

## **Reducing the Fault Currents and Over Voltages and Enhancing the Security of Electric Power System through Active SFCL**

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### **Abstract:**

Superconducting fault current limiter is an attractive electronic device to solve the problem of very high fault current in the power system. 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 active type SFCL is introduced in the higher capacity system. Fault current in this system is limited by active type SFCL to the level of the presented switchgear.

For a Power distribution system with distributed generation (DG) units, its fault current and induced overvoltage under abnormal conditions should be taken into account seriously. In consideration that applying superconducting fault current limiter (SFCL) may be a feasible solution, the effects of a voltage compensation type active SFCL on them are studied through theoretical derivation and simulation. The active SFCL is composed of an air-core superconducting transformer and a PWM converter.

The magnetic field in the air-core can be controlled by adjusting the converters output current, and then the active SFCLs equivalent impedance can be regulated for current-limitation and possible overvoltage suppression. During the study process, in view of the changes in the locations of the DG units connected to the system, the DG units injection capacities and the fault positions, the active SFCLs current-limiting and

overvoltage-suppressing characteristics are both simulated in MATLAB. The simulation results show that the active SFCL can play an obvious role in restraining the fault current and overvoltage, and it can contribute to avoiding damage on the relevant distribution equipment and improve the systems safety and reliability.

### **Introduction:**

The electrical energy produced at the generating station is conveyed to the consumers through a network of transmission and distribution systems. It is often difficult to draw a line between the transmission and distribution systems of a large power system. It is impossible to distinguish the two merely by their voltage because what was considered as a high voltage a few years ago is now considered as a low voltage. In general, distribution system is that part of power system which distributes power to the consumers for utilization.

The transmission and distribution systems are similar to man's circulatory system. The transmission system may be compared with arteries in the human body and distribution system with capillaries. They serve the same purpose of supplying the ultimate consumer in the city with the life-giving blood of civilization-electricity. In this chapter, we shall confine our attention to the general introduction to distribution system. In this chapter the MATLAB/SIMULINK software tools will be explained. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning.

This allows solving many technical computing problems, especially those with matrix and vector formulations.

**TYPES OF FAULT CURRENTS**

The shunt type of faults involves short circuit between conductor and ground (or) short circuit between two (or) more conductors. The shunt faults are characterized by increase in current and fall in voltage and frequency. The shunt faults can be classified as shown below:

- Line-to-ground fault
- Line-to-line fault
- Double line-to-ground fault
- Three phase fault

The series fault may occur with one (or) two broken conductors which creates open circuits. It also happens in circuits controlled by fuses (or) breakers which do not open all the three phases, i.e., one (or) two phases of the circuit may open and the other phases may be closed. The series faults are characterized by increase in voltage and frequency and fall in current in the faulted phase. The series faults may be classified as one open conductor fault and two open conductor fault.



**Fig(1) Fault Current Due To Lightning**

**1.4 OVER VOLTAGE:**

When the voltage in a circuit or part of it is raised above its upper design limit, this is known as overvoltage. The conditions may be hazardous. Depending on its duration, the overvoltage event can be transient a voltage spike or permanent, leading to a power surge.

**CAUSES OF OVER VOLTAGE:**

The over voltages on a power system may be broadly divided into two main categories:

**internal causes**

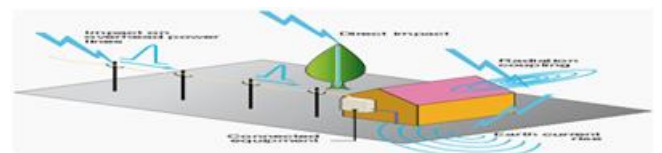
- Switching surges
- Insulation failure
- Arcing ground
- Resonance

**External causes**

**Lightning**



**Fig (2)-Over Voltages Due To Lightning**



**Fig(1.7)- Lightning Impacts**



**Fig(3)- Lightning Strike On Lightning**

**The Matlab Application Program Interface (Api):**

This is a library that allows writing in C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

**Matlab Documentation:**

MATLAB provides extensive documentation, in both printed and online format, to help to learn about and use all of its features. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format.

**Simulink:**

Simulink is a software add-on to mat lab which is a mathematical tool developed by The Math works,(<http://www.mathworks.com>) a company based in Natick. Matlab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries. Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, DSP, Statistics etc. are available with Simulink, which enhance the processing power of the tool. The main advantage is the availability of templates / building blocks, which avoid the necessity of typing code for small mathematical processes.

**Concept of Signal And Logic Flow:**

In Simulink, data/information from various blocks are sent to another block by lines connecting the relevant blocks as shown in Fig5.1. Signals can be generated and fed into blocks dynamic / static). Data can be fed into functions. Data can then be dumped into sinks, which could be scopes, displays or could be saved to a file. Data can be connected from one block to another, can be branched, multiplexed etc. In simulation, data is processed and transferred only at Discrete times, since all computers are discrete systems. Thus, a simulation time step (otherwise called an integration time step) is essential, and the selection of that step is determined by the fastest dynamics in the simulated system.



**Fig(4)-Simulink Library Browser**

**Block Diagram:**

A Simulink block diagram is a pictorial model of a dynamic system. It consists of a set of symbols, called blocks, interconnected by lines. Each block represents an elementary dynamic system that produces an output either continuously (a continuous block) or at specific points in time (a discrete block). The lines represent connections of block inputs to block outputs.

Every block in a block diagram is an instance of a specific type of block. The type of the block determines the relationship between a block's outputs and its inputs, states, and time. A block diagram can contain any number of instances of any type of block needed to model a system. Blocks represent elementary dynamic systems that Simulink knows how to simulate.

A block comprises one or more of the following:

- A set of inputs,
- A set of states, and
- A set of outputs

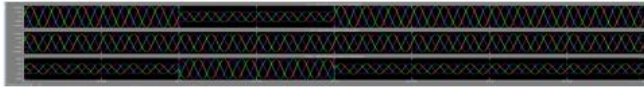
A block's output is a function of time and the block's inputs and states (if any). The specific function that relates a block's output to its inputs, states, and time depends on the type of block of which the block is an instance. Continuous Versus discrete Blocks Simulink's standard block set includes continuous blocks and discrete blocks. Continuous blocks respond continuously to continuously changing input. Discrete blocks, by contrast, respond to changes in input only at integral multiples of a fixed interval called the block's sample time. Discrete blocks hold their output constant between successive sample time hits. Each discrete block includes a sample time parameter that allows you to specify its sample rate. The Simulink blocks can be either continuous or discrete, depending on whether they are driven by continuous or discrete blocks. A block that can be either discrete or continuous is said to have an implicit sample rate. The implicit sample time is continuous if any of the block's inputs are continuous. The implicit sample time is equal to the shortest input sample time if all the input sample times are integral multiples of the shortest time. Otherwise, the input sample time is equal to the fundamental sample time of the inputs, where the fundamental sample time of a set of sample times is defined as the greatest integer divisor of the set of sample times.

Simulink can optionally color code a block diagram to indicate the sample times of the blocks it contains, e.g., black (continuous), magenta (constant), yellow (hybrid), red (fastest discrete), and so on. The block contains block name, icon, and block library that contain the block, the purpose of the block.



**Simulation Block Diagram and Results:**

**Fig(5.1)-Block Diagram of Three Phase SFCL**



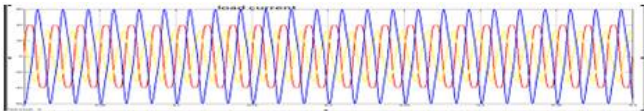
**Fig(5)-Wave Form Of Three Phase SfcI**

The above figure is shown graph between long time and voltage . In this graph shows x axis takes long time and y axis takes (source voltage(vs)&load voltage(vL)&injected voltage(vinj)) In this wave forms shows fault occurs time 0.1 to 0.2



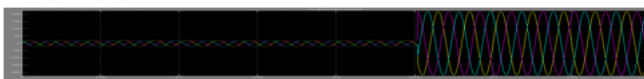
**FIG(6)**

The above figure shows x axis takes long time and y axis takes (dc capacitor voltage and neutral current).



**FIG(7)**

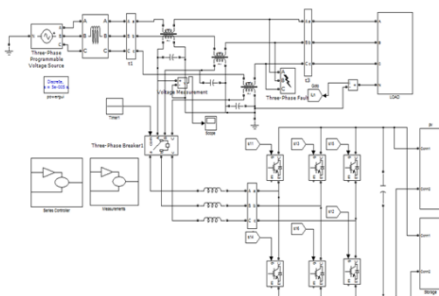
The above figure shows x axis takes long time and y axis takes load current.



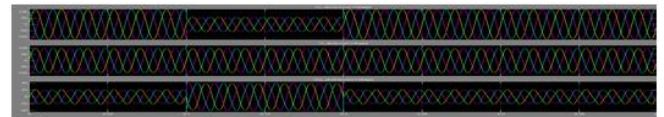
**FIG(8)**

The above figure shows x axis takes long time and y axis takes source current

**4.7 BLOCK DIAGRAM OF THREE PHASE SFCL WITH PVCELL.**

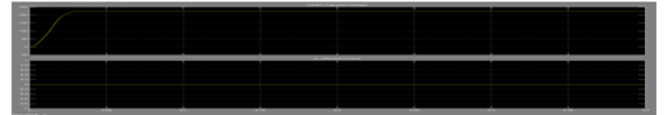


**FIG(9)**



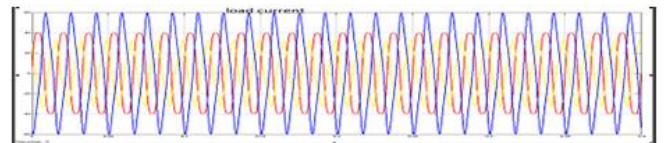
**FIG(10)**

The above figure is shown graph between long time and voltage . In this graph shows x axis takes long time and y axis takes (source voltage(vs)&load voltage(vL)&injected voltage(vinj)).In this wave forms shows fault occurs time 0.1 to 0.2 .



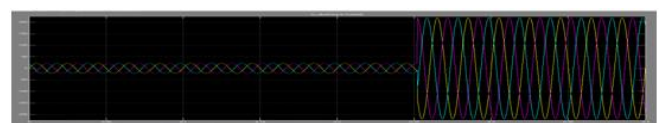
**FIG(11)**

The above figure shows x axis takes long time and y axis takes (dc capacitor voltage and neutral current).



**FIG(12)**

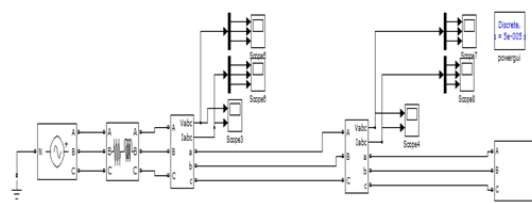
The above figure shows x axis takes long time and y axis takes load current.



**FIG(13)**

The above figure shows x axis takes long time and y axis takes source current

**4.8 BLOCK DIAGRAM OF WITH OUT SFCL**



FIG(14)



FIG(15)



FIG(16)



FIG(17)

### Conclusion:

The application of the PV based active SFCL into in a power distribution network with DG units is investigated. For the power frequency overvoltage caused by a single-phase grounded fault, the PV based active SFCL can help to reduce the overvoltage's amplitude and avoid damaging the relevant distribution equipment. The PV based active SFCL can as well suppress the short-circuit current induced by a three-phase grounded fault effectively, and the power system's safety and reliability can be improved. Moreover, along with the decrease of the distance between the fault location and The PV based SFCL's installation position, the current-limiting performance will increase.

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