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Effect of Using Dc Reactor Type Fault Current Limiter on Circuit Breaker Operation

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Abstract: This paper presents a study of Transient Recovery Voltage (TRV) of a Circuit Breaker (CB) connected to transmission line with presence of Fault Current Limiter (FCL). This study describes a method for reduction of the rating required for circuit breakers by using DC reactor type fault current limiter. Limiter connects in series with circuit breaker and has no effect in normal operation of system. Simulation results are obtained using EMTP software to verify the valuable operation of proposed fault current limiter circuit. The results are used for comparison of TRV and RRRV of circuit breaker and fault current with using and without the proposed limiter.

Key word: Fault Current Limiter, Circuit Breaker, TRV, RRRV.

INTRODUCTION

By growth of interconnections in electrical systems the short circuit capacity increases. This not only affects the reliability of system but also it could result in damaging, degradation, mechanical forces, extra heating and electrical stresses of power apparatus. On the other hand, the increasing demand of electric energy makes these problems more important in future. High power circuit breakers have developed trying to keep pace of the growth of the electric power systems. In this case, large costs are result in not only to produce the high power circuit breakers, but also to upgrade the entire substation buswork. Another way to solve the problem of large fault currents is the use of a fault current limiter to reduce the short-circuit current so that the existing lower-rated circuit breakers can still be used (Faried, *et al*, 2011), (Weiwei *et al*, 2010), (Hongshun *et al*, 2009; E. Calixte *et al*, 2005).

FCL is a novel technology and brings benefits for limiting a high short circuit current in power systems. On the other hand, some papers have so far shown that the FCL will not only limit a fault current, but also gives several effects on the electric power system. The following effects were reported:

(1) Power quality improvement by reduction effect of voltage sags during a short-circuit fault (Hosseini *et al*, 2007), (C.S. Chang *et al*, 2001)
(2) Improvement of power system stability (Shirai *et al*, 2008), (M. Tsuda *et al*, 2001).
(3) Reduction in the peak electrical and mechanical torques of a generator (Sun Shu *et al*, 2008)
(4) Reduction inrush current of transformers (Hagh *et al*, 2007), (abapour *et al*, 2006)
(5) Reliability Enhancement (Haghifam *et al*, 2009)

Because of conventional circuit breakers require several cycles and many milliseconds to open; the large amount of energy flowing into the line and other equipment of power system during this fault can be disturb the line or other equipments of power system. Though such a fast circuit breaker nowadays can protect the equipment against its thermal limit, it cannot avoid the dynamic force from the high current which may cause a permanent fault in the power system when the current at the operation time of circuit breaker reaches the value much higher than the circuit breaker capacity. Based on this system protection concept, we may obtain a smaller SFCL capacity by including the sub-transient and transient phenomena of short circuit current in the analysis (K. Hongesombut *et al*, 2003). In proposed method a fault current limiter combine with a solid-state circuit breaker. This method has been developed to reduce the potential damage of a fault by limiting fault power and energy. An ideal FCL should have zero resistance/impedance at normal operation, no power loss in normal operation and fault cases, large impedance in fault conditions, quick appearance of impedance when fault occurs, fast recovery to normal state after fault removal, reliable current limitation at defined fault current and low cost (M. Yamaguchi *et al*, 1999). Also, the burden on the circuit breaker depends not only on the interrupting current but also on a transient recovery voltage (TRV) and raise of rate of recovery voltage (rrrv) appearing across the contacts of a circuit breaker. Therefore, it is important to evaluate the behavior of the interrupting condition of a circuit breaker in the presence of the fault current limiter.

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The presented limiter consists of a control-less three phase diode-bridge, a single coil and a power source for initial charge of the magnet and compensation of losses in diodes. Also if uses copper coil in DC rector type FCL power source used for compensation of losses in DC reactor resistance.

Power Circuit Topology:

Fig. 1 shows the power circuit topology. The presented circuit is proposed to limiting fault current. The system has no control circuit. DC reactor inductance is shown by L_d. The capacitor FCL simulates a stray capacitance of the fault current limiter to the ground and is set to be 1nF.

In the case of the inductive FCL, a capacitance C_p is connected in parallel with the limiting coil to simulate a stray capacitance appearing in the winding of the coil and a necessary additional capacitor. The capacitance C_p is set to be equal to 10 and 100nF. The reactance of the capacitor C_p is very much higher than that of the inductance L_d. Therefore; the impedance Z_d is equal to the reactance of L_d. By choosing appropriate value for inductor L_d, it is possible to achieve a nearly DC current in DC reactor in normal operation of system and has not significant rule on normal operation of system. The Load is assumed to be an *R-L* load. The utility voltage is a sinusoidal waveform with power frequency 60Hz, and rms value 275kV, and its impedance consists of series connection of resistor r_s, and inductor L_s. A symmetrical three-phase-to-ground short-circuit fault is assumed to occur at a distance 8 km away from the load-side terminals of the fault current limiter. The inductance and the capacitance per unit length of the transmission line are 0.8mH/km and 15nF/km, respectively.

Simulation Results:

A series of simulations were conducted to analyze the performance of FCL effect. Figs. 2,3 show the waveforms of short line fault TRV and line current after short line fault in the absence of DC reactor type FCL.

A. Effect of Using DC Reactor on TRV Without Considering DC Reactor Capacitance:

Fig. 4 shows the variation of maximum TRV versus inductance of DC reactor for three phases without considering reactor capacitance. Considering fig. 4 illustrate that with increasing DC reactor inductance slow decreasing in TRV results.

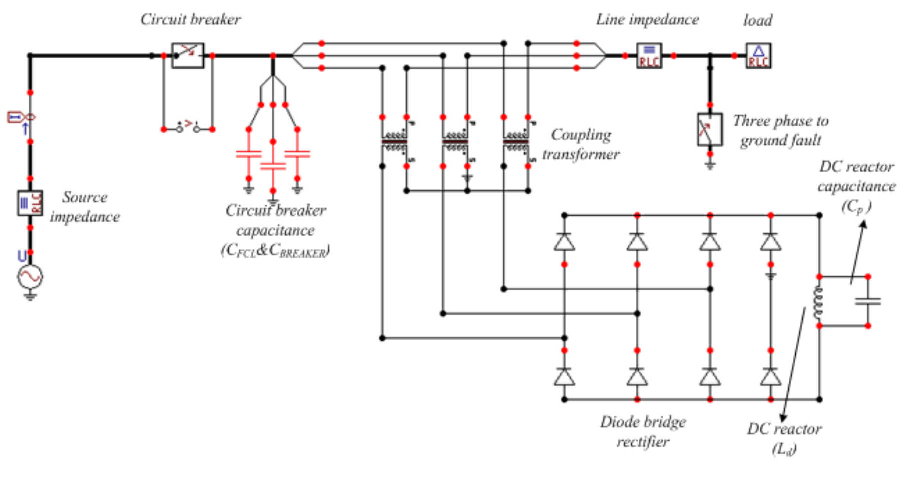

Fig. 1: Power circuit topology.

B. Effect of Using DC Reactor on TRV Considering DC Reactor Capacitance:

Figs. 5,6 show variation of maximum TRV versus inductance of DC reactor for three phases. In these figures DC reactor capacitance are chosen 10 (nF) and (100nF) respectively.

As shown in fig. 5,6 considering DC reactor capacitance results in a few decreasing in maximum TRV. Fig. 7,8 and 9 show the variation of maximum TRV versus inductance of DC reactor in different DC reactor capacitances in phase (A), (B), and (C) respectively. Decreasing in maximum TRV with considering DC reactor type fault current limiter are shown in these figures again.

The insertion of a DC reactor type fault current limiter with C_P=10 and 100nF is shown to reduce the severity of the interrupting duty of the circuit breaker so that a circuit breaker with a lower interrupting performance can be used. In other words, the calculation results show that connecting fault current limiters in series with circuit breakers may enhance the availability of circuit breakers.

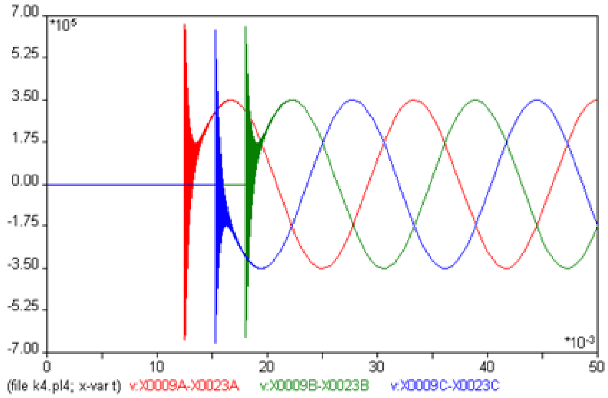

Fig. 2: Waveforms of short line fault TRV in the absence of DC reactor type FCL.

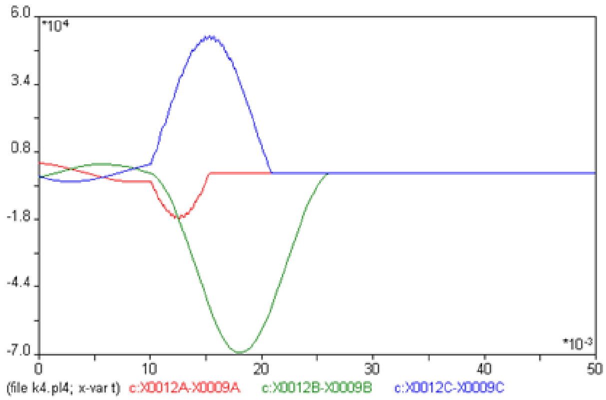

Fig. 3: Waveforms of line current after short line fault in the absence of DC reactor type FCL.

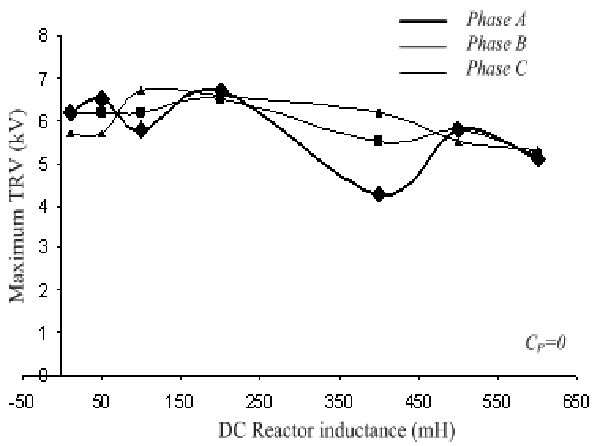

Fig. 4: Variation of maximum TRV vs inductance of DC reactor for three phases.

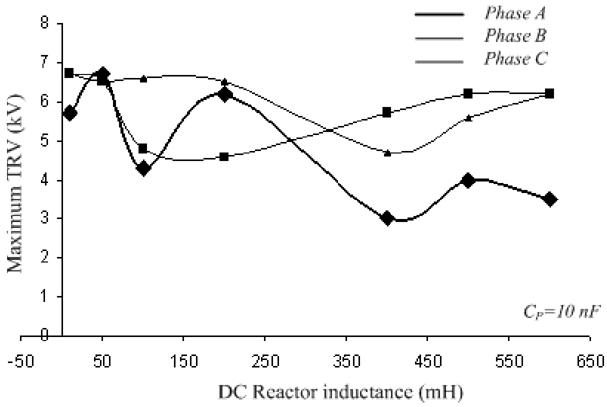

Fig. 5: Variation of maximum TRV vs inductance of DC reactor for three phases (C_P=10 Nf).

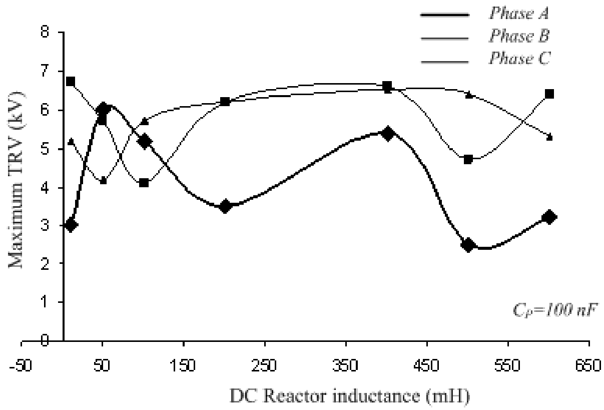

Fig. 6: Variation of maximum TRV vs inductance of DC reactor for three phases (C_P=100 nF).

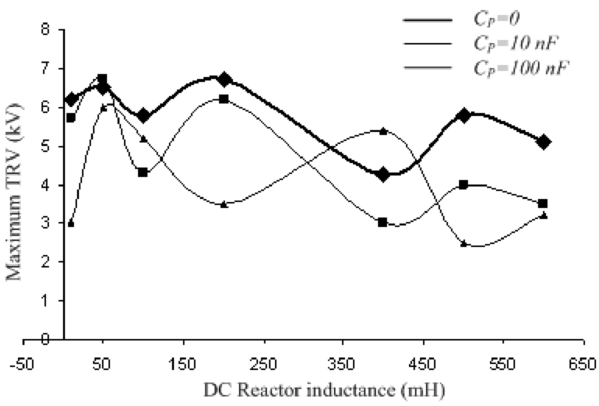

Fig. 7: Variation of maximum TRV vs inductance of DC reactor in different DC reactor capacitances for phase A.

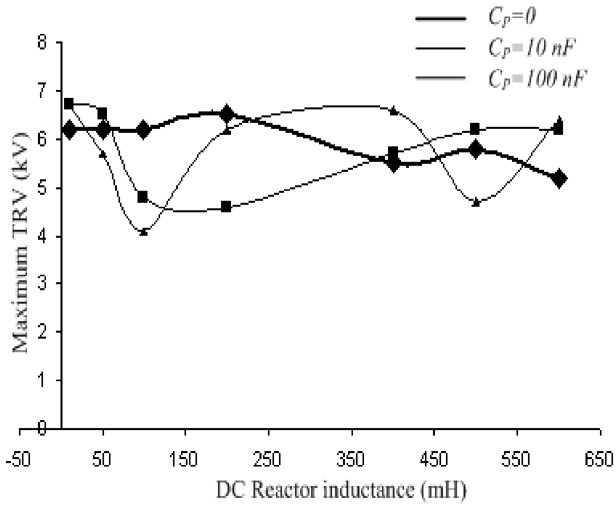

Fig. 8: Variation of maximum TRV vs inductance of DC reactor in different DC reactor capacitances for phase B.

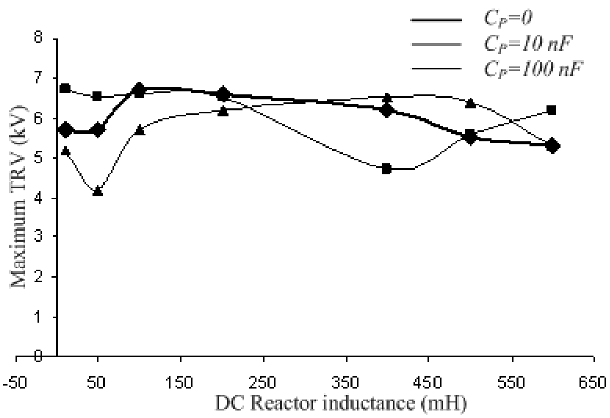

Fig. 9: Variation of maximum TRV vs inductance of DC reactor in different DC reactor capacitances for phase C.

Conclusion:

The investigations in EMTP/ATP environment shows that using fault current limiter not only improves the fault current levels but also eliminates TVR in CB and decreases the RRRV value significantly. TVR phenomena are analyzed for different types of faults in different parameters of FCL. In all the cases FCL eliminates the TVR across a Circuit Breaker. The calculation results show that connecting fault current limiters in series with circuit breakers may enhance the availability of circuit breakers.

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