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REDUCTION OF FAULT CURRENT IN DISTRIBUTION SYSTEM USING SUPERCONDUCTING FAULT CURRENT LIMITER

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Abstract

Superconducting fault current limiter is an attractive electronic device to solve the problem of very high fault currentin the power system. In this paper, the performance of enhanced system capacity with existing switchgear by superconducting fault current limiter is studied. At first, a resistive type SFCL is modeled in Simulink. A three phase system with a nominal capacity is designed and then it is replaced by higher capacity keeping switchgear unchanged. Finally, the SFCL is introduced in the higher capacity system. Fault current in this system is limited by SFCL to the level of the presented switchgear. Thus, it is revealed that the outstanding current limiting performance of SFCL can be used to limit the fault to the level of the existing switchgear if the system capacity is improved.
Keywords-superconducting fault current limiter; system capacity; fault current; switchgear; simulink/simpowersystem.

I. INTRODUCTION

The power generation capacity of electric system is being increased because of the growing demand. As a result, fault current level rises which can go beyond the maximum designed ratings of the presented switchgear. The requirement of replacing existing switchgears with higher ratings is a major concern in this situation. But to design switchgear with higher ratings for every different capacity system is not economically feasible . It may result in decreasing the stability and reliability of the system. This huge short circuit current of higher capacity system is limited by fault current limiters which can be an alternative solution rather than replacing existing switchgear. High fault current can be limited to alevel of highest designed short circuit current rating of presented switchgear. It creates a cost-effective way to improve the power system capacity keeping switchgear unchanged. Thus, the fault current limiter can be an excellent technique to protect power system equipments. Limit fault current but also to develop stability of the system .Many studies have been carried out for the practical application of SFCL in electric power system in the past few years . It includes current limiting characteristics of SFCL, optimal resistive value of SFCL to improve transient stability, optimal place to install the SFCL etc. But most of the important practical application concern of SFCL in power system to enhance system capacity with existing switchgear has not been studied. In this paper, a resistive SFCL model is developed with the help of Simulink. The model is used in a single phase system to prove the current limiting behavior of the SFCL. Then a three phase system is designed with a nominal capacity and the fault current characteristics are investigated. Finally, the SFCL is implemented in a higher capacity three phase system and the overall performance is studied.

II. BASICS OF SFCL

Superconducting fault current limiter is a promising technique to limit fault current in power system. Normally non-linear characteristic of superconductor is used in SFCL to limit fault current. In a normal operating condition SFCL has no influence on the system due to the virtually zero resistance below its critical current in superconductors. But when system goes to abnormal condition due to the occurrence of a fault, current exceeds the critical value of superconductors resulting in the SFCL to go resistive state. This capability of SFCL to go off a finite resistive value state from zero resistance can be used to limit fault current. Different types of SFCLs have been developed until now. Many models for SFCL have been designed as resistor-type, reactor-type, and transformer-type etc. In this paper a resistive-type SFCL is modeled using simulink. Quench and recovery characteristics are designed on the basis of an impedance of SFCL according to time t is expressed by (1)

(1)

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

Where R_m is the maximum resistance of the SFCL in the quenching state, T_{sc} is the time constant of the SFCL during transition from the superconducting state to the normal state. Furthermore, t0 is the time to start the quenching. Finally, t_1 and t_2 are the first and second recovery times, respectively.

Quenching and recovery characteristics of the SFCL modeled by MATLAB using (1) are shown in Fig. 1. In normal condition impedance of SFCL is zero which is shown in Fig. 1. Quenching process of SFCL start at t=1s due to the occurrence of fault causing impedance rises to its maximum value. Impedance again becomes zero after the fault clears.

III. MODELING AND SIMULATION

A. Resistive SFCL Model

Simulink/SimPowersystem is chose to design resistive SFCL. Four fundamental parameters is used for modeling resistive-type SFCL. The parameters and their values are: Transition or response time = 2ms, minimum impedance= 0.01Ω & maximum impedance= 20Ω, triggering current =550A, recovery time =10ms.

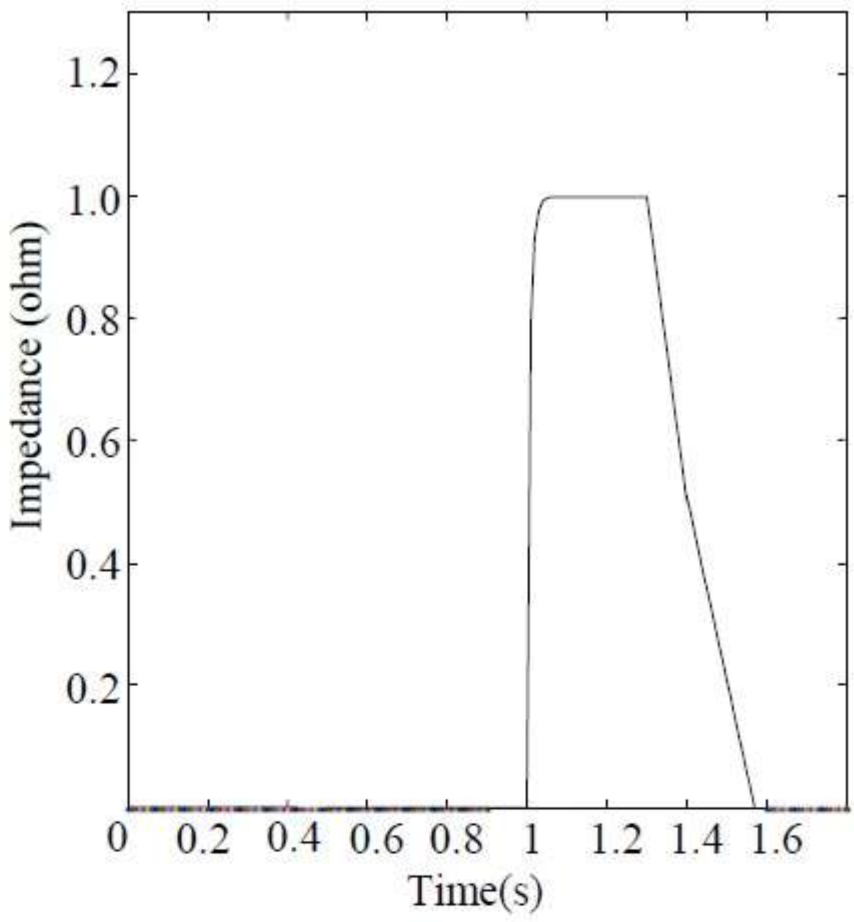

Figure 1. Quench and Recovery characteristics of SFCL

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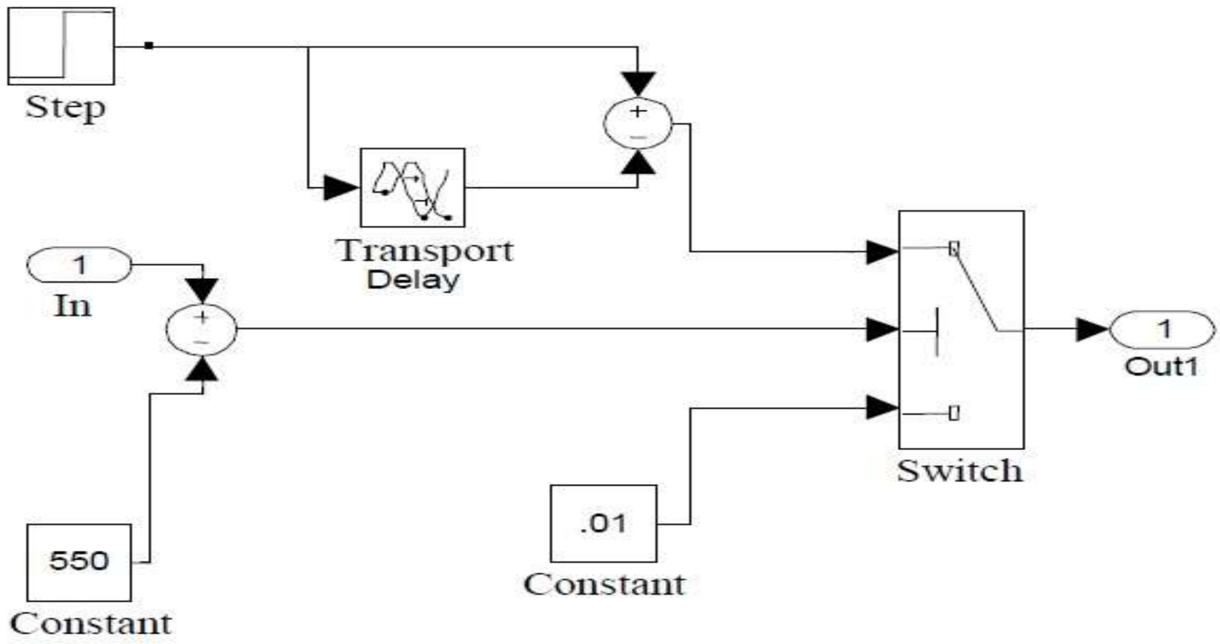

Figure 2. Implementation of resistive SFCL characteristics in simulink

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These parameters are used for implementing resistive SFCL characteristic is shown in Fig. 2. Quenching and recovery time of SFCL are specified using step and transport block respectively. A Switch block is used to give minimum or maximum impedance in output which is determined considering the incoming current. The simulation model of SFCL for a single phase system is shown in Fig. 3.

The working principle of the SFCL model developed in Simulink/SimPowersystem is described below. Firstly, RMS value of incoming current (passing through current measurement block) is measured by RMS block. Then it compares the current with the specified current in the SFCL subsystem. SFCL gives minimum resistance, if the incoming current is less than the triggering current level. But if the current is larger than the triggering current, SFCL's impedance rises to maximum state. It ultimately raises the total impedance of the system which results in limiting the fault current. Finally, the SFCL's resistance will be minimum when the limited fault current is below the triggering value.

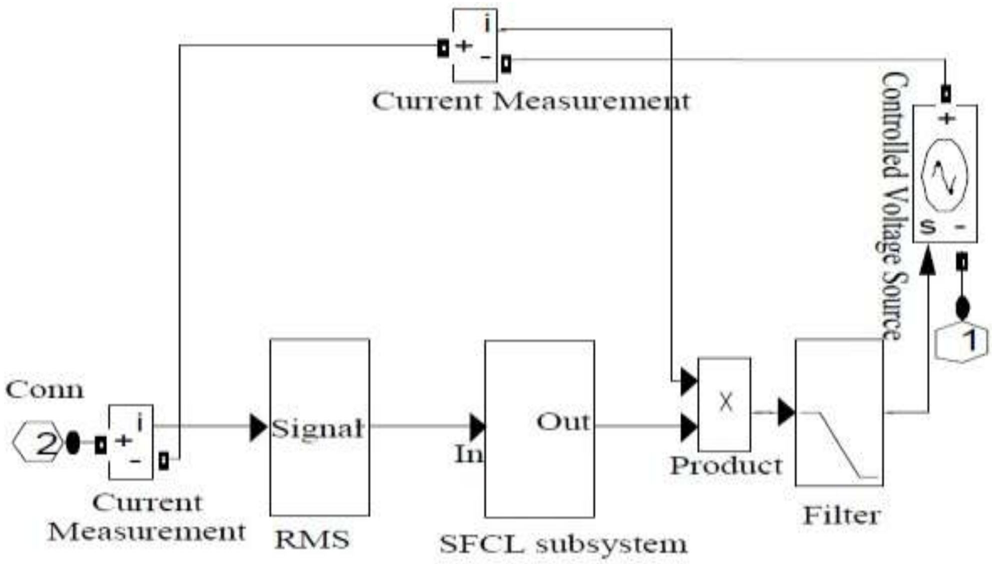

Figure 3. Resistive SFCL model in Simulink

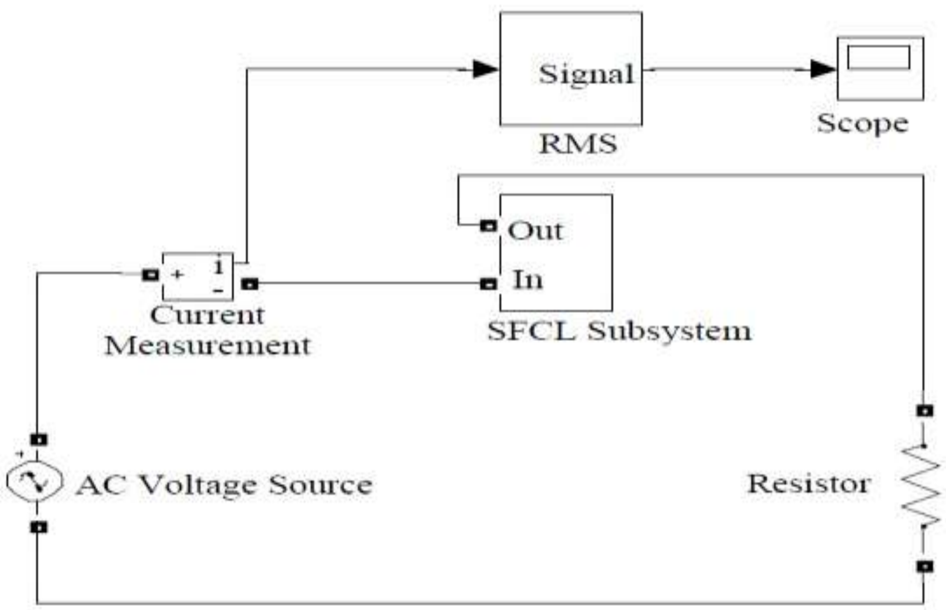

Figure 4. Simulation model of single phase system with SFCL

B. Modeling of SFCL to demonstrate Current Limiting Characteristics

The designed model of SFCL is implemented in single phase system and fault current characteristics are taken with and without SFCL. The simulation model for this purpose is shown in fig.4 and fig.5 respectively. The fault is introduced directly through AC source in order to decrease the difficulty of simulation. An RMS block is used to calculate the RMS value of the incoming current and scope is used to see the output o the sytem.

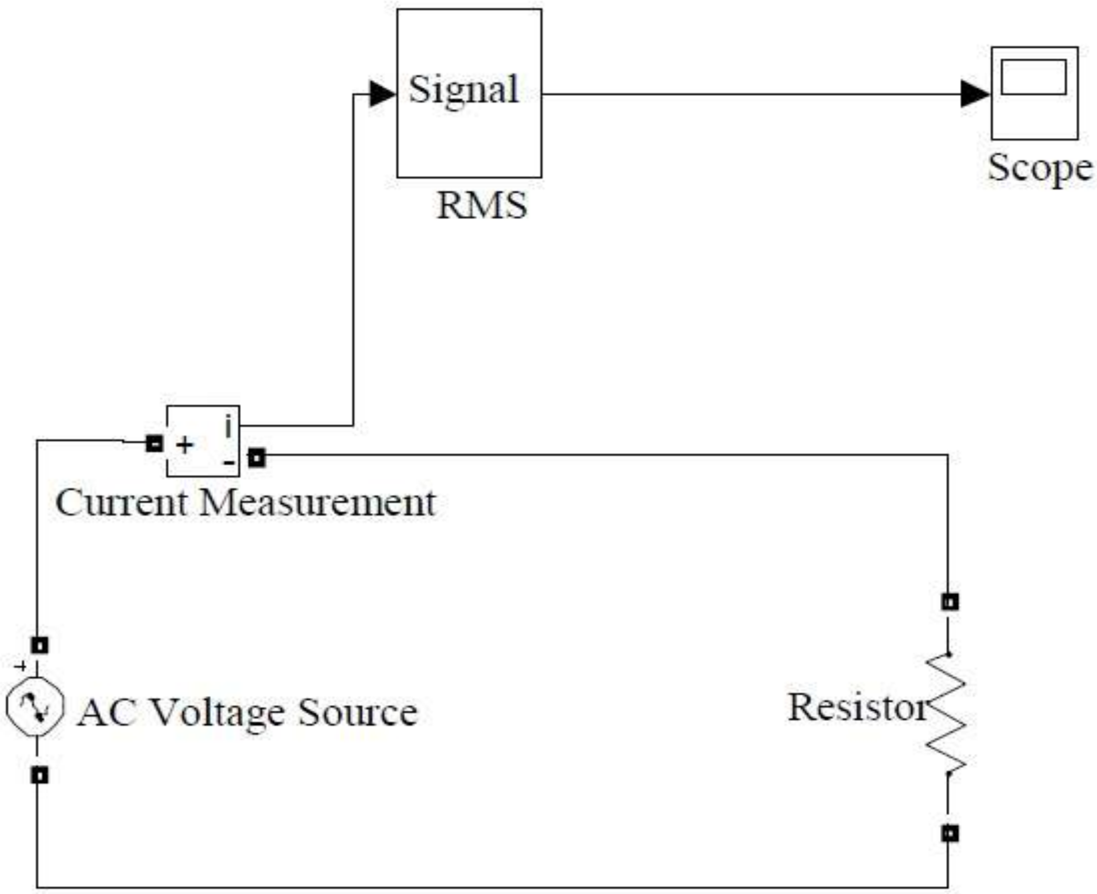

Figure 5. Simulation model of single phase system without SFCL

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C. **Modeling of Anticipated System.**

A three phase system with a nominal capacity (110 MW) is designed in Simulink/Sim-PowerSystem shown in Fig.6. Here a 3 phase simplified synchronous machine having 140MVA rating is used as a synchronous machine. The generating capacity of the machine is 20KV. A step up transformer (20/154 KV) is used to step up the generating voltage which is ultimately connected to an industrial load.

Now the capacity of the conventional system is increased to 220MW which is shown in Fig.9. Here also a 3- phase Simplified synchronous machine is used as a synchronous machine having rating 275MVA for the purpose of supplying improved capacity 220MW. Here also the generation voltage is 20KV. A SFCL is connected to each phase of the system keeping other equipments unchanged .

IV.**RESULTS AND DISCUSSION**

The outstanding current limiting behavior of SFCL is exemplified in this paper. The type of the fault induced in the model shown in Fig. 4 and Fig. 5 is single phase to ground fault where it is induced through the AC voltage source. The simulated current waveforms of the single phase system model with and without SFCL are shown in Fig. 8. Due to the absence of SFCL the current value is first 720A shown in Fig. 8. But with the presence of SFCL limits this current to 450 A in a pre-defined response time. This excellent current limiting performance of SFCL in single phase is used in three phase system for improving system capacity. A three phase to ground fault is introduced in both the system shown in Fig. 6 and Fig. 7 at t=0.05s using a fault block. The simulated output of fault current is shown in fig.9. It is seen that for the 110MW system the fault current level goes to near 1800A and then a circuit breaker takes 0.05 s for transition time and clears the fault at t=.17s. This current is recovered with the switchgear present in the system. Now for 220MW system current rose to 2750A but the presence of SFCL in each phase limits the current to 1800A in a very short period of time. So, the effective fault current is 1800A. It is now as same as current level of 110MW system. Now this fault current can be cleared by switchgear present in the 110MW system. Therefore, 110MW system can be moved up to 220MW using SFCL without varying the switchgear.

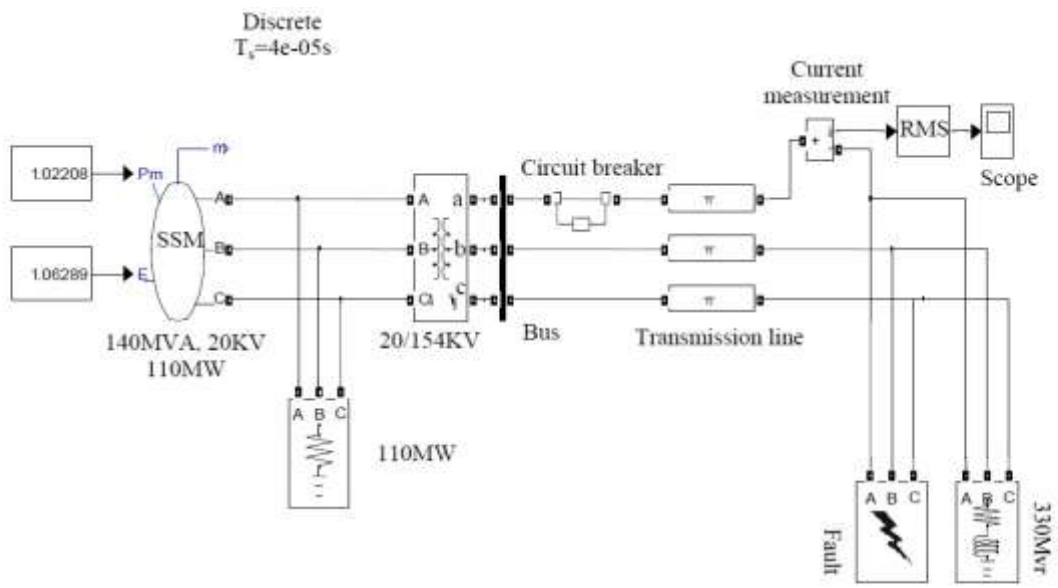

Figure 6. 110MW system designed in Simulink/SimPowersystem with out SFCL

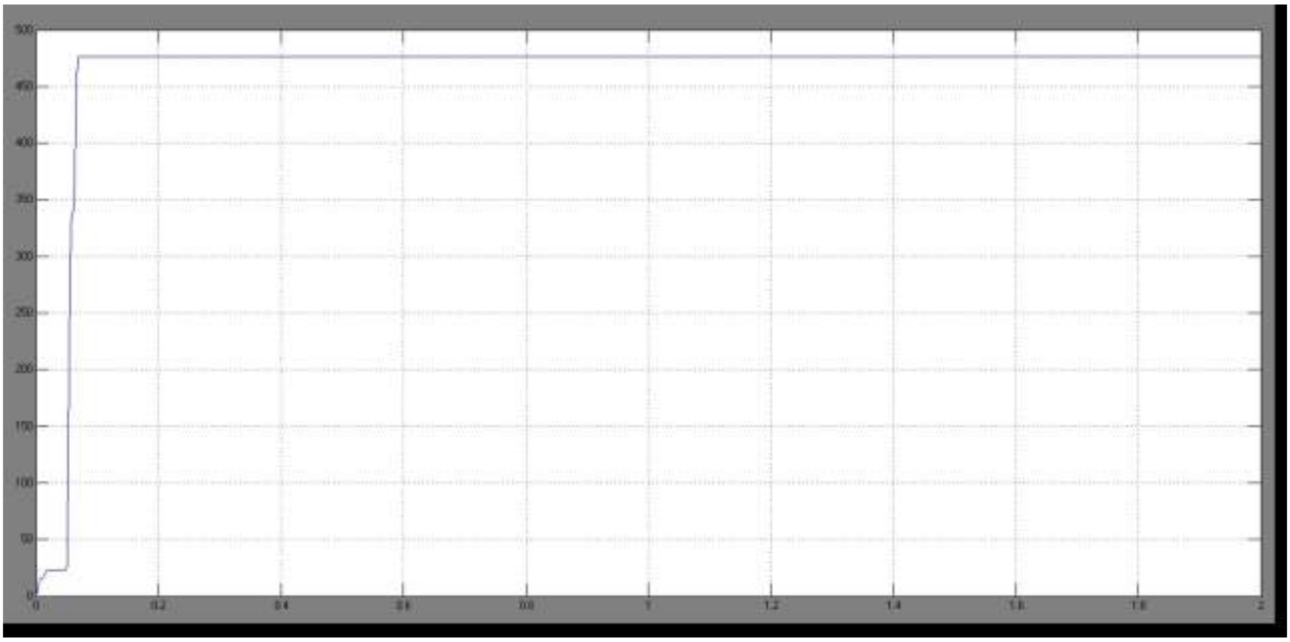

Figure 8. Simulated fault current waveforms without SFCL

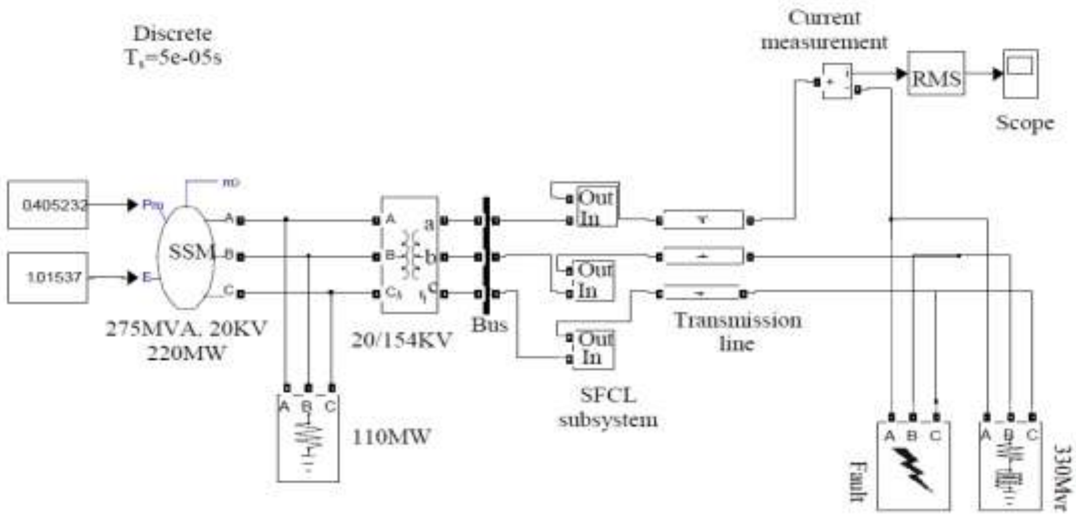

Figure 7. 110MW system designed in Simulink/SimPowersystem with SFCL

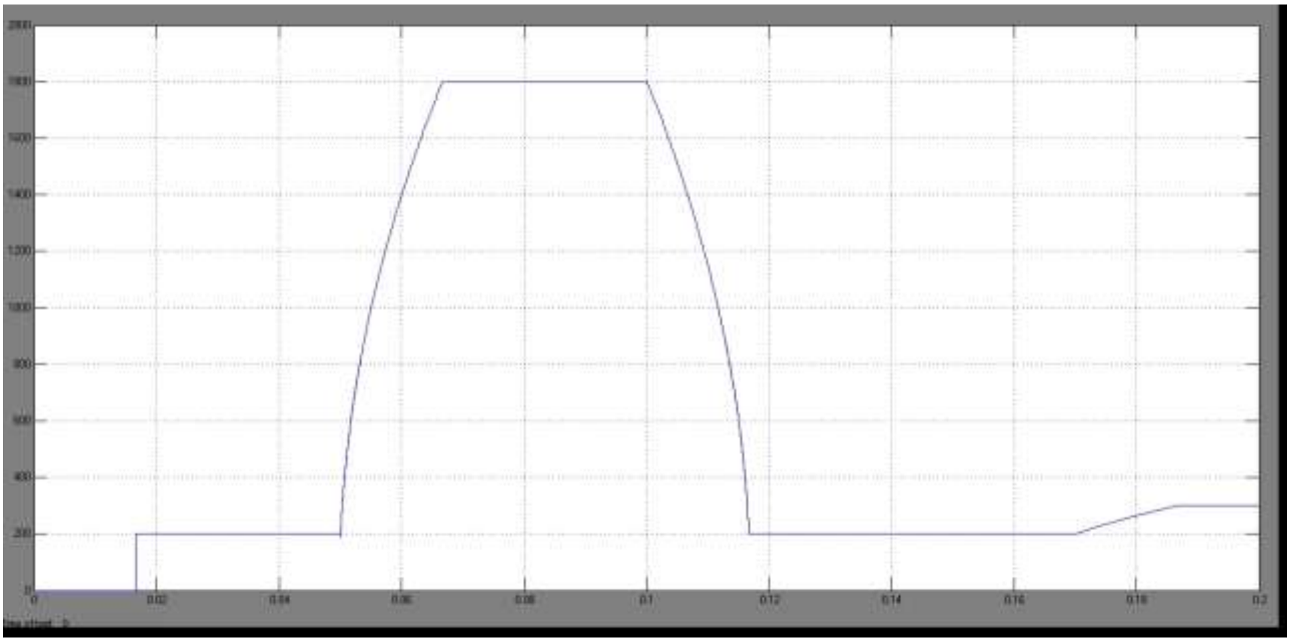

Figure 9. Simulated fault current waveforms with and with SFCL

V. CONCLUSION

This paper has proposed a study to increase the capacity of a power system by SFCL without changing the existing protective devices. The fault current 2700A of bigger system has been decreased to 1800A, in the range of smaller system, due to the use of SFCL. It is clear from the results that this inventive current limiting device is very efficient to decrease the fault current level significantly to the previous switchgear level. But coordination between the existing switchgear and SFCL is necessarily important for the practical application of this system. Otherwise it causes great hamper in the operation of protective devices which may results to get out of their original setting values. Thus, effective coordination between SFCL and existing protecting device will make it more successful in practical application issue. This coordination work may be the future issue.

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