THE TEST AND INSTALLATION OF MEDIUM CLASS(22.9KV) HYBRID TYPE FAULT CURRENT LIMITER IN KEPCO GRID

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ABSTRACT

Hybrid type fault current limiter using superconducting device is one of the various type fault current limiters(FCL). Because of a small superconductor which acts as a trigger of FCL while it is operating and the size can be compact. The proto-type of hybrid type FCL in the grid at KEPCO Power Testing Center for several years. The limitation of fault current plays a main role of FCL. It is a very difficult technology, but we should consider other conditions according to applied positions. The main objectives of FCL are different if it is installed with main transformer of substations, at feeder lines or at bus-ties for parallel operation of transformers. This paper proposes protective coordination another role of FCL. This paper shows that the limitation of FCL helps protective coordination in distribution lines and the installation of FCL for 22.9kV commercial KEPCO grid, especially manufacturing and tests. For protective coordination, FCL should not operate under the current setting value. We call the value 'minimum limiting current'. This paper shows specifications and characteristics of FCL including minimum limiting current. The basic test is performed, but the reliability and of FCL should be improved continuously.

INTRODUCTION

Superconducting fault current limiter is one of the well developed power machine based on high-Tc superconductors (HTS). Though any developed FCL demonstrates its current limiting capability by short circuit tests, the machine needs to be proved operation performance and reliability by a field test. Several FCLs were actually field-tested in the electrical power grid. The tests are essential to show the usefulness of an FCL before use in a live grid for commercial application. The field test is to check basic properties such as current limitation, non-stop operation for long time, maintenance, and so on. It is also used to prove whether the FCL satisfies local needs, particularly in the coordination with other protective devices. The FCL at a feeder requires high readiness in continuous operation. For instance, cryogenic failure of the FCL may cause blackout in the feeder, otherwise the line must be bypassed, which means there is no FCL. Currently, the local utility, KEPCO are carrying out a project for commercial operation in the 22.9 kV live grid for the local utility. Prior to the operation, discussions were made on the local requirements associated with the FCL, which is to be installed in a 22.9 kV feeder. The operation test in this article is basically to backup the above project. Two major topics are to be studied in this operation test, (1) long term operation, and more importantly, (2) coordination with other protective devices. The long term operation test includes maintenance free operation, handling emergency cases such as power failures, and operation cost assessment. The protection coordination study will provide how this new machine can co-work with conventional protection devices. For this purpose, we have constructed the 22.9 kV simulated test grid, and installed the hybrid type of FCL in the grid at KEPCO Power Testing Center. The grid includes circuit breakers, reclosers, and an artificial fault generator (AFG). In this study, we will discuss long term operation and short circuit test of the SFCL in the test grid. The SFCL has been run for more than a year and have experienced multiple emergencies. Short circuit tests were performed for protection coordination study.

FAULT CURRENT LIMITER

COORDINATION

154/22.9kV substations are typically composed of 4~5 transformer in KEPCO grid which is public utility in Korea. To limit the fault current at 22.9kV distribution level, %Z is higher than that of industrial utility and bus section is normally open. It means that this could ~~be~~

reduce the percent impedance of transformer and bus section could be normally closed, if fault current could be lower than at present. Two kinds of application are possible in this grid.
One is bus section of transformer and another is 22.9kV distribution line. If all CBs of bus section are closed in this grid, maximum fault current exceeds rating of circuit breaker (25kA) to reduce transformer loss by the load balance of transformer.

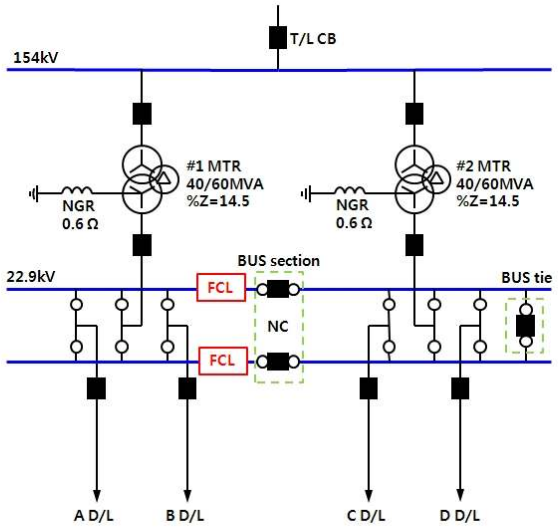

Fig.1 Application of the bus section of transformer.

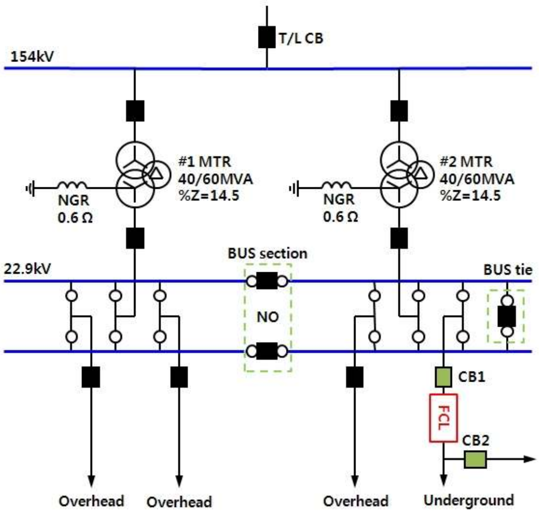

Fig.2 Application of a 22.9kV distribution line

In case of application of FCL in the 22.9kV distribution line, the effect is quite different. That is why maximum fault current(7.4kA) is lower than ratings of circuit breaker. Normally over current relaying system is used for the protection in a radial power system. Protection coordination is not the work of closed series circuit breaker at a high fault current. Fig.3 is an example of needs of fault current limiter for OCR protection coordination. In case over 4,000A fault current at the branch line through the CB2, two of OCRs are tripped result from lower breakout of normal distribution line without fault current limiter. If we insert fault current limiter, it can be reduced to less than 4,000A in the yellow box which is resulted from enable protection coordination as increasing coordination time between two over current relay. But over limitation is unnecessary because it only brings time delay of removing fault by the CB2.

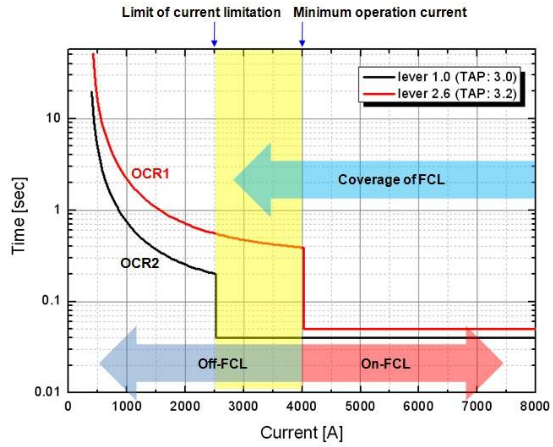

Fig.3 OCR protection coordination.

MANUFATURE

The simple circuit of FCL which is installed in Icheon S/S is shown in fig.1. FCL is made up of HTS, fast switch module and limiting impedance. HTS acts as trigger of FCL operation . HTS keeps superconductivity in normal condition, but it quenches when large fault current flows through HTS. As impedance of HTS is increased, fault current flows to parallel path include coil(Thomson drive). FCL's fast switch module starts to operate. The fast switch module is composed of Thomson dive coil, VI, protection switch of coil and PMA. Because this FCL is installed in public utility, it should perform reclosing operation. PMA does duty as running gear of VI close and additional backup operation. Limiting impedance can be chosen between a resistor type and a reactor type. According to utility which FCL is used, we made a reactor type of 0.4ohm.

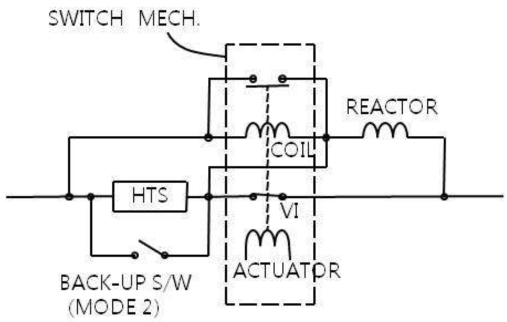

Fig.4 Circuit diagram of Hybrid type FCL in Icheon S/S

The most important characteristics of above mentioned HTS are uniform current distribution and simultaneous quench. Fig.5,6 is picture of a single phase module and three phase arrangements of HTS and critical current.

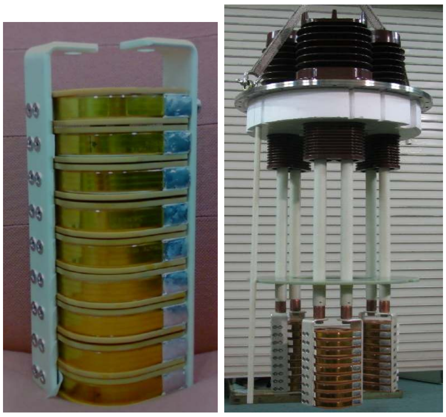

Fig.5 single phase module and three phase arrangements of HTS

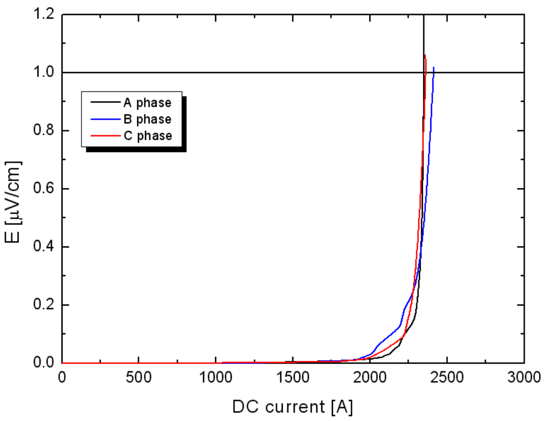

Fig.6 Critical current for each trigger module of 9 parallels

Fast switch module is one of the most important components because it actually carries out inserting the impedance into the fault circuit. VI is used as a main contact. As it has one weak point which cannot disconnect the current before zero, this FCL cannot limit first peak of fault current. Current limiting impedance value have to be considered protection coordination.

For protection coordination it should be selected a minimum operation current value which isn't high overcurrent, for example right end of yellow zone of fig.3. It is decided by HTS's physical characteristics, but it has an unclear region because fault current may have DC portion and so on. Fault detector(FD), additional part settable operating current level will cover unclear region. If FD detects fault, then it sends operating signal to PMA whatever HTS operates sucessfully or not. Even if FD is an additional part in this FCL, it can be used various applications. In addition to FCL, monitoring & control system is run for cryo-cooling system.(fig.9)

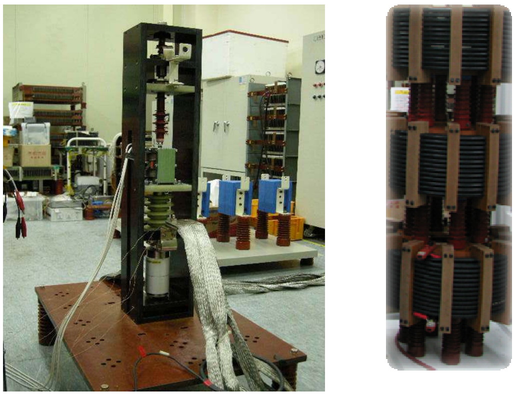

Fig.7 Fast switch module and reactor

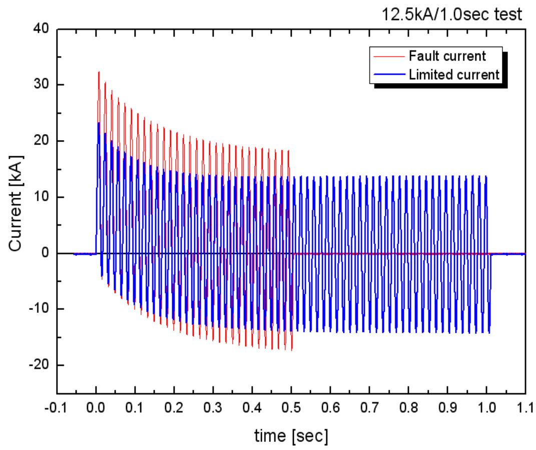

Fig. 8 Limitation of fault current

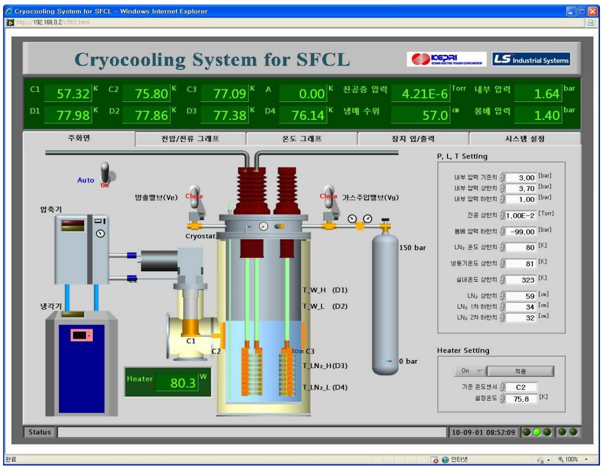

Fig.9 Monitoring and Control Display of Cryo-cooling System

Table 1 shows specification of FCL. In this table we defined 'minimum limitation current'. It means minimum current value of FCL's operating region. We selected it according to the protection coordination and protection of HTS.

Table1. Specification of FCL in Icheon S/S

Parameter	**Specification**
Rated Voltage (rms)	**22.9 kV**
Rated Current (rms)	**630 A**
Rated Power Frequency	**60 Hz**
Rated Power Frequency withstand voltage (rms)	**70 kV**
Rated Impulse withstand voltage	**150 kV. BIL**
Rated short circuit current (rms)	**12.5 kA/1.0 sec**
Insulation type	**Air**
Minimum Limiting Current (rms)	**1.4 kA**
Current Limiting Reactor	**0.4 [Ω]**
Recovery time	**< 0.5 sec**
Critical Current of HTS	**> 2,000 A**
Cooling Power	**220W at 80K**
Operation temperature	**75~77K**

TEST AND INSTALLATION

It was carried out for the insulation, temperature rising, and short circuit current test. Picture of FCL in test field and the oscillograms of short circuit current are shown in fig.10-11. Above mentioned oscillograms of reclosing operation is shown in fig.12.

This FCL is installed in Jangpyeong D/L of Icheon S/S. Diagram of power system and picture of FCL installed are shown fig.13.

Fig.10 Test of short circuit current

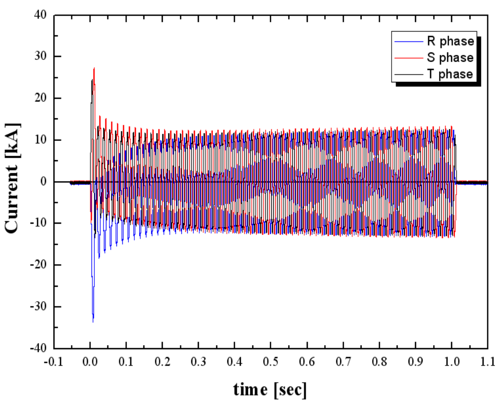

Fig.11 Rated Short Circuit Current

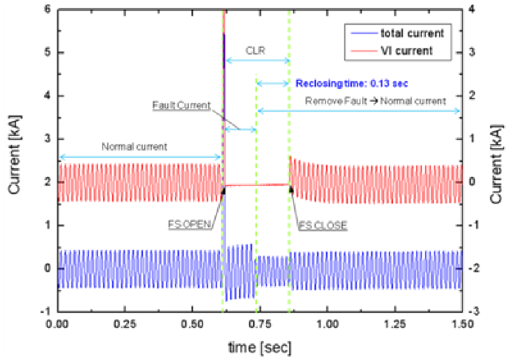

Fig.12 Reclosing operation

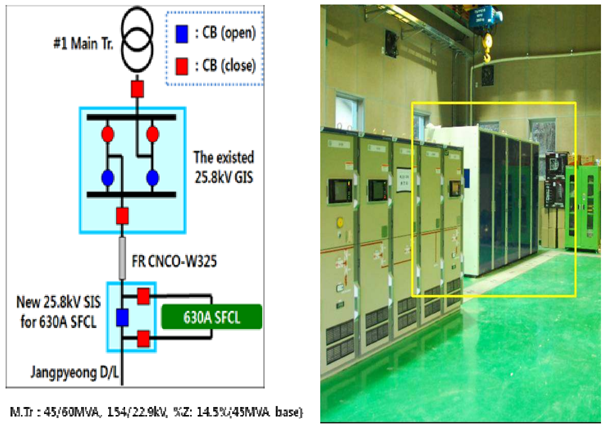

Fig.13 Diagram and installation of FCL in Icheon S/S

CONCLUSION

Hybrid type fault current limiter was installed in Icheon S/S successfully. In this type of FCL, the operation reliability of a cryogenic cooling system for superconductor should be improved, and the error, which is related to minimum limiting current, should be reduced.

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