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SUPERCONDUCTING FAULT CURRENT LIMITER

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ABSTRACT

The superconducting fault current limiter concept explains two types of superconducting materials firstly resistive SFCL, Secondly, Inductive-SFCL. We also study some applications of SFCLs which is used to limit the fault - current that occurs in power system. SFCL is not only used to decrease the fault current but also used to can offer a connection to improve the reliability of the power system. The superconducting fault current limiter also make electric power network more powerful and integrated.

Keywords: *SFCL, Fault current limiter, superconducting FCL*

I. INTRODUCTION

Increase in power generation capability of power systems has diode to extend within the fault current level which may exceed the most designed short circuit ratings of the switchgear. several standard protective devices put in for defense of excessive fault current in power systems, particularly at the facility stations are the circuit breakers, tripped by over-current protection relay. To beat the high fault current, several forms of fault current limiting devices are employed in the last decades. Current-limiting fuses, series reactors, and high-impedance transformers were used. They need the interval delay that permits initial of 2 and 3 fault current cycles to tolerate before obtaining activated. Howe ever, these alternatives could cause alternative problems, like loss of power grid stability, high value and increase in power losses, which can ultimately result in de-creased operational flexibility and lower dependability.

Superconducting Fault Current circuit (SFCLs) is innovative electrical instrumentality that has the aptitude to cut back fault current level at intervals the primary cycle of fault cur-rent. SFCL have zero ohmic resistance below the conventional condition and enormous ohmic resistance below fault condition. There are many forms of SFCLs being employed for current limitation like saturated iron care SFCL, inductive SFCL and resistive SFCL. Every variety of SFCL has its deserves and demerits and may be complete with vaso-constrictivesuperconductors (LTSs) and warmth superconductors (HTSs). Saturated iron core SFCL, uses LTSs wherever inductive-SFCL and resistive-SFCL area unit typically designed by HTSs. A warmth superconducting fault current circuit (SFCL) may be answer to cut back the extent of short-circuits current throughout fault. SFCLs will contribute considerably to increasing the security, availableness of electrical systems in power stations. Consistent with consultants, they even have a crucial role to play in increasing the facility grid.

The traditional devices, used for fault current limitation, are:

- Fuses are easy, reliable and that they area unit typically utilized in low voltage and in middle voltage distribution grids. The most disadvantages area unit the single-use and therefore the manually replacement of the fuses;
- Circuit-breakers are normally used, reliable protecting devices. The circuit-breakers for prime current interrupting capabilities area unit high-priced and have vast dimensions. They need periodical maintenance and have restricted range of operation cycles;
- Air-core reactor and transformers with exaggerated outflow electrical phenomenon increase the electrical resistance of distribution network and consequently limit the short-circuit currents;
- System reconfiguration and bus-splitting.

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II. SUPERCONDUCTORS

An element, inter-metallic alloy or compound that may conduct electricity whiles no resistance below an explicit temperature. The Dutch scientist Heike Kamerlingh Ones of metropolis University was the primary person to watch electrical conduction in mercury. The Fig 1 shows the arrangement of SFCL

Superconductivity could be a development of specifically zero electric resistance sure materials once cooled below a characteristic crucial temperature. It's a quantum mechanical development.

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

LTS area unit the substances that lose all electric resistance on the point of 4K, a temperature getable solely by liquid helium. HTS area unit the substances that lose all resistance below temperature getable solely by liquid nitrogen at 77k.

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

The different varieties FCLs are designed:

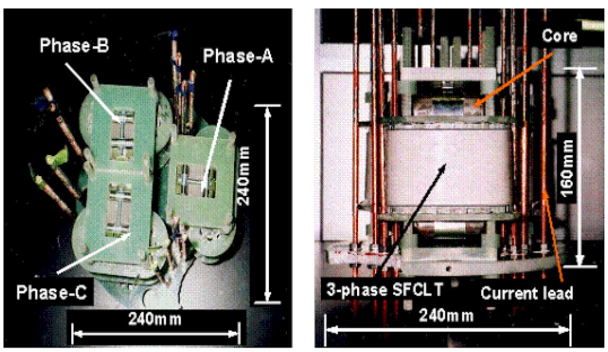

Fig 1 Arrangement of SFCL

Storable core FCLs (fig.1) – they exploit the non-lineal characteristics of magnetism materials to appreciate a high inductance. In traditional case, the core is saturated by a bias current; the coil inductance is negligible. If the fault happens, the core is taken out of saturation, the coil attain a high inductance and limits the fault current. The styles take issue within the core form, core bias arrangement and magnetic style [5].

Solid-state FCLs – they use the high power semiconductor devices - SCR, GTO, and IGBT to appreciate a FCL. The solid-state FCL may be classified into 3 major groups:

The serial varieties FCLs are composed of two-way controlled switch and bypass circuit (fig.2). The bypass circuit contains traditional state bypass, fault current bypass, over voltage protection bypass and a snubbed. The conventional state bypass sometimes is associate mechanical device switch. Its purpose is to cut back the losses and distortion within the traditional state. The fault current bypass restricts the fault current – some schemes close up the switches to interrupt the present, alternative modulate the fault current to stay it inside the suitable limits. The over voltage protection bypass and therefore the snubbed square measure essential, as a result of they limit the voltage and dv/dt across the semiconductor switch and absorb some quantity of the energy, keep within the line inductance [5].

The bridge varieties FCLs square measure realized employing a current-fed diodes/ thyristors full bridge arrangement. The present rating of diodes/ thyristors and therefore the limiting reactor square measure settled by the height fault current. Since the present limiting reactor is on the DC aspect of the rectifier, throughout the fault conditions the electrical device is subject to high DC voltage that might cause electrical device saturation, the present will increase in no time and FCL could lose the present limiting capabilities. Another disadvantage of those devices could be vital physical phenomenon losses in traditional state operation [5].

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]:

Yttrium-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 *Tc*and 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 Z*SH* 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].

III. IDEAL FAULT CURRENT LIMITER

An Ideal fault current electric circuit ought to posses following properties: - Invisible throughout traditional system operation i.e.Insert zero electrical resistance within the system once there's no fault within the system. Insert giant electrical resistance once fault occur within the sys-tem. Operate at intervals the primary cycle of the fault current. It ought to have short time recovery i.e. it comes back to its traditional operation at intervals short interval once limiting the worth of the fault current. It ought to operate and come back back to its traditional state mechanically. Capable of continual system operation and may have long life. It shouldn't have an effect on relay coordination. It ought to be of little size and price effective. The traditional devices, used for fault current limitation, area unit: Fuses are straightforward, reliable and that they are sometimes employed in low voltage and in middle voltage distribution grids. The most disadvantages area unit the single-use and also the manually replacement of the fuses;

Circuit-breakers area unit usually used, reliable protecting de-vices. The circuit- breakers for top current interrupting capabilities area unit costly and have vast dimensions. They need periodical maintenance and have restricted range of operation cycles;

Air-core reactor and transformers with redoubled outpouring reactance increase the electrical resistance of distribution network and consequently limit the short-circuit currents; System reconfiguration and bus-splitting.

Fault-current drawbacks

Electric power system designers usually face fault-current issues once increasing existing buses. Larger transformers end in higher fault-duty levels, forcing the replacement of existing bus work and switchgear not rated for the new fault duty. Orelse, the present bus are often broken and served by 2 or additional smaller transformers. Another different is use of one,large, high-impedance electrical device,leading to degraded voltage regulation for all the purchasers on the bus. The classic exchange between fault management, bus capability, and system stiffness has persisted for many years' shows the com-pact arrangement of transmission lines that leads for fault within the installation.

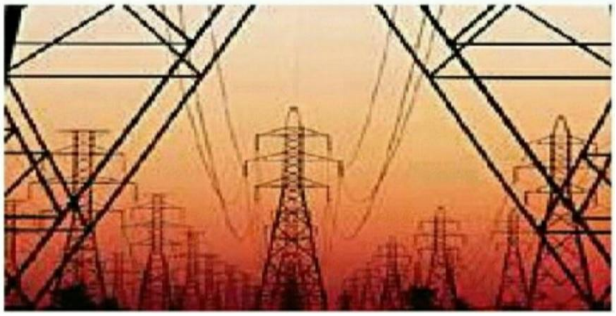

Fig 3 Compact Arrangement of Transmission Lines

Other common system changes may end up during a fault management problem:

- In some areas, like the u. S. further generation from co generators and freelance power producers (IPPs) raises the fault duty throughout a system.
- Older however still operational instrumentation step by step be-comes underrated through system growth some instrumentation, like transformers in underground vaults or cables, are often terribly high-priced to

interchange.

- Customers request parallel services that enhance the reliableness of their provide however rise: the fault duty.

IV. NEED OF FCLS

The need for FCLs is driven by rising system fault current levels as energy demand will increase and additional distributed generation and clean energy sources , like wind and solar, are superimposed to associate already loaded down system. Currently, explosive fault-limiting fuses are utilized to limit fault current, however they need a trip to switch the fuse when it blows and that they square measure solely obtainable for voltages below thirty five kilovolt. Series reactors are used however they need constant high reactive losses, are bulky, and contribute to grid voltage drops. FCLs overcome these weaknesses .in addition, rising fault current levels increase the requirement for larger and infrequently expensive high electrical resistance transformers. However, in distinction to those transformers, FCLs operate with very little to no electrical resistance throughout traditional operation that permits for a additional stable system. FCLs are supporting technology within the sensible grid. The main purpose of the installation of FCL into the distribution system is to suppress the fault current. The FCL is series component that has terribly little impedance throughout a nor-mal operation. If the fault happens the FCL will increase its impedance and then prevents over-current stress which ends up as damaging, degradation, mechanical forces, further heating of electrical instrumentation.

The main requirements to the FCLs are:

- To be able to withstand distribution and transmission voltage and currents;
- To have low impedance, low voltage drop and low power loss at 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;
- To withstand the fault conditions for a sufficient time;
- To have a high temperature rise endurance;
- To have a high reliability and long life;
- To have fully automated operation and fast recovery to normal state after fault removal;
- To have a low cost and low volume. [8]

V. APPLICATION

The FCLs applications afford a chance to [2, 1].

- avoid instrumentality damaging.
- avoid instrumentality replacement.
- use lower fault rated equipment.
- avoid series reactor, split busses, bus-tie breakers.
- cut back voltage dips on adjacent feeders.
- enhance facility transient stability.

VI. BENIFITS OF FCLS TO UTILITIES

FCLs provide varied edges to electrical utilities .for example, utilities pay innumerable bucks annually to keep up and defend the grid from probably destructive fault currents. These massive currents will injury or degrade circuit breakers and alternative expensive T&D system elements. Utilities will scale back or eliminate these re-placement prices by putting in FCLs.

Other edges include:

- increased system safety, stability, and potency of the ability delivery systems.
- Reduced or eliminated wide-area blackouts, reduced localized disruptions, and accumulated recovery time

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once disruptions do occur.

- Reduced maintenance prices by protective expensive downstream T&D system instrumentation from constant electrical surges that degrade instrumentation and need pricey replacement. Improved system responsibility once renewable and decigram are more to the electrical grid.
- Elimination of split buses and gap bus-tie breakers.
- Reduced voltage dips caused by high resistive system elements.
- A bigger electrical device is often wont to meet accumulated demand on a bus while not breaker upgrades.

VII. FAULT-CURRENT LIMITER

Conventional FCLs square measure of 3 sorts: series type, shunt type, and solid-state diodes sort.
1. Series sort: operating of this kind of FCL takes place by shorting the electrical condenser in tuned LC parallel resonance circuit.
Disadvantages: giant size, High cost of capital, High operating expense.
2. Shunt sort: It works by gap a bypass switch, in parallel with associate electric resistance that is generally closed.
Disadvantages: problem in shift, slow latent period.
3. Solid-state diode sorts: Works by exploitation current conservation law in an exceedingly bridge. Disadvantages: Applicable just for high voltage systems.

From this it's conclude that, no standard FCL is technically and economically economical. Exciting developments in superconducting technologies had overcome these problems. 1st SFCL made of cold material, in 1983. That is of fabric NbTi having high current carrying capacity to manufacture .once more it's one disadvantage i.e. high cooling value. To beat these drawbacks HTSFCLs square measure developed.

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

It is necessary to enhance this carrying capacity of HTS to satisfy the ability system necessities. Substrate employed in parallel to superconductor, limits the traditional state resistance of SFCL.Therefore SFCLs square measure created exploitation film square measure unremarkably used substrate materials. There specific resistance is sort of 100times on top of the superconducting material. This superconducting film sort FCL has smart agent performance, short recovery time, and might meet the requirement of re-closer easier than LTSFCL and HTSFCL.

- SFCLs could be a new power device to mechanically limit a fault current to safe level with the superconducting property.
- Once superconductor is cooled right down to vital temperature (about -186°C) or less, the resistance becomes zero. However, superconductor loses.
- Electrical conduction and resistance happens quickly (quench), once excessive current flows and exceeds bound price (critical current). SFCL device uses this property.
- A superconductor could be a material that may conduct electricity or transport electrons from one atom to another with no resistance

Superconductors supply the simplest way to interrupt through system style constraints by presenting electric resistance to the electrical system that varies reckoning on operational conditions. Superconducting fault-current limiters ordinarily operate with low electric resistance and square measure "invisible" parts within the electrical system .within the event of a fault, the circuit inserts electric resistance into the circuit and limits the fault current. With current limiters, the utility will give a low-impedance, stiff system with an occasional fault-current level.

- I2t injury to the electrical device is proscribed.
- Reduced fault-current flows within the high-voltage circuit that feeds the electrical device, that minimizes the volt-age dip on the upstream high-voltage bus throughout a fault on the medium-voltage bus.
- Associate in Nursing FCL may be wont to defend individual masses on the bus. The selective application

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of tiny and fewer expensive limiters are often wont to defend previous or over-stressed instrumentation that's troublesome to switch, like underground cables or transformers in vaults.

- Associate in Nursing FCL is often employed in the bus-tie position. Such a electric circuit would need solely a tiny low load current rating however would deliver the subsequent benefits:
- Separate buses are often tied along while not an oversized increase within the fault duty on either bus.
- Throughout a fault, an oversized drop across the electric circuit maintains voltage level on the unfaulted bus.
- The paralleled transformers lead to low system impedance and smart voltage regulation; tap-changing transformers are often avoided.
- Excess capability of every bus is out there to each buses, therefore creating higher use of the electrical device rating.

VIII. ADVANTAGES OF SFCL

- SFCL is applied with the distribution generation
- SFCL scale back the extent of short-circuit current throughout a fault.
- No external managements required.
- Speedyresponse.
- SFCLs square measure invisible in traditional operation and don't intro-duce unwanted aspect effects.
- SFCLs square measure economically competitive with dearly-won conventional solutions.
- Negligible loss throughout traditional system operation.

IX. DISADVANTAGES OF SFCLS

- Needs cooling that end in increase in its price.
- One current disadvantage is that there's energy loss caused by this leads passing from space temperature to refrigerant temperature which will end in a loss of roughly 40-50 W/kA heat loss per current lead at cold temperature.
- Superconductors tend to the event of thermal in-stabilities (the therefore known as hot spots). So as to safeguard the materials against these hot spots typically a traditional conducting bypass is used.

X. APPLICATIONS OF SFCLS

Applications of SFCL in installation
1) SFCL Limits the fault current.
2) SFCL Secure interconnector to the network
3) It reduces the voltage sag of distribution system.

XI. CONCLUSION

Due to the growth of interconnections in electrical systems the short-circuit capacity of the fault increases. Due to which the fault current is limited for a pre-defined time interval to enable fault-identification.The SFCLs application in power systems is used for reduction the current stresses on the equipment during faults occurs. In this paper we briefly discussed about the various application of SFCL in the power system.

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