A Novel Approach on Voltage Unbalance Improvement using SFCL on Electric Railway System

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Abstract— This paper presents a novel approach to determine the power system stability using resistive superconducting fault current limiter (SFCL) of an electric power grid (EPG). In addition, the electric railway system has rapidly changing load characteristics in time. An unbalance is generated owing to therapeutically changing large single-phase loads. Subsequently, the unbalanced load causes an unbalanced transmission line. A voltage unbalance in the source influences the power equipment by causing a reduction in the power generation capacity of the generator and a decrease in the output of the other facilities in the transmission line. In addition, many flexible ac transmission systems are applied to transmission lines to compensate for and control electric power. A voltage unbalance causes a control error in these systems. In addition, we analyzed the effects of the proposed method using MATLAB simulation.

I. INTRODUCTION

WITH the increasing of system capacity, fault occurrence probability becomes higher, that can induce severe damages in electrical power system [1]. For example, the high value of the short circuit current can damage the insulation strength of electrical devices, synchronous generators, protective relays, lines transmission, and loads. In addition, the electrical power needed by the system when a fault occurs is modified and induced instable state of the power generators. Recently, the development of superconducting fault current limiters (SFCL) offers one of the most attractive alternatives to solve the fault current problems [3]–[5]. Thanks to their fast transition from a low to a high impedance, superconducting devices can limit, in a very short time, the value of any fault current. What is attractive is that the transition is due to an intransit behavior of the material itself.

The presence of the SFCL in a power system can increase the system stability and distributed energy quality [10]–[15]. When an SFCL is introduced in an electric power grid (EPG), three important factors must be considered: 1) optimal location of the SFCL in the EPG [16]; 2) optimal resistive value of the SFCL [17]; 3) protection-coordination problem with other existing devices (circuits breaker, OCR, etc.).

In response to the unbalances, flexible AC transmission systems (FACTs) are applied to control transmission system powerflow and to improve system stability. A thyristor-controlled series capacitor (TCSC) is one of the practical devices that can improve the implementation of FACTs [4]. Actual line voltage and current information is quite important TCSC control scheme. However, voltage and current unbalance produced by an electric railway load causes serious TCSC control errors. This problem can influence system stability. In particular, a voltage and current unbalances after fault will cause further problems.

The simulation results show the effectiveness of the proposed method. In fact, the optimal location determined for the SFCL improves the transient stability of the power system and decreases the low frequency oscillation of the generator speed when a severe damage is introduced (three-phase fault). The advantage of the proposed method is that the selected location of the SFCL takes into account the fact that the fault can occur anywhere in the studied grid.
II. PROPOSED SYSTEM

An electric railway is connected to a 154 kV transmission line through a Scott transformer in Korea. Fig. 1 shows a transmission system connected with railway equivalent model.

Fig. 1. Transmission system connected with a railway.

A TCSC facility is installed to control power flow in transmission line, and an electric railway includes a single phase load that causes a voltage unbalance. In addition, the self- and mutual impedance of transmission and rail of the Korean electric railway system were considered [1]. Here, in order to analyze the influence of an electric railway connection on the transmission line fault, we simulated a fault situation.

Fault starting time is 0.4 s and fault duration time is 0.1 s. Fig. In case of fault on the transmission line without electric railway, 3-phase voltage decreased owing to fault and after fault removal, there is a transient phenomenon that has a small offset voltage but returned to a steady state. In addition, this simulation showed a small magnitude difference between offset voltages. Current is generated a large transient current during fault and reach to steady state, load current, after fault removal. In contrast, large offset voltages are represented in simulation result about fault on transmission line with electric railway.

Especially, voltage of phase B is increased up to 350 kV in a moment. In addition, voltage unbalances of transmission line became more serious compared with above case. Line currents are also increased and caused unbalance owing to transient voltage. We think that closing phase angle control of TCSC system is influenced by generated transient voltage and current as the cause of these results. These phenomenon will cause problem about voltage stability and malfunction of protection scheme in the transmission system. These results show that an electric railway connection aggravates voltage unbalance in the transmission line.

III CONTROL SCHEME

Power transmitted between a sending-end bus and a receiving-end bus in an AC transmission system is dependent on the series impedance. Further, impedance of a transmission line consists mainly of inductive reactance, with resistance accounting for only 5–10% of impedance [5], [6]. If a series capacitor is inserted into transmission line, the inductive reactance of transmission line could be compensated by a capacitive supply. This concept of series compensation is illustrated in Fig. 2. Typical configuration of a TCSC from a steady-state perspective involves a fixed capacitor (FC) with a thyristor-controlled reactor (TCR). TCSC structure is shown in Fig. 3.

Control of α typically applies open-loop control or closed-loop control. Fig. 4 details a schematic of a constant current closed-loop control [8]. In Fig. 4, Iref is desired transmission line current, IM is actual current, and Ierror is the difference between Iref and IM. In particular, Ierror is an important quantity in this control loop. A current unbalance can cause serious issues for TCSC control.

we discovered following features: 1) the larger resistance of a resistortype SFCL, the more voltage unbalance was improved. 2) InSFCL operating process, there are differences of recovery time between superconducting elements owing to unbalance fault current. If a fault occurs, the proposed method clears voltage unbalance and protects TCSC. Thus, transmission system can quickly return to operating in a conventional state. As a result, we will expect improvement effect for the problems about voltage stability and protection scheme malfunction.
IV SIMULATION RESULTS

Fig. 5 Simulation circuit

Fig. 6 Typical primary and secondary voltages of a Scott transformer under a T-phase load.

Fig. 7 Simulation circuit for three-phase fault(a) without railway

Fig. 8. Voltage and current results from the simulation: (a) without railway

Fig. 9. Simulation circuit for three-phase fault(a) with railway

Fig. 10. Voltage and current results from the simulation: (a) with railway
Fig. 11 Simulation results for electric railway system and SFCL

Fig. 12. Voltage & Current

Fig. 13. SFCL simulation circuit

Fig.14. Voltage & Current Results

V. CONCLUSION

This paper proposed a method to reduce voltage unbalance for a TCSC-compensated transmission line using an SFCL. First, the configuration and operation of a compensated transmission line and connected electric railway system were modeled and detailed. Next, voltage unbalance in transmission lines was studied when line fault occurs. Finally, the method for alleviating this problem with SFCL was considered.

REFERENCES


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