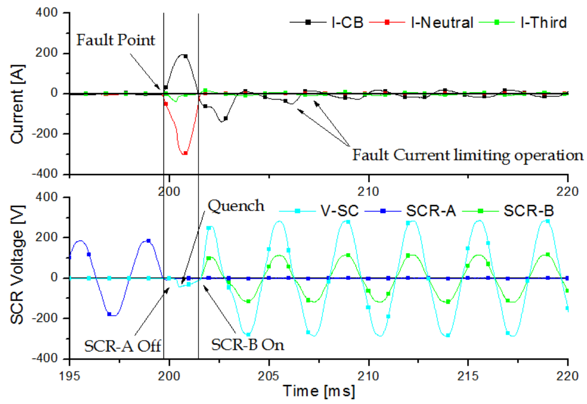

Fig. 6 Superconducting fault current limiter

result, the track where the fault current flowed was changed. That is, the fault current having flowed to the secondary coil of a transformer was flowed into the third coil. At this time, the fault current was limited to 17A through SFCL connected to the third coil.

2.3 Comparative Analysis on Work Characteristics by Each Fault Current Element

This experiment analyzed limited volume and time of fault current by the fault current element. Only when installing the breaker, fault current of 213A occurred, and then breaked after 23 cycles. This means that occurring rate of the second accident becomes increased owing to the protection equipment in case the fault current over nominal rating current for breaker in the distribution system. When installing the breaker and 10Ωesistance, 196A occurred, and SCR work was restricted to 49A because SCR work was operated within half a cycle. In case of setting up the superconducting element, fault current of 196A occurred, and then restricted to 17A because the SCR point of contact was operated within half a cycle. If installing the fault current limiter, it reduces the risk of the second faultby restricting the fault current and reducing the protection equipment, and time margin by which abnormal signals can be repaired is gotten. In relation with the experimental result, there occurs limitation in case of applying normal conducting fault current limiter on the happened fault, but problems happen such like doing reinstallation with proper impedance values according to following linkages with other systems afterwards. On the other hand, in case of apply SFCL, it limited the current more quick and lower compared to the fault current limiter even though increases and decreases of the fault current were repeated owing to recovery characteristics. In addition, it can be applied to larger systems through capacity increases.

3. Conclusion

This study analyzed sizes and time of the fault current limited by types of the fault current element so as to ensure work reliability in case of applying SFCLto the distribution system. The experiment was processed by using the fault current element on normal conducting impedance and superconductors together with the caseof no fault current limiter. The study applied voltage of 240V, and operated single line-to-ground fault. CT detected the occurred fault current, and SCR control changes the point of contract between SCR-b and SCR-b connected to the secondary and third coils. By changes from the point of contact, the fault current was flowed into the third coil after the track waschanged, and then restricted by linked fault current element. As the result of experiment, stable limitation characteristics were appeared after half a cycle after fault current in case of applying normal fault current limiter. In case of applying SFCL, restriction and recovery were repeated owing to critical properties of the superconducting element. However, SFCL showed excellent characteristics in limited scale of fault time and restricted time, and it seems to be improved sufficiently through research development. It is considered that these findings will be a new alternative for solving occurred problems by being connected to current distribution system in case of applying SFCL to the system. Also, comparing SFCL with the fault currentlimiter using normal fault current element to apply the former to the distribution system is expected to be utilized as a basic data for doing protective coordination.

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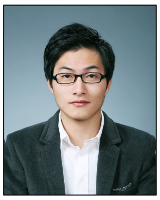

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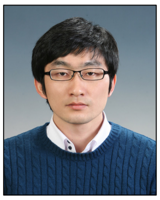

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