

MODELLING AND ANALYSIS OF SOLID STATE FAULT CURRENT LIMITER

¹J.P.SHARMA, ²VIBHOR CHAUHAN, ³HR KAMATH

^{1,2,3}JK LakshmiPat University, Suresh Gyan Vihar University, Malwa Institute of Technology India
E-mail: jpsharma.cseb@gmail.com, vibhor.chauhan@gmail.com, Rskamath272@gmail.com

Abstract- In modern power system, an increase in the growth of electrical energy demand is inevitable resulting in a corresponding increase in the short circuit in the power system. For this, Fault Current Limiter (FCL) became best option to reduce circuit breakers rated capacity and may limit the electromagnetic stress in associated equipment's. In this paper modelling of solid state fault current limiter (SSFCL) under various fault conditions are carried out. The proposed SSFCL is implemented on 11 KV feeders. The performance of proposed SSFCL is evaluated in the forms of fault current. The simulation results reveal the applicability of SSFCL. The evaluation is done on MATLAB/Simulink.

Keywords- Solid State Faults Current Limiter, Control Strategies, Fault, Matlab /Simulink

I. INTRODUCTION

The electric power system is the heart of alternative energy system, including wind and solar electric, geothermal and small scale hydroelectric generation [1, 2]. The high dependency on Electric power system has made the system loaded and faults are inevitable. The short circuit current can't remain unnoticed as it causes a heavy inrush of currents in a short time and as a consequence heating of the equipment's and ultimately leading to power failure. The fault current in many places has often exceeded the withstand capacity of existing power system equipment's. As implication to this matter; security, stability and reliability of power system is affected [2]. Thus limiting the fault current of the power system to a safe level can greatly reduce the risk of failure of the power system equipment's due to high fault current flowing through the system. Since, this technology may limit the fault current to a lower level; it has grabbed a concern of research in recent past [3].

From the design point of view of the power system, limiting the fault current to a safe level can reduce the design capacity of some electrical equipment in the power system. This one will led to the reduction in the investment cost of high capacity circuit breakers and construction of new transmission line.

Consequently, from both technical and economical point of view, fault current limiting Technology for reducing short circuit current to a lower level is needed [4,5].

II. FAULT CURRENT LIMITER (FCL)

Fault Current Limiter (FCL) is a variable-impedance device connected in series with a circuit to limit the current under fault conditions. The FCL should have very low impedance during normal operating condition and high impedance under fault conditions.

On the basis of the above characteristics, various types of FCL have been developed. Some of these FCL is based on superconductor, power electronic switches and tuned circuit impedances [5, 6]. The fault current limiting technology has attained a significant concern and has become a hot spot in power system protection research. However, the ongoing research concentrates on the superconducting and power electronic switch types of FCL, solid state fault current limiter has a far better result to give.

A. The Role of Fault Current Limiter (FCL)

A sample power system network as shown in figure (1), consisting of a supply (voltage, V_s and impedance, Z_s) and a load (Z_{LOAD}).

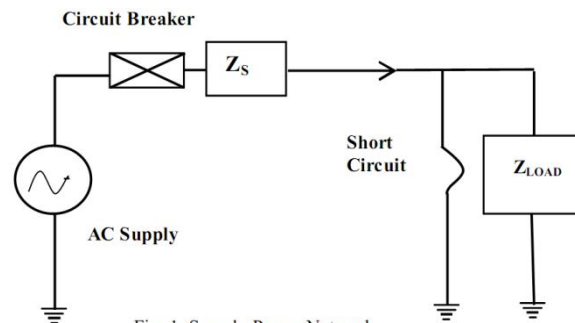


Fig. 1 Sample Power Network

In normal operating condition, the circuit current I , is given by the equation

$$I = \frac{V_s}{(Z_s + Z_{LOAD})} \quad (1.)$$

If a fault occurs and causes load to be shorted out, the circuit current is given by the equation

$$I = \frac{V_s}{(Z_s)} \quad (2.)$$

Since the supply impedance (internal impedance), Z_s has been much lower than the load impedance, the

current during faults are significantly large compared with normal current. Though, circuit breaker one will stop this fault current, it does this immediately, taking about 2-3 cycles to act. Within this span of time, a heavy inrush of current may damage to components among the supply and load. Therefore proper precautions must be taken to ensure the safety of the components and protect them under fault conditions. The role of a fault current limiter is to prevent damage faster than 2-3 cycles of a fault current rising [7]. Figure (2) shows the similar power circuit with additional fault current limiting element with impedance of FCL. To work as a fault current limiter, impedance of FCL should automatically increase on the event of the fault. Ideally impedance of FCL shall be equal to zero in the normal (non-faulty condition) state and equal to load impedance when a fault occurs. Even if the impedance of FCL is equal to source impedance Z_S during the presence of a fault, the fault current would be half that without the FCL in the circuit [7].

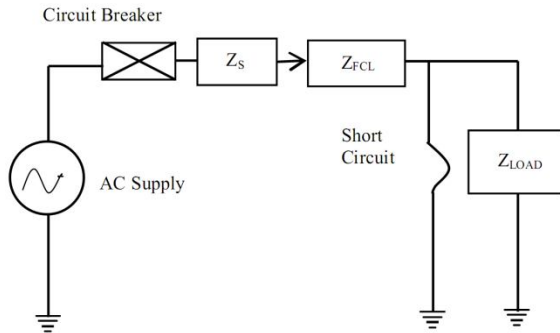


Fig. 2 Sample Power Network with FCL

III. PROPOSED SOLID STATE FAULT CURRENT LIMITER: MODELING AND SIMULATION

Solid State Fault Current Limiter (SSFCL) used in this paper consist of two parallel connected circuit branches with one branch connected to the solid state switch comprising of only two thyristor connected in inversely parallel manner and the other branch, consists of two thyristor connected in inversely parallel but with current limiting impedance (reactor) connected in series with it. The first branch (with thyristor switch only) acts as a main circuit breaker and is used to clear the fault when it occurs.

The first branch is normally closed and conducts current during normal operation. Nevertheless, when the magnitude of the current exceeds a pre-set level, the switches one will open the circuit instantly interrupts the current flow. The switches from the other branches (with thyristor and current limiting reactor in series) are normally open and have no continuously current rating during normal condition. Its function is to conduct fault current to facilitate operation of the conventional protective device on the

load side of the SSFCL.

A. Basic Configuration

The basic configuration of the SSFCL consisting of two parallel connected solid state switches is shown in figure (3). The first branch (thyristor Branch 1) comprising of thyristors switches and the other branch (thyristor branch 2) consist of thyristor and current limiting reactor. Switches are connected in inversely parallel manner for both branches. Surge arrester is used to protect the system from voltage surge during switching.

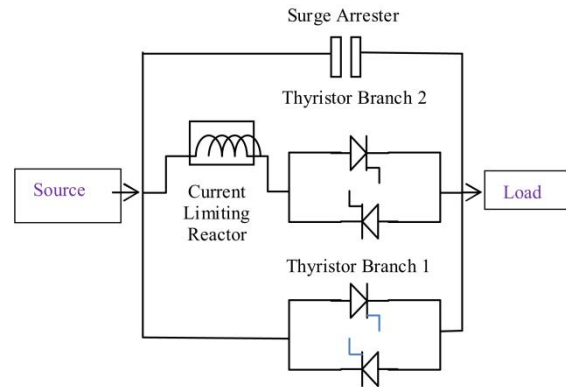


Figure 3 Basic arrangement of solid-state FCL

The inductance of the limiting reactor may be determined by taking into account the magnitude of the FCL impedance equal to the inductive reactance of the limiting reactor [13,14], which is given by equation (3)

$$|Z_{FCL}| = |\omega L_{FCL}| = \frac{V}{I_{FCL}} \quad (3.)$$

Where, L_{FCL} : Inductance of limiting reactor

Z_{FCL} : Impedance of limiting reactor

I_{FCL} : Fundamental current of FCL

V : Magnitude of system phase voltage

Thus, equation (3) can be rewritten as equation (4)

$$|L_{FCL}| = \frac{V}{2\pi f * I_{FCL}} \quad (4.)$$

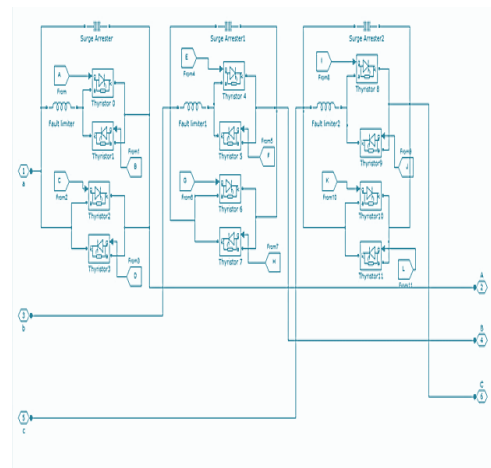


Figure 4 Simulation Model of the SSFCL

B. SSFCL Control Strategies

The block diagram of SSFCL control system is shown in figure (5). In the operation of SSFCL, fault current need to be detected promptly before it becomes harmful to other equipment's. The fault current detection is done by comparing the RMS current level with a predetermined reference value. The output from the comparator used to generate switching signals for the thyristor [14].

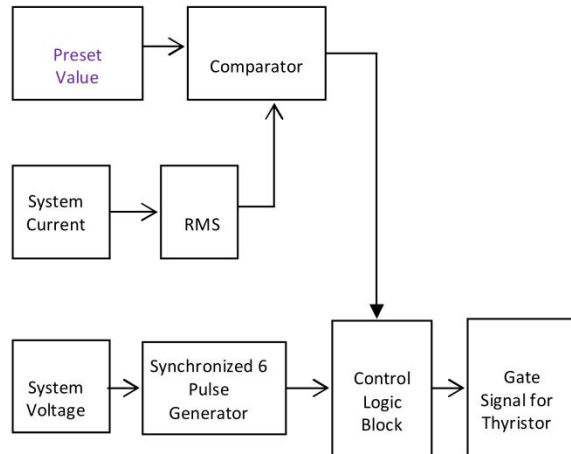


Figure 5 Block Diagram of SSFCL Control System

The Synchronized 6-Pulse Generator block is used to fire six thyristor for each state of operation. For each state of operation, 6 thyristor need to be gated continuously. Thus, for 2 states of operation, 12 thyristor need to be controlled and 2 synchronized 6-Pulse Generators are needed for the whole operation. The output of the block is a vector of six pulses individually synchronized on the six thyristor voltages. The pulses are generated alpha degrees after the increasing zero crossings of the thyristor commutation voltages [14]. Figure (6) show the SSFCL control system.

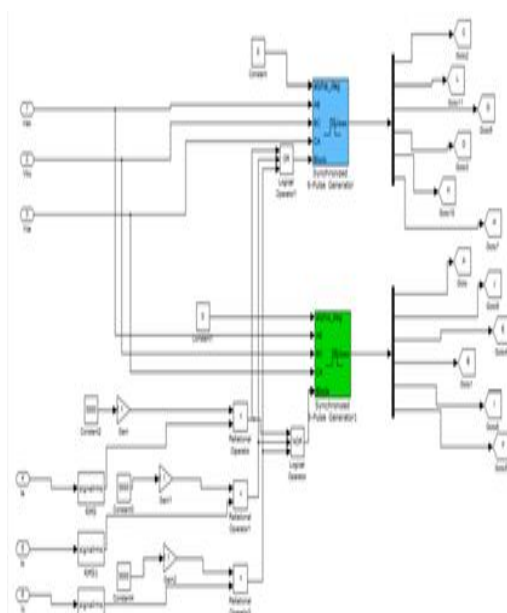


Figure 6 SSFCL control system

C. Simulation

Proposed model shown in figure (7) is simulated on a distribution power system fed from single source used. It consist a single 11 kV source, a 11/0.415 kV step down distribution transformer, and two parallel connected 415 V induction motor, all in three phase configuration. The 3 -phase short circuit at rated voltage for the three phase source is set to 31.125 MVA and its X/R ratio is set to 10. As for the transformer, the nominal power used is 33 MVA and using Y to ground connection for both sides (primary and secondary) of winding. As for load, two induction machine used for this project and connected in parallel. The power consumed by each motors is 370 kW at power factor of 0.9. SSFCL were located before the load and fault occurred at load [17] [20].

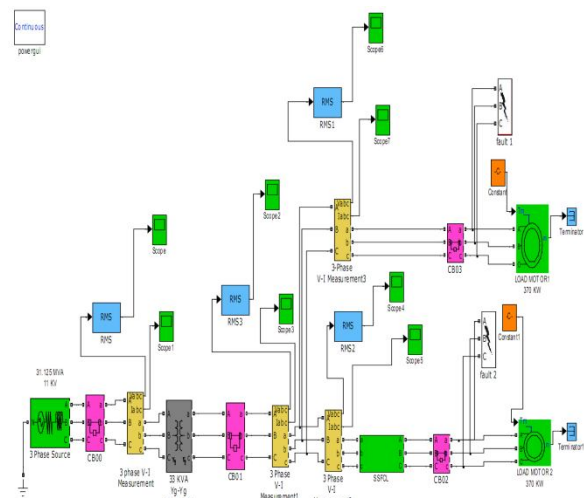


Figure 7 Distribution power system fed from single source

IV. PERFORMANCE OF SSFCL UNDER VARIOUS FAULT CONDITION

Table1 represents the case of the radial system when subjected to single phase to ground, phase to phase, double line to ground and three phase fault with and without SSFCL. Fault was applied during 0.02 second for about 0.02 second. Comparing the system with and without SSFCL, the fault current for the system with SSFCL is reduced to more than 20 times compared to the fault current for the system without SSFCL.

Table 1 SSFCL Operation in Radial System		
Faults	Without SSFCL (KA)	With SSFCL (KA)
Single Line to Ground	49	2.2
Phase To Phase	46	1.7
Double Line To Ground	55	2.2
Three Phase	54	2.2

A. Single Line to Ground Fault

Single line to ground fault is considered as the most

common fault that occurs in power system. About 90 percent of the energy system's faults are mostly due to single line to ground faults. Figure (8) shows the current waveforms of the distribution radial system without SSFCL. The 49 KA peak current as the fault phase current. It can be obviously seen that the current has a very high peak as compared to the other phases. Figure (9) shows current waveform for the system with SSFCL. Both figures were subjected to the phase to ground fault. After fault detection, the limiter starts limiting the fault current. After the first transient current, the SSFCL is able to reduce the 49 kA peak fault current to 2.2 kA peak.

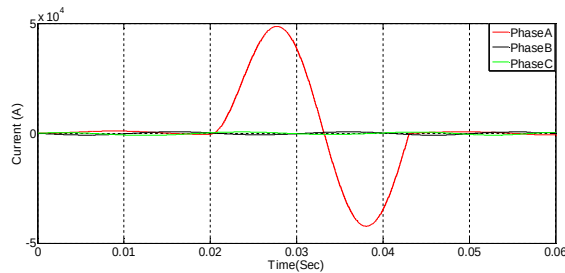


Figure 8 Line current for single line to ground fault without SSFCL

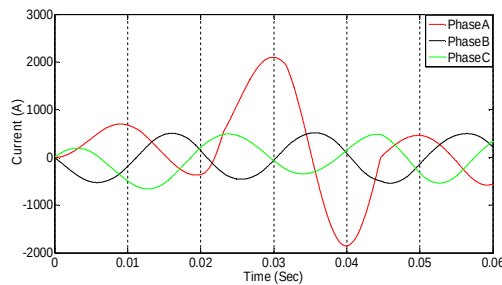


Figure 9 Line current for single line to ground fault with SSFCL

B. Phase to Phase Fault

Phase to phase fault can cause more severe damage to the power systems compared to the single phase fault.

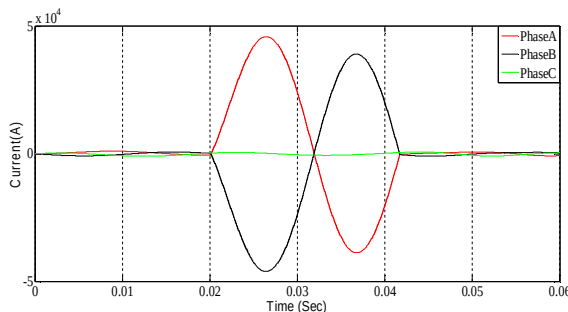


Figure 10 Line current for phase to phase fault without SSFCL

Figure (10) shows the current waveforms of the distribution radial system fed from single source without SSFCL subjected to phase to phase fault. It can be seen from figure (11) that, for phase to phase fault, only two phases experiencing high current flowing through the lines. After the first transient current, the SSFCL is able to reduce 46 KA peak fault current to 1.7 kA peak.

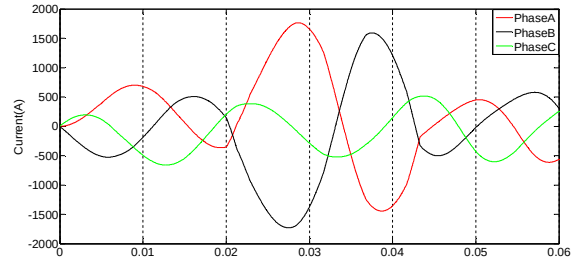


Figure11 Line current for phase to phase fault with SSFCL

C. Double Line to Ground Fault

Figure (11) shows the current waveforms of the radial distribution system without SSFCL and Figure (12) shows the system with SSFCL. Both of these figures were subjected to the double phase to ground fault. After the first transient current, the SSFCL is able to reduce 55 kA peak fault current to 2.2 kA peak.

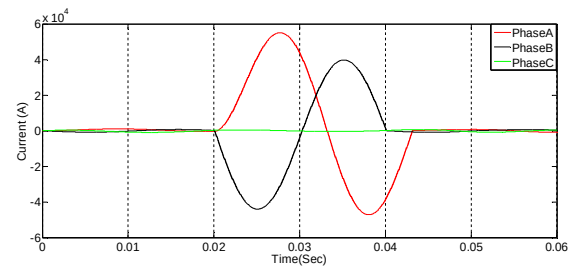


Figure 11 Line current for double line to ground fault without SSFCL

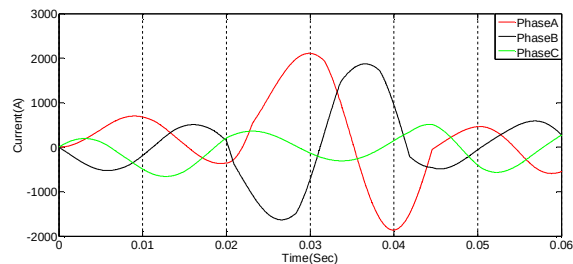


Figure12 Line current for double line to ground fault with SSFCL

D. Three Phase Fault

Three phase fault or balance fault is the most severe fault that occurs in the power systems. Figure (13) envisages the current waveforms of the radial distribution system without SSFCL when three phase fault occurred in the system. It can be seen from Figure (13) that, for three phase fault, all three phases experiences high current flowing through the lines. Figure (14) shows the similar system and condition of fault with inclusion of SSFCL in the system. After the first transient current, the SSFCL is able to reduce 54 kA peak fault current to 2.2 kA peak.

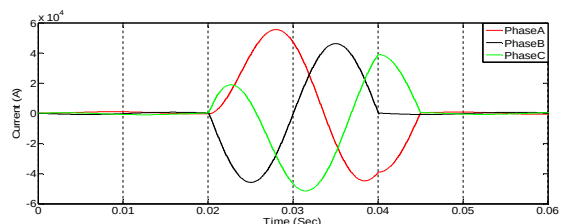


Figure13 Line current for three phase fault without SSFCL

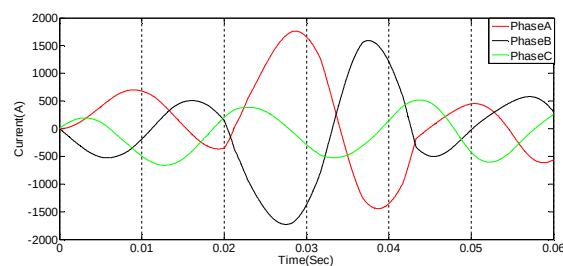


Figure14 Line current for three phase fault with SSFCL

CONCLUSION

This paper presents the modelling of solid state fault current limiter (SSFCL) using MATLAB SIMULINK. The function of SSFCL in power system is to work as circuit breaking element as well as limiting the fault current to a safe level. SSFCL is considered as the solution to the increment of short circuit level in power system. It is the most economical option compared with any other conventional solution to overcome this matter. Despite, it may limit the fault current, SSFCL offer advantages to the electricity supply industry, technically and economically. This modelled is tested on an 11 KV Distribution feeder fed from a single source. Simulation results show that the SSFCL detects the fault current and activates the control circuit. After that control circuit sends the firing signal to thyristor switches to divert the fault current to limiting reactor. Comparison of current has been made between the system without SSFCL and the system with SSFCL for various types of fault. Simulation results show that SSFCL effectively limits the current during fault incident.

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