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New Control Strategy in Series Compensator for Fault Current Limiting Function

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Abstract: In this paper fault current limiting effect of series compensator (SC) and its control strategy for this purpose are presented. In proposed control strategy after fault detection, SC achieves the current limiting function through the magnitude and phase control of its injection current. In this method when fault occur, the control strategy is changed. Hence during fault PCC voltage is perpendicular to fault current. In this state we have not any absorbed power by the SC and therefore the maximum voltage across the terminals of the energy storage capacitor is fixed and it is not rise. The results show that the SC is also effective in improving the supply quality of the power system through fault current limiting in downstream faults. The simulation results are obtained by PSCAD/EMTDC software to verify the effectiveness of the SC and its control strategy for power quality improvement (sag & swell mitigation and harmonic elimination) and fault current limiting.

Key words: Series Compensator, Fault Current Limiter, Voltage Restoration.

INTRODUCTION

Power quality has become more and more important topic in the performance of many industrial applications. One of the major issues in improvement power quality in distribution networks is the mitigation of voltage sages. Power quality studies show that 80% to 90% of the customer's displeasure is due to voltage sags and most of them are due to short circuits in the power system (Bollen, M.H.J, 1994). The series compensators for mitigating the effect of un pleasure voltages (sags, swells and voltage distortions) has become established. Therefore SC is a preferred approach for improving power quality at sensitive load locations. In several papers the effect of SC to maintaining downstream load voltages in the event of upstream faults are investigated (Ghosh, A., et al, 2002), (Godsk Nielsen, J et al, 2004), (Fitzer, C. et al, 2004). But its ability to maintaining supply quality and fault current limiting in the event of downstream faults is less considered. The idea of using SC as a fault current limiter has been investigated in (S. S. Choi et al, 2005), but the most important problem in (S. S. Choi et al, 2005) is voltage rise within the energy storage device.

In this paper for solving this problem a new method is proposed. In proposed method the energy storage device prevented from absorbing the active power and thus the voltage across capacitor bank will be constant and the storage capacitor is protected from damaging when the fault duration is long. It is beyond the scope of this extended summary to speak about control scheme, but it will be presented in detail in full paper.

Analysis of SC Performance:

Schematic diagram of SC is shown in fig. 1. As shown in this figure the proposed control is designed for two functions.

Voltage Restoration:

At first the effect of proposed SC to maintaining downstream load voltages in the event of upstream events are presented. As shown in fig. 1 it is possible to assume series reactance of the injection transformer is negligible and protected load have constant power factor.

As shown in fig. 2 under normal condition we have

$$\vec{V}_L = \vec{V}_S - jX_S\vec{I}_L \tag{1}$$

The phasor diagram of the current and voltage at normal operation is shown in fig. 2(b).

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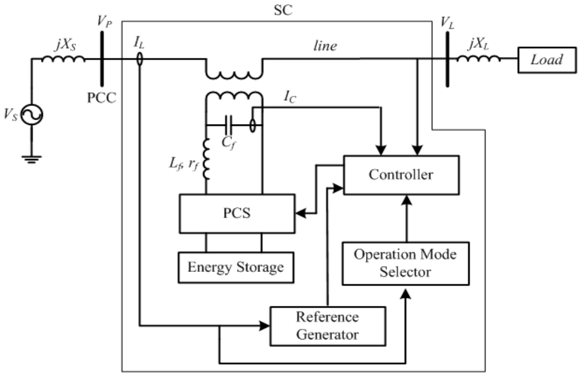

Fig. 1: The schematic diagram of SC with dual function.

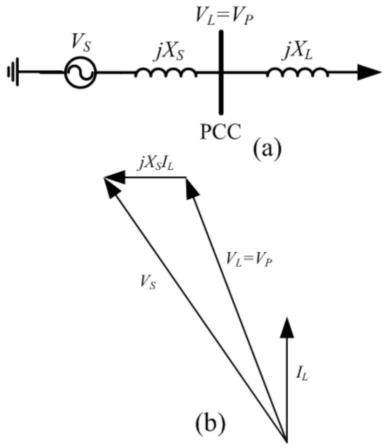

Fig. 2: Equivalent circuit of power system at normal operation and its corresponding phasor diagram.

When fault occur in upstream side the voltage of PCC is decreased. To protect load against this voltage sag, the SC injects a voltage V_{SC} to restore the load-side voltage to its normal condition (V_L). In fig. 3(a) the SC represented by voltage source under this condition, so SC inject V_{SC} in series with system, to know the value of V_{SC} we have

$$\vec{V}_{SC} = \vec{V}_L - \vec{V}_{sag} + jX_S\vec{I}_L \tag{2}$$

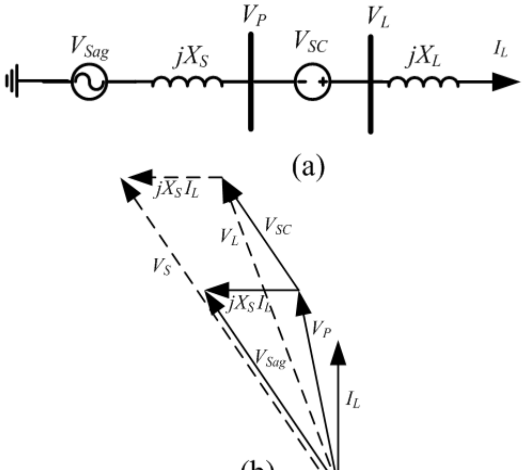

Fig. 3: Equivalent circuit of power system under an upstream fault and its corresponding phasor diagram.

The phasor diagram of the current and voltage at voltage sag is shown in fig. 3(b).

Fig. 4 shows the equivalent circuit and corresponding phasor diagram to protect load against the voltage swell. In fig. 4(a) the SC represented by voltage source under this condition, so SC inject V_{SC} in series with system, to know the value of V_{SC} we have

$$\vec{V}_{SC} = \vec{V}_L - \vec{V}_{swell} + jX_S\vec{I}_L \tag{3}$$

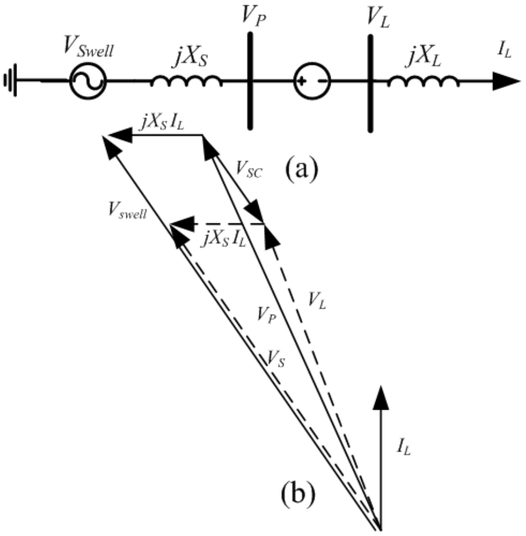

Fig. 4: Equivalent circuit of power system under a voltage swell and its corresponding phasor diagram.

Fault Current Limiting:

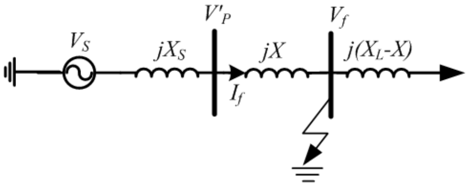

Fig. 5: Equivalent circuit of power system under a downstream fault.

The single-phase equivalent circuit of SC is shown in Fig. 5.

This figure used to clarify the behavior of the fault current limiting function of the SC. The X stand for effective reactance between the PCC and fault location. At downstream fault condition the voltage of *f* (V_f=0) assumed.

The equivalent circuit of proposed method to limit the fault current and its corresponding phasor diagram is shown in fig. 6. In this figure the I_f and V'_{Pf} stand for the fault current and PCC voltage at fault condition.

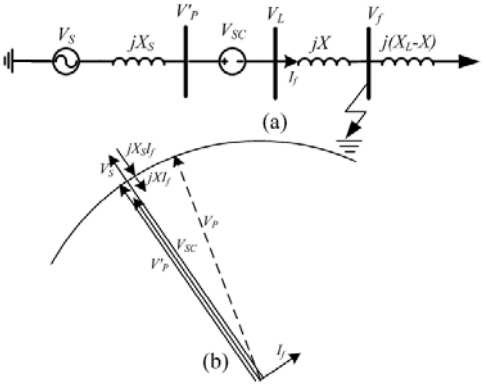

Fig. 6: Downstream fault condition by using SC and corresponding phasor diagram.

As shown in this figure as soon as the fault is detected, the SC controlled the fault current and therefore injected the V_{SC} . Furthermore the PCC voltage magnitude restored back to its value same to before the fault occurrence, but its phase angle has a brief changes as shown in fig. 6. Thus after full restoration of SC and fault current limiting $|V_{pf}| = |V_p|$ and the voltage phasors are perpendicular to fault current. In this situation $|I_f| < |I_L|$. The relationship between fault current and voltages are

$$\vec{V}'_P = \vec{V}_S - jX_S\vec{I}_f \tag{4}$$

$$\vec{V}_{SC} = \vec{V}'_P - jX\vec{I}_f \tag{5}$$

This control strategy is possible by controlling the fault current instead of PCC voltage. In this method as shown in fig. 6 the energy storage device prevented from absorbing the active power and thus the voltage across capacitor bank will be constant and the storage capacitor is protected from damaging when the fault duration is long.

Simulation Results:

The simulation results are obtained by PSCAD/EMTDC software for circuit topology of Fig. 1. The system parameters are

$V_{S(L\text{-}L)}$=308	(V)
Power frequency=50	(Hz)
C_f= 48	(μF)
L_f= 0.2	(mH)
X_S= 30	(Ω)
Coupling transformer turns-ratio=1	

Fig.7 shows the behavior of PCC voltage without SC due to fault applied at t=0.2s. It shows that PCC voltage is significantly reduced during the fault. Fig. 8 shows the behavior of the PCC with SC. It shows the magnitude of PCC voltage has been constant and the phase of PCC voltage a little changed. Fig. 9 and 10 shows the line current without and with using SC under adown stream fault. As shown in these figures with using SC the line current has been fully limited. Fig. 11 shows the energy storage capacitor voltage with using new control strategy. As shown in this figure when fault occur the capacitor voltage in steady state condition has been an approximately constant value and we solved the rise of capacitor voltage that was the main problem at previous papers.

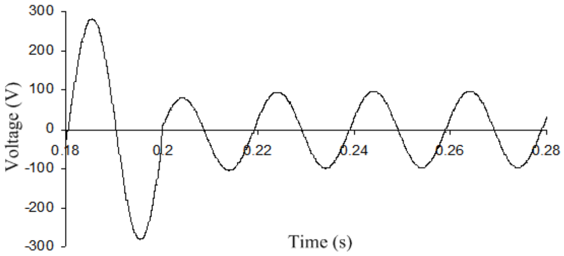

Fig. 7: PCC voltage without SC under a downstream fault.

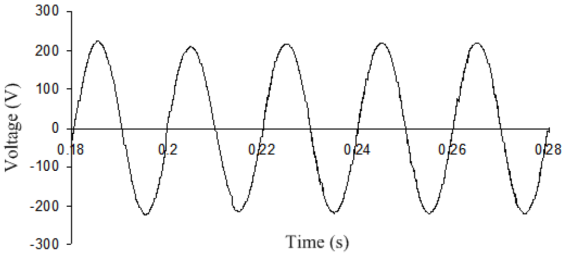

Fig. 8: PCC voltage using SC under a downstream fault.

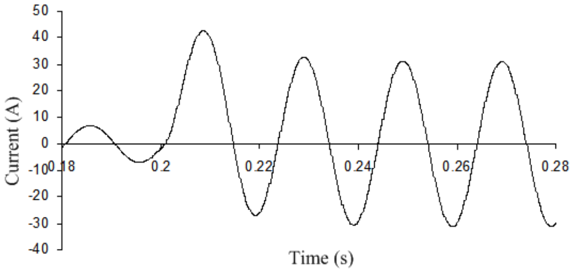

Fig. 9: Line current without SC under a downstream fault.

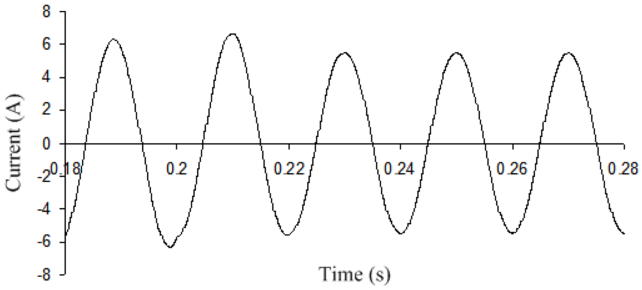

Fig. 10: Line current using SC under a downstream fault.

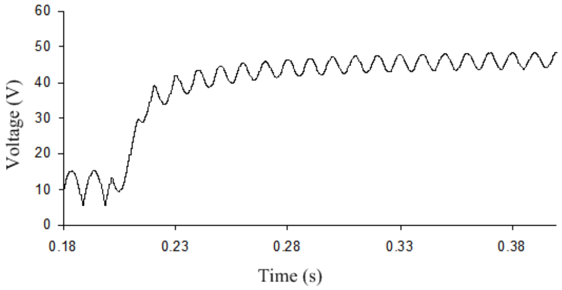

Fig. 11: Energy storage capacitor voltage under a downstream fault.

Conclusion:

In this paper a new control strategy for fault current limiting function of sc is proposed .the consequence is preventing the energy storage device from absorbing active power, therefore under this condition, the problem of capacitor size determination has been solved, so the effectiveness of the proposed series compensator system for FCL, as well as for voltage restoration function has been verified through simulation.

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