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Improvement of the transient stability using SFCL in Korean power systems

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ABSTRACT

This paper proposed a novel hybrid SFCL system for the enhancement of the transient stability in Korean power transmission system with auto-reclosing operation. The proposed SFCL system has an operation mechanism that the current limiting impedance is eliminated from the power system in a fault clearing time for the enhancement of the transient stability. Also, the system can cover the auto-reclosing operation of the transmission power system. This study analyzed an improvement of the special protection system by applying the proposed SFCL system to real power system in Korea.

1. Introduction

The recent Korean power systems have been operated under stressed conditions close to stability limits. Under these circumstances, an important problem that is frequently considered for secure operation is the problem of transient stability. In Korea, the Special Protection System (SPS) is applied for protecting the power system from the viewpoint of the transient stability. The SPS generally adapts generator tripping and load shedding. Also, the splitted bus is operated in Korean power plants because of the fault current problem. The superconducting fault current limiter (SFCL) is one of the actions for the enhancement of the transient stability as well as a solution for the fault current problem in Korean power plants. In Korea, a 22.9 kV hybrid SFCL was developed through GENI (Green superconducting Electric power Network at the Icheon substation) project [1,2]. The 22.9 kV SFCL has been successfully operated at the Icheon substation in Korea since 2011. A new project for the development of a 154 kV Hybrid-SFCL started in July 2011. According to the operation mechanism of the 154 kV SFCL, a current limiting resistor or reactor (CLR) cannot be eliminated from the power system during about a minute because of long recovery time of the high temperature superconductor. This mechanism has a bad impact on the transient stability when the SFCL is installed at power plant systems for the enhancement of the transient stability. In general, auto-reclosing operation is adapted in 154 kV and 345 kV power transmission systems, but the 154 kV SFCL cannot recover the auto-reclosing operation. This paper proposed a new hybrid SFCL system for the application to power plant systems auto-reclosing operation in Korea. The application of the proposed SFCL system to power plant systems can enhance the transient stability of the system. In this paper we simulated the improvement of the SPS operation by installing the proposed SFCL system to Taean power system in Korea, using a transient analysis program, PSS/E.

2. Hybrid SFCL for power transmission systems in Korea

A 154 kV hybrid SFCL system has been designed for the application to a real power system in Korea. The SFCL has two main parts, the high temperature superconductor (HTS) and the current limiting resistor/reactor (CLR). The two parts are connected in parallel like Fig. 1. In a normal state, all of the load currents flow into the HTS because the impedance of the HTS is almost zero. In a fault condition, the fault currents flow through the CLR and the CLR limits the fault currents.

3. Novel hybrid SFCL for the enhancement of the transient stability in Korea

In general, the recovery time of the HTS of the above 154 kV SFCL is longer than the reclosing time of the power transmission system in Korea. This type has disadvantages that the CLR cannot be eliminated from the power system during about a minute and the SFCL cannot recover an auto-reclosing operation in power transmission systems. So, this paper proposed a novel hybrid SFCL system for the enhancement of the transient stability in Fig. 2 with the supplementation of the disadvantage.

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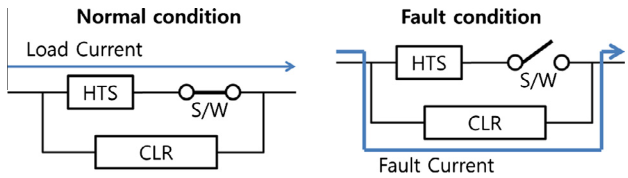

Fig. 1. Basic operation mechanism of 154 kV SFCL developed in Korea.

The newly suggested hybrid SFCL in Fig. 2 has a structure of adding an HTS module and a circuit breaker in parallel with the conventional hybrid SFCL in Fig. 1. In a normal state, the load current flows through the HTS1 with the closed CB 1 like ① in Fig. 2b and the impedance of the HTS is almost zero. In this time, CB 2 and CB 3 are closed. When the fault current flows into the HTS 1 in a power fault condition, the HTS 1 is quenched and the resistance of the HTS 1 is dramatically increased. At this moment, the CB 1 is opened and the HTS 1 becomes a recovery state. In this time, the fault current is limited by the CLR like ② in Fig. 2b. The CB 2 is closed in a reclosing time after clearing the fault like ③ in Fig. 2b. If the fault continues in the power system after 48 cycles of reclosing time, the HTS 2 is quenched and the fault current is limited again by the CLR like ④ in Fig. 2b. If the fault is removed after 6 cycles, the CB 3 is closed and the load current flows to the CB 3 like ⑤ in Fig. 2b. When the recovery of the HTS 1 finishes, the CB 1 is closed and the load current flows through the HTS 1 in a normal state.

4. Transient stability of Korean power system

The Special Protection System (SPS) is under the operation in Korea power system. It prevents the loss of synchronism of generators by the generator tripping and load shedding when a transmission line fault occurs near a power plant. The generator tripping and the load shedding are effective for improving the transient stability. Table 1 presents the SPS operation for Taean Thermal Power Plant (TPP) in Korean power system. As shown in the Table 1, the operator of the Korean power system must trip two generators among eight generators in service to stabilize the power system when the fault occurs at an incoming line of the power plant and the line is opened. The study sequence for the transient stability of the 345 kV system including the auto-reclosing operation is shown in Table 2. The reclosing time is 36cycles

5. Simulation results

We performed a simulation on the transient stability for the Korean power system with the proposed SFCL system, using a power analysis program, PSS/E. The simulated system is a peak Korean power system in 2011. We studied the transient stability in the Taean TPP system with or without the SFCL when a three phase fault occurs at a Sinseosan3-Asan3 transmission line. Fig. 3 illustrate the one-line diagram of the power system.

Table 1
SPS Operation (in case of a fault at a Sinseosan-Asan 345 kV transmission line).

TPP Operation state	Number of tripped generators (Taean TPP)
Taean TPP 8, Dangiin TPP 7–8	2
Taean TPP 8, Dangiin TPP 6	1
Taean TPP 7, Dangiin TPP 7–8	1

Table 2
Sequence of the transient stability study in 345 kV Korean power system.

Time	0s	0.5s	0.6s	~	1.2s	1.3s	10s
Event	Start	Fault	Clear fault Branch trip Machine trip	Reclosing time	Fault	Clear Fault	End

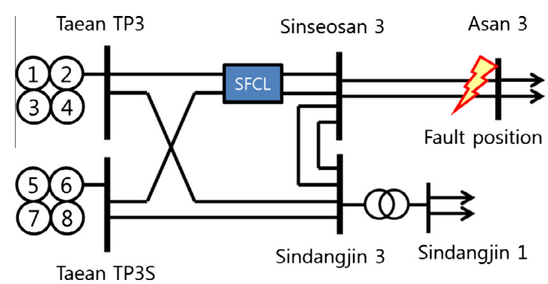

Fig. 3. One-line diagram of the Taean power system with the proposed SFCL system in Korea.

Table 3
Simulation CASE (TPP operation state: Taean TPP 8, Dangjin TPP 8).

CASE	Number of tripped generator (taean TPP)	Application of hybrid-SFCL
Basecase	2	Without SFCL
CASE 1	2	With existing SFCL
CASE 2	1	With proposed SFCL

As shown in Table 3, we considered the three cases for the transient stability study. It is supposed that the impedance of the CLR is 10 Ω as the resistance-type.

When the transmission line Sinseosan3-Asan3 is opened, the power system is unstable in terms of transient stability without tripping generators in Taean TPP. Thus, we were going to verify enhancement of transient stability as the number of tripped

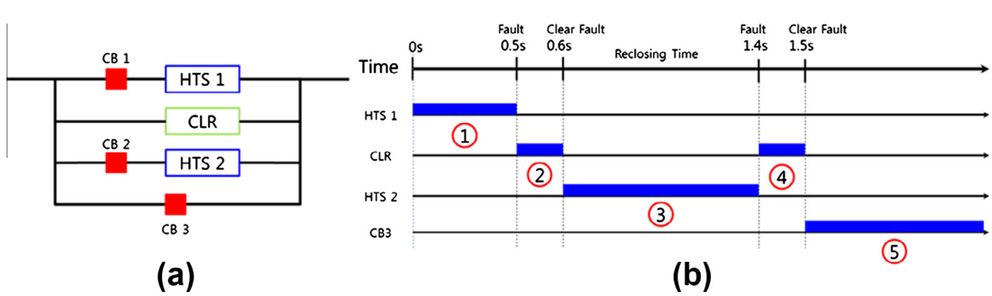

Fig. 2. (a) Structure of the novel hybrid SFCL, (b) operation sequence of the novel hybrid SFCL.

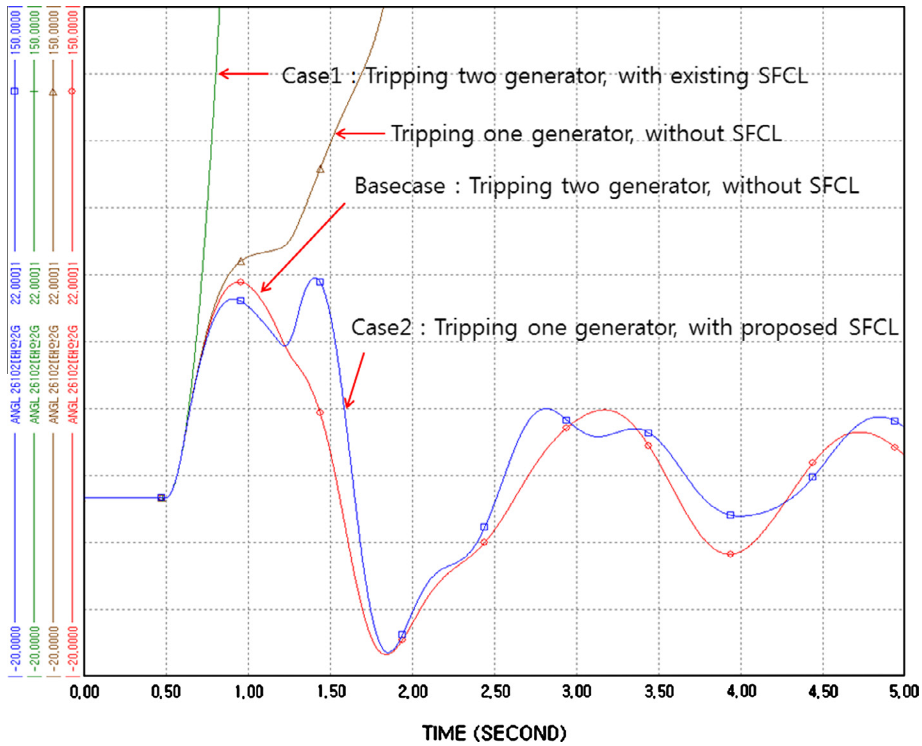

Fig. 4. Simulation result (angle of Taean TPP#2G).

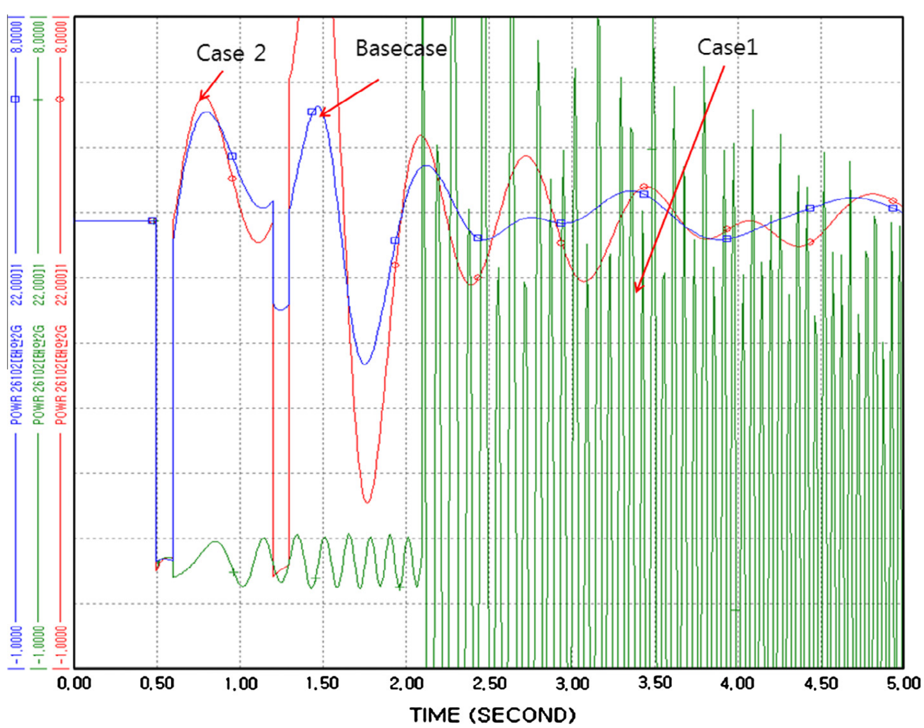

Fig. 5. Simulation result (electric power of Taean TPP#2G).

generators. Fig. 4 shows the result of transient stability simulation on three different cases as follows:

(1) Base case: SPS based operation
(2) Case 1: existing SFCL
(3) Case 2: proposed SFCL

In the Base case without SFCL, the number of tripped generators is two in order to be stable in transient stability.

In Case 1, the power system is unstable installing the existing SFCL in tripping one generator. In Case 2, the power system is stable by installing the proposed SFCL. Fig 5 shows the electrical power of cases.

6. Conclusion

This paper presented an application of SFCL in order to enhance transient stability in transmission system operation. A novel hybrid SFCL was proposed in case of reclosing the opened transmission line by a fault. According to the simulation results, the application of the novel hybrid SFCL reduced the number of tripped generators in the existing SPS operation in Korea. The results prove that the proposed method can enhance transient stability, and give flexibility to power system operators in SPS operation.

Acknowledgements

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