Power System Protection Using Superconducting Fault Current Limiter (SFCL)

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Abstract: Due to increase in size of grid and generating stations this also increase the possibility of abnormal operations in the system. There may be sudden decreases in the impedance of the power systems network, which lead to increase in current known as fault current. Fault current are the transient current that flows through an electrical power system when a short circuit occur. In a normal operating condition has no influence on the system due to the virtually zero resistance below its critical current in superconductors. In this paper a Matlab/Simulink model for a resistive type SFCL (Superconducting fault current limiter) is proposed. The model is developed for a distribution substation in Matlab/Simulink and then simulates different types of unsymmetrical faults and analysis is done with SFCL. The study shows that SFCL not only reduce the magnitude of fault current to a satisfactory level, but also able to detect the fault within a short period of time. The simulation results obtained have demonstrated the effectiveness of SFCL in improving the system performance, reliability and security.

Keywords: Power systems, Fault current, SFCL, Matlab/Simulink, Unsymmetrical faults

I. INTRODUCTION

In today's world electrical energy is most versatile and useful form of energy available. Electricity is used in industries, homes, business and transportation [1]. Due to increase in size of grid and generating stations this also increase the possibility of abnormal operations in the system. There may be sudden decreases in the impedance of the power systems network, which lead to increase in current known as fault current. Due to flow of very high current in the system during fault, damage can occur to any equipment installed in the system. The equipment in power grid like circuit breakers and transformers are very expensive which is affected by means of fault current [2]. The large faults current generate large mechanical forces which endanger the mechanical integrity of power system hardware, transformer and other equipment. As the equipment in power network is expensive, their protection from large fault current is needed [3]. To have continuous and reliable operation of the power systems the fault current in the system needed to limit to a lower value. In this paper Superconducting Fault Current Limiter is used as protective device to limit the fault current system. The equipment in power grid like circuit breakers and transformers are very expensive which is affected by means of fault current.

Superconducting Fault Current Limiter is used to limit the fault current. During normal operation, SFCL gives negligible voltage drop and energy losses.

II. SUPERCONDUCTING FAULTCURRENT LIMITER (SFCL)

The principle of SFCL is based on superconductivity [4]. 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 state to normal operating state which offers maximum preferred impedance to electric network instantaneously, which limits the current more rapid and effective way. SFCL is an electronic device based on the principle of superconductivity. The current limiting behavior depends on their nonlinear response to current, Temperature and magnetic field variations. These parameters cause a transition between and normal conducting state to the superconducting state. Superconducting fault current limiters are basically of two types resistive SFCL is simply connected in series with the network. And the inductive SFCL is based on a transformer with a superconducting shielding tube in the secondary.

III. BASIC PRINCIPLE OF SFCL

SFCL considered in this work is of resistive type. The SFCLs of resistive type are simply a length of superconductor. The current density of superconductor would exceed the critical current density J_C, whenever, there is a fault. Fig. 1 shows the Temperature, Magnetic Field and Current Density (T–B–J) characteristics of a superconductor material. It can be seen that the superconductor material can operate in three states, marked as 1, 2 and 3 (see Fig. 1). The innermost surface-1 concerns with the zero resistance state. The surface beyond surface-2 is the normal conducting state and the transition state is a particular state between surface-1 and surface-2. It is observed, with the increase in units of T, B and J. When the current density exceeds, critical current density (J_C), the superconductor quickly reaches to a high resistance state, and the fault current is limited to a lower value.[5]

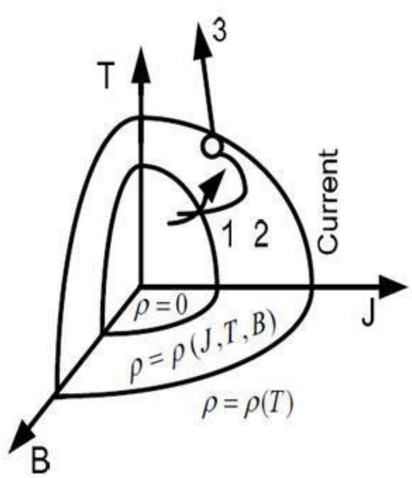


Fig 1: T-B-J characteristics of superconductor material

IV. MATLAB/SIMULINK MODEL

Simulink/Sim Power system is chose to design resistive SFCL foe a 110 kv substation. Some basic parameters having different values are: Transition or response time = 2ms, minimum impedance=0.01Ù & maximum impedance= 20Ù, triggering current=550A, recovery time =10ms.

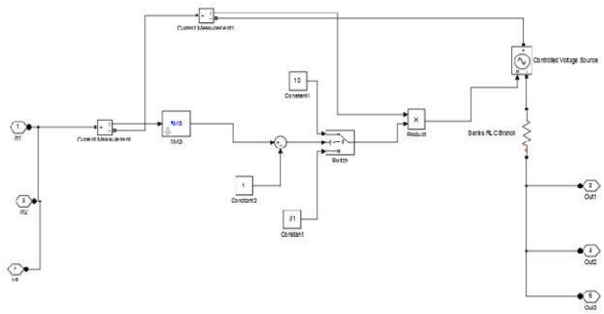


Fig 2: Resistive SFCL model in Simulink

The step and transport block are used to determine quenching and recovery time of SFCL. A Switch block is used to give minimum or maximum impedance in output which is determined considering the incoming current. The simulink model a for resistive SFCL are shown in fig 2. The 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. If the incoming current is less than the triggering current level then the SFCL gives minimum resistance. But if the current is larger than the triggering current, SFCL's impedance rises to maximum state. Finally, the SFCL's resistance will be minimum when the limited fault current is below the triggering value. The analysis and simulation is carried out with and without SFCL using Matlab in substation related to distribution purpose substation. In this paper, an investigation has been carried out to limit the fault current in the event of temporary fault by installing SFCL at suitable point in the substation. The substation consists of four, 110kV transmission line and the substation is a ring system.

Table 1. Parameter values of the proposed system

Parameters	**Values**
AC voltage	110kv
Source resistance	.001 Ohms
Transmission line Resistance	1 Ohms
Load resistance	50 Ohms

Fig 3 shows the 110 kv substation at three phase fault condition, fault with circuit breaker and fault with SFCL.

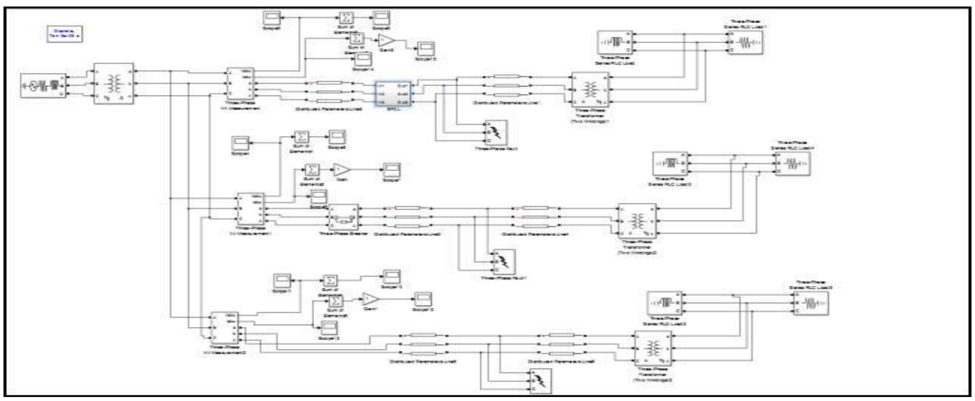
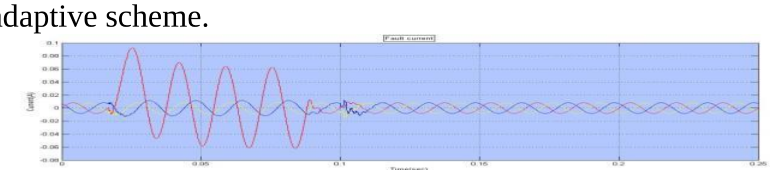


Fig 3: 110kV substation model in Matlab

V. RESULTS & DISCUSSION

From the observation of the waveform, it is clear that the fault occurs and the only protection is circuit breaker. When SFCL is connected to the transmission line, it reduces the fault current to normal value and system is protected from asymmetrical and symmetrical fault. Hence this system protection is only for temporary fault in the power system. Also the results have shown that the current limitation of SFCL is greatly affected by the prospective current, and consequently, by the fault resistance. However, this effect was different among phases due to the difference in the phase angle of each phase at which the fault occurs. It was found that the higher the prospective current the higher the percentage limitation, i.e., SFCL behaves as an adaptive scheme.



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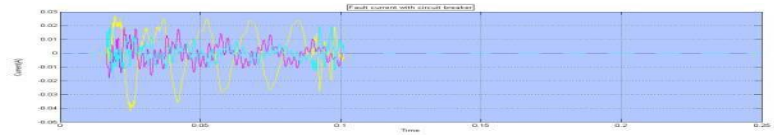

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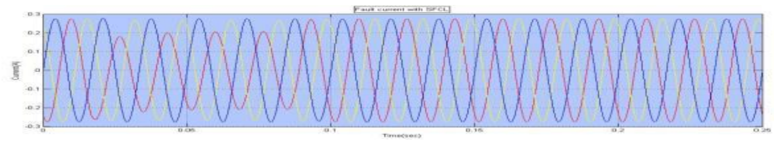

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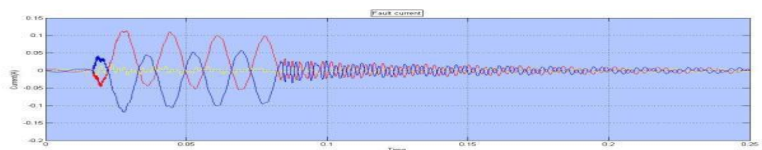
Fig 4. Single line to ground fault (a) fault current (b) fault current with circuit breaker (c) fault current
with SFCL



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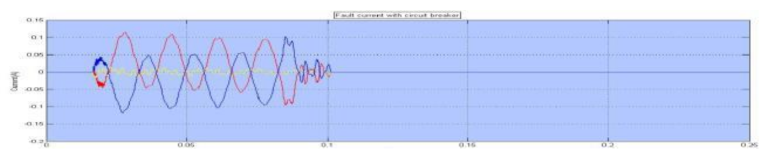

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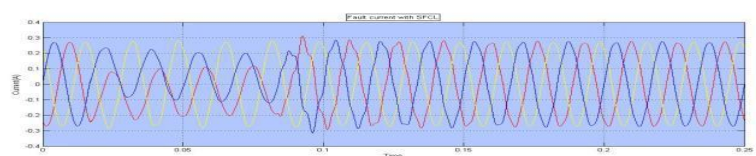

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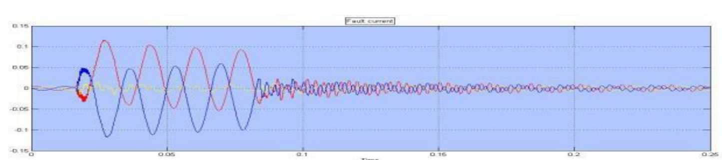
Fig5. Line to line fault (a) fault current (b) fault current with circuit breaker (c) fault current with SFCL



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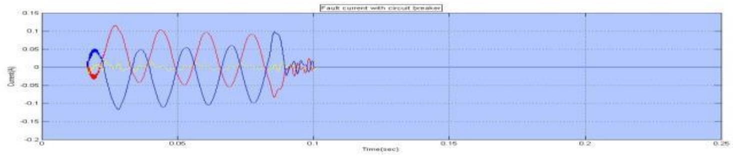

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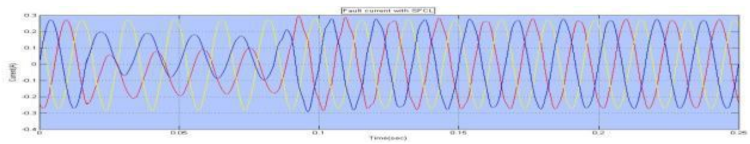

Fig 6. Double line to ground fault (a) fault current (b) fault current with circuit breaker (c) fault current with SFCL

Table 2. Fault current values for different faults

Type of fault	**Magnitude of Fault Current(A)**		
	Without using circuit breaker and SFCL	**With circuit breaker**	**With SFCL**
Single Line to Ground Fault	2230	2139	150
Line to Line Fault	1910	1890	95
Double Line to Ground fault	2340	2250	90

VI. CONCLUSION

This project introduces the SFCL as new technology for reducing the short circuit currents at the 110kV level of substation network. Therefore, the SFCL improves the system security with minimum short circuit currents. Subsequently, improving the system reliability and minimizing the loading on the feeders in steady state and under contingency. The installation of SFCL in the substation removes the temporary fault. The device is efficient in temporary fault and if permanent fault occurs the SFCL does not play any role. So the development should be done to make SFCL more opera table during permanent fault. Hence SFCL can be installed in any substation to improve the reliability and to meet the demand of the consumer effectively.

REFERENCES

[1] Nur Amalina Abu Samah and Wan Norainin Wan Abdullah "Application of Superconducting Fault Current Limiter in Power System", IEEE, PEOCO, 2010.

[2] Yi Chi, Congmei Jiang, Ke Zhang "Safe Operation Improvement of an Electrical Power System by Superconducting Fault Current Limiters" IEEE, 2016.

[3] Maloth Naresh, Navneet Kumar Singh, Asheesh Kumar Singh "Superconducting Fault Current Limiter for Grid Connected Power System Protection", IEEE, 2016.

[4] D.E. A. Mansour and D. M. Yehia, "Analysis of 3-phase superconducting fault current limiters in power systems with inhomogeneous quenching," IEEE Trans. Appl. Supercond., Vol. 23, p. 5602605, 2013.

[5] Won-Sik Moon, Jong-Nam Won, Jae-Sun Huh, and Jae-Chul Kim"A Study on the Application of a Superconducting Fault Current Limiter for Energy Storage Protection in a Power Distribution System", IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 22, NO. 3, JUNE 2012

[6] G. Slade, et al, "The Utility Requirements for A Distribution Fault Current Limiters", IEEE Transactions on Power Delivery, Vol. 7, No. 2 April 1992 507-515.

[7] M. Noe and M. Steurer, "High-temperature superconductor fault current limiters: concepts, applications, and development status," Supercond. Sci. *Technol.,* Vol. 20, pp. R15-R29, 2007.