Hybrid-STATCOM with Wider Compensation Range & Lower DC Link Voltage

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Abstract— A hybrid static synchronous compensator (hybrid-STATCOM) for a three-phase power system having a wider compensation range and lower DC-link voltage. Besides, these characteristics, the system costs can be significantly reduced by reducing the DC voltage requirement. It's V-I characteristics are then analysed & compared with Traditional STATCOM. A control strategy for hybrid-STATCOM is proposed to allow operation under different load conditions such as inductive, capacitive and change of load from capacitive to inductive load. We here want to reduce the source current provided to the system and also voltage and current should be in phase so as to reduce power losses.

Key words: Hybrid Static Synchronous Compensator (Hybrid-STATCOM), Static Synchronous Compensator (STATCOM), Wide Compensation Range, Low DC-Link Voltage

I. INTRODUCTION

In the modern transmission systems the major problem in the system retains with the compensation of reactive power. We need effective mechanism to deal with this problem because if left unperturbed this can lead to voltage fluctuations etc. We use many devices for such compensation like the static VAR compensators (SVC's) but they have their own disadvantage like slower response and resonance problems, harmonic current injection.

For overcoming these problems we use STATCOM (Static synchronous compensators) and active power filters, yet again these STATCOMs or APFs usually require multileveled structures to reduce the high voltage stress across each power switch and DC link capacitor. Later we used other devices for the

Compensation such as series type capacitive-coupled STATCOMs (C- STATCOMs) for reducing the system DC link Voltage requirement. But however the C-STATCOMs and other series type PPF STATCOMS, comprise of narrow reactive power compensating range.

For reducing the ratings of the current required for STATCOMs or APF a hybrid combination structure of PPF behold parallel with STATCOM. This feature had its own disadvantages of operating only in inductive operation. When operated for capacitive loading compensation, it lost its active inverter rating to a small extent.

Therefore, in this paper we overcome the drawbacks of various reactive power compensators by a hybrid-STATCOM consisting of a thyristor controlled LC part and an active inverter part. The part containing TCLC provide large compensating range and larger voltage drop between system voltage and inverter voltage so that active inverter part may continue to operate at lower DC link voltage.

II. CIRCUIT CONFIGURATION OF THE HYBRID-STATCOM

The circuit comprises of a TCLC part and an active inverter part. Following this, the TCLC part consists of an inductor L_c, a parallel capacitor C_{pf} and thyristor controlled reactor with L_{pf}. The role of TCLC part is to provide wider capacitive and inductive reactive power compensation via controlling the triggering or firing angles of thyristors. On the other hand active inverter part comprise of a voltage source inverter accompanied by DC link capacitor C_{dc} and it is used to improve the performance of other part i.e TCLC part.

In Fig. 1 configuration of Hybrid- STATCOM where subscript "x" stands for a,b and c phase for following analysis. V_{sx} and v_x are the source and load voltages, i_{sx},i_{lx} and i_{cx} being the source, load and compensating currents. L_s being the transmission line impedance.

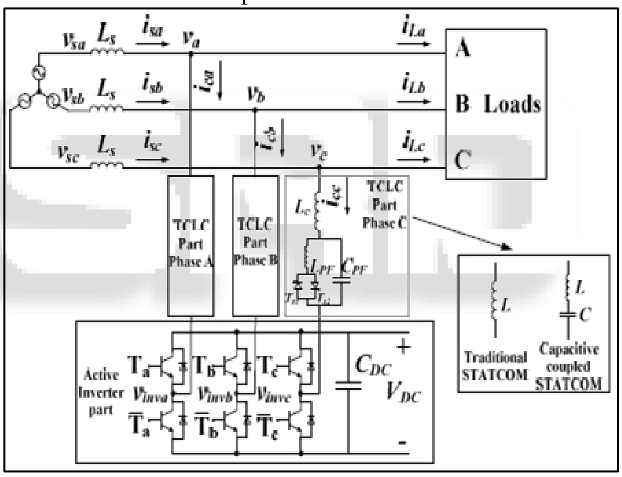

Fig. 1: Circuit Configuration of the Hybrid STATCOM

III. V-I CHARACTERISTICS OF THE TRADITIONAL STATCOM AND HYBRID STATCOM

The functioning of hybrid-STATCOM is providing the opposite polarity reactive power(Q_{cx}=-Q_{Lx}) to that of the load reactive power(Q_{Lx}). This compensating reactive power Q_{cx} is the sum of reactive power Q_{TCLC} that is provided by the TCLC part and the reactive power Qinvx which is provided by the active inverter part.

We get to the relationship between these such as

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

We can express this with terms containing voltage and current as

$$Q_{Lx}= V_xI_{Lqx} = - (X_{TCLC} (\alpha x) I^2_{cqx} +V_{invx}I_{cqx}) \quad (2)$$

Here XCLC(αx) is the coupling impedance of the part TCLC and αx is the corresponding firing angle.

From the coupling impendences we derive in theory graph of most commonly used traditional STATCOM and Hybrid- STATCOM where X_L >>X_C.

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In traditional STATCOM as we can say from the figure when loading is inductive the V_{invx} is larger than V_x and the required inverter voltage V_{invx} is close to the coupling voltage due to coupling inductor.

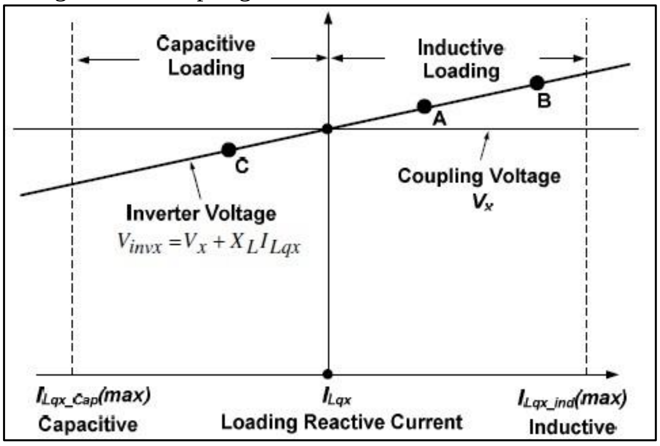

Fig. 2: V-I Characteristics of Traditional STATCOM

For the hybrid-STATCOM (fig 3) which is proposed in this paper we see the required V_{invx} can be upheld at a lower level $V_{invx(min)}$ for a large inductive and capacitive reactive range. For compensating of load reactive power Cpf , Lpf and Lc can be designed so as to form two kind of modes. First, where Lc in series with Cpf which would be called LC mode and second, Lc in series with combination of Lpf parallel with Cpf.

$$C_{pf} = \frac{Q_{Lx(maxind)}}{\omega\, 2Q_{Lx(maxind)} L_c + \omega V_x^2} \quad (3)$$

$$L_{pf} = \frac{V_x^2 + \omega L_c Q_{Lx(maxind)}}{-\omega Q_{Lx(maxind)} + \omega^3 L_c C_{pf} Q_{Lx(maxind)} + \omega^2 V_x^2 C_{pf}} \quad (4)$$

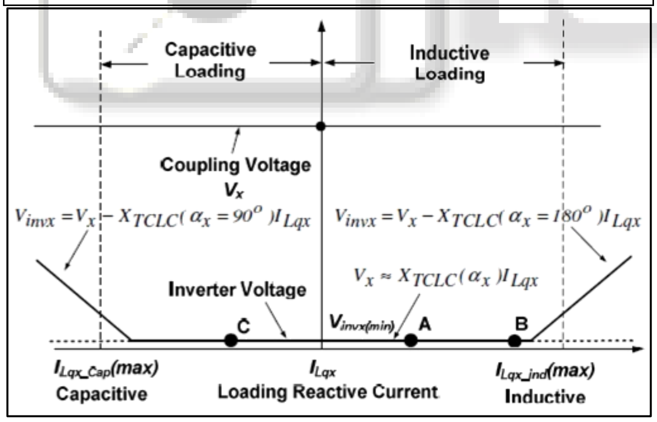

Fig. 3: V-I characteristics of Hybrid STATCOM

IV. CONTROL BLOCK DIAGRAM OF HYBRID-STATCOM.

For the TCLC part of the Hybrid-STATCOM two back to back thyristor are connected and those are triggered alternatively. But however we also have a active inverter part which significantly improve the response time of Hybrid-STATCOM. The control block diagram of the proposed Hybrid- STATCOM is given in the figure.

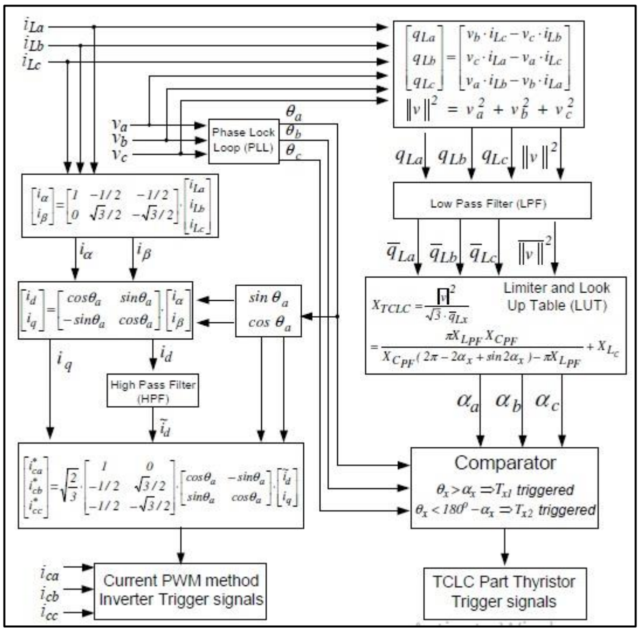

Fig. 4: Control Block Diagram of Hybrid- STATCOM

The main compensating for reactive power is TCLC part and obtaining the inverter voltage approximately equal to zero.

V. SIMULATION UNDER DIFFERENT LOADS

We now check the performance of Hybrid-STATCOM for different loads. The simulation study is carried out in MATLAB software. This is done with objective to show the effectiveness of Hybrid-STATCOM in various load conditions.

In figure 5 the load which we have used is inductive (RL) load where R=14 ohms and L= 30 mH. From the figures 5,6,7 we can clearly see the source current isx and load voltage Vx are in phase with each other. The source currents get reduce after the compensation. For the figure 6 we have taken the load as RC load where R=20 ohms and C= 200 microfarads

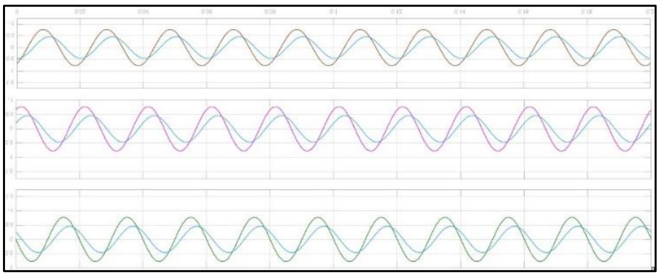

Fig. 5: Vx & Isx Waveforms for Inductive Load

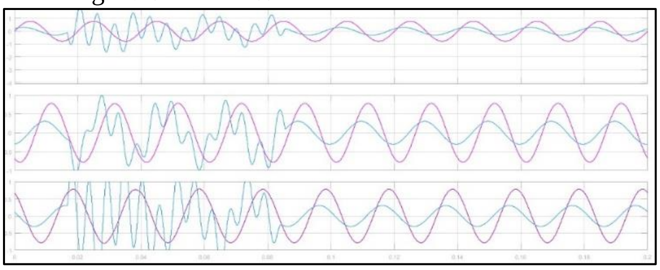

Fig. 6: Vx And Isx Waveforms for Capacitive Load

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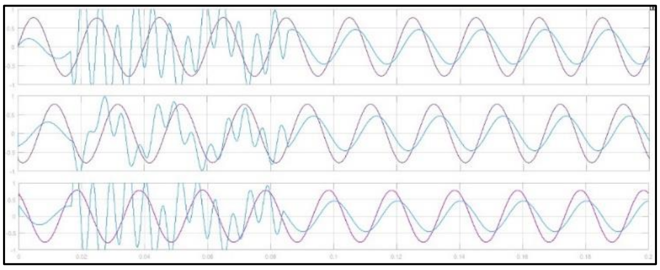

Fig. 7: Vx & isx Waveforms for Changing From Capacitive To Inductive Load

We can clearly see from the graphs in the figure 5,6 and 7 that after compensation the current value decreases and also the current and voltage become in phase thus decreasing the THD values. In all the conditions above the Hybrid-statcom is switched on at 80 ms. Hence we see the changes in the graph after 80ms only. Also we see that there is not much change in the performance of RL load condition or inductive load condition, it is approximately same as that of before the compensation.

In the next condition we check the Hybrid statcom for unbalanced load 3phase which would be a RL type load. The following figure shows the source current and load voltage graph.

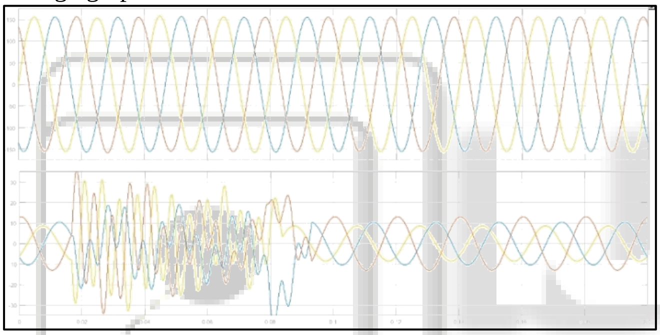

Fig. 8: Vx And Isx Waveforms For Unbalanced RL Load

After the switching on of the Hybrid-STATCOM we can clearly see the source current values lowers down. This is evident for the fact the fact reactive power compensation is taking place. Hence here in fig 8 we see load voltage Vx and source current isx.

Different loads	Comp.	Isx (Amps)		
		A	B	C
Capacitive	Before	9.3	9.3	9.3
	After	9.2	9.2	9.2
inductive	Before	24	14	14
	After	6	5	5
Capacitive to inductive	Before	13.4	16.8	22.2
	After	9.2	9.2	9.2
Unbalanced	Before	30	20	25
	After	8	10	13

Table 1: Compensation Results for Different Loading for a Hybrid-Statcom

VI. Conclusions

In this paper, we saw a Hybrid-STATCOM for a 3 phase system and its effective reactive power compensation. We saw the V-I characteristics of a Hybrid compensator and compared it with Traditional STATCOM. We also discussed control strategy or control block diagram for the Hybrid-STATCOM. We clearly got the results which show lower current required while compensation by Hybrid STATCOM than not having compensated at all also the waveforms are more symmetrical. These results are also superior to previous studies including that of C-STATCOM. Hence, the wider compensation range and low DC-link of the Hybrid-STATCOM are proved by simulations.

	Parameters	Values
System parameters	V_x,f,L_s	110V,50Hz,1mH
Hybrid-statcom	L_c,L_{pf}, C_{pf}	5 mH,30 mH, 160µF
Inductive load	L_{L1},R_{L1}	30 mH, 14ohms
Capacitive load	R_{C2},C_{C2}	20ohms,200 µF
Capacitive to inductive load	R_{C3},C_{C3} R_{L3},L_{L3}	20ohms,200 µF 30 mH, 14ohms
Unbalanced	R4a, L4a	18, 40 mH
	R4b, L4b	14,30 mH
	R4c, L4c	7,15 mH

Appendix

Table 2: Simulation Parameters for Hybrid Statcom

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