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Elimination of the Voltage Unbalance Condition by Using the SFCS from the Line Fault

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Abstract:

Scott transformer was used for transferring of power for electric train which is single-phase system. The load conditionsof these systems are unbalance with respect to time. 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. The controlling of power can be done by FACTS devices. The control errors are the main drawbacks of these devices. To overcome these problems superconducting fault current suppressor (SFCS) has proposed in this paper. The performance characteristics of proposed technique are verified by MATLAB/simpower systems toolbox.

Key words:
voltage balance, FACTS, SFCS, fault current elimination.

I.INTRODUCTION:

Current research towards the development of a superconducting fault current suppressor (SFCS) for large scale power grid applications has led to the establishment of long term pilot installations on existing power grids and test grids to prove operability and performance. These installations are testimony that SFCS's have now evolved to a position wherein it too may be considered as an effective means of fault level management. This paper compares, from a financial and operational perspective, high temperature superconductor tape based resistive SFCS's against traditionally power utility employed methods of fault level management on a large scale power grid. A high fault level is not intrinsically undesirable as it is an indication of the strength and robustness of a power system, but becomes so when it is larger than the rating of the installed equipment. This then requires an intervention to militate against the inherent operational and safety risks.

Fault levels are increasing, primarily due to network interconnectivity, in an effort to improve power delivery reliability, and an increase in generation to meet the demands of increasing growth. 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 [1]. Actual line voltage and current information is quite important TCSC control.

II.FAULT CURRENT MITIGATION OPTIONS:

There are four possible ways of fault current mitigation solutions.

Air core reactor:

The series connected air core reactor represents the traditional option for fault current management in a power network. It is a passive device that requires minimal maintenance, has a small physical footprint and is available at a cost that is significantly lower than any of the other options considered. It is however continuously connected and therefore consumes considerable electrical power. The associated volt drop is compensated for by on-load transformer tap changers that regulate the voltage on the MV busbar.

High impedance transformers:

High impedance transformers with an impedance range between 18 – 20% have recently been introduced as a fault level management measure. This passive mitigation measure operates on the same electrical principle as an air core reactor and therefore shares many of its advantages and disadvantages. The one major advantage it has over an air core reactor is that it requires no additional space in an electrical yard and is therefore an ideal option when a retrofit solution is required.

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When considered as a solution to lower the fault level due to the availability of localized generation on the MV busbar, the losses are not technically higher, as the energy loss is a function of the load current that passes through the transformer, and the load current is often reduced in these instances. Although often cited [2] as a costly option, these high impedance transformers are available via long term contracts at a premium that ranges between 5.6% and 6.4% of the price of a standard transformer for the various voltage options. It is therefore an ideal option for new installations where it is perceived that fault levels are, or will become, a concern. When utilizing this option however, power utility needs to also consider the additional costs associated with increased strategic spare holding.

Equipment uprating:

As discussed above, high fault levels are not undesirable, as long as equipment is appropriately rated. Many of the substations identified where the fault level of the breaker has been exceeded have equipment installed that has passed or is nearing the end of its service life. Replacement of these breakers during refurbishment projects, with those that comply with the current breaker specification (fault level rating of 25kA) [3], would eliminate the need for any further fault level management intervention. This is however a costly and time consuming option. The choice of merely replacing the equipment in a substation yard when it is identified that the fault level has increased beyond the equipment rating is not always practical. For example, substation components like the substation earth mat, would have been designed for a particular fault level, and would have to be strengthened to ensure compliance viz. touch and step potentials. The equipment uprating option does however have no increased maintenance or operation (energy loss) cost.

Superconducting Fault Current Limiter:

Recent installations of resistive superconducting fault current limiters on power grids have propelled this technology from the laboratory into a potentially viable alternative for fault level management. It is the only active device to be considered for this study i.e. a device that only 'engages' when a fault isintroduced to the power system. The device operates byallowing load current to transparently pass throughsuperconductor tape/wire that have been cooled to below theircritical temperature thereby presenting no resistance andtherefore no loss to the network. When a fault is introduced,the current increases above a threshold value which causes thesuperconducting tape to change phase and introduce resistanceinto the system within the first half cycle thereby"instantaneously" reducing the fault current. It is assumed thatthe SFCS is installed on the 11 kV busbar in Figure 1, but ifthe SFCS replaces the existing bus-section breaker, then itwould result in reduced operational flexibility. To overcomethis, the SFCS should be installed in conjunction with a bus-section breaker.

The energy required for this option is primarily for thecooling requirements and is therefore independent of loadcurrent. Operating costs were determined using calculatedenergy losses based on the 'Eccoflow' installation in Mallorca [4] which was a closed cycle cooling system. Although anopen cycle cooling system would utilize significantly lesselectrical energy, it would require increased specializedmaintenance and operation. The purchase price for a resistiveSFCS was obtained from the recent procurement by WesternPower Distribution (WPD) of two SFCS's to "future-roof"the Birmingham power distribution network [5]. This was themost recent cited example of a SFCS purchased to managefault levels on a utility grid.

III.TCSC USED IN TRANSMISSION LINE 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 [6], [7]. If a series capacitor is inserted into transmission line, the inductive reactance of transmission line could be compensated by a capacitive supply.

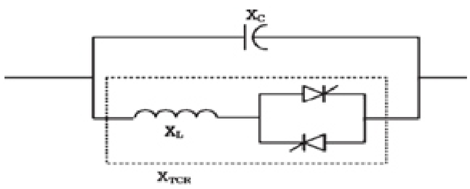

Fig 1: Configuration of a typical TCSC.

The equivalent impedance XTCSC of TCSC is as follows:

XTCSC=XCXTCR/XC−XTCR

=(XCXL/XC)/(π(2(π−α)+sin2α)XL

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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.

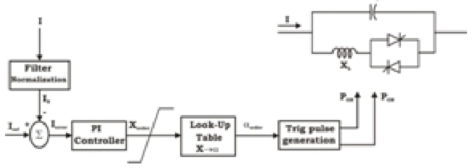

Fig 2: TCSC closed-loop constant current control topology.

IV.MODELING THE SFCS:

A faultcurrent limiter in which a superconductor is directly connected inseries to the line to be protected and is immersed in a coolant which ischilled by a refrigerant, and the connection fromtheline at room temperatureto the superconductor is provided by special current leads, which aredesigned to minimize the heat transfer to the coolant. Superconducting Fault Current Limiters are described as being in one of two major categories: resistive or inductive. In a resistive FCS, the current passes through the superconductor and when a high fault current begins, the superconductor quenches: it becomes a normal conductor and the resistance rises sharply and quickly. This extra resistance in the system reduces the fault current from what it would otherwise be (the prospective fault current).

High temperature superconductors quench in FCSs because a small amount of non-superconducting current heats the material and raise it above the critical transition temperature.GridON Ltd has developed the first commercial inductive FCS for distribution & transmission networks. Using a unique and proprietary concept of magnetic-flux alteration - requiring no superconducting or cryogenic components - the self-triggered FCS instantaneously increases its impedance tenfold upon fault condition. It limits the fault current for its entire duration and recovers to its normal condition immediately thereafter. This inductive FCS is scalable to extra high voltage ratings.

In order to limit a fault current, many models for the SFCS have been developed: resistor-type, reactor-type, transformer type, etc. [9]. In this study, we modeled a resistor-type SFCS that is mostly basic and used widely which represents the experimental studies for superconducting elements of SFCS. Quench characteristics and recovery characteristics of a resistor-type SFCS are modeled based on [9] and [10]. An impedance of the SFCS according to time t is given as follows:

$Z(t) = 0 \ (t < t0)$
$= Zn \ [1 - \exp[-(t-t0)/TF \quad]]\ 1/2 \ (t0 \le t < t1)$
$= a1(t - t1) + b1 \ (t1 \le t < t2)$
$= a2(t - t2) + b2 \ (t \ge t2)$

Where Zn and TF are the impedance saturated normal temperature and time constant. In addition, t0, t1, and t2 are the quench-starting time, first recovery-starting time, and secondary recovery-starting time, respectively. a1, a2, b1, and b2 are coefficients of the first-order linear function to denote the experimental results of the recovery characteristics of the SFCS. The recovery time of the SFCS is set to the value until fault clearing to protect the TCSC and transmission line.

V.SIMULATION REULTS:
Output Waveforms Of Proposed System:

In addition, the self- and mutual impedance of transmission and rail of the Korean electric railway system were considered. Here, in order to analyze the influence of an electric railway connection on the transmission line fault, we simulated a fault situation.

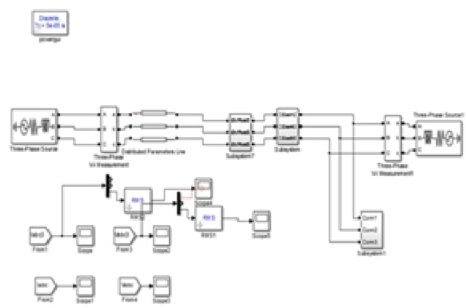

Fig 3: Proposed system simulation diagram

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.

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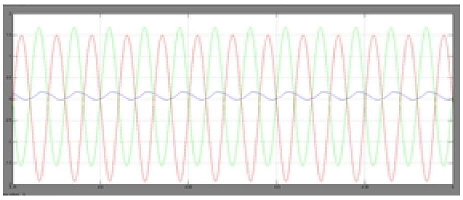

Fig 4:SFCS has an impedance of 10 and 20Ω respectively.

The results showed fault current limiting characteristics and improvement in voltage unbalance. In addition, we discovered following features shown in Fig. 5. If a fault occurs, the proposed method clears voltage unbalance and protects TCSC.

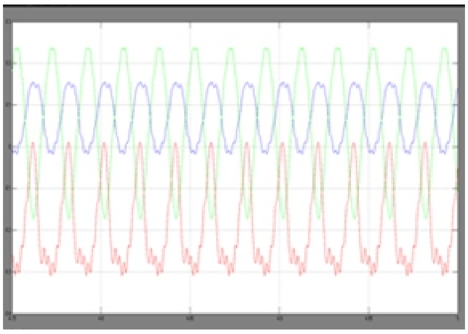

Fig 5: Voltage and current results from the simulation: with railway

Fault starting time is 0.4 s and fault duration time is 0.1 s. Fig. 5 and 6 show simulation results for a 3-phase fault for an electric railway connection, respectively. 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

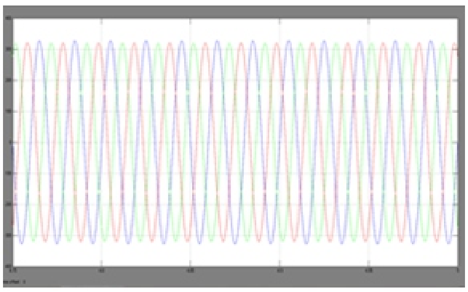

Fig 6: Voltage and current results from the simulation: without railway

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 such as Fig.6.These results show that a electric railway connection aggravates voltage unbalance in the transmission line

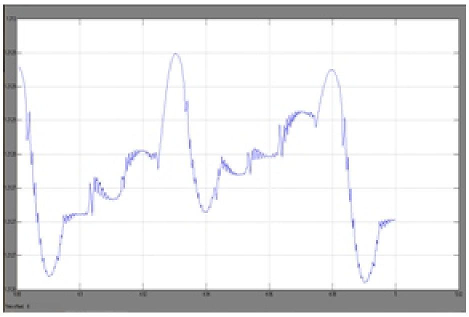

Fig.7: The larger resistance of a resistor- type SFCS,the more voltage unbalance was improved.

In SFCS operating process, there are differences of recovery time between superconducting elements owing to unbalance fault current shown in Fig7. 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.

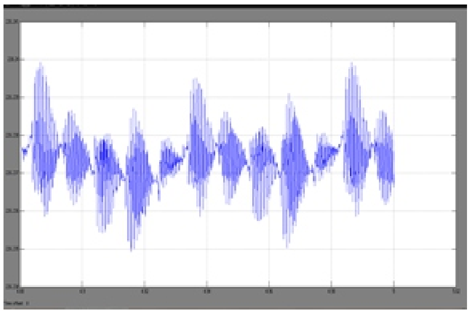

Fig 8: Fault current limiting, improvement in voltage unbalance, and SFCS quenching characteristics of the proposed method.

Specially, 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. This phenomenon will cause problem about voltage stability and malfunction of protection scheme in the transmission grid.

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VI.CONCLUSION:

This proposed method to reduce voltage unbalance for a Thyrister-Controlled Series Capacitor (TCSC)-compensated transmission line using a Superconducting Fault current Suppressor (SFCS). 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 SFCS 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. In future, we will study a protection scheme using an SFCS for a compensated transmission system to improve system stability..

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