International Journal of Research
Available at https://edupediapublications.org/journals
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 04 Issue 08
July 2017

Study on Voltage Unbalance Improvement Using SFCL in Power Feed Network with Electric Railway System with wind turbine generator system as power source

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ABSTRACT.
An electric railway system uses a single-phase source that is supplied through a Scott transformer from a three-phase transmission system. In addition, the electric railway system has rapidly changing load characteristics in time. An unbalance is generated owing to the rapidly 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. We propose the application of a superconducting fault current limiter to improve the voltage unbalance in a transmission system linked to a Scott transformer. In addition, we analyzed the effects of the proposed method using transient simulations and application of wind turbine generator system as input power source.

INTRODUCTION

Recently, Electric railway systems have gained great interest owing to depletion of fossil fuels and limits on carbon emissions to prevent global warming. The use of an electric railway causes a large-scale load owing to demand increase and performance improvement [1]. This system uses a single-phase source supplied through a Scott transformer from a 3-phase transmission system and has rapidly changing load characteristics in time. These characteristics can cause voltage unbalances [2], [3]. From the utility viewpoint, single-phase loads that cause voltage unbalances in the transmission lineare constantly being increased. In response to the unbalances, flexible AC transmission systems (FACTs) are applied to control transmission system power flow 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. **FACTS:**

Flexible AC Transmission Systems, called FACTS, got in the recent years a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice.

In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. The basic applications of FACTS-devices are:

- Power flow control
- Increase of transmission capability
- Voltage control

- Reactive power compensation
- Stability improvement
- Power quality improvement
- Power conditioning
- Flicker mitigation
- Interconnection of renewable and distributed generation and storages

The usage of lines for active power transmission should be ideally up to the thermal limits. Voltage and stability limits shall be shifted with the means of the several different FACTS devices. It can be seen that with growing line length, the opportunity for FACTS devices gets more and more important.

The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second.

The development of FACTS-devices has started with the growing capabilities of power electronic components. Devices for high power levels have been made available in converters for high and even highest voltage levels. The overall starting points are network elements influencing the reactive power or the impedance of a part of the power system. Figure 1.2 shows a number of basic devices separated into the conventional ones and the FACTS-devices.

For the FACTS side the taxonomy in terms of 'dynamic' and 'static' needs some explanation. The term 'dynamic' is used to express the fast controllability of FACTS-devices provided by the power electronics. This is one of the main differentiation factors from the conventional devices. The term 'static' means that the devices have no moving parts like mechanical switches to perform the dynamic controllability. Therefore most of the FACTS-devices can equally be static and dynamic.

TRANSMISSION LINE WITH TCSC AND ELECTRIC RAILWAY

TCSC -Compensated Transmission:

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. 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. Typical configuration of a TCSC from a steady-state perspective involves a fixed capacitor (FC) with a thyristor controlled reactor (TCR).

Operation and Control of A TCSC System:

The equivalent impedance *X*TCSC of TCSC is as follows:

$XTCSC = XCXTCR/XC - XTCR = XCXL/XC/\ (\pi\ (2(\pi-\alpha)+\sin 2\alpha)) - XL$ Where XL is the reactance of the fixed reactor

α is firing angle of the thyristor measured from the zero crossing, and *XC* is reactance of the fixed capacitor.

Control of α typically applies open-loop control or closed loop Control. Fig. 3 details a schematic of a constant current Closed-loop control [8]. In Fig. 3, Iref is desired transmission Line current, IM is actual current, and Ierror is 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. **Unbalanced Load In An Electric Railway System:**

An electric railway characteristic that most utilities are concerned with is current unbalance produced by large single-phase loads [9], [10]. These unbalanced currents cause 3-phase voltage unbalance. To minimize voltage unbalances in 3-phase power feed networks, Scott transformers are widely used.

Nevertheless, an unbalance can be generated owing to large rapidly changing single-phase loads. Fig.2.1.1 shows an unbalance in a 3-phase transmission line voltage produced by a single-phase load in T-phase of the railway.

MODELING THE SFCL AND FAULT OF THE TRANSMISSION LINE IN AN ELECTRIC RAILWAY

Resistor-Type SFCL Modeling:

In order to limit a fault current, many models for the SFCL have been developed: resistor-type, reactor-type, transformer type, etc. [11]. In this study, we modeled a resistor-type SFCL that is mostly basic and used widely which represents the experimental studies for superconducting elements of SFCL. Quench characteristics and recovery characteristics of a resistor-type SFCL are modeled based on [11] and [12]. An impedance of the SFCL according to time t is given as follows: **Fault Modeling of the Transmission Line in the Electric Railway:**

An electric railway is connected to a 154 kV transmission line through a Scott transformer in Korea. Fig. 5 shows a transmission system connected with railway equivalent model. 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. Table 1shows the transmission and electric railway system parameters of simulation. 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. Operation in the first and third quadrants corresponds to reduction of power through the DFC, whereas operation in the second and fourth quadrants corresponds to increasing the power flow through the DFC.

The slope of the line passing through the origin (at which the tap is at zero and TSC / TSR are bypassed) depends on the short circuit reactance of the PST.Starting at rated current (2 kA) the short circuit reactance by itself provides an injected voltage (approximately 20 kV in this case).

If more inductance is switched in and/or the tap is increased, the series voltage increases and the current through the DFC decreases (and the flow on parallel branches increases). The operating point moves along lines parallel to the arrows in the figure.

The slope of these arrows depends on the size of the parallel reactance. The maximum series voltage in the first quadrant is obtained when all inductive steps are switched in and the tap is at its maximum.

Now, assuming maximum tap and inductance, if the throughput current decreases (due e.g. to changing loading of the system) the series voltage will decrease.

At zero current, it will not matter whether the TSC / TSR steps are in or out, they will not contribute to the series voltage. Consequently, the series voltage at zero current corresponds to rated PST series voltage.

Next, moving into the second quadrant, the operating range will be limited by the line corresponding to maximum tap and the capacitive step being switched in (and the inductive steps by-passed).

In this case, the capacitive step is approximately as large as the short circuit reactance of the PST, giving an almost constant maximum voltage in the second quadrant.

APPLICATION OF SFCL TO WIND TURBINE GENERATOR SYTEM

Superconducting Fault Current Limiter (SFCL)

In this chapter we discuss about the working of SFCL. As there is a huge increase of electricity demand and change of concerning environment, we are looking to utilize the of renewable energy generation systems in order to supply the power demand.Even more the .Renewable energy sources are known as clean and prospective energy sources of the future world. Coming wind power about to 12% of world’s electricity is generated from wind power.

The application of wind-turbine generation system (WTGs) as the power source also advantageous in the ways such as

Advantages:

1. Does not cause pollution problem.

2. Lowest maintenance cost. Disadvantage:

WTGs increases the level of short-circuit current during a fault in a distribution system.

Inorder to reduce the short circuit current during fault condition we use a high temperature superconducting fault current limiter (SFCL) .

Reasons to apply SFCL:

1.Reduces the peak value of fault current.

2. Improves the transient stability of the power system.

3.Provides the system effective damping for low-frequency oscillations.

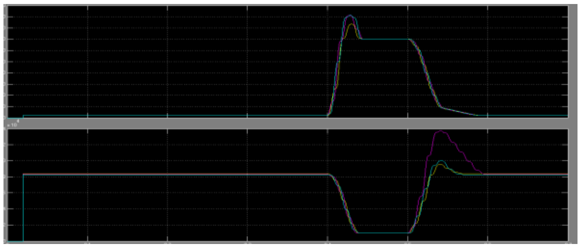
4.Causes no power loss in steady-state condition.

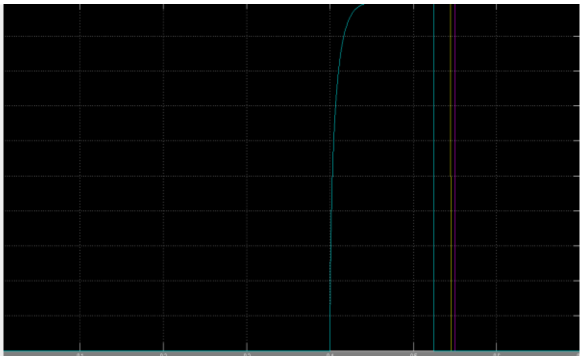
Connection of SFCL to an electric power grid:

Optimal place to install the SFCL.
The optimal location to apply to introduce SFCl in a transmission line is in series with the line.

Potential protection-coordination problem with other existing protective devices such as circuit breakers.

OUTPUT WAVE FORMS





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 line was studied when line fault occurs. Finally, the method for alleviating this problem with SFCL was considered. The proposed method showed the following improvements for transmission line faults:

1) The fault current was decreased as compared to the existing system fault current and

2) Voltage unbalance in the transmission system was quickly improved after the fault was removed.

3) In future, we will study a protection scheme using an SFCL for a compensated transmission system to improve system stability.

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