International Journal of Researc
Available at https://edupediapublications.org/journa
p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 14
October 2016

Simulation of Superconducting FCL to Protect Energy Storage in Distribution System

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Abstract— Superconducting fault-current limiters (SFCLs) have been the subject of research and development for many years and offer an attractive solution to the problem of rising fault levels in electrical distribution systems. SFCLs can greatly reduce fault currents and the damage at the point of fault, and help improve the stability of a power system. The resistance of an SFCL should be chosen to limit fault currents as much as possible. Not only does this benefit an electrical system through reduction in the potentially damaging effects of high fault currents, which is the primary purpose of the SFCL, but increasing the limitation of fault currents also has a consequence of shortening the recovery time of the SFCL by reducing the energy dissipated in the resistance of the SFCL. Superconducting fault-current limiters (SFCL) provide a new efficient approach to the reliable handling of such faults.(SCFLs) can be used for various nominal voltages and currents, and can be adapted to particular limiting characteristics in case of short circuits. Electrical equipment that controls high fault currents can increase the security of the network and allow power equipment to be designed more cost effectively. The SCFL is such a device. In contrast to a high-voltage fuse it does not disconnect the line in case of a short circuit but limits the very high currents to defined values. In addition, it allows electrical interconnections of existing systems, which would not be possible without limiters .Finally, the SFCL is introduced in the higher capacity system. 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. The simulation results are presented by using Matlab/simulink software.

Index Terms— Power Quality (PQ), Superconducting Fault Current Limiter (SFCL), Switch Gear Units

I. INTRODUCTION

In today circumstances, rapid development of power network cause the fault current of the system increased greatly. The levels of fault current in many places have often exceeded the withstand capacity of existing power system equipment. As implication to this matter; security, stability and reliability of power system will be negatively affected [1]. Thus, limiting the fault current of the power system to a safe level can greatly reduce the risk of failure to the power system equipment due to high fault current flowing through the system. Because of that, there is no surprise to fault current limiting technology has become a hotspot of fault protection research since this technology can limit the fault current to a low level[2,3].

The traditional devices, used for fault current limitation, are:

- Fuses are simple, reliable and they are usually used in low voltage and in middle voltage distribution grids.
- The main disadvantages are the single-use and the manually replacement of the fuses;
- Circuit-breakers are commonly used, reliable protective devices. The circuit-breakers for high current interrupting capabilities are expensive and have huge dimensions. They require periodical maintenance and have limited number of operation cycles;
- Air-core reactor and transformers with increased leakage reactance increase the impedance of distribution network and consequently limit the short-circuit currents;
- System reconfiguration and bus-splitting.

There have been an increase in the number of studies on the alternative solution to improve the reliability of electrical systems and one of them is the application of a fault current limiter (FCL).

Many types of fault current limiter have been developed in the past few years [2-3]. Superconducting fault current limiter (SFCL) is the most inventive fault current limiting device [4]. It offers many advantages which include having no impact on the system in typical conditions, limiting fault current quickly and response automatically in an abnormal condition. In power system, studies of SFCL are anticipated not only to limit fault current but also to develop stability of the system [5-6]. Many studies have been carried out for the practical application of SFCL in electric power system in the past few years [7-9]. 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. SUPERCONDUCTING FAULT CURRENT LIMITER

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 [10-13]. 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 [14].

An impedance of SFCL according to time t is expressed by (1)

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

Where Rm is the maximum resistance of the SFCL in the quenching state, Tsc 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, t1 and t2 are the first and second recovery times, respectively. Quenching and recovery characteristics of the SFCL modelled 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.

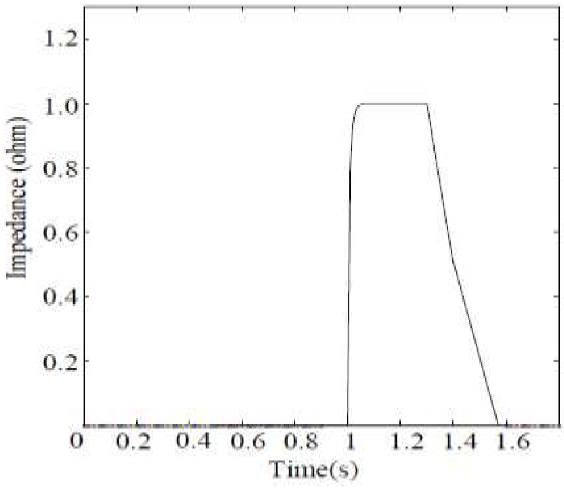

Fig 1 Quench and Recovery characteristics of SFCL

III. DESIGNING OF SFCL

The working principle of the SFCL model developed in Simulink/Sim Power system 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.

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.

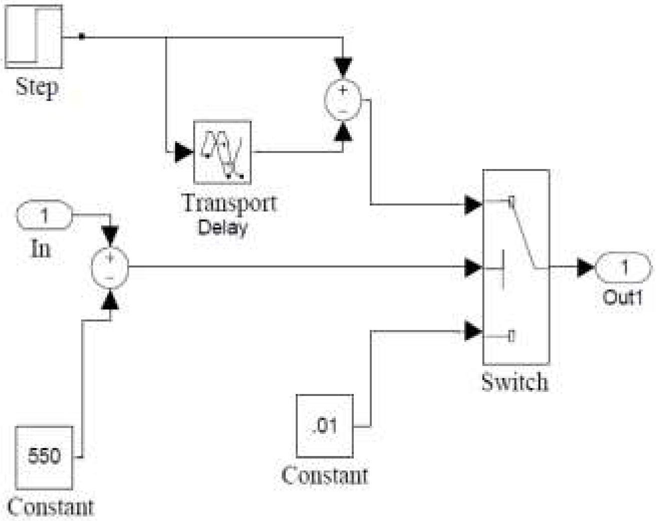

Fig.2 Implementation of Resistive SFCL Characteristics in Simulink

Simulink/Sim Power system 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.

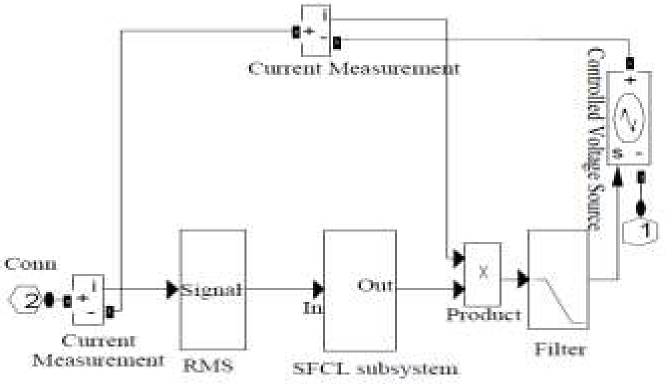

Fig.3 Resistive SFCL model in Simulink

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 system.

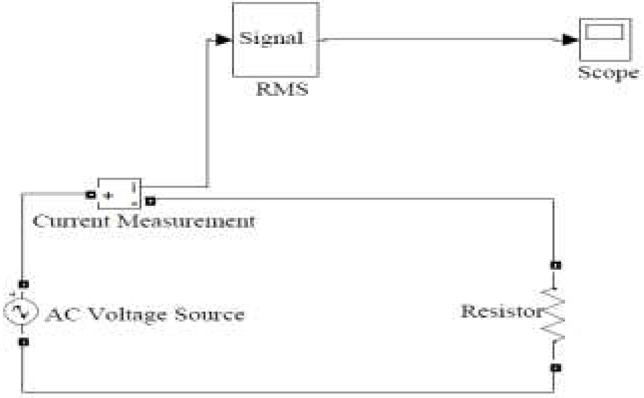

Fig. 4 Simulation model of single phase system without SFCL

A three phase system with a nominal capacity (110 MW) is designed in Simulink/Sim- Power System 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.

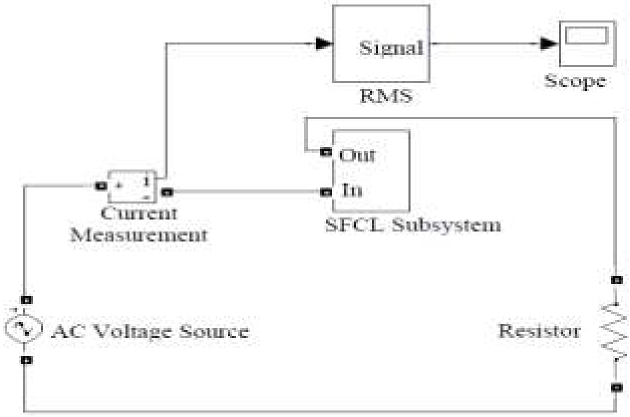

Fig.5 Simulation model of single phase system with SFCL

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. MATLAB/SIMULINK RESULTS

Here the simulation is carried out by different casaes 1) Single phase with and without SFCL under fault condition 2) three phase SFCL with switch gear 3) Three phase with and without SFCL 4) BESS with and without SFCL

Casaes- 1 Single phase with and without SFCL under fault condition

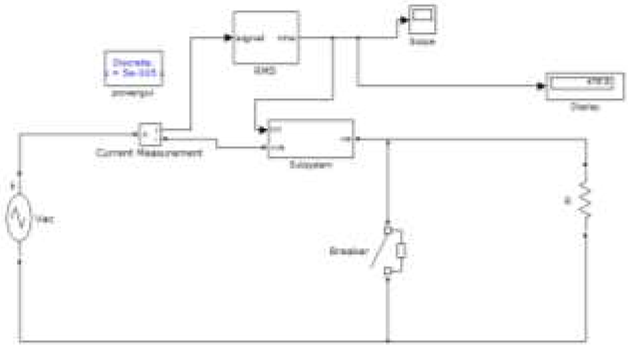

Fig.6 Single phase with SFCL under fault condition

Fig.7 simulated output waveform of Single phase with SFCL under fault condition

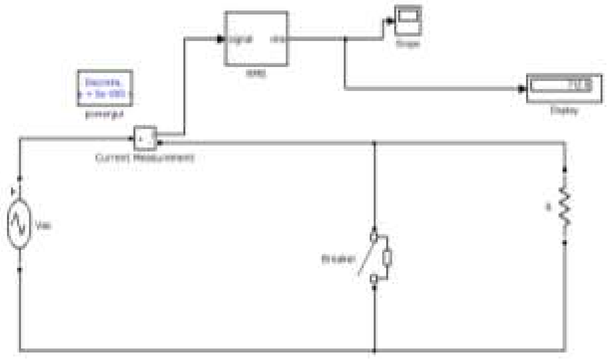

Fig.8 Single phase without SFCL under fault condition

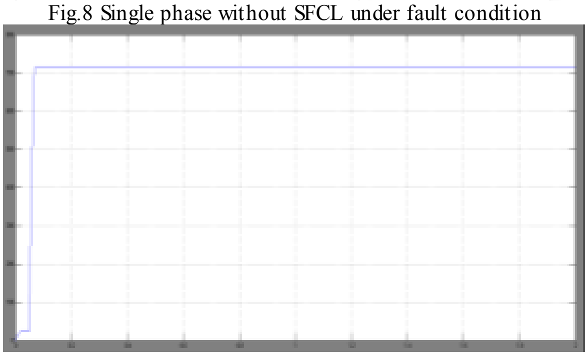

Fig.9 simulated output waveform Single phase without SFCL under fault condition

Casaes- 2 Three Phase SFCL with switch gear

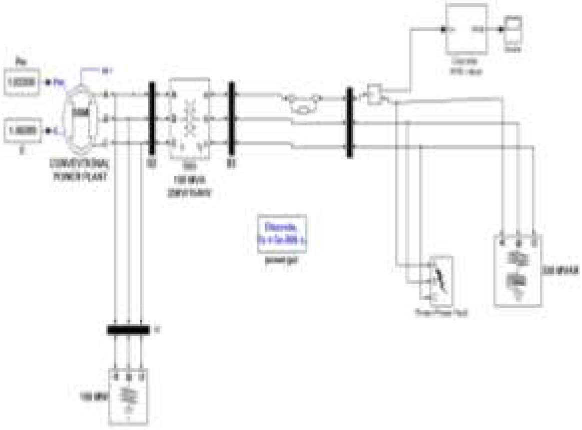

Fig.10 Three phase 110MW with switch gear

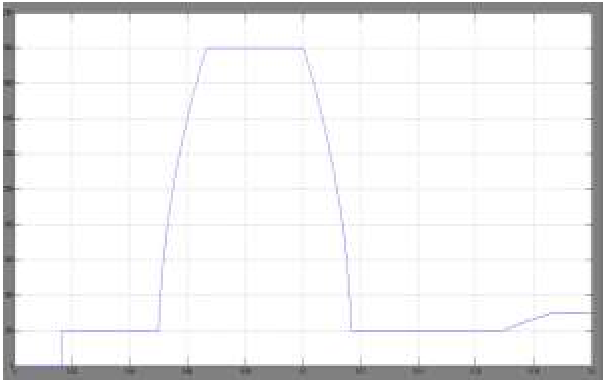

Fig.11 Simulated fault current waveforms with switch gear

Casaes- 3 Three phase with and without SFCL

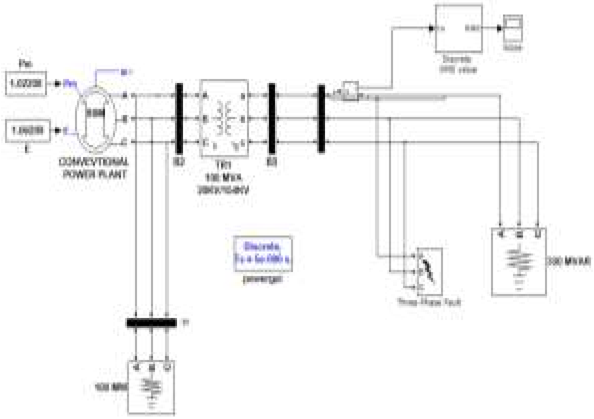

Fig.12 Matlab/simulink model of Three phase without SFCL

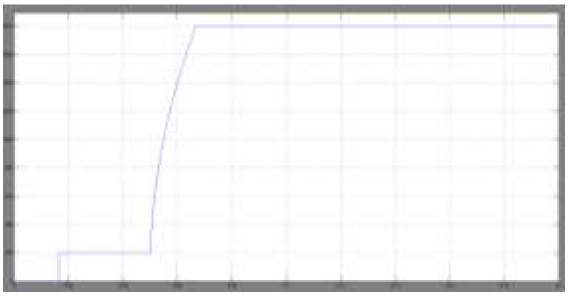

Fig.13 shows output of three phase without SFCL

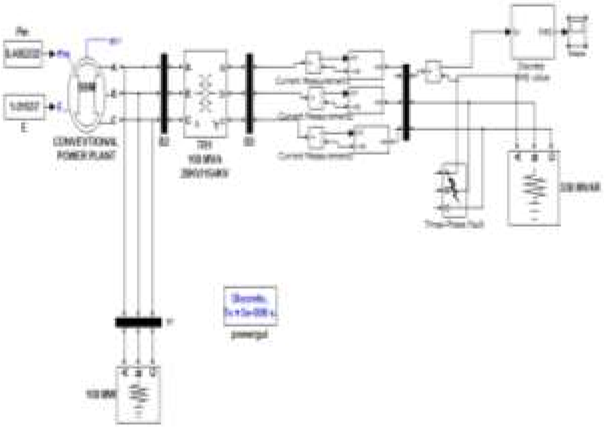

Fig.14 Matlab/simulink model of three phase 220MW with SFCL

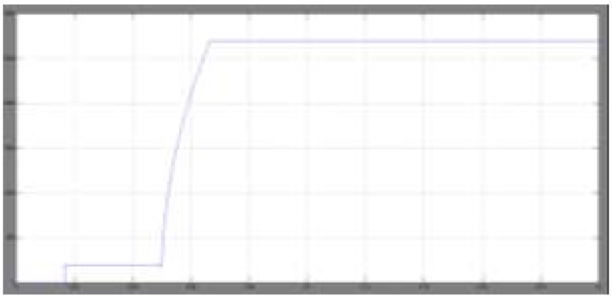

Fig.15 shows output of three phase 220MW with SFCL

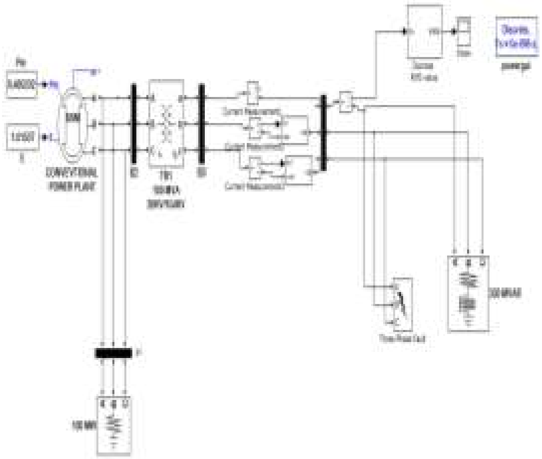

Fig.16 Matlab/simulink model of Three phase 220MW without SFCL

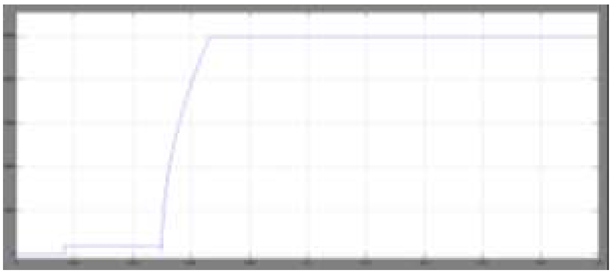

Fig.17 shows output of three phase 220MW without SFCL

Case-4 BESS with and without SFCL

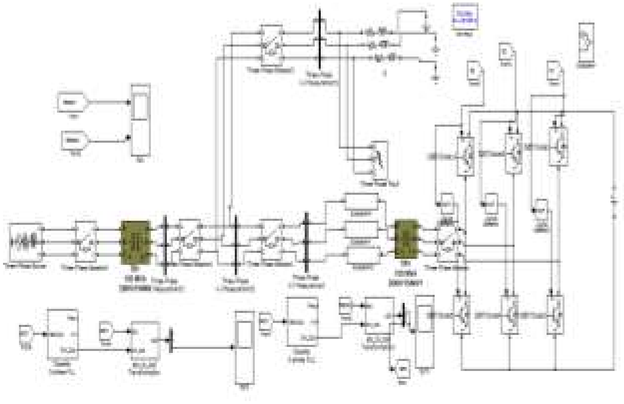

Fig.18 Matlab/simulink model of battery energy storage system

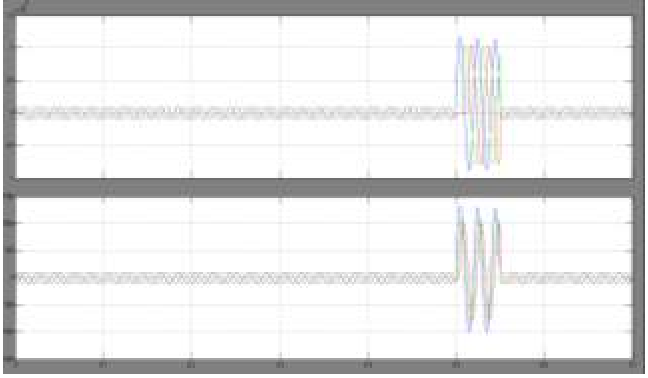

Fig.19 Shows the BESS without and with feeder currents 1 and 2

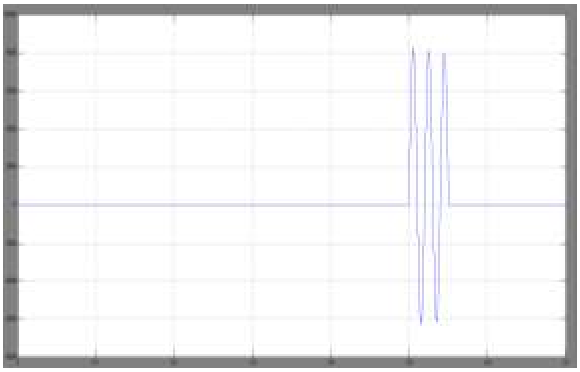

Fig.20 Zero sequence current of main transformer

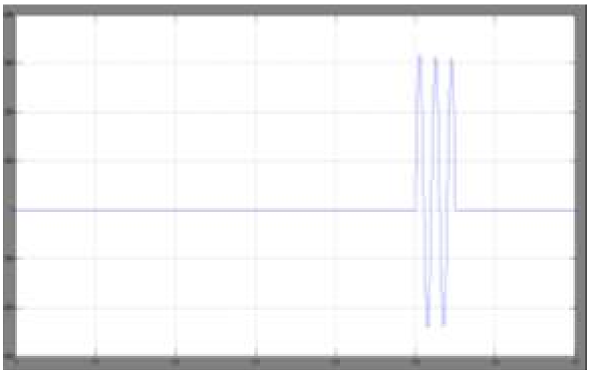

Fig.21 Zero sequence current of main interconnecting transformer

V. CONCLUSION

In this concept energy storage is used by protection of BESS by growth of interconnections in electrical systems the short-circuit capacity increases. The bus-tie position appears to be the most economical option among other alternatives. The benefit of SFCLs application in power systems is reduction the current stresses on equipment during faults, transient stability of the power grid enhancement and reduction of voltage dips and sags. The maximal over-current is one of the most important dimensioning parameter for the power equipment. The development of effective SFCLs is becoming very important in relation to rising fault current levels in modern power networks. There are many possible locations in power systems where SFCLs installation offers technical and economical benefits. 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.

REFERENCES

[1] Hye-Rim Kim, Seong-Eun Yang, Seung-Duck Yu, Heesun Kim, Woo Seok Kim, Kijun Park, Ok-Bae Hyun,Byeong-Mo Yang, Jungwook Sim, and Young-Geun Kim, "Installation and Testing of SFCLs," IEEE
Trans. Appl. Supercond , vol. 22, no. 3, June 2012.

[2] M. Firouzi, G.B.Gharehpetian, and M. Pishvaie, "Proposed New Structure for Fault Current Limiting and Power Quality Improving Functions," International Conference on Renewable Energies and Power Quality (ICREPQ'10) Granada (Spain), 23rd to 25th March, 2010.

[3] M. T. Hagh and M. Abapour, "Nonsuperconducting Fault Current Limiter With Controlling the Magnitudes of Fault Currents," IEEE Trans. Power Electronics, Vol.24, PP. 613–619, March 2009

[4] Steven M. Blair, Campbell D. Booth, Nand K. Singh, and Graeme M.
Burt, "Analysis of Energy Dissipation in Resistive Superconducting Fault-Current Limiters for Optimal Power System Performance," IEEE Trans. Appl. Supercond , vol. 21, no. 4, August 2011.

[5] A. S. Emhemed, R. M. Tumilty, N. K. Singh, G. M. Burt, andJ. R. McDonald, "Analysis of transient stability enhancement of LV connectedinduction micro generators by using resistive-type fault current limiters," IEEE Trans. Power Syst., vol. 25, no. 2, pp. 885–893, May 2010.

[6] Gum Tae Son, Hee-Jin Lee, Soo-Young Lee, and Jung-Wook Park, "A
Study on the Direct Stability Analysis of Multi-Machine Power System
With Resistive SFCL," IEEE Trans. Appl. Supercond , vol. 22, no. 3,
June 2012.

[7] Jin-Seok Kim, Sung-Hun Lim, and Jae-Chul Kim, "Study on Application Method of Superconducting Fault Current Limiter for Protection Coordination of Protective Devices in a Power Distribution System," IEEE Trans. Appl. Supercond , vol. 22, no. 3, June 2012.

[8] B. C. Sung, D. K. Park, J.-W. Park, and T. K. Ko, "Study on optimal location of a resistive SFCL applied to an electric power grid, "IEEETrans. Appl. Supercond., vol. 19, no. 3, pp. 2048–2052, June 2009.

[9] S. M. Blair, C. D. Booth, I. M. Elders, N. K. Singh, G. M. Burt, McCarthy, "Superconducting fault current limiter application in a power-dense marine electrical system," IET Elect. Syst. Transp., vol.1, no. 3, pp. 93–102, Sep. 2011.

[10] Mathias Noe, Achim Hobl, Pascal Tixador, Luciano Martini, and Bertrand Dutoit, "Conceptual Design of a 24 kV, 1 kA ResistiveSuperconducting Fault Current Limiter," IEEE Trans. Appl.
Supercond , vol. 22, no. 3, June 2012

[11] Jin Bae Na, Young Jae Kim, Jae Young Jang, Kang Sik Ryu, Young Jin
Hwang, Sukjin Choi, and Tae Kuk Ko, "Design and Tests of Prototyp HybridSuperconducting Fault Current Limiter With Fast Switch," IEEE
Trans. Appl. Supercond , vol. 22, no. 3, June 2012.

[12] S. Elschner, A. Kudymow, S. Fink, W. Goldacker, F. Grilli, C. Schacherer, A. Hobl, J. Bock, and M. Noe, "ENSYSTROB—Resistive
fault current limiter based on coated conductors for medium voltage application," IEEE Trans. Appl. Supercond., vol. 21, no. 3, pp.1209– 1212, June 2011.

[13] T. Yazawa, et al, "Design and Experimental Results of Three-Phase Superconducting Fault Current Limiter Using Highly-Resistive YBCO Tapes", IEEE Transactions on Applied Super-conductivity, Vol. 19, Issue 3, Part 2, June 2009.

[14] Jong-Fil Moon, Sung-Hun Lim, Jae-Chul Kim, and Sang-Yun Yun, "Assessment of the Impact of SFCL on Voltage Sags in Power Distribution System," IEEE Trans. Appl. Supercond , vol. 21, no. 3, June2011.

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