Improvement of Recloser-Fuse Operations and Coordination in a Power Distribution System With SFCL

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Abstract—**In this paper, we describes how to coordinate between recloser and fuse in power distribution system with superconducting fault current limiters (SFCL). The recloser and fuses are the main overcurrent protective devices in power distribution system. Universally, to protect against permanent faults, fuses are installed on overhead feeder laterals and the reclosers as a backup protection against temporary faults remove many unnecessary outages. Here, the recloser is set to trip using TCC curve for a temporary fault before any of the fuses can melt. If the fault is a permanent fault, the fuse has to melt just before the last delay trip of the recloser. However, the application of a resistive SFCL in power distribution system affects the recloser- fuse operation and coordination as decreased fault currents. In case that when a permanent fault occurs, the recloser could be locked-out after the last delay trip before the fuses operate.**

Therefore, to solve these cases, we performed experiments which are the recloser-fuse operation and coordination in the modeled power distribution system with the SFCL. Based on the experimental verification, we improved to coordinate the recloser-fuse in power distribution system with SFCL.

Index Terms—**Fuse, power distribution system, protection coordination, protective device, recloser, superconducting fault current limiter (SFCL).**

I. Introduction

RECENTLY, as the power demand is being more increasing and the power system including the power distribution system become increasingly more interconnected and complicated. In this condition, the short circuit currents of the power grid could exceed the rated interrupting capacity of conventional protective devices such as circuit breakers (CB), recloser, switchgear, and so on. Also, theses may generate problems that the protective coordination of them [1]–[3]. So, to solve these problems, there are some conventional alternative such as replacing the protective devices, using series reactors or transformers of high impedance or current limiting fuses. However, theses ways could generate other problems which are power loss, high replacing cost, voltage drop and reliability, and so on. Therefore, it is necessary to the improved current limiting equipments to limit the short circuit current quickly and effectively [4], [5].

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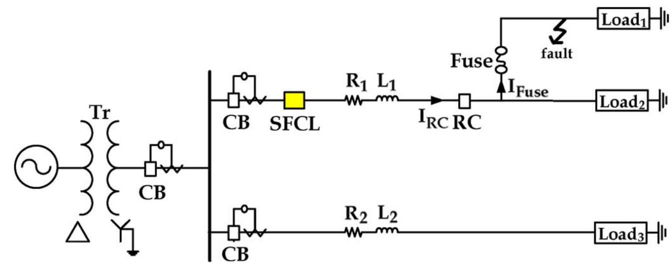

Fig. 1. Configuration of power distribution system.

In these days, the most practical ways to limit short circuit current is application of the Superconducting Fault Current Limiter (SFCL) which has been researched and designed [6]–[10]. However, this way like the SFCL which is limiting short circuit current could generate the error of coordination among the protective devices [11]–[13].

In this paper, we analyzed the problems of relcoser-fuse operation and coordination in a power distribution system with SFCLs by experiment. In other to solve this one, we composed for experiment that is the recloser, fuses, a resistive SFCL, loads and lines in a tested power distribution system. Finally, we performed experimental verification that when SFCLs are applied in a power distribution system, we resolved and improved the problems of the recloser-fuse operation and coordination by proposing the newly replaced coordination range.

II. Configuration of a Power Distribution System and Protective Coordination for Experiment

A. A Power Distribution System for Experiment

Fig. 1 shows a configuration of a power distribution system for experiment with a resist type SFCL to analyze recloser-fuse protective coordination. There are some power equipments such as transformer (Tr), distribution lines, loads, protective devices and the SFCL. And, circuit breakers, recloser(RC), and fuse are installed to protect a transformer, distribution lines, and loads in Fig. 1. Furthermore, we installed the SFCL between an outgoing point of main feeder and the bus and the short circuit tests are performed behind the fuse at "fault" in Fig. 1. It is to analyze the recloser-fuse operation and coordination whit SFCL for us. Tables I and II represent respectively specifications of a power distribution system, parameters of protective devices and SFCL for experiment.

TABLE I
SPECIFICATIONS OF A POWER DISTRIBUTION SYSTEM FOR EXPERIMENT

Transformer (Tr)	Value	Unit
Capacity	125	kVA
Voltage of primary side	220	V
Voltage of secondary side	360	V
Distribution line	**Value**	**Unit**
R_1+jX_1	0.097+j0.68	Ω
R_2+jX_2	0.097+j0.68	Ω
Load	**Value**	**Unit**
$Load_1$	41.2	Ω
$Load_2$	41.2	Ω
$Load_3$	10.3	Ω

TABLE II
PARAMETERS OF PROTECTIVE DEVICES AND SFCL

Recloser (RC)	Value	Unit
Sequence	1F 1D	
Reclosing time	0.1	sec
Pickup current	3	A_{rms}
Fast operation	5	Cycle
Delay operation	8	Cycle
Fuse	**Value**	**Unit**
Ratings	4, 5	A_{rms}
Type	Axial lead	
Material	Tine plated copper	
Diameter	0.8	mm
SFCL	**Value**	**Unit**
Material	YBCO	
Manufactured form	Thin film	
Critical current	19	A
Critical temperature	87	K
Shunt resistance	3.45	Ω

B. Operation of Recloser and Fuse

The recloser is a general overcurrent protective device that automatically trips and recloses a preset sequence to remove momentary faults or permanent faults in power distribution system. Also, it has condition for manually tripping and reclosing the circuit that is installed [13].

For example, if faults occur behind the recloser and they are bigger than the preset value, the recloser is instantaneously operated the fast operations (F). After several fast-operation of one, the recloser operates the delay operations (D). If the fault is not cleared after several recloser operations, the recloser could recognize the fault to a permanent fault and trip permanently (lockout). We preset the operation sequence of recloser to 1 fast—1 delay (1F1D) in this experiment and there are some detailed parameters of the recloser in Table II.

Fig. 2 shows waveforms of recloser operation for experiment. Fig. 2(a) represents the fault current in peak (I_{RC}) and rms (I_{RC-rms}) value during the recloser operations. Here, after the permanent fault occur at 0.2 [s], the recloser has operated 1-fast and 1-delay which is called "lock out". And the fault current didn't flow as well as load currents because the fault is cleared following recloser's delay operation. If the temporary fault occur at 0.2 [s] during 0.1 [s], it could be only to remove the fault by recloser's 1-fast operation and the load current flow like as normal. Fig. 2(b) represents recloser's operation signal which is integral of one called "$Integral_{RC}$" for a fast and delay one. When the fast and delay signals of recloser reach at the "1" point, the recloser operate at "$Trip_{RC}$" which has some delay time for mechanical margin.

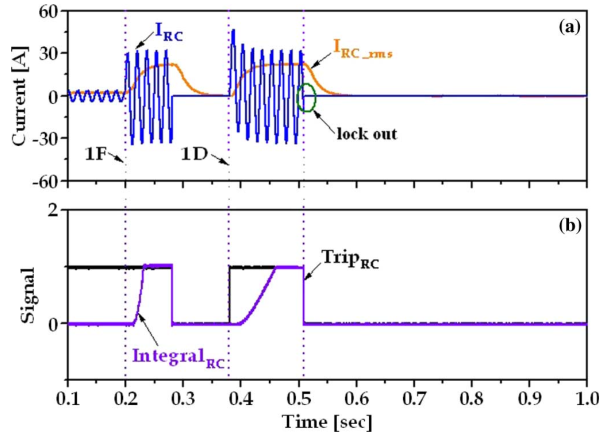

Fig. 2. Waveform of recloser operation for experiment. (a) The fault current for peak and rms of recloser. (b) Operation signal of recloser for trip and integral.

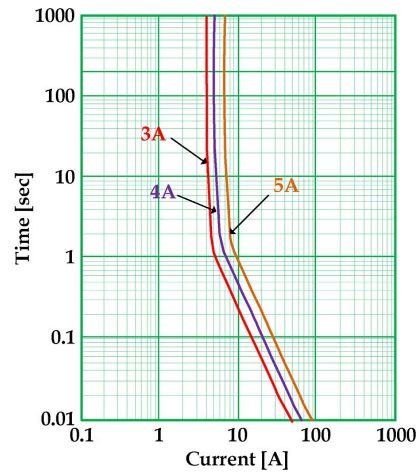

Fig. 3. Time current characteristic (TCC) curve of fuse links.

Fuses are the most basic overcurrent protective devices in the power distribution system. Their main function is to serve as inexpensive weak links which is being able to clear fault current easily and protect equipment against overloads and short circuits. When the fault happen behind a fuse and the fault current pass the fuse link, it must melt by heating energy I^2Rt generated by the fault current to protect other electrical devices. Furthermore, the melting time of fuses is dependent on their material and we could select the fuse rating referred to the melting time. The fuse rating could be decided considering load currents, fault currents, and protective coordination with other protective devices. Universally, many electrical engineers could select the fuse rating using time current characteristic (TCC) curve of fuse links. Most overcurrent protective devices have their TCC curves [14], [15]. Fig. 3 shows TCC curves of fuse links used in this experiment. These are 3A, 4A, and 5A but there are actually fuse links of various types [16].

C. Coordination of Recloser and Fuse

We studied the coordination of recloser and fuse. Generally, to provide protection against permanent faults, fuses are in-