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Transient Stability Improvement of a Conventional Power System by Superconducting Fault Current Limiter

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TRANSIENT STABILITY IMPROVEMENT OF A CONVENTIONAL POWER SYSTEM BY SUPERCONDUCTING FAULT CURRENT LIMITER

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Abstract - Occurrence of faults in a power system causes transients which decrease transient stability of that system. Superconducting fault current limiter (SFCL) is a promising solution to reduce and control this fault (short circuit current) which is inevitable to electric power systems due to growing interconnection of electrical power systems. In this paper, a simulated proof of the capability of SFCL in improving the system transient stability is revealed. At first a SFCL model is designed using simulink. Then, that model is introduced in a so-called three phase system. After that, the system is taken under different fault conditions to investigate transient stability for each. Finally, it is shown from the simulation result that, the system transient stability has improved.

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I. Introduction

Due to increased customer requirements and advanced technological enhancements, the demand for electric power is increasing. Thus, power systems are becoming larger and more interconnected day by day. As a result, the fault current increases and transient stability problems has drawn attention. Excessive fault currents cause stresses and lead to high electrical, mechanical and thermal instabilities of electric networks. Consequently, in order to maintain the stability of power system, replacement of equipment or updating the configuration of the system will be needed in substations. This ultimately leads to low reliability and lower operational flexibility. Furthermore, it is also not economically viable to design the switchgear for every system with different capacity that can maintain sound power system stability. Still now, mechanisms like transformer with high impedance, split bus burs and fuses have been applied to reduce the magnitude of fault currents. But the uses of those devices lessen the reliability of the system and raise the power loss [1]. But a Superconductive fault current limiter (SFCL) can be a dependable alternative to substitute the aforesaid conventional devices. In addition, SFCL ensures the improvement of transient stability of power system by dropping the level of fault current in a rapid and efficient approach.

An SFCL has virtually zero resistance at normal operating conditions. But in the occasion of a short circuit, due to the increasing temperature of the SFCL, the shift from the superconducting status into normal conducting status offers maximum preferred impedance to electric networks instantaneously, which limits the current more rapid and effective way. After the clearance of fault, the resistance of SFCL goes to zero level owing to the decreasing temperature of the SFCL [2-7]. Thus the SFCL is invisible and harmless when the grid is operating at steady state condition.

In this paper, a SFCL model is intended using Matlab Simulink. Then that model is introduced in a conventional three phase system. Finally, its transient stability at different fault conditions is studied.

II. Superconducting Fault Current Limiter

SFCL is an electronic device based on the principle of superconductivity. The hypothesis of using the superconductors to hold electric power and to bound peak current level has been around since the innovation of superconductors and the realization that they have extreme non-linear properties. More explicitly, the current limiting behavior depends on their nonlinear response to current, temperature and magnetic field variations. These three parameters possibly cause a transition between and the normal conducting and the superconducting system, when they are increased. Generally, three types of SFCL have been developed so far, they are: reactor-type, transformer-type and resistor-type. In this paper, resistor-type SFCL has been modeled based on [8] and [9] which illustrate the experimental studies for superconducting properties of SFCL being applied to three phase power distribution systems. Quench and recovery characteristics are modeled based on [10]. The impedance of SFCL according to time t is specified by (1).

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$$R_{SFCL}=\begin{cases} 0, & (t_0>t) \\ R_m\left[1-\exp(-\frac{t-t_0}{T_{sc}})\right]^{\frac{1}{2}}, & (t_0\le t<t_1) \\ a_1(t-t_1)+b_1, & (t_1\le t<t_2) \\ a_2(t-t_2)+b_2, & (t_2\le t) \end{cases} \quad (1)$$

Here, the maximum resistance of the SFCL in the quenching condition is expressed by R_m, where, T_{sc} is the time constant. Moreover, t_0 indicates the time to start the quenching. In addition, t_1 and t_2 are expressing the first and second recovery times.

Figure 1 interprets quenching and recovery characteristics of the SFCL derived from (1). It is clear from Fig. 1 that at normal operating condition impedance of SFCL is zero. But when fault takes place at t=1s, quenching progression starts and then impedance goes to its peak value. After recovery of fault impedance again goes back to zero.

III. Modeling and Simulaton

a) SFCL Modeling

SFCL was designed with the help of Simulink/SimPowerSystem. To design this resistive-type SFCL, four fundamental parameters are used. The parameters are given below with their values:

Transition or response time = 2ms, maximum impedance= 20Ω & minimum impedance= 0.01Ω, recovery time =10ms, triggering current =550A.

In Fig. 2, a resistive characteristic table is shown using these parameters. In this figure, to specify the transition or response time and recovery time of SFCL, step block and transport delay block are used respectively.

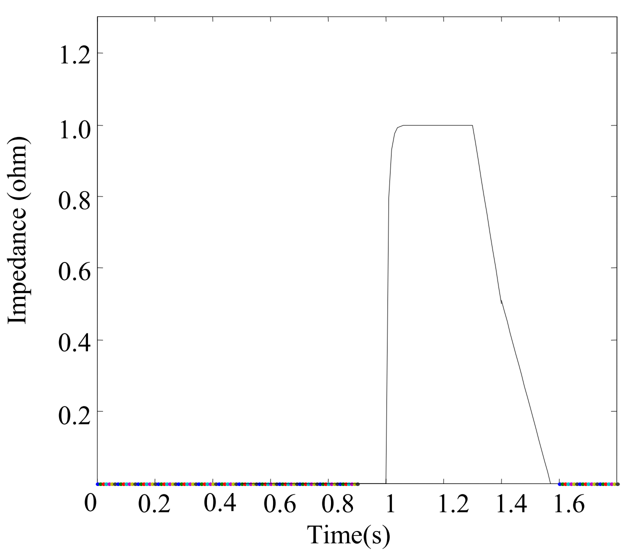

Figure 1 : Quench and Recovery Characteristics of SFCL

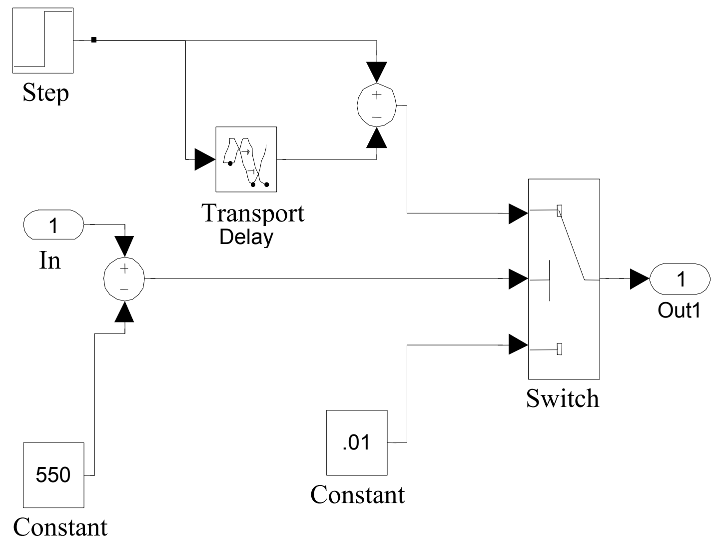

Figure 2 : Resistive SFCL characteristics table

To determine the minimum or maximum impedance to output switch block is used. In figure 3 , simulation model of SFCL is shown. Here the RMS value of the incoming current is calculated using RMS block. To reduce harmonics, first order filter is used. The induced fault current causes voltage sag. To compensate this controlled voltage source is connected.

The developed SFCL model in Simulink/SimPowersystem works as follows: At first, the model measures the RMS value of the current passing in the system. Then, with the result of comparison between the current and the characteristics table shown in figure 2, the model decides whether the impedance level of SFCL goes maximum or minimum. SFCL's resistance remains minimum, if the passing current is below the triggering current level; on the other hand, if current exceeds triggering current its resistance reaches to the maximum impedance level.

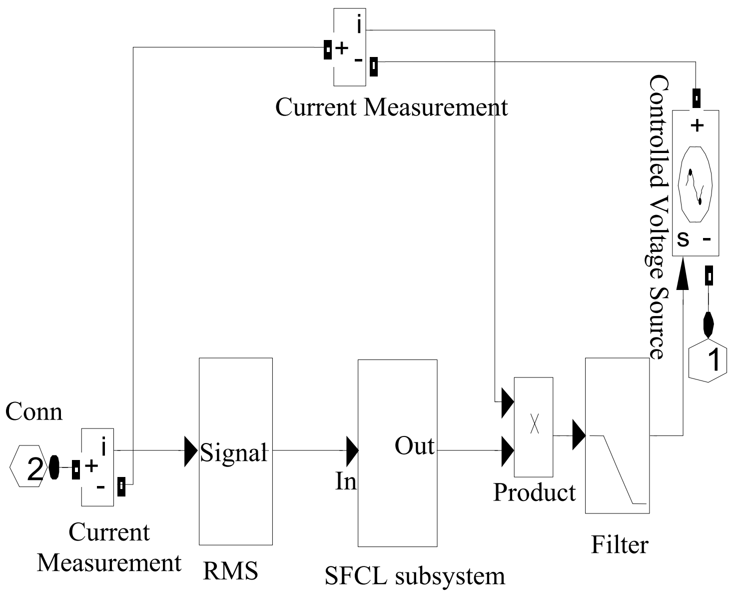

Figure 3 : SFCL model in Simulink

As a result, the increased impedance limits the short circuit fault current. However, SFCL's resistance again goes minimum when current is lower than triggering current level.

b) Modeling and simulation of projected System

Here, a typical three phase system is designed using Simulink/SimPower system which is given in Fig. 4 for the purpose of examining transient stability. Generation capacity of this system is about 105 MW. Here a conventional synchronous machine is generating the power. The machine is rated as 130 MVA. The generation voltage is 20 KV. A 20/154 KV transformer is stepping up the voltage which is connected to a large industrial load.

Then the system is taken under four types of faults (with and without using SFCL) which are:

1. Three-phase- to-ground fault
2. Double line-to-ground fault
3. Line-to-line fault
4. Single line-to-ground fault

A fault block is used to introduce these faults which is shown in Fig. 5. Then a SFCL is added in the system for same condition that is shown in Fig. 6.

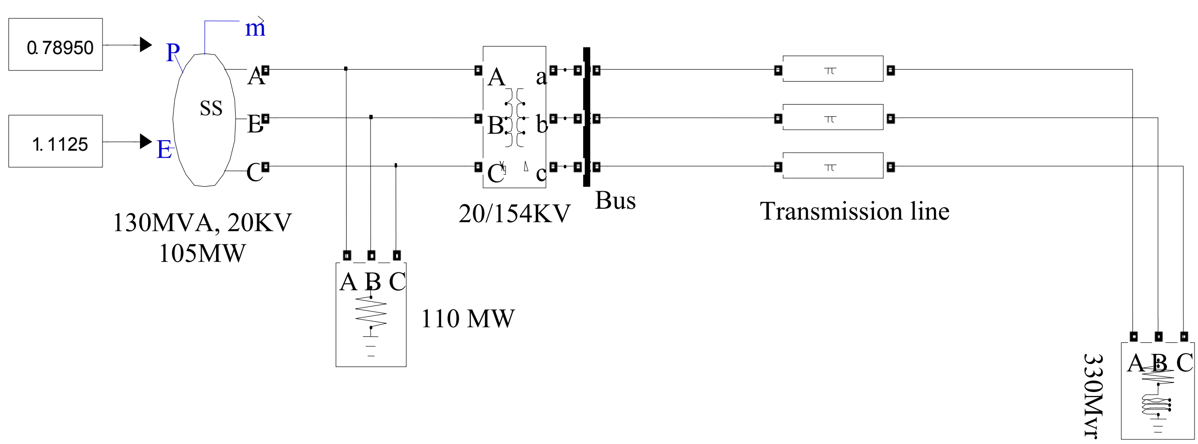

Figure 4 : Anticipated three phase system

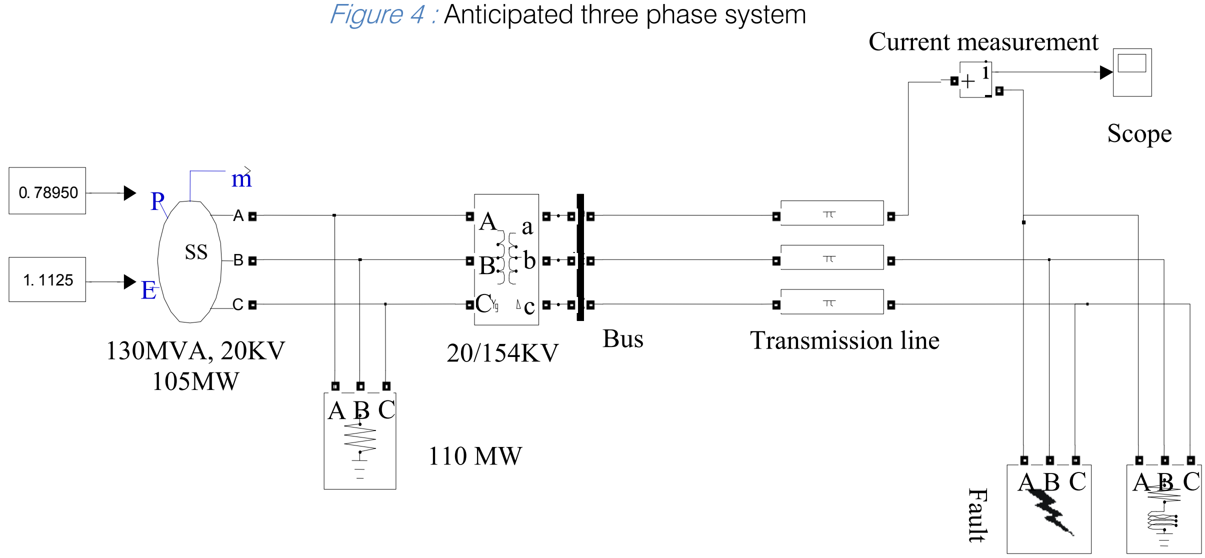

Figure 5 : System during the occurrence of fault without SFCL

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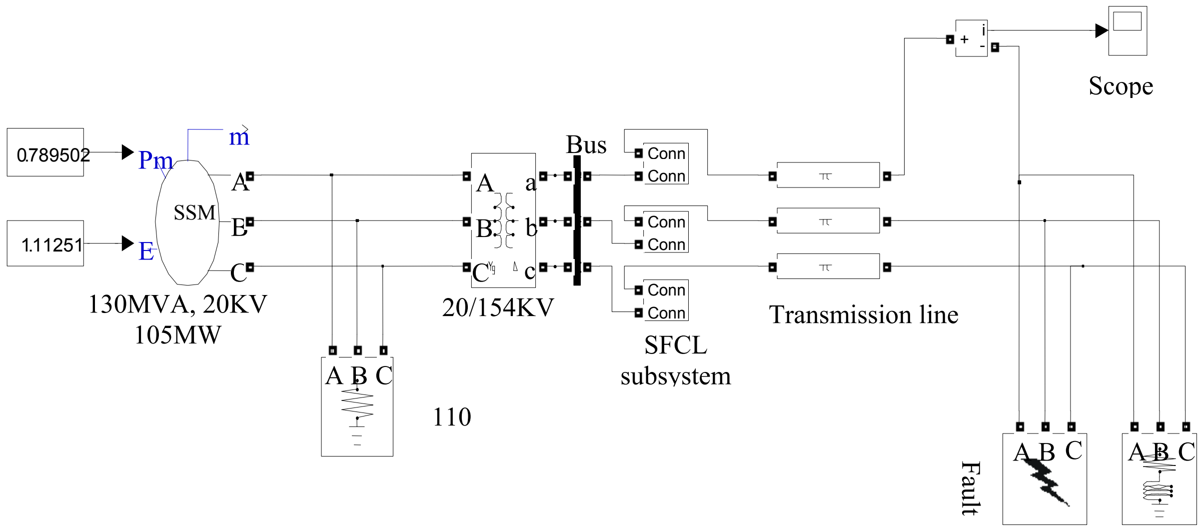

Figure 6 : System during the occurrence of fault with SFCL

IV. Result and Discussion

The excellent transient stability improvement behavior of SFCL is studied in this paper. In a conventional power system shown in Fig. 4, various types of faults are made occurred with and without SFCL shown in Fig. 5 and Fig. 6 respectively. The effect of these faults is depicted in Fig. 7, Fig. 8, Fig. 9 and Fig. 10. From these figures it is clearly seen that, fault current is reduced drastically due to the use of SFCL. It is also clear from Table I. It shows the value of fault current with and without SFCL.

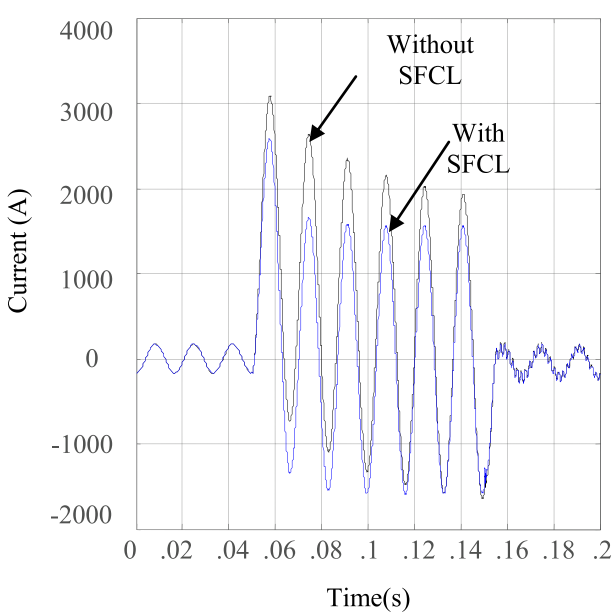

Figure 7 : Fault current for three phase to ground fault

Fault current is responsible for decreasing transient stability of a system. Lower the fault current higher the transient stability. As SFCL reduces the fault current level tremendously therefore, improves transient stability in a great extent.

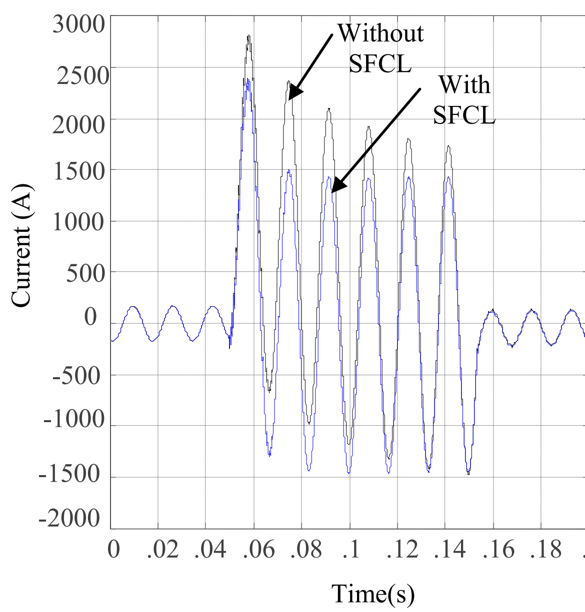

Figure 8 : Fault current for double line to ground fault

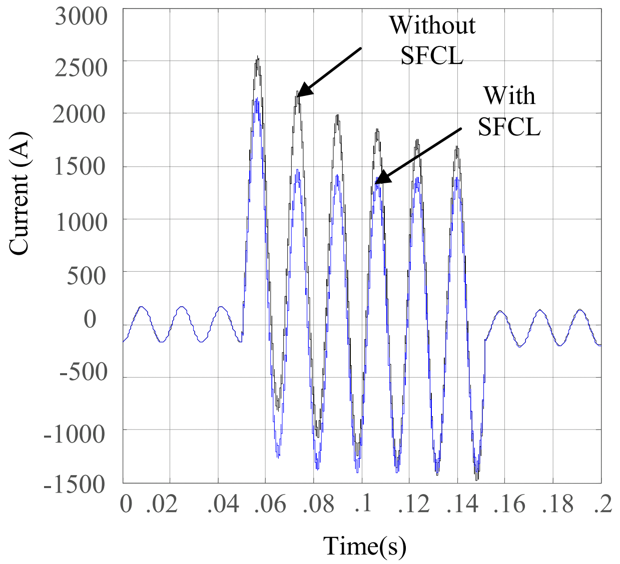

Figure 9 : Fault current for line to line fault

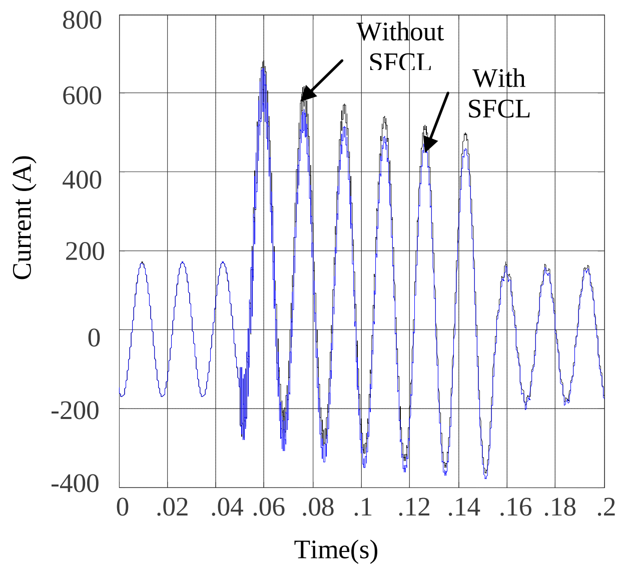

Figure 10 : Fault current for single line to ground fault

Table I : Fault current value with and without SFCL for different faults

Types of Faults	Magnitude of Fault Current (Ampere)	
	Without SFCL	*With SFCL*
Three phase to ground fault	3100-2200	1600
Double line to ground fault	2750-1850	1400
Line to line fault	2520-1750	1350
Single line to ground fault	700-550	500

V. Conclusion

This paper has successfully shown the simulated proof of the ability of SFCL to improve the power system transient stability. Four case studies are taken into account and for each of them it is shown that, SFCL has tremendous competence of suppressing the fault current quasi instantaneously, which leads the system to more reliable and stable condition. Nevertheless, the launching of SFCL in a system requires perfect co-ordination with other protective device otherwise it will mess the original setting values of these devices and the effect of SFCL will be useless. Thus proper co-ordination will make it more convenient for bettering transient stability.

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