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BEHAVIOUR OF SUPERCONDUCTING FAULT CURRENT LIMITER UNDER FAULT CONDITION

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ABSTRACT
Now a days due to increase in electricity demand for the purpose of industrialization, agriculture, domestic and educational etc there exists more chances of fault occurance. The Faults occurs due to insulation damaging, breaking of conductor, short circuit, lightning etc. Till now we used various mechanical devices for protection purpose of a transmission line against fault like a relay, circuit breakers etc. But it is impossible to reduce the magnitude of fault current totally. So in addition to circuit breaker another electrical device is connected in series in a network called as superconducting fault current limiter i.e SFCL. The elimination of the fault current completely is not possible, but we can minimize the fault current in large amount by using SFCL.

INTRODUCTION
When there is occurrence of an accidental events like lightning, conductor breaking, insulation damaging or downed power lines in a power system, a large amount of power flows through the grid which results in a failure of the electric supply. That's why protection of the system is an important. For that point of view SFCL i.e superconducting fault cuurent limiter is implemented in transmission system. SFCL is an electrical equipment which has capability to minimize the fault current level, also reduce the stress of energy and mechanical energy loss on circuit breaker. [1] The best and usable method to reduce the fault current by reducing the investment of circuit breaker (CB) of high capacity and also of high cost, is the use of superconducting fault current limiter (SFCL). There exists various kinds of superconducting fault current limiters for limiting excessive fault current. [2]
The use of superconducting fault current limiters (SFCL) in power system provides an effective technique to minimize the fault current. This SFCL is made of thin film of Yttrium Barium Copper Oxide (YBCO) which is of low cost. The metal organic deposition (MOD) method has been used for making SFCL. The (MOD) i.e metal organic deposition method can generate large Yttrium barium copper oxide (YBCO) thin film having with peak current density without technique of evaporation method [3].
Basically there are three types of SFCL

- Resistive superconducting fault current limiter
- Inductive superconducting fault current limiter and
- Bridge type superconducting fault current limiter

Some Bridge type limiter concepts have been developed too, but will not be include here.

Given Fig.1 shows an arrangement of resistive superconducting fault current limiter (SFCL). When current exceeds its certain limit then superconductor losses it's superconductivity and becomes normal conducting with infinite resistance. This resistive superconducting fault current limiter has capability to absorb most of energy of fault current and then keep it within a limit.

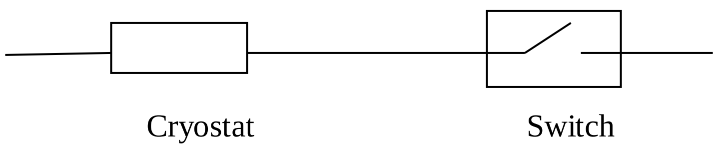

Figure 1. Equivalent arrangement of Resistive Superconducting Fault Current Limiter.

Figure 2 shows the simplified electrical view of an inductive superconducting fault current limiter. This SFCL is like as a transformer having two windings. The primary coil has several winding tuns and is normal conducting. While the secondary coil has only one turn and it is superconducting winding.

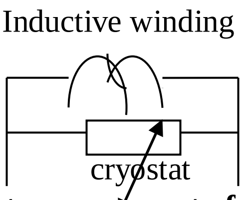

Fig. 2 Equivalent arrangement of Inductive Superconducting Fault Current Limiter.

When fault occurs in a system the current value reached to its peak value at the same time this maximum fault current induces in secondary winding, thus secondary winding loose it's conductivity and become resistive. This large resistance reduce the value of fault current level. [4]

SUPERCONDUCTING FAULT CURRENT LIMITER BEHAVIUOR IN HVDC SYSTEM

To study the effect of SFCL under fault condition the simple HVDC transmission line model as shown in given figure 3.

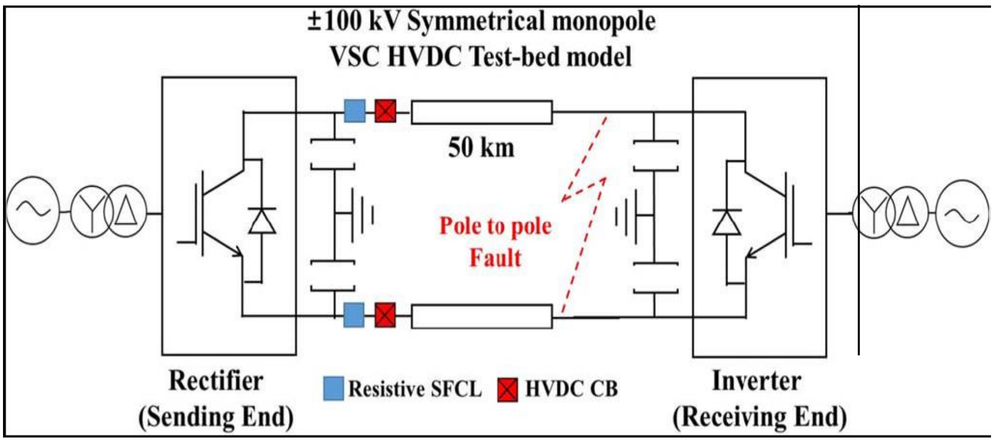

Fig.3 HVDC transmission model for pole to ground fault

The specifications of the HVDC line are given as, the rated voltage is ±100 kV, nominal current of 1 kA, nominal power flow is 100 MW and the transmission line length of 50 km. When single line to ground fault is occurred on a HVDC transmission line at receiving end initially circuit breaker trip. The circuit breaker will tries to interrupt the fault current, at a same time transient recovery voltage appear across the contacts of circuit breaker. Due to this circuit breaker may fails to interrupt the fault current. For such a purpose SFCL means superconducting fault current limiter is connected in series with circuit breaker. When fault current attains it's peak value, SFCL loose it's superconductivity and it's resistance becomes very large. This infinite resistance lowers the magnitude of fault current and keep it within limit. Thus the remaining system remains healthy.

The resistive system has capacity to consume the fault current energy and thus improves the stability of power system as well as reliability also.

By considering the theoretical concepts for resistive superconducting fault current limiter (SFCL) , the arc quenching phenomenon of superconducting fault current limiter can be expressed as:

$$R_{SFCL}(t) = \begin{cases} 0 & (t < t_{quenching}) \\ R_m \left(1 - \exp(-t/T_{sc})\right) & (t_{quenching} < t) \end{cases} \quad \ldots(1)$$

Where Rm is maximum quenching resistance and Tsc is time constant for quenching state transition. In this system HVDC system is of 100 KV, with a 2 kA of critical current. The maximum quenching resistance, Rm, is 10 Ω, maximum power of 100 MW.

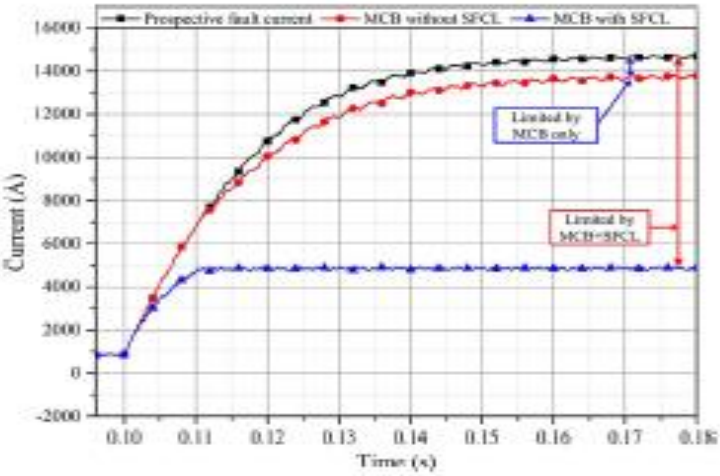

Fig.5.Interruption characteristics of HVDC system by applying SFCL

Above figure shows fault current interruption of HVDC (High voltage direct current) system with SFCL and without SFCL. In this system the prospective or maximum fault cuttent (I_{total}) was measured as 14.5 KA without SFCL, and by using MCB (Mechanical DC circuit breaker) the value of fault current is reduced by small amount i.e 13.9 KA. When SFCL is used this fault current minimize greatly, now it is of value 5 KA. This shows that there is 83% reduction in fault current by using SFCL.[5]

ANALYSIS OF ENERGY DISSIPATION

From above graph energy dissipated in HVDC circuit breaker is shown.. This dissipated energy cause thermal energy loss,this dissipated energy can be calculated by using given equation number (2). This equation consider system voltage across circuit breaker contacts and total current through the system.

$$E_{dissipated} = \int_{t.fault}^{t.interruption} P\,dt = \int_{t.fault}^{t.interruption} V_{cb} \cdot I\,dt \qquad \ldots\ldots(2)$$

where Vcb, is voltage HVDC circuit breaker during fault interruption. [6]

CONCLUSION

This paper shows the effect of SFCL (Superconducting Fault Current Limiter) on HVDC transmission system under fault condition. With the application of Superconducting Fault Current Limiter (SFCL) there exists much reduction in magnitude of fault current, also the total mechanical energy stress on circuit breaker. This will extend the capacity as well as life of circuit breaker and power system stability improved too.

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