Grid connected power system protection by superconducting fault current limiter (SFCL)

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Abstract. In present day, SFCLs are found increasing demand in power systems due to their advancements in recent years. SFCLs are implemented to limit the fault current during faults within the grid in power system. SFCL has manifested to be the most effective protection scheme in power system. Here we propose the implementation of SFCL for protection against any faults. An analysis is made for three phase Unsymmetrical faults (Namely L-G fault). To observe the influence of the SFCL in the system, analysis with and without SFCL, is implemented in MATLAB/SIMULINK. With this analysis effectiveness of SFCL is identified during a fault. Resistive type SFCL is proposed here. Outcomes obtained reinforce the implementation of SFCL for protection during faults.

Keywords- SFCL, MATLAB/ SIMULINK, L-G fault, FCC, Smart Grid.

1. Introduction

In recent years, Power system advancement has been followed by increase in use of SFCL to control the fault current during faults [1]. Power system equipments are so designed that they offer low impedances, such that the losses are minimal. However, a disadvantage of this minimum impedance results in significantly large fault currents during faults, i.e., 5-25 times of normal operating level. Previously reactors (inductors) connected in parallel were used to limit the current during faults, but they offer fixed impedance [3]. So shunt reactors cannot vary their impedance accordingly with different fault currents. Whereas SFCL have ability of rapidly altering their impedances. In grid connected power system, SFCL aspire to be one of the prominent devices for the protection against faults. Here a SFCL has been proposed for the protection against faults. An analysis is made considering L-G faults in the grid. With this analysis, fault current during disturbances is limited to nominal values is identified within the grid [5]. Here we first discuss the constructional blocks and operational principles of the Resistive type SFCL, which is proposed here.

2. Operation Principle

A FCL is an series connected electrical device connected to line to be protected and ensues minimum impedance under normal condition, and maximum impedance under fault condition, thus altering current flow fastly.
Basic Principle of SFCL

A Resistive type SFCL is implemented here. The Resistive type SFCLs are basic resistors made with superconducting materials [4]. During normal operating conditions it offers low impedance thus allowing more current and during fault conditions it offers more impedance thus limiting current through it. Temperature, Magnetic Field and Current Density \((T-B-J)\) characteristics of a superconductor material is shown in fig. 1.

![T-B-J characteristics of superconductor material](image)

Most widely used SFCLs in recent years are the resistive type and the inductive type [2]. Resistive type FCL is connected in series with the line to be protected and Inductive type FCL is magnetically coupled into the line to be protected [6].

Flowchart of the methodology

![Flow chart of methodology](image)

To analyse the operation of SFCL in power system a flow chart is developed and is shown in Fig. 2.
3. Design Analysis and Simulation Results

To analyze the effect of SFCL during fault, a Power System using MATLAB/ SIMULINK for a three phase to ground fault with SFCL at different locations in the grid has been designed and is shown in Fig. 3.

Resistive type SFCL

As Resistive type SFCLs are connected in series. Simulink model of the SFCL is shown in fig. 4. The parameters and their selected values are given as:
1) Switching time = 5mSec
2) Lower impedance limit = 0.01ohms and Higher impedance limit = 20ohms
3) Initiating current=550A
4) Recovery time=10msec, its normal voltage = 22.9 kV.

In Fig. 4, three different locations of SFCL are proposed and analyzed. The operation of SFCL automatically initiates when a fault occurs, hence no initiation equipment is required. It is intrinsically fool proof. If it fails, SFCL will burn out.

Fig. 3. Resistive SFCL

Fig. 4. Basic Simulation model designed in Sim-Power System
Fault in the Distribution Grid (F1)
To analyze the difference in fault currents in distribution grid, fault at location F1 is initiated and change in fault current is noted considering the SFCL and not considering SFCL. From Fig. 5 we can clearly observe that the magnitude of fault current with SFCL is lesser than that of fault current with “No FCL” state.

Fault in Customer Grid (F2)
To analyze the difference in fault currents in customer grid, fault at location F2 is initiated. Fig. 6 shows a relative comparison of fault-currents with and without SFCL (measured at TR3, in Fig. 3), when a fault occurred on the customer side. As expected condescending results are obtained.
**Fault in Transmission Line (F3)**

Considering fault in transmission line will in surge very large fault currents in the grid. To analyze the difference in fault currents in transmission line, fault is considered at location F3. Fig. 7 depicts the change in fault current with and without SFCL.

![Current waveforms for (a) fault at location 1, fault at location 2, and (b) fault at location 3 and fault at location 4](image)

**4. Conclusion**

A SFCL is a series connected electrical device used in power system to control and limit fault currents during the disturbances. In power system, SFCL aspires to be one of the prominent devices used for the protection. Here SFCL is proposed for the protection against faults. An analysis is made for three phase unsymmetrical faults. To reflect the effectiveness of the SFCL, analysis with and without SFCL is performed. From the results obtained from analysis we can conclude that inclusion of SFCL in the grid will limit the fault current to significant nominal values.

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