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A Study on Superconducting FCL

***Mrutyunjay Rout*[1], *Dr. Vijay Behera*[2]**
Student[1], *Professor*[2]
Department of Electrical Engineering
Paladugu Parvathi Devi College of Engineering & Technology
Corresponding Author's Email id: *mrutyunjayrout3@gmail.com*

Abstract

The notion of a superconducting fault current limiter discusses two types of superconducting materials: resistive and inductive. We also look at some of the uses of SFCLs, which are used to restrict fault current in power systems. SFCL is utilised not only to reduce fault current but also to provide a connection to increase the power system's reliability. The superconducting fault current limiter also improves the power and integration of the electric power network.

Keywords*:- FCL (Fault current limiter), Superconducting materials, Electric power network, LTSs, HTSs*

INTRODUCTION

Increased power generation capabilities of power systems has caused diodes to stretch within the fault current level, potentially exceeding the switchgear's highest designed short circuit limits. Circuit breakers, tripped by an over-current protection relay, are one of the typical safety devices installed in power systems to protect against excessive fault current, particularly at facility stations. Several types of fault current limiting devices have been used in recent decades to combat high fault current. High-impedance transformers, current-limiting fuses, and series reactors were utilised. They require an interval delay that allows them to survive 2 to 3 fault current cycles before becoming triggered. However, these options may result in other issues such as loss of power grid stability, high value, and increased power losses, all of which can lead to reduced operational flexibility and reliability.

Superconducting Fault Current Circuits (SFCLs) are cutting-edge electrical instruments that can reduce fault current levels during the primary fault current cycle. Under normal conditions, SFCL has zero ohmic resistance and large ohmic resistance under fault conditions.

Saturated iron care SFCLs, inductive SFCLs, and resistive SFCLs are among the various types of SFCLs used for current restriction. Each type of SFCL has advantages and disadvantages, and may include vaso-constrictive superconductors (LTSs) and warmth superconductors (HTSs). Where inductive-SFCL and resistive-SFCL are commonly designed by HTSs, saturated iron core SFCL uses LTSs.

A warm superconducting fault current circuit (SFCL) could be the solution to reducing the amount of short-circuit current in a fault. SFCLs will make a significant contribution to improving the security and availability of electrical systems in power plants. They even have a significant role to play in improving the facility grid, as consultants do.

Traditional devices for fault current limiting include:

- Fuses are simple and reliable, and they are commonly employed in low and moderate voltage distribution grids.
- Circuit-breakers are commonly used, reliable protecting devices;

- Single-use and thus manual replacement of fuses are the most significant disadvantages. Circuit breakers with high current interrupting capability are expensive and have large size.

- Air-core reactors and transformers with enhanced outflow electrical phenomena increase the electrical resistance of the distribution network and hence minimise short-circuit currents;

- System reconfiguration and bus-splitting

SUPERCONDUCTORS

An element, intermetallic alloy, or combination capable of conducting electricity without resistance below a specified temperature. The first person to see electrical conduction in mercury was Dutch scientist Heike Kamerlingh Ones of metropolis University. The SFCL layout is shown in Figure 1.

Once cooled below a critical temperature, superconductivity is the formation of materials with precisely zero electric resistance. It's the result of quantum mechanics.

Types of Superconductors:

1. Vaso-constrictive Superconductor (LTS)
2. Heat Superconductors (HTS)

LTS are compounds that lose all electric resistance at 4K, a temperature that can only be reached by liquid helium. HTS are compounds that lose all resistance when exposed to liquid nitrogen at 77 degrees Celsius.

Examples of LTS: Lead and Mercury.
Examples of HTS: YBCO, BSCCO, etc.
Non-superconducting FCL

The different varieties FCLs are designed:

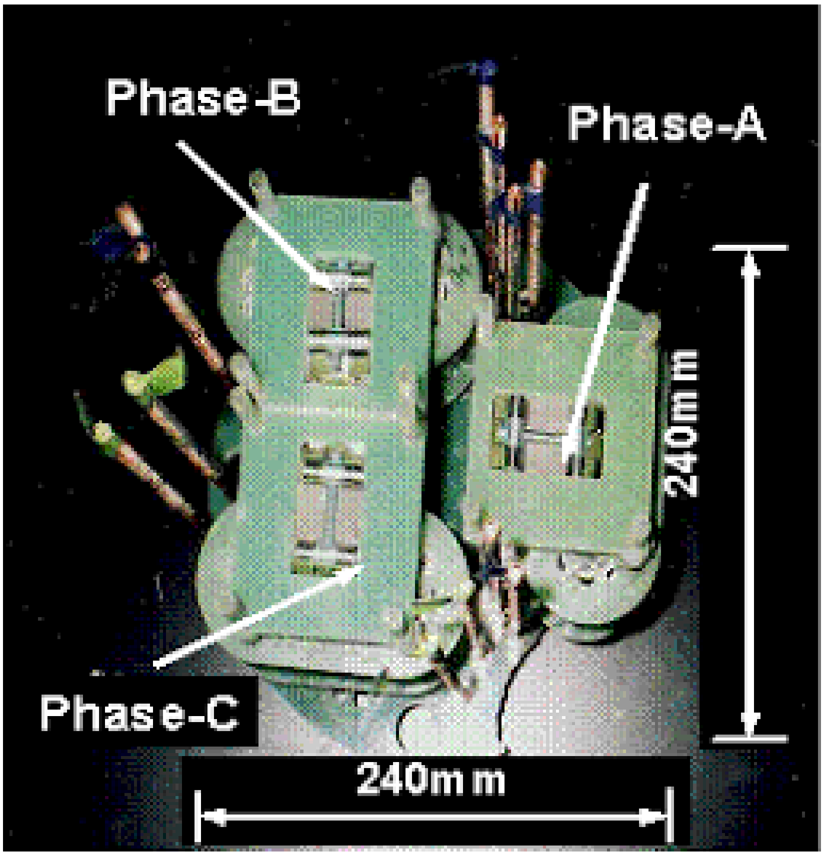

Figure (a)

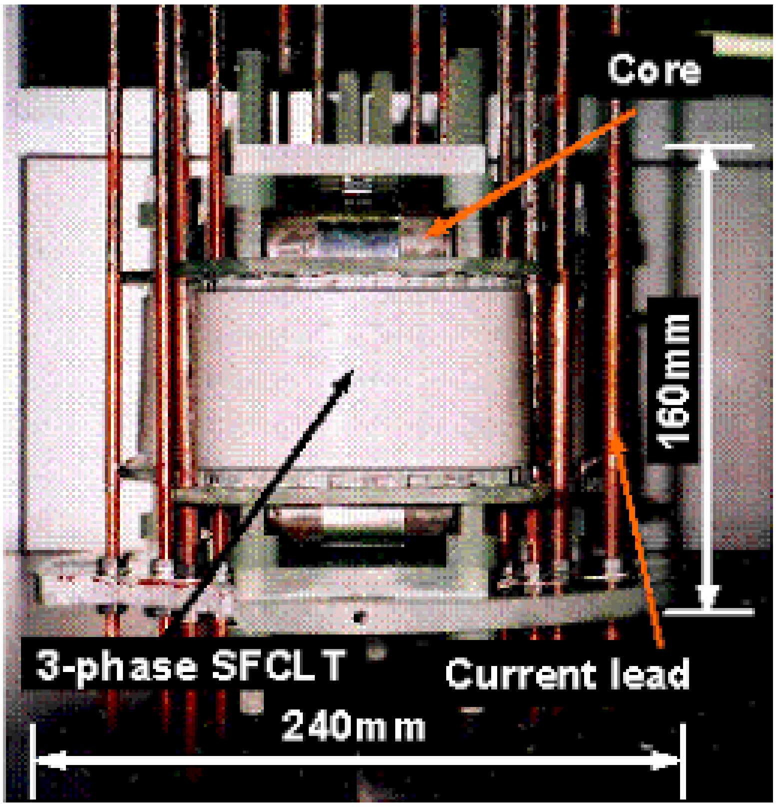

Figure b 1 Arrangement of SFCL

FCLs with a storable core (fig. 1) take advantage of the non-linear properties of magnetic materials to achieve a high inductance. The core is saturated by a bias current in the typical situation, and the coil inductance is minimal. If a fault occurs, the core is de-saturated, the coil achieves a high inductance, and the fault current is limited. The magnetic style [5] is affected by the core form, core bias configuration, and magnetic style.

Solid-state FCLs — to appreciate an FCL, they use high-power semiconductor devices such as SCR, GTO, and IGBT.

The solid-state FCL can be divided into three categories:

The serial variations are the most common. A two-way controlled switch plus a bypass circuit make up an FCL (fig.2). Traditional state bypass, fault current bypass, over voltage protection bypass, and a snubbed are all included in the bypass circuit. The mechanical device switch is sometimes associated with the traditional state bypass. Its goal is to mitigate the traditional state's losses and distortions. The fault current bypass limits the fault current - some techniques close the switches to interrupt the current, while others modulate it to keep it below acceptable limits. The over voltage protection bypass and therefore the snubbed are necessary because they limit the voltage and dv/dt across the semiconductor switch and absorb some of the energy, keeping the line inductance within acceptable limits [5].

The various bridge types FCLs are created using a complete bridge configuration of current-fed diodes and thyristors. The height fault current determines the current rating of diodes/thyristors and, as a result, the limiting reactor. Because the present limiting reactor is on the DC side of the rectifier, the electrical device is exposed to high DC voltage during the fault conditions, which could cause electrical device saturation, causing the current to rise quickly and FCL to lose its present limiting capabilities. Another drawback of those devices could be the loss of crucial physical phenomena during classic state operation.

The resonance varieties FCLs use switches to reconfigure their topologies either into the conventional state or into the fault condition square measure composed. They use series electrical circuit tuned to the road frequency and therefore gift negligible resistance to the road. Beneath the fault conditions the circuit is switched to the fault state sub-topology and far higher resistance is conferred to the road. The resonance FCLs scale back the fault current however they are doing not have interruption capability [5,7].

Fig.2.Superconducting FCL

Because superconducting materials have a highly non-linear behavior they are very useful FCLs to be built. The low temperature superconductors operating at the temperature of liquid helium (4K) as well as high temperature superconductors, called IInd generation (2G) superconductors with critical temperature around the boiling point of nitrogen (77K) have been studied. The two most important 2G superconducting ceramics are used industrially as a coated conductor [3]:

Yittrium-Barium-Copper-Oxide YBa2Cu3O7 (often abbreviated YBCO) and is used for thin film techniques; Bismut-Strontium-Calcium-Copper-Oxide Bi2Sr2Ca nCun-1O2n+4+x, (abbreviated as BSCCO and with trade mark of the compound Bi-2212 / Bi-2223) are used for filament.

There are three major type superconducting fault current limiters (SFCLs):

The resistive type SFCLs is shown in line with the source and load (fig.3). During the normal operation the current is flowing through the superconducting element RSC dissipates low energy. If the current raises above the critical current value the resistance RSC increases rapidly. The dissipated losses heats the superconductor above the critical temperature Tcand the superconductor RSC changes its state – from superconducting into the resistive state, some resistance is generated and fault current is reduced. This phenomenon is called "quench of superconductors". When the fault current has been reduced, the element RSC recovers its superconducting state. The parallel resistance or inductive shunt ZSH is needed to avoid hot spots during quench, to adjust the limiting current and to avoid over-voltages due to the fast current limitations. The resistive SFCLs are much smaller and lighter than the inductive ones. They are vulnerable to excessive heat during the quench state [1, 2, and 4].

The inductive type SFCLs works like transformer with shorted superconducting secondary winding . In normal operation the primary winding resistance and leakage inductance determine the impedance of the limiter. If the fault occurs, the resistance of the secondary winding is the superconductor quenches. The value RSC is transferred into the primary side by the k2= (w1/w2)2 and the FCL impedance increases [1,3]. Despite of the size and the weight this type FCL led to prototypes of higher power rating the resistive FCL [3];

Under normal operation the combined DC current and AC current remains low enough to allow all of the diodes or thyristors to be biased forward and therefore the AC current bypasses the inductance. In these conditions the FCL impedance is low, the total voltage drop and loss are dominated by the power diodes. If a fault occurs and the magnitude of the AC current exceeds the DC bias current two diodes will switch into a blocking mode for each half cycle and insert the inductor into the circuit. The coil impedance will limit the transient current. If thyristors are used instead of the diodes it is possible to turn off the current within the half-cycle. The main disadvantage of bridge type FCL is the relatively high total losses [8,9].

IDEAL FAULT CURRENT LIMITER

An ideal fault current electric circuit should have the following characteristics: - Invisible during normal system operation, i.e., insert zero electrical resistance into the system when there is no problem. When a failure occurs in the system, add a massive electrical resistance.

The primary cycle of the fault current should be operated at regular intervals. It should have a short time recovery, that is, it should return to its normal operation at short intervals after limiting the fault current's value. It should be able to operate and return to its previous state mechanically. Long-lasting and capable of continuous system operation. It should not interfere with relay coordination. It should be small in size and inexpensive.

Traditional devices for fault current limitation use the following area unit: Fuses are simple and dependable, and they are sometimes used in low voltage and moderate voltage distribution grids. The single-use and manual replacement of fuses are the most significant drawbacks.

Circuit breakers are commonly used and are effective protection devices. Circuit breakers with high current interrupting capability are expensive and large in size. They require routine maintenance and have a limited number of operation cycles.

The electrical resistance of the distribution network is increased by air-core reactors and transformers with redoubled outpouring reactance, which limits short-circuit currents. Bus splitting and system reconfiguration.

Fault-current drawbacks

When expanding existing buses, electric power system designers frequently run across fault-current concerns. Higher fault-duty levels result from larger transformers, necessitating the replacement of existing bus work and switchgear not rated for the greater fault duty. Otherwise, the current bus is frequently broken and served by two or more smaller converters.

Another distinction is the employment of a single, massive, high-impedance electrical device, which results in poor voltage regulation for all passengers on the bus. For many years, the classic interchange between fault management, bus capability, and system stiffness has persisted. The compact configuration of transmission lines leads to fault inside the installation.

Other common system modifications that may occur as a result of a fault management issue include:

- In some locations, including as the United States, additional generation from co generators and independent power producers (IPPs) increases the fault obligation across a system.
- As systems grow, older but still usable instrumentation becomes undervalued. Some instrumentation, such as transformers in underground vaults or cables, is frequently prohibitively expensive to replace.
- Customers desire parallel services that improve the reliability of their service, yet the fault duty rises.

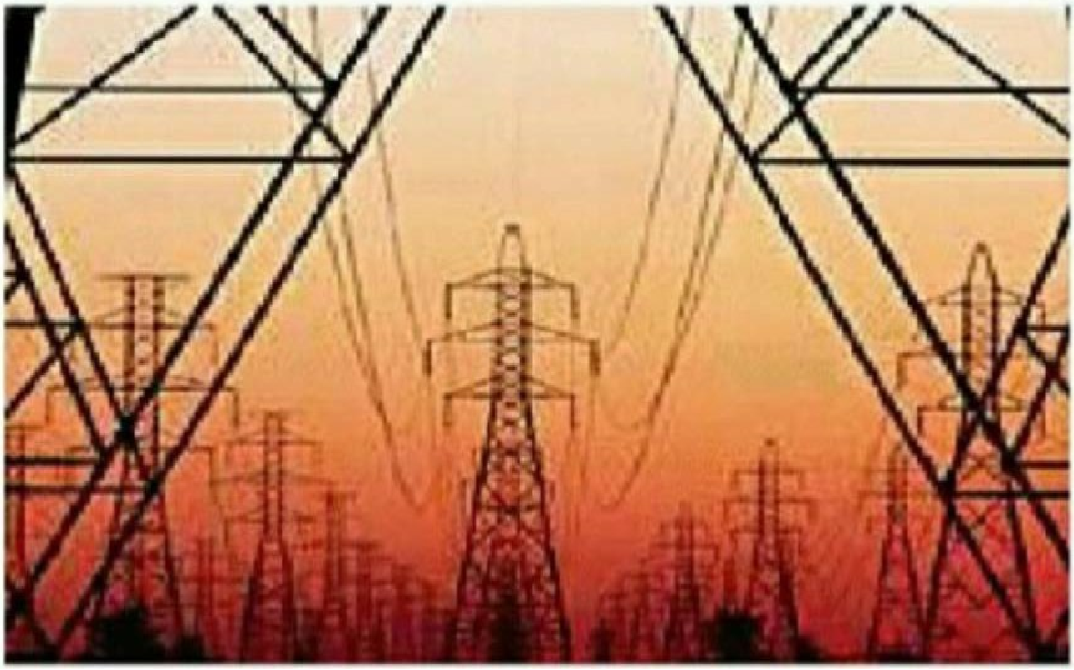

Fig 3 Compact Arrangement of Transmission Lines

NEED OF FCLS

The need for FCLs is being pushed by rising system fault current levels as energy demand rises and more distributed generation and renewable energy sources, such as wind and solar, are added to an already overburdened system. Explosive fault-limiting fuses are now used to control fault current, however they require a trip to switch the fuse when it blows, and they are only available for voltages below 35 kilovolt. Series reactors are utilised, however they have substantial reactive losses, are bulky, and contribute to voltage drops on the grid. FCLs compensate for these flaws. Furthermore, when fault current levels rise, larger and more expensive high electrical resistance transformers become necessary. In contrast to those transformers, FCLs run with extremely little to no electrical resistance during traditional operation, allowing for a more reliable system. The sensible grid relies on FCLs to support technology. The primary goal of incorporating FCL into the distribution system is to reduce fault current. The FCL is a series component with extremely low impedance during normal operation. If a failure occurs, the FCL will raise its impedance, preventing over-current stress, which results in electrical instrumentation damage, degradation, mechanical pressures, and further heating.

The following are the primary requirements for FCLs:

- To be able to withstand distribution and transmission voltages and currents;
- To have low impedance, low voltage drop, and low power loss during normal operation;
- To have large impedance in fault conditions;
- To have a very short time recovery and to limit the fault current before the first peak;
- To properly respond to any fault magnitude and/or phase combinations;

APPLICATION

The FCL applications provide an opportunity to: • avoid instrumentality harm.

- Avoid substituting instrumentalities.
- Use equipment with a lower fault rating.
- Stay away from series reactors, split buses, and bus-tie breakers.
- reduce voltage drops on nearby feeders
- improve the facility's transient stability

BENIFITS OF FCLS TO UTILITIES

FCLs give electricity utilities a variety of advantages. Utilities, for example, spend a lot of money every year to keep up with and protect the grid against potentially harmful fault currents. These huge currents will damage or destroy circuit breakers and other costly T&D system components. By installing FCLs, utilities will reduce or eliminate these re-placement expenses.

Other edges include:

- Increased system safety, stability, and potency of the ability delivery systems are among the other benefits.

- Wide-area blackouts were reduced or eliminated, as were localised disruptions and accumulated recovery time when they did occur.

- Lower maintenance costs by shielding expensive downstream T&D system instrumentation from electrical surges, which deteriorate instrumentation and necessitate costly replacement. Improved system accountability when renewable and decigram energy become more integrated into the electrical grid.

- Split buses and gap bus-tie breakers will be eliminated.

- Voltage dips induced by high-resistive system elements are reduced.

- In the absence of breaker upgrades, a larger electrical device is frequently used to accommodate cumulative demand on a bus.

FAULT-CURRENT LIMITER

There are three types of conventional FCLs: series type, shunt type, and solid-state diodes type.

1. Series sort: the electrical condenser in a tuned LC parallel resonance circuit is shorted to operate this type of FCL.

Large scale, high construction costs, and high running costs are all disadvantages.

2. Shunt type: It works by gapping a bypass switch in parallel with a normally closed electric resistance.

Disadvantages include a shift difficulty and a long latent period.

3. Solid-state diode types: These work by utilising the current conservation law in an extremely bridge. Drawbacks: Only applicable to high-voltage systems.

This leads to the conclusion that no conventional FCL is technically or economically feasible. These issues had been solved thanks to exciting breakthroughs in superconducting technologies. In 1983, the first SFCL was made of cold material. That is made of NbTi fabric with a high current carrying capacity. One disadvantage remains, namely, the high cooling value. HTSFCLs were created to overcome these problems.

HTS is additional appropriate than LTS for SFCL as a result of,

1. It needs less refrigeration value
2. Higher thermal stability
3. Its high traditional specific resistance

To meet the requirements of the ability system, HTS' carrying capacity must be increased. The typical state resistance of SFCL is limited by the substrate used in tandem with the superconductor. As a result, SFCLs are made using exploitation film, which is an uncommon substrate material. There is a 100-fold increase in specific resistance over the superconducting material. This superconducting film sort FCL has smart agent performance, a quick recovery time, and may be able to meet the re-closing requirement more easily than LTSFCL and HTSFCL.

- SFCLs could be a novel power technology that uses the superconducting property to physically limit a fault current to a safe level.
- The resistance of a superconductor drops to zero when it is cooled to a critical temperature (about -186°C). The superconductor, however, loses.
- When an excessive current flows and the bound price is exceeded, electrical conduction and resistance occurs quickly (quench) (critical current). This attribute is used by SFCL devices.
- A superconductor is a substance that can conduct electricity or move electrons without resistance from one atom to another.

By supplying electric resistance to the electrical system that varies depending on operational conditions, superconductors provide the simplest means to break past system style limits. Superconducting fault-current limiters are "invisible" portions of the electrical system that typically work with low electric resistance. The circuit adds electric resistance into the circuit and limits the fault current in the case of a fault. The utility will provide a low-impedance, rigid system with an occasional fault-current level using current limiters.

- I2t electrical device injury is prohibited.

- Fault-current flows are reduced within the high-voltage circuit that supplies the electrical device, reducing the voltage dip on the upstream high-voltage bus during a fault on the medium-voltage bus.

- On the bus, Associate in Nursing FCL is prone to defending individuals. Smaller, less expensive limiters are frequently used to protect previous or over-stressed instrumentation that is difficult to switch, such as underground cables or vault transformers.

- The Associate in Nursing FCL is frequently used as a bus-tie. Such an electric connection would only require a very small low load current rating, yet it would provide the following advantages:

- Separate buses are frequently linked together without an excessive increase in fault obligation on either route.

- An enormous drop across the electric circuit preserves voltage on the unfaulted bus during a fault.

- Low system impedance and clever voltage management result from paralleled transformers; tap-changing transformers are frequently avoided.

- Every bus has excess capability, resulting in increased use of the electrical device rating.

ADVANTAGES OF SFCL

- SFCL is used in the distribution process.
- SFCL reduces the amount of short-circuit current flowing via a defect.
- No need for external management.
- Speedyresponse.
- In traditional operation, SFCLs are undetectable and do not introduce undesired side effects.
- SFCLs are cost-effective when compared to hard-won conventional solutions.
- Minimal loss during typical system operation

DISADVANTAGES OF SFCLS

- Requires cooling, resulting in a price rise.

- One existing problem is that this leads lose energy as they travel from room temperature to refrigerant temperature, resulting in a heat loss of 40-50 W/kA per current lead at freezing temperatures.

- In the presence of thermal instabilities, superconductors tend to (the therefore known as hot spots). A standard conductive bypass is often utilised to protect the materials from these hot spots.

APPLICATIONS OF SFCLS

Applications of SFCL in installation

a) SFCL Limits the fault current.

b) SFCL Secure interconnector to the network

c) It reduces the voltage sag of distribution system.

CONCLUSION

The short-circuit capacity of the fault increases as the number of interconnections in electrical systems grows. As a result, the fault current is limited for a pre-determined time span to allow for problem detection. The application of SFCLs in power systems is to reduce current strains on equipment when faults occur. We briefly covered the many applications of SFCL in the power system in this paper.

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