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HYBRID-STATCOM : A Reactive Power Compensation and Resonance Avoidance Approach

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ABSTRACT

Reactive current poses a lots of problem in transmission systems and leads to increase in transmission losses and lowers the stability of a power system. In this work we try to present a technique for a three phase power transmission system which has a wide compensation range and low dc-link voltage and we call it as an Hybrid-STATCOM. As the system has a wide compensation range and low dc-link voltage, the system becomes quite inexpensive. In this paper, we present the circuit configuration of hybrid-STATCOM then its analysis on the basis of V-I characteristics along with the parameter selection criteria. As the we intend to avoid the potential resonance problem we try to develop the control strategy which achieves the same. Simulation are carried out to verify the 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

Reactive current poses a lots of problem in transmission systems and leads to increase in transmission losses and lowers the stability of a power system[1]–[19]. Power compensators like SVCs come to the rescue but they suffer resonance, harmonic current injection and slow response [2], [3]. Static synchronous compensators STATCOMs) and active power filters (APFs) come to rescue from these disadvantages. However they require multilevel structure and more so they become complex and expensive. Progressively C-STATCOMs , PPFSTATCOMs were proposed but they suffered from relatively narrow reactive power compensation ranges thus limiting their range of operation. To improve the performances of the traditional STATCOMs, C-STATCOMs, and other PPF-STATCOMs, lots of control scheme have been proposed such as the instantaneous *p*–*q* theory [4], [10], [11], [17]–[19], the instantaneous *d*–*q* theory [5], [6], [14], the instantaneous *id*–*iq* method [7], negative- and zero-sequence control [8], the back propagation (BP) control method [9], nonlinear control [12], Lyapunov-function-based control [13], instantaneous symmetrical component theory [15], and hybrid voltage and current control [16]. To reduce the current rating of the STATCOMs or APFs,a hybrid combination structure of PPF in parallel with STATCOM (PPF//STATCOM) was proposed in [20] and [21].

To overcome the shortcomings of different reactive power compensators [1]–[22] for transmission systems, this paper proposes a hybrid-STATCOM that consists of a thyristor-controlled LC (TCLC) part and an active inverter part, as shown in Fig. 1. 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 contributions of this paper are summarized as follows.

1. Parameter Design Of Hybrid-Statcom:
   A. Design of CPF and LPF:
   B. Design of Lc:
   C. Design of Vdc:
2. Control Strategy Of Hybrid-Statcom:
   A. TCLC Part Control:
   B. Active Inverter Part Control:

In this paper, the problem identification is discussed in Section II. Section III, presents the details of the methodology follower by implementation details in section IV. Section V gives the result and its discussion .

II. PROBLEM IDENTIFICATION

Reactive current poses a lots of problem in transmission systems and leads to increase in transmission losses and lowers the stability of a power system[1]–[19]. Many system such as SVC , APF, STATCOM'S have been proposed and used to reduce the problem. These system have suffered either from resonance problems, harmonic current injection issue or slow response . APF, STATCOM'S give a better performance in overcoming the above mentioned problems but they are complex and costly. C-STATCOMs were proposed but had a low compensation range giving a very poor performance when operated outside their specified range.

A hybrid combination structure of SVC in parallel with APF (SVC//APF) in three-phase distribution systems comes to the rescue however it suffers from a resonance problem.

Thus there is a need to a technique to overcome the above shortcomings by providing a wide 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 and avoids the mistuning of the firing angles, and prevents the resonance problem.

III. METHODOLOGY

IV.

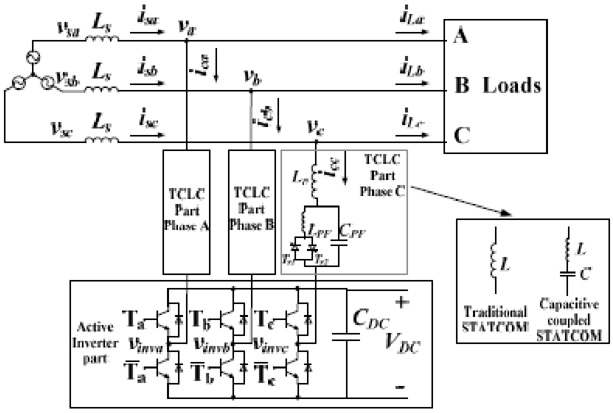

Figure 1. Circuit configuration of the hybrid-STATCOM

Figure 1 shows the proposed circuit configuration of hybrid- The STATCOM, in which the subscript *x* stands for phase *a, b*, and *c* in the following analysis. *vsx* and *vx* are the source and load voltages; *isx, iLx*, and *icx* are the source, load, and compensating currents, respectively. *Ls* is the transmission line impedance. The hybrid-STATCOM consists of a TCLC and an active inverter part. The TCLC part is composed of a coupling inductor *Lc*, a parallel capacitor *C*PF, and a thyristor-controlled reactor with *L*PF. 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. In addition, the coupling components of the traditional STATCOM and C-STATCOM are also presented in Figure 1.

V. IMPLEMENTATION DETAILS

The Parameter Design Of Hybrid-Statcom: The proposed TCLC part is a newly proposed SVC structure which designed based on the basis of the consideration of the reactive power compensation range (for *L*PF and *C*PF) and the prevention of the potential resonance problem (for *Lc*). The active inverter part (dc-link voltage *V*dc) is designed to avoid mistuning of the firing angle of TCLC part.

Design of CPF and LPF: The purpose of the TCLC part is to provide the same amount of compensating reactive power Qcx, TCLC(αx) as the reactive power required by the loads QLx but with the opposite direction. Therefore, CPF and LPF are designed on the basis of the maximum capacitive and inductive reactive power.

Design of Lc: For exciting resonance problems, a sufficient level of harmonic source voltages or currents must be present at or near the resonant frequency. Therefore, *Lc* can be designed to tune the resonance points to diverge from the dominated harmonic orders $nd = 6n \pm 1$th ($n = 1, 2, 3$, etc.) of a three-phase three-wire transmission system to avoid the resonance problem.

Design of Vdc: Different with the traditional *V*dc design method of the STATCOM to compensate maximum load reactive power, the *V*dc of Hybrid-STATCOM is design to solve the firing angle mistuning problem of TCLC (i.e., affect the reactive power compensation) so that the source reactive power can be fully compensated. Reforming (3), the inverter voltage *V*invx can also be expressed as

$$V_{\text{invx}} = V_x\left[1+\frac{V_x I_{Lqx}}{V_x^2/X_{\text{TCLC}}(\alpha_x)}\right] = V_x\left[1+\frac{Q_{Lx}}{Q_{cx,\text{TCLC}}(\alpha_x)}\right] \quad (1)$$

Control Strategy Of Hybrid-Statcom: In this section, a control strategy for hybrid-STATCOM is proposed by coordinating the control of the TCLC part and the active inverter part so that the two parts can complement each other's disadvantages, and the overall performance of hybrid-STATCOM can be improved.

TCLC Part Control: Different with the traditional SVC control based on the traditional definition of reactive power [2], [3], to improve its response time, the TCLC part control is based on the instantaneous pq theory [4]. The TCLC part is mainly used to compensate the reactive current with the controllable TCLC part impedance *X*TCLC.

Active Inverter Part Control: In the proposed control strategy, the instantaneous active and reactive current *id–iq* method [7] is implemented for the active inverter part to improve the overall performance of hybrid-STATCOM under different voltage and current conditions, such as balanced/unbalanced, voltage dip, and voltage fault. Specifically, the active inverter part is used to improve the TCLC part characteristic by limiting the compensating current *icx* to its reference value so that the mistuning problem, the resonance problem, and the harmonic injection problem can be avoided.

VI. RESULTS

The results obtained are given below

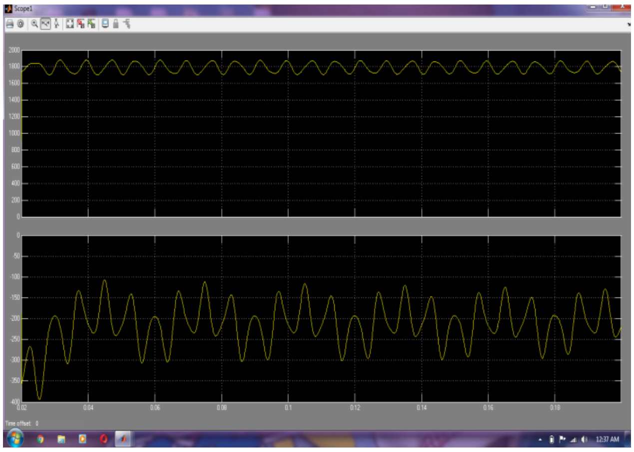

Figure 2. Source active and reactive power with TCLC

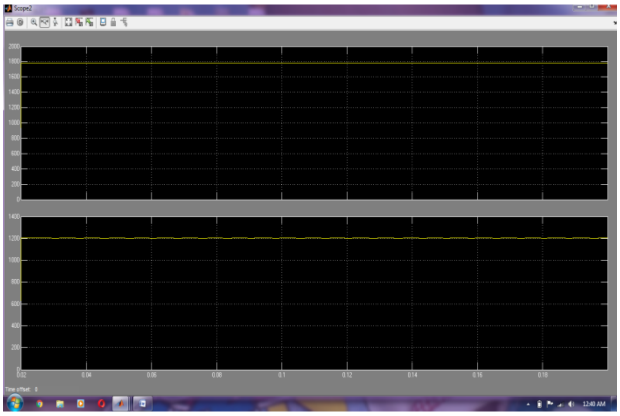

Figure 3. Load active and reactive power with TCLC

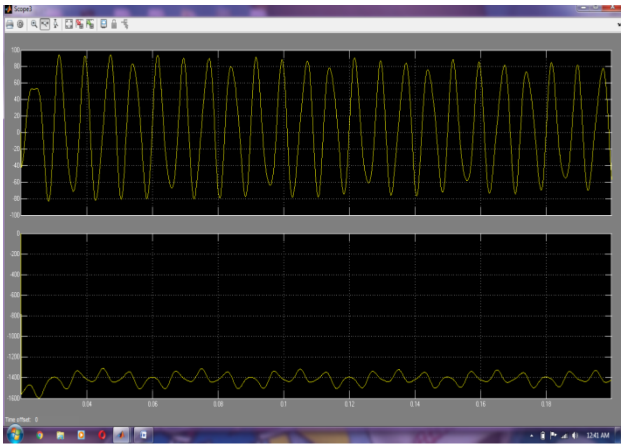

Figure 4. TCLC active and reactive power

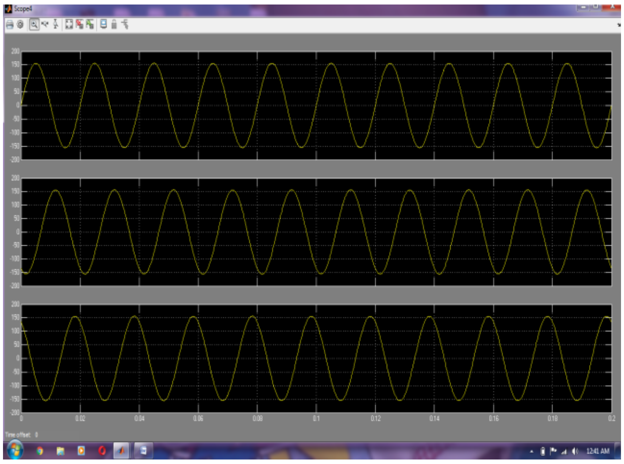

Figure 5. Voltages at Point of Common Coupling

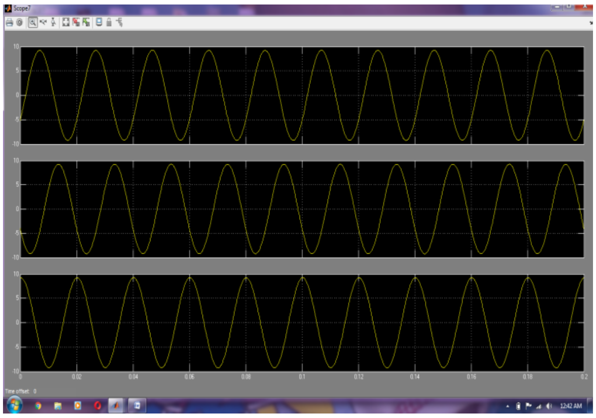

Figure 6. Load Currents

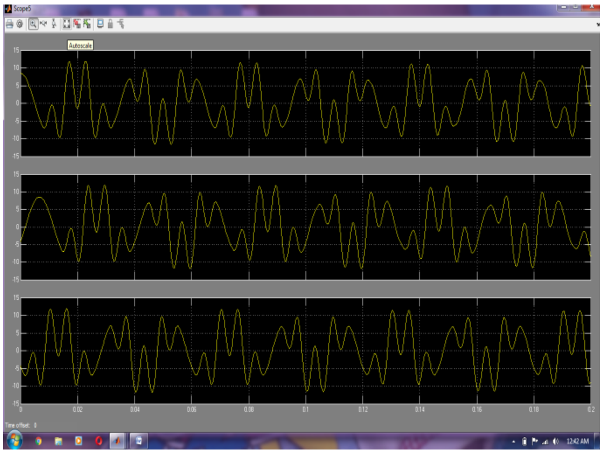

Figure 7. Compensating current from TCLC

VII. CONCULUSION

Thus we have been able to develop hybrid-STATCOM that consists of a hyristor-controlled LC (TCLC) part and an active inverter part.The simulation was carried out and partial results are presented.

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