Impact of Superconducting Fault Current Limiter on Passive Resonance Circuit Breaker (PRCB) in HVDC System

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Abstract:- For several decades HVDC technology was used primarily for point-to-point bulk power transmission. Although multi-terminal HVDC systems are very few in number, it is expected that multiple HVDC links may be interconnected into HVDC transmission grid. Since every meshed grid requires reliable protection solution, an HVDC circuit breaker must be developed and introduced. When sudden short circuit fault is happened on transmission line, it will cause sudden increase in current magnitude. Various electrical devices used for protection of such a transmission line against serious fault current. Circuit breakers, current limiting reactor are used to protect the system from fault current, superconducting fault current limiter is one of them. This paper focuses on the performance evaluation of Passive Resonance HVDC circuit breaker concepts. The performance evaluation study is carried out by means of MATLAB simulations. The obtained quantitative results describe capabilities and limitations of Passive Resonance circuit breaker concepts as well as the reaction of HVDC network on switching operations. Different converter protection measures and in particular application of fault current limiter were considered, too. In this paper comparative results of Passive Resonance circuit breaker without and with superconducting fault current limiter (SFCL) are observed. For simulation two cases of PRCB are considered, PRCB without using SFCL and PRCB with using SFCL.

Keywords: HVDC circuit breaker, Fault protection methods, Network response, Simulation-based performance evaluation.

Introduction:

As we see most of the time fault current interruption is easily achieved by AC circuit breakers or by using fault current limiter. For AC circuit breakers it easily possible to limit that fault current level by natural zero current crossing but this facility is not available in DC circuit breakers. To achieve that zero current by DC circuit breakers a forced commutation should be used, this obtained by making some modifications. Several types of HVDC circuit breakers are available in market like Mechanical Circuit Breaker (MCB), Passive Resonance Circuit Breaker (PRCB), Inverse Current Injection Circuit Breaker (I-CB), and Hybrid Circuit Breaker. But in this paper we only were focusing on Passive Resonance Circuit Breaker (PRCB) to achieve artificial zero current crossing. As an alternative the combining effect of Superconducting Fault current Limiter and HVDC circuit breakers gives much reduction in fault current level, also improves the transmission line performance. SFCL is best solution for transmitting a bulky High Voltage power over a long distance. [1]

Superconducting fault current limiter (SFCL) has capability to limit fault current level within first cycle and not only decrease the stress on HVDC circuit breaker but also improves the transmission line performance. Superconducting fault current limiter has three type's Resistive type, Inductive type and Bridge type SFCL according to material used for construction. In this paper here we used resistive type SFCL with Passive resonance circuit breaker (PRCB). For simulation purpose a test bed model of PRCB with SFCL is used in MATLAB/Simulink [2]

A) HVDC transmission line model :

For analyzing the effect of superconducting fault current limiter on PRCB HVDC circuit breaker a test model of HVDC transmission line is consider. This model is designed in MATLAB/Simulink as shown in Fig.1. The system test bed model is designed with different components of different ratings. Initially three phase AC system is taken of 230 KV, the system voltage is stepped down to 110 kV by transformer. AC voltage then convert to DC by rectifier. At both ends of system converter stations are implemented. The required specifications of this system are transmission line length = 50 km, rated voltage 100 kV, Nominal current is of 1 kA, rated power 100 MW.

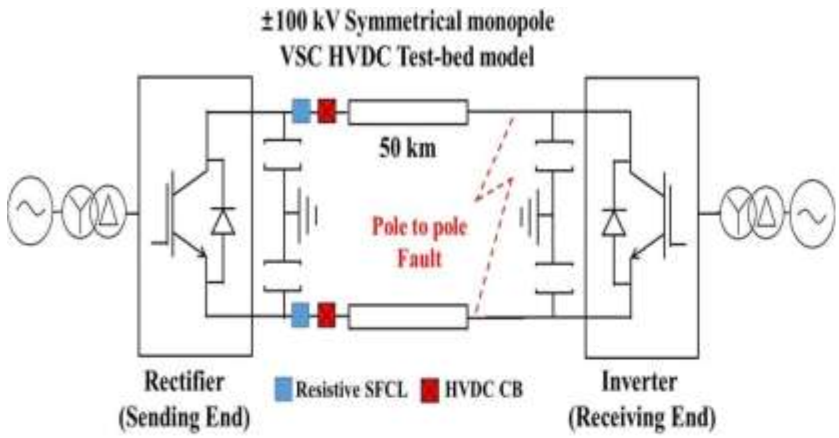

Fig. 1. Two-level point-to-point HVDC test bed model

In this system Passive Resonance circuit breaker (PRCB) is used in series with Resistive Superconducting Fault Current Limiter (SFCL). [3]

B) Passive Resonance circuit breaker (PRCB):

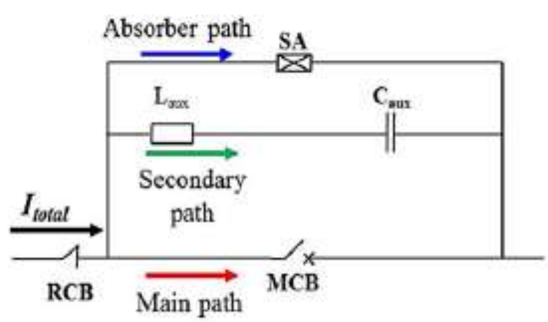

Fig. 2. Passive Resonance Circuit Breaker

A passive resonance HVDC circuit breaker consists of a mechanical switch and a parallel coupled oscillating circuit composed of capacitor and inductor as shown in Figure 2. To dissipate the energy stress on the MCB, the secondary path with a series L-C circuit is added. When the fault occurred at 0.1 sec, MCB opens with 10 ms of delay considering opening delay. As soon as the mechanical switch starts to open its contacts, an electric arc arises between them, and resonance occurs in the loop formed by mechanical switch, inductor and capacitor. This phenomenon is possible owing to the electric arc property of displaying negative differential resistance. Resonance developing within the HVDC circuit breaker entails increase in the magnitude of the current oscillating in the L-C circuit. The DC current begins to commutate and resonate in the secondary path after the arc impedance exceeds the L-C impedance. When a DC current of the primary path meets zero crossing, this current being superimposed on the breaking current provides current zero and enables the mechanical switch to quench the arc. An additional parallel surge arrester (SA) circuit is supplemented to prevent voltage stress across the PRCB during arc extinction. This current being superimposed on the breaking current provides current zero and enables the mechanical switch to quench the arc. [4]

C) Simulation results of PRCB without SFCL:

Following fig. 3 shows main current characteristics of PRCB without applying SFCL and its value is 24 kA. The fault current interruption time of PRCB in this case is approximate 55 ms.

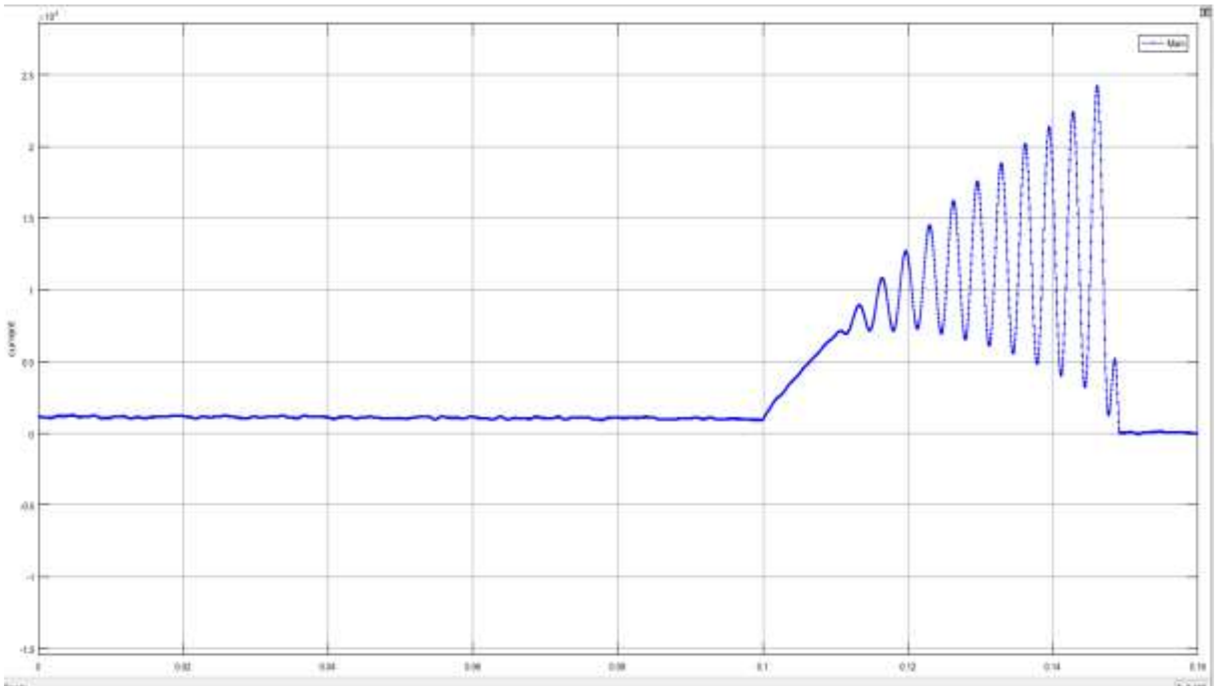

Fig.3. Main current of PRCB without SFCL

Fig. 4 shows secondary path current of PRCB without SFCL and its value is of 11 kA.

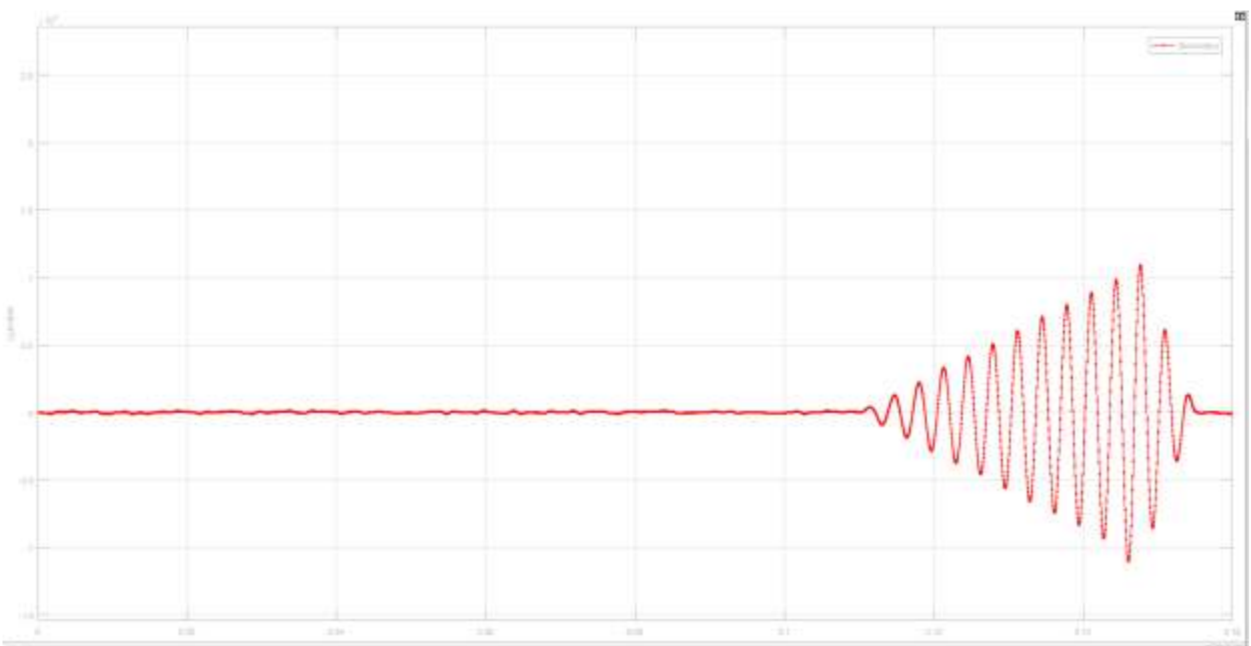

Fig. 4 Secondary path current of PRCB without SFCL

Absorber path current of PRCB without SFCL is 17.5 kA as shown below. This is current thorough surge arrester. This SA is used for protection of whole system from high voltage.

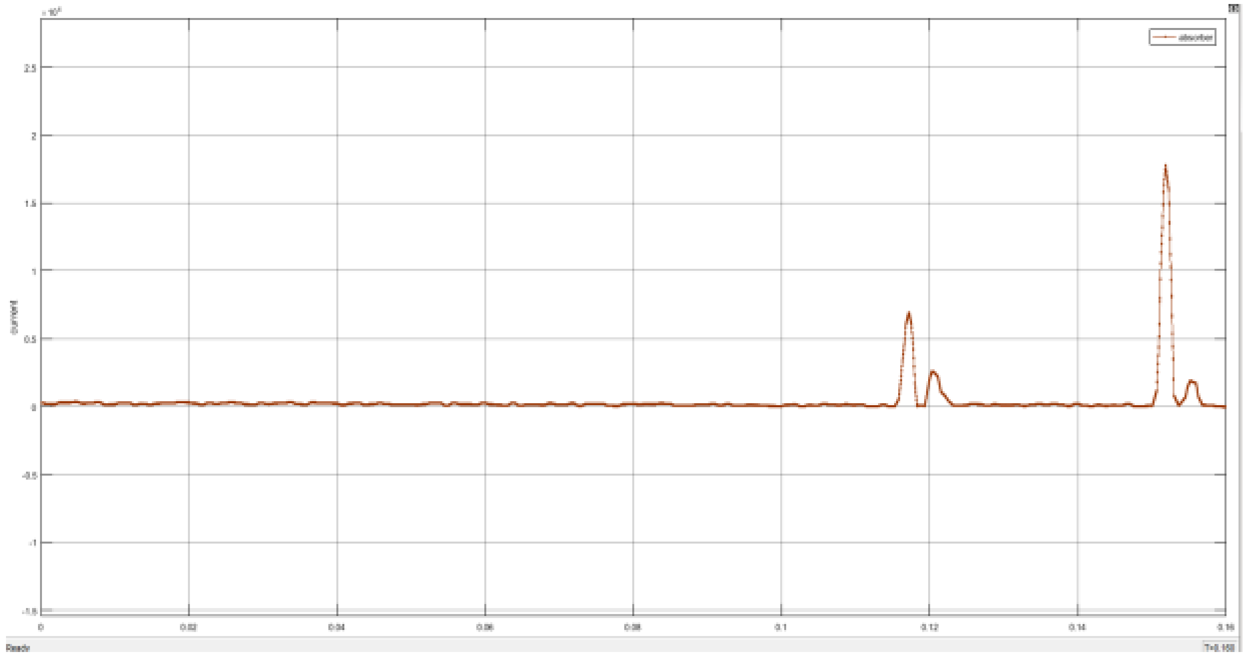

Fig.5 Absorber path current of PRCB without SFCL

Now our intension is to find PRCB characteristics when SFCL is applied in this system. Here we observed much difference in value of currents.

Given fig.6 shows main current of PRCB. The main current value is about 7.2 kA. Fault current interruption time is 25 ms and achieves nearly 62.1 % reduction in fault current level.

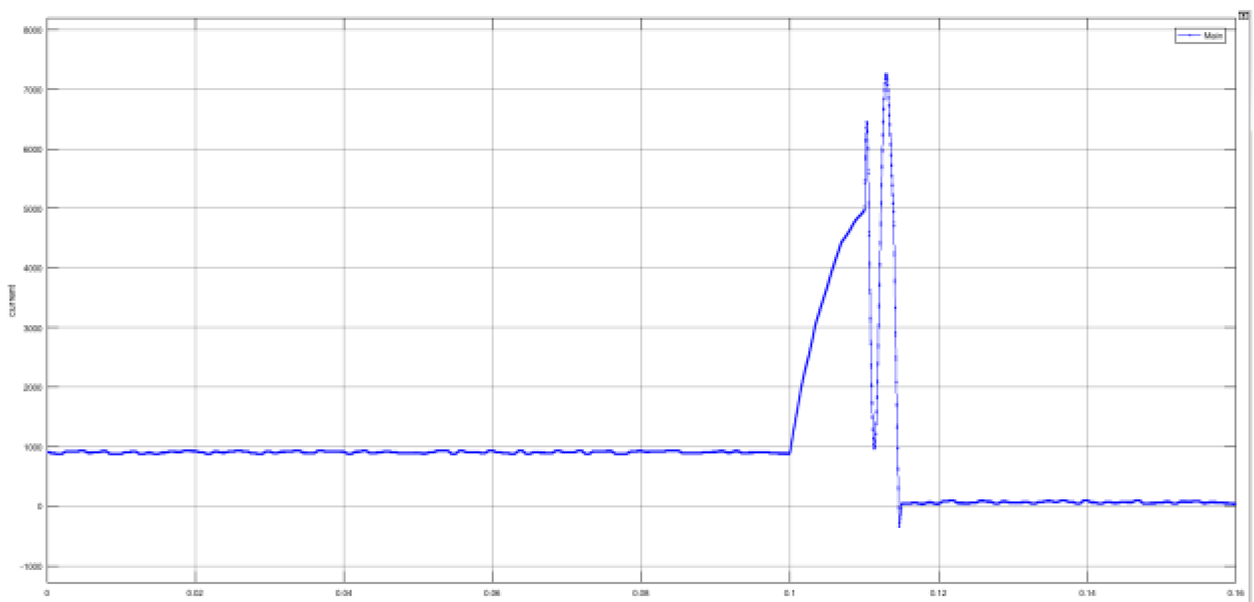

Fig. 6 Main current of PRCB with SFCL

The secondary path current is the current through inductor and capacitor series branch. In this with SFCL case the value of secondary path current is 4 kA.

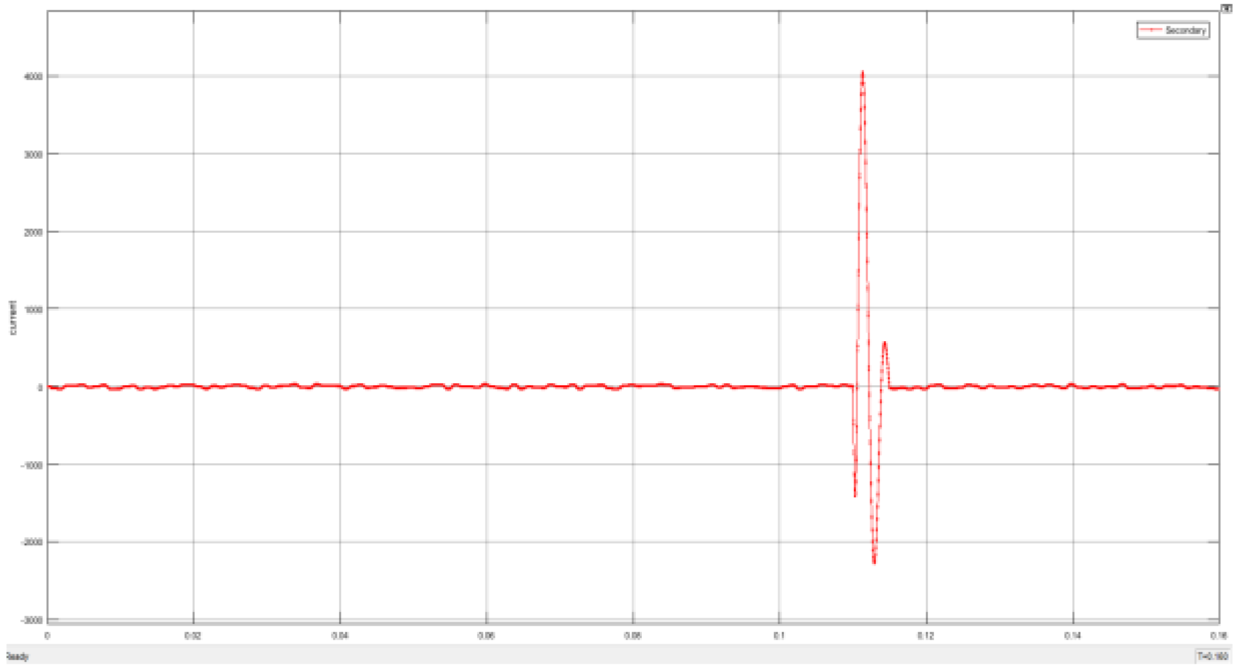

Fig. 7 Secondary path current of PRCB with SFCL

Given fig. 8 shows absorber path current of PRCB when SFCL is used in HVDC transmission system. The value of these current is 6.9 approximate 7 kA.

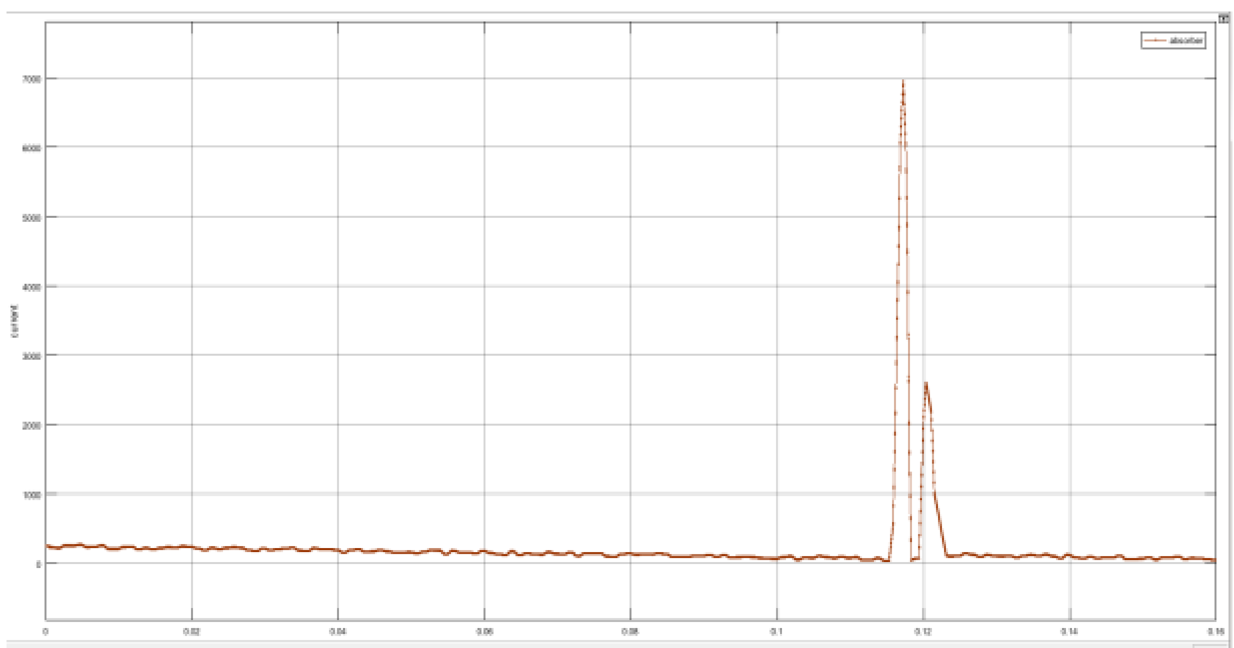

Fig. 8 Absorber path current of PRCB with SFCL

Where the main current is current through main path, secondary path means current through inductor and capacitor components while absorber current is the current through surge srrester path [5]

Table I: Current values of PRCB without and with SFCL

Parameters	PRCB without SFCL	PRCB with SFCL
Main current	24 kA	7.2 kA
Secondary current	11 kA	4 kA
Absorber current	17.5 kA	6.9 kA

Conclusion:

Every time it is not possible to limit maximum value fault current by using circuit breaker only. For that purpose in addition to HVDC circuit breaker a superconducting fault current limiter is applied and results are observed in this paper. The noticeable improvements are observed in case of PRCB with using SFCL, without SFCL the maximum fault current interruption was achieved, also the fault current values are more. When SFCL was applied, The L/R time constant of secondary path was decreased, and therefore fast interruption with less oscillations are observed.

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