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An efficient Approach for Hybrid-STATCOM with Wide Compensation Range and Low DC-Link Voltage

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Abstract: A hybrid-STATCOM in three-phase power system is proposed and discussed as a cost-effective reactive power compensator for medium voltage level application is proposed in this paper. In this paper, the circuit configuration of traditional and capacitive STATCOM are introduced first. The system parameter design for the hybrid STATCOM is then proposed on the basis of consideration of the reactive power compensation range. Because of the low dc-link voltage, the system costs can be reduced considerably. Finally, simulation is carried out in MATLAB to verify the wide compensation range and low dc-link voltage characteristics and the good dynamic performance of the proposed hybrid-STATCOM.

Keywords-Capacitive-coupled static synchronous compensator (C-STATCOM), hybrid-STATCOM, low dc-link voltage, STATCOM, wide compensation range

I. INTRODUCTION

The control of voltage and reactive strength is of paramount importance in energy gadget operation. The massive reactive modern in transmission systems lowers the stability of a power device and increases transmission losses. Reactive strength compensators may be used as one of the solutions for this trouble. While reactive electricity does not offer beneficial works, it's far important for AC transmission and distribution structures and many other sorts of customer loads. Therefore, real electricity structures need each real and reactive electricity to feature well. Increasing var load diminishes the potential of the system to supply real strength and carry out beneficial work. In severe cases, an excessive var load can shift the voltage and current a lot that it reduces the energy systems transport capability in order that nearly no energetic electricity can be brought. There can additionally be different undesirable results which include extended system heating and device losses. Series and shunt Var repayment are employed to improve the natural electric characteristics of ac lectricity structures. Series compensation modifies the transmission or distribution system parameters, even as shunt compensation alters the equivalent impedance of the burden. In both instances, the reactive strength that flows via the gadget can be correctly controlled and thereby enhancing the performance of the ac power system. Static Var Compensators (SVCs) are traditionally used to dynamically compensate reactive currents as the hundreds fluctuate from time to time.

Due to the resonance issues, harmonic current injection, and gradual the reaction of SVCs, static synchronous compensators (STATCOMs) had been evolved for reactive contemporary compensation with quicker response, less harmonic present day injection, and superior overall performance. However, the STATCOMs or APFs commonly require multilevel structures in a medium- or excessive voltage stage transmission system to lessen the excessive-voltage stress throughout each electricity transfer and dc-hyperlink capacitor, which escalates the initial and operational charges of the gadget and additionally increases the control complexity. Later, series-type capacitive coupled STATCOMs (C-STATCOMs) were encouraged to reduce the gadget dc-link operating voltage requirement, however, their device performances can considerably deteriorate while the desired compensating reactive power is outside their compensation variety.

The large reactive current in transmission systems is one of the most common power problems, which increases transmission losses and lowers the stability of a power system. Application of reactive power compensators is one of the solutions for this issue. Static Var compensators (SVCs) are traditionally used to dynamically compensate reactive currents as the loads vary from time to time. However, SVCs

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suffer from many problems, such as resonance problems, harmonic current injection, and slow response. To overcome these disadvantages, static synchronous compensators (STATCOMs) and active power filters (APFs) were developed for reactive current compensation with faster response, less harmonic current injection, and better performance. Hybrid compensator is dedicated for inductive loading operation. When it is applied for capacitive loading compensation, it easily loses its small active inverter rating characteristics. To enlarge the compensation range and keep low current rating characteristic of the APF, proposed another hybrid combination structure of SVC in parallel with APF (SVC//APF) in three-phase distribution systems. In this hybrid structure, the APF is controlled to eliminate the harmonics and compensate for the small amounts of load reactive and unbalanced power left by the SVC. However, if this structure is applied in a medium- or high-voltage-level transmission system, the APF still requires a costly voltage step-down transformer and/or multilevel structure. In addition, these two parallel connected-hybrid STATCOM structures may suffer from a resonance problem.

However, the STATCOMs or APFs usually require multilevel structures in a medium- or high-voltage level transmission system to reduce the high-voltage stress across each power switch and DC-link capacitor, which drives up the initial and operational costs of the system and also increases the control complexity. A new control strategy for hybrid-STATCOM is proposed to coordinate the TCLC part and the active inverter part for reactive power compensation under different voltage and current conditions, such as unbalanced current, voltage fault, and voltage dip.

II. PROPOSED CONTROL SCHEME

Hybrid-STATCOM consists of a thyristor-controlled LC (TCLC) part and an active inverter part, as shown in Figure. The TCLC part provides a wide reactive power compensation range and a large voltage drop between the system voltage and the inverter voltage so that the active inverter part can continue to operate at a low dc-link voltage level. The small rating of the active inverter part is used to improve the performances of the TCLC part by absorbing the harmonic currents generated by the TCLC part, avoiding mistuning of the firing angles, and preventing the resonance problem. The TCLC part is composed of a coupling inductor L_c, a parallel capacitor CPF, and a thyristor-controlled reactor with LPF. The TCLC part provides a wide and continuous inductive and capacitive reactive power compensation range that is controlled by controlling the firing angles αx of the thyristors. The active inverter part is composed of a voltage source inverter with a dc-link capacitor C_{dc}, and the small rating active inverter part is used to improve the performance of the TCLC part.

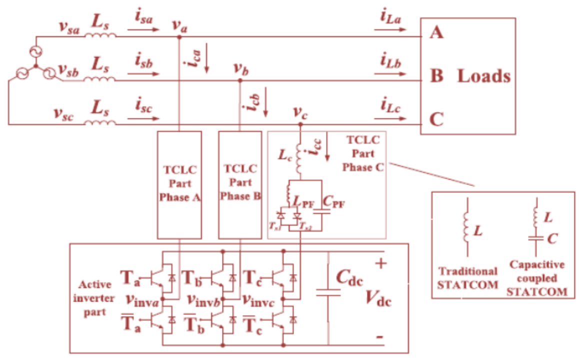

Fig.1. System configuration for hybrid STATCOM

The purpose of the hybrid-STATCOM is to provide the same amount of reactive power as the loadings (Q_{Lx}) consumed, but with the opposite polarity ($Q_{Lx} = -Q_{cx}$). The hybrid-STATCOM compensating reactive power Q_{cx} is the sum of the reactive power Q_{TCLC} that is provided by the TCLC part and the reactive power Q_{invx} that is provided by the active inverter part. Therefore, the relationship among Q_{Lx},and Q_{TCLC} can be expressed as

$$Q_{Lx} = -Q_{cx} = -(Q_{TCLC} + Q_{invx}) \quad (1)$$

The reactive powers can also be expressed in terms of voltages and currents as

$$Q_{Lx} = V_x I_{Lqx} = -(X_{TCLC}(\alpha_x) I_{cqx}^2 + V_{invx} I_{cqx}) \quad (2)$$

where $X_{TCLC}(\alpha_x)$ is the coupling impedance of the TCLC part; α_x is the corresponding firing angle; V_x and V_{invx} are the root mean square (RMS) values of the coupling point and the inverter voltages. And the minimum inductive and capacitive impedances (absolute value) of the TCLC part can be obtained by substituting the firing angles α_x=90 and α_x=180°

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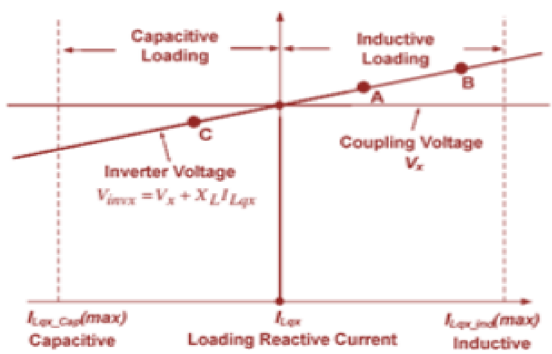
respectively. In the following discussion, the minimum value for impedances stands for its absolute value.

In this case, the switching loss and switching noise can be significantly reduced. A small inverter voltage $V_{invxmax}$ is necessary to absorb the harmonic current generated by the TCLC part, to prevent a resonance problem, and to avoid mistuning the firing angles. If the loading capacitive current or inductive current is outside the TCLC part compensating range, the inverter voltage V_{invx} will be slightly increased to further enlarge the compensation range. The coupling impedances for traditional STATCOM and C-STATCOM, as shown in Fig. 1.

For traditional STATCOM as shown in Fig. 2(a), the required V_{invx} is larger than V_x when the loading is inductive. In contrast, the required V_{invx} is smaller than V_x when the loading is capacitive. Actually, the required inverter voltage V_{invx} is close to the coupling voltage V_x, due to the small value of coupling inductor L [5]-[8].



(a)

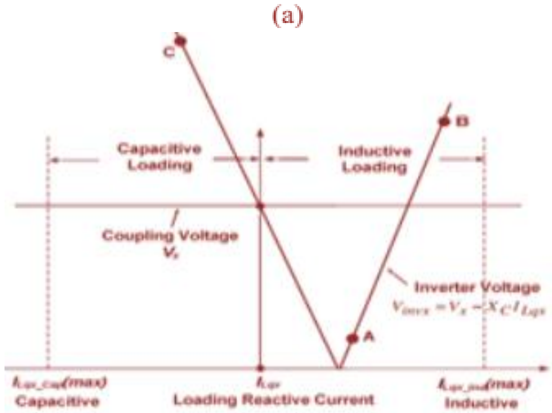
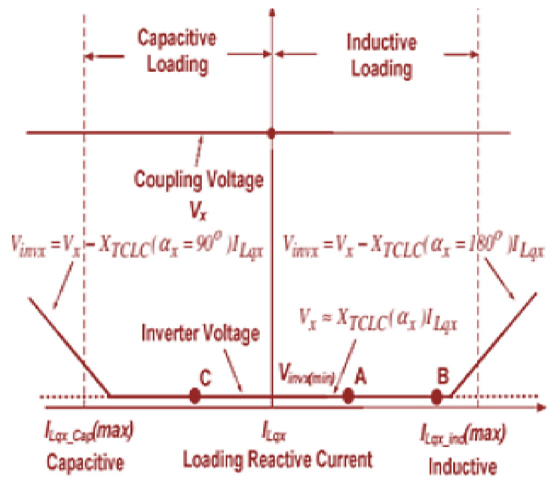


Fig. 2. V-I characteristic of (a) traditional STATCOM (b) C-STATCOM.

The required V_{invx} can be as low as zero when the coupling capacitor can fully compensate for the loading reactive current. In contrast, V_{invx} is larger than V_x when the loading is capacitive or outside its small inductive loading range. Therefore, when the loading reactive current is outside its designed inductive range, the required V_{invx} can be very large. For the proposed hybrid-STATCOM as shown in Fig. 2(c), the required V_{invx} can be maintained at a low (minimum) level ($V_{invx(min)}$) for a large inductive and capacitive reactive current range.



(c)

Fig. 2. V-I characteristic of (c) hybrid-STATCOM

Moreover, when the loading reactive current is outside the compensation range of the TCLC part, the V_{invx} will be slightly increased to further enlarge the compensating range. The TCLC part has two back-to-back connected thyristors in each phase that are triggered alternately in every half cycle, so that the control period of the TCLC part is one cycle (0.02 s).

Multilevel Inverter: Now a days many industrial applications have begun to require high power. Some appliances in the industries however require medium or low power for their operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Some medium voltage motor drives and utility applications require medium voltage.

Types of Multilevel Inverter:

Multilevel inverters are three types.

- Diode clamped multilevel inverter

- Flying capacitors multilevel inverter
- Cascaded H- bridge multilevel inverter

Cascaded H-Bridge Multilevel Inverter: The cascaded H-bride multi level inverter is to use capacitors and switches and requires less number of components in each level. This topology consists of series of power conversion cells and power can be easily scaled. The combination of capacitors and switches pair is called an H-bridge and gives the separate input DC voltage for each H bridge. It consists of H-bridge cells and each cell can provide the three different voltages like zero, p sitive DC and negative DC voltages.

III. SIMULATION RESULTS

In this section, the simulation results among traditional STATCOM, C-STATCOM, and the proposed hybrid-STATCOM are discussed and compared.

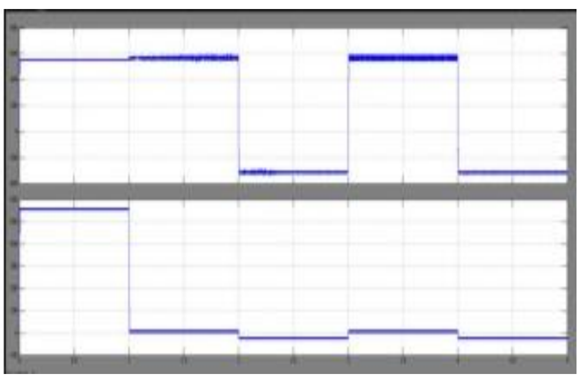


Fig. 3. Dynamic reactive power compensation of phase a by applying hybrid-STATCOM

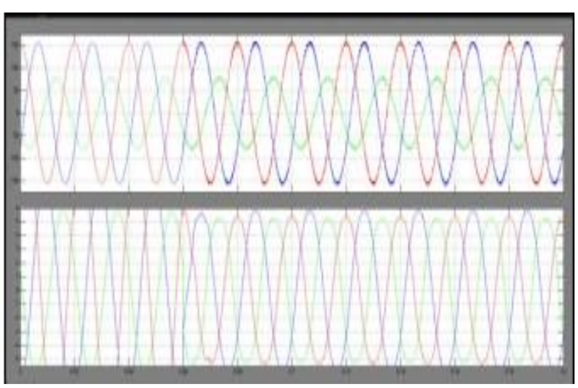


Fig. 4.Dynamic compensation waveforms of and by applying hybrid STATCOM under voltage fault condition

IV. CONCLUSION

Simulation of hybrid-STATCOM has been correctly completed using MATLAB Simulink software. Also, simulation of conventional STATCOM in addition to C-STATCOM is also done to examine the 3 models deeply. From the simulation effects, it is obvious that the performance of the hybrid-STATCOM is advanced than the conventional and CSTATCOMs. Hybrid-STATCOM is realized by means of correctly coordinating each TCLC part and lively inverter element. With this, the main troubles confronted inside the systems consisting of resonance trouble, harmonic present day injection problem and firing attitude mistuning trouble of thyristors and many others are prevented. The hybrid-STATCOM has been tested below distinct loading conditions such as capacitive loading, inductive light loading and inductive heavy loading. The reactive power reimbursement capability of hybrid-STATCOM could be very high for different loading conditions as properly.

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