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# A Novel and Smart Design of Solid State Fault Current Controller for Thermal Power Station

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**ABSTRACT**

Modern power systems are highly dynamic in nature. Today customers are highly sensitive towards quality and reliable power supply. Continuous growth of electrical energy demand is resulting in a large network. It will increase the occurrence of the short circuit in power system. Fault elimination is very important to provide a reliable power supply to the various components available in power system. Power transmission overhead lines are much prone to external faults. So an intelligent approach to limit the fault current in power system is essential. Several solutions have been implemented, including the use of Fault Current Limiter (FCL), in order to reduce circuit breakers rated capacity and to limit the electromagnetic stress in the associated equipments. This project is a simulation based project and we aim at generating different fault types by the MATLAB/SIMULINK software .This project presents a comprehensive study of the impact of fault current limiter in power system performance. The FCL used for this study is solid-state type because it has advantages in terms of flexibility and control over superconducting type. In order to evaluate the impact of fault current limiter in power system performance, simulation model of power system performance with SSFCL are used.

## INTRODUCTION

Modern power system is a large complex and highly interconnected manmade network. The performance of the power system is measure by security, stability and reliability. Power systems are subjected to different type of faults

(equipment malfunction, lighting, insulation failure, human error.etc.).In an electric power system, a fault is any abnormal electric current. For example, a short circuit is a fault in which current bypasses the normal load. An open-circuit fault occurs if a circuit is interrupted by some failure. Due to fault the voltages and current take extreme values. The fault current if not isolated within a prescribed time period can propagate to the down stream equipment and damage them. So relays and circuit breakers are used to sense the fault and isolate the faulty section. The levels of fault current in many places have often exceeded the withstand capacity of existing power system equipment. 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.

In power system design view, limiting the fault current to a low level can reduce the design capacity of some electrical equipment in the power system. This will lead to the reduction to the investment cost for high capacity circuit breakers and construction of new transmission line. Consequently, from A both technical and economical point of view, fault current limiting

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technology for reducing short circuit current is needed.

Recent researches show that the implementation of FCL can be used to control the short circuit capacity of power system. Thus, a study needs to be carried out to investigate the performance of power system when using FCL in various conditions;

i) Normal condition
ii) Balanced fault condition
iii) Unbalanced fault condition

**OBJECTIVE**

The objectives of this project are as follows

- To review fault current limiting technologies
- To develop a simulation model of SSFCL
- To study the power system performance with and withoutSSFCL in abnormal condition
- To compare the power system performance with and without SSFCL .
- To investigate the voltage sag mitigation of the load voltage using FCL

**TUTICORIN THERMAL POWER STATION**

A coal based thermal power plant converts the chemical energy of the coal into electrical energy. This is achieved by raising the steam in the boilers, expanding it through the turbine and coupling the turbines to the generators which converts mechanical energy into electrical energy.The Tuticorin Thermal Power Station (T.T.P.S) is located in Tuticorin.

It is A 5 X 210 MW power station. One of the largest in India. It is managed by Tamilnadu Electricity Board. It has Quarters for its employees, Camp 1 and camp 2. A thermal power station is a power plant in which the prime mover is steam driven. Water is heated, turns into steam and spins a steam turbine which drives an electrical generator. Almost all coal, nuclear, geothermal, solar thermal electric and waste incineration plants, as well as many natural gas power plants are thermal. Such power stations are most usually constructed on a very large scale and designed for continuous operation.

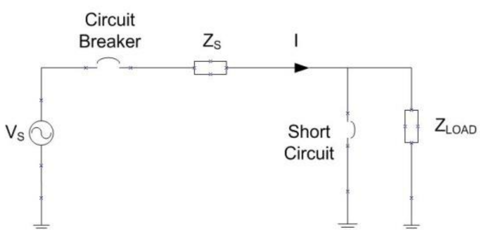
**FAULT CURRENT LIMITER**

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 condition and high impedance under fault condition. On the basis of the above characteristic, various types of FCL’s have been developed. Some of these FCL’s are based on superconductor power electronic switches and tuned circuit impedance.

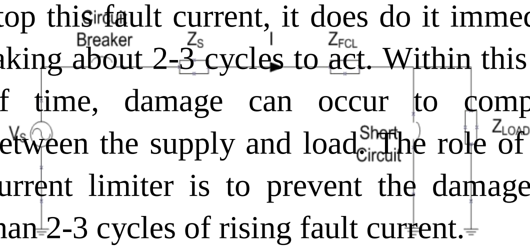
The fault current limiting technology has become hotspot in power system protection research. However, the research is concentrated on the superconducting and power electronic switches types of FCL’s. Over the last four decades, different types of FCL’s have been under the spotlight in power protection research. In recent years, various types of FCL’s have been proposed and developed in many countries. Mainly two types of them are discussed at the most. One is Superconductor Fault Current Limiter (SFCL) and the other one is Solid State Fault Current Limiter (SSFCL). This interest comes not just due to their excellent current limiting characteristics but also due to their positive contribution to the quality of power supply. FCL's can be effective in reducing supply outage and mitigate voltage sag in power network.

**The Role of a Fault Current Limiter**

Consider the power network, shown in Figure 3.1, consisting of a supply voltage $V_S$ , impedance, $Z_S$ and a load $Z_{LOAD}$.




Since the supply impedance, $Z_S$ is much lower than the load impedance, the current during fault are significantly large compared to t h e normal current. Although circuit breaker will eventually stop this fault current, it does do it immediately, taking about 2-3 cycles to act. Within this period of time, damage can occur to components between the supply and load. The role of a fault current limiter is to prevent the damage faster than 2-3 cycles of rising fault current.




The similar power circuit with addition of fault current limiting element with impedance $Z_{FCL}$. To work as a fault current limiter, $Z_{FCL}$ should automatically increase on the occurrence of the fault. Ideally, $Z_{FCL}$ would be equal to zero in the normal (non-fault) state and equal to $Z_{LOAD}$ when a fault occurs. Even if the $Z_{FCL} = Z_S$ during the presence of fault, the fault current will be half that without the FCL in the circuit.

**POWER NETWORK WITH FCL**

**SOLID STATE FAULT CURRENT LIMITER AND MODELLING**

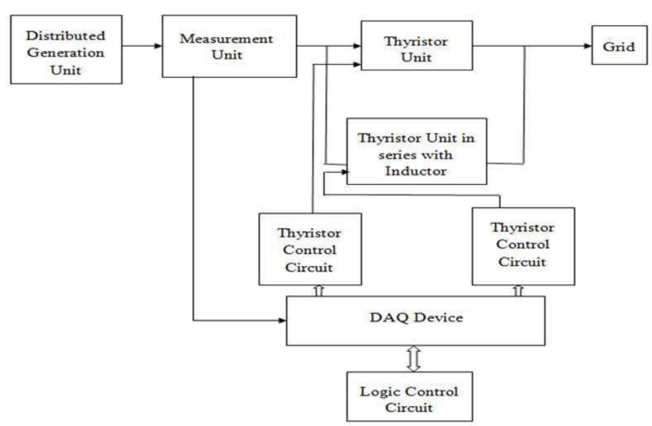
This chapter discusses in detail the concepts of various components used in solid state fault current limiter. It also discusses the modelling of fault current limiter using software simulator (SIMULINK).figure 4.1 shows the block diagram of SSFCL.

Measurement unit

3 phase current and voltage measurement unit is used to measure the currents and voltages.

**Thyristor unit**

basic configuration of the SSFCL consisting of two parallel connected solid state switches. The first branch (Thyristor Branch 1 ) comprises of thyristor switches and the other branch (Thyristor consists 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 surges during switching



During normal condition, the Thyristor Branch 1 is gated continuously and allows the current to flow to the load. When a fault occurs on the load side and if the load current exceeds a certain pre-set level, control circuit is activated and rapidly turns off thyristor switches at Thyristor Branch 1. Immediately after the thyristors are turned off, the current will be diverted into Thyristor Branch 2 through the current limiting reactor.

The surge current level that thyristors need to withstand during fault can be limited by a proper design of a limiting reactor. When the fault is cleared and the line current drops back to its normal value, the thyristor switches from Thyristor Branch 1 will turn back on at an instant.

DAQ device

Data acquisition is the process of sampling signals that measure real world physical conditions and convert the resulting samples into digital numeric values that can be manipulated by a computer. Data Acquisition Systems (abbreviated with the acronym DAS or DAQ) typically converts analog waveforms into digital values for processing. The components of data acquisition systems include

- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

## SOFTWARE SPECIFICATION

MATLAB is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy to use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithms Development
- Modeling, Simulation and Prototyping
- Data analysis, Exploration and Visualization
- Scientific and Engineering Graphics
- Application Development including Graphical user interface building.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows one to solve many technical computing problems, especially does with matrix and vector formulation in a

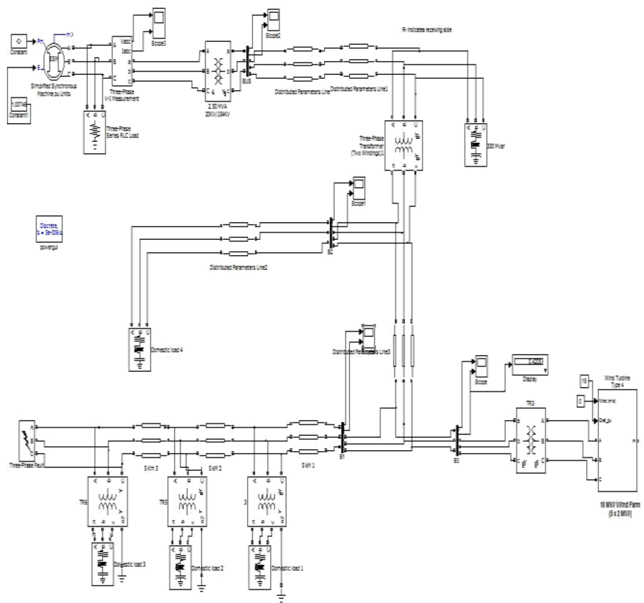
## SSFCL MODELLING

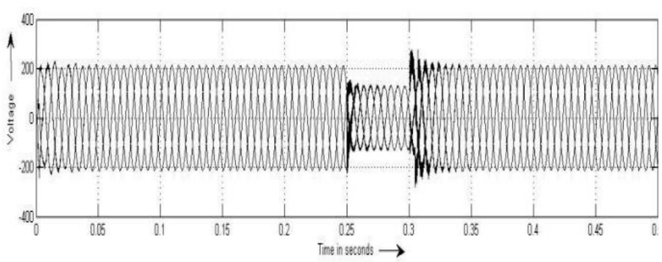
As mentioned in Chapter 1, this study will be based on simulation of SSFCL in the power system. In order to congregate data to be analysed, simulation model of SSFCL needs to be modelled. SSFCL modelling is the vital part throughout this project and needs to be modelled appropriately.

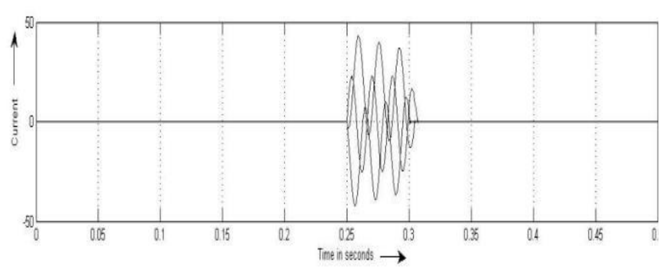
SSFCL used in this project consists of two parallel connected circuit branches with one branch connected to the solid state switches comprising of only two thyristors connected in inversely parallel manner and the other branch, two thyristor connected in inversely parallel but with current limiting impedance (reactor) connected in series with it. The first branch (with thyristors switch only) acts as the main circuit breaker 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 will open the circuit instantly and interrupt the current

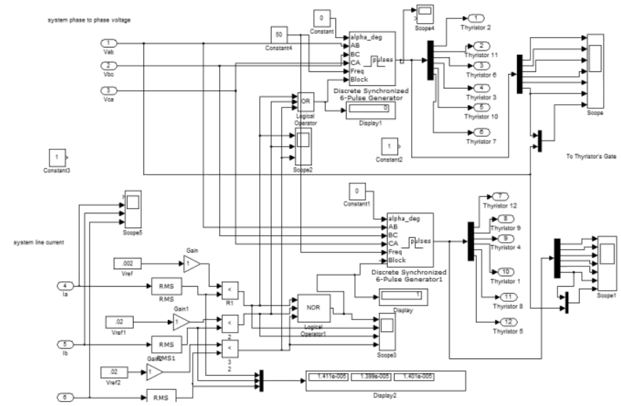
**Simulation Model of SFCL and performance of SSFCL for various faults**



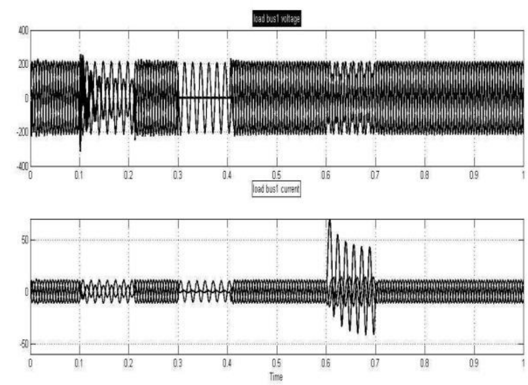



**CONTROL STRATEGY FOR SFCL IN SIMULINK**



**VOLTAGE AND CURRENT WAVEFORMS DURING FAULT CONDITION OF LOAD BUS1WITHOUT SSFCL**




**SYMMETRICAL THREE PHASE FAULT USING- WITHOUT**

| S.NO | BUS | PRE FAULT (AMP) | FAULT (AMP) | POST FAULT (AMP) | BUS BAR VOLTAGE (V) |
|---|---|---|---|---|---|
| 1 | LOAD BUS - 2 | 0.1 | 20 | 20 | 130/200 |
| 2 | LOAD BUS -1 | 10 | 8 | 10 | 175/200 |
| 3 | SOURCE | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | 4300/5000 |
| 4 | WIND | 1 | 0.8 | 1 | 130/200 |

**WITH SSFCL**

| S.NO | BUS | PRE FAULT (AMP) | FAULT (AMP) | POST FAULT (AMP) | BUS BAR VOLTAGE (V) |
|---|---|---|---|---|---|
| 1 | LOAD BUS - 2 | 0.1 | 20,0.1 | 0.1 | 230/200 |
| 2 | LOAD BUS -1 | 10 | 8 | 10 | 200/200 |
| 3 | SOURCE | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | 5000/5000 |
| 4 | WIND | 1 | 0.8 | 1.2 | 200/200 |

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## UNSYMMETRICAL THREE PHASE FAULT USING- WITHOUT SSFCL

| S.NO | BUS | PRE FAULT (AMP) | | | FAULT (AMP) | | | POST FAULT (AMP) | | | BUS BAR VOLTAGE (V) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 ph | 2 ph | 2 ph & G | 1 ph | 2 ph | 2ph & G | 1 ph | 2 ph | 2ph & G | 1 ph | 2 ph | 2ph & G |
| 1 | LOAD BUS - 2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.8 | 2 | 0.1 | 0.1 | 0.3 | 110/ 200 | 0 | 100/ 200 |
| 2 | LOAD BUS -1 | 10 | 10 | 10 | 75, 55 | 2 | 5 | 10 | 10 | 10 | 110/ 200 | 0 | 100/ 200 |
| 3 | SOURCE | $3*10^{3}$ | $3*10^{3}$ | $3*10^{3}$ | $3*10^{3}$ | 4 | $4*10^{3}$ | 0.3 | 0.3 | $3*10^{3}$ | 4300/ 5000 | 3000/ 5000 | 6000 /5000 |
| 4 | WIND | 1 | 1 | 1 | 0.5 | 0.7 | 0.8 | 1 | 1 | 1 | 100/ 200 | 0 | 100/ 200 |

## WITH SSFCL

| S.NO | BUS | PRE FAULT (AMP) | | | FAULT (AMP) | | | POST FAULT (AMP) | | | BUS BAR VOLTAGE (V) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 ph | 2 ph | 2 ph & G | 1 ph | 2 ph | 2ph & G | 1 ph | 2 ph | 2ph & G | 1 ph | 2 ph | 2ph & G |
| 1 | LOAD BUS - 2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 1 | 0.3 | 0.3 | 0.3 | 200 | 200 | 200 |
| 2 | LOAD BUS -1 | 10 | 10 | 10 | 20 | 10 | 10 | 10 | 10 | 10 | 200 | 200 | 200 |
| 3 | SOURCE | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | $3*10^{-3}$ | 5000 | 5000 | 5000 |
| 4 | WIND | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 200 | 200 | 200 |

## CONCLUSION

This project presents the impact of SSFCL to power system performance. The purposes of SSFCL in power system are it works as circuit breaking element as well as limiting fault current. SSFCL is considered as the solution to the increment of short circuit level in power system. It is the cheapest option compared to any others conventional solution to overcome this matter. Despite limiting the fault current, SSFCL offer advantages to the electricity supply industry, technically and economically.

Performance evaluation of the power system is carried out by the simulations using MATLAB Simulation Tool- Simulink. A simulation model of SSFCL as well as its control system for the device has been developed and verified. On the other hand, the simulation model of distribution system has been developed to test its performance when inserting SSFCL during fault conditions.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 fault condition. Simulation results proved that SSFCL effectively limits the current during fault incident.

Faults in the power system will lead to voltage sag at the load bus bar. Voltage sags lead to improper working of the load and this will affect the system reliability and power quality of the power system. The study on the use of SSFCL to protect the bus bar from voltage sags has been analyzed by considering different types of fault. Results show that applying SSFCL can help mitigating the voltage sags at the load bus bar.

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