Hybrid Statcom With Wide Compensation Range And Low DC Link Voltage

**** G.HARIKA,** K.SRAVANTHI***

**PG SCHOLAR,DEPARTMENT OF EEE ANU BOSE INSTITUTE OF TECHNOLOGY,K.S.P ROAD, NEW PALONCHA, BHADRADRI KOTHAGUDEM(DIST)*

***ASSISTANT. PROFESSOR, DEPARTMENT OF EEE, ANU BOSE INSTITUTE OF TECHNOLOGY,K.S.P ROAD, NEW PALONCHA, BHADRADRI KOTHAGUDEM(DIST)*

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. Because of these prominent characteristics, the system costs can be greatly reduced. By using five level inverter is developed and applied for injecting the real power of the renewable power into the grid to reduce the switching power loss, harmonic distortion, and electromagnetic interference caused by the switching operation of power electronic devices. Its V-I characteristic is then analyzed, discussed, and compared with traditional STATCOM and capacitive coupled STATCOM (C-STATCOM). The system parameter design is then proposed on the basis of consideration of the reactive power compensation range and avoidance of the potential resonance problem. After that, a control strategy for hybrid STATCOM is proposed to allow operation under different voltage and current conditions, such as unbalanced current, voltage dip, and voltage fault. By using the simulation results we can verify the wide compensation range and low DC link voltage characteristics and the good dynamic performance of the proposed hybrid-STATCOM.

Index Terms*—Capacitive-coupled static synchronous compensator (C-STATCOM), hybrid STATCOM, low dc-link voltage, STATCOM, wide compensation range.*

I. INTRODUCTION

A hybrid-STATCOM is proposed, with the distinctive characteristics of a much wider compensation range than C-STATCOM [10] and other series-type PPF-STATCOMs and a much lower DC-link voltage than traditional STATCOM [4]-[9] and other parallel-connected hybrid

STATCOMs. To improve the operating performances of the traditional STATCOMs, C-STATCOMs, and other PPFSTATCOMs, many different control techniques have been proposed. THE large reactive current in transmission systems is one of the most common power problems that increases transmission losses and lowers the stability of a power system [1]. 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 suffer from many problems, such as resonance problems, harmonic current injection, and slow response [2]-[3]. 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 [4]-[9]. 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. To reduce the current rating of the STATCOMs or APFs, a hybrid combination structure of PPF in parallel with STATCOM was proposed. However, this 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 overcome the shortcomings of different reactive power compensators [1]-[10] for transmission systems, this paper proposes a hybrid STATCOM that consists of a thyristor-controlled LC part (TCLC) 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.

LITERATURE SURVEY

TITLE: Reactive power compensation technologies: State-of-the-art review

AUTHORS: J. Dixon, L. Moran, J. Rodriguez, and R. Domke

PUBLICATION: IEEE, vol. 93, no. 12, pp. 2144–2164, Dec. 2005

This paper presents an overview of the state of the art in reactive power compensation technologies. The principles of operation, design characteristics and application examples of Var compensators implemented with thyristors and self-commutated converters are presented. Static Var generators are used to improve voltage regulation, stability, and power factor in ac transmission and distribution systems. Examples obtained from relevant applications describing the use of reactive power compensators implemented with new static Var technologies are also described.

TITLE: Assessing the performance of a static var compensator for an electric arc furnace,"

AUTHORS: T. J. Dionise

PUBLICATION: Trans. Ind. Appl., vol. 50, no. 3, pp. 1619–1629, Jun. 2014.a

The advantages of a Static VAR Compensator (SVC) for electric arc furnace (EAF) and ladle melt furnace (LMF) applications are well known. The SVC minimizes the impact of the EAF and LMF on the utility as well as improves the efficiency of both furnaces. In this application, it was desirable to quantify the performance of the SVC. This paper describes power quality measurements which were taken on the electrical distribution system to evaluate the performance of the SVC. The purpose of the power quality measurements was to monitor the voltage regulation, harmonics, flicker and other power quality quantities at the 138 kV utility point-of-common-coupling (PCC) as well as the 34.5 kV system serving the SVC, EAF and LMF. The measurements and subsequent analysis established a baseline for the SVC performance and identified areas of concern. This paper describes the analysis of the measurements and evaluation of the SVC performance.

TITLE: Negative-sequence reactive-power control by a PWM STATCOM based on a modular multilevel cascade converter (MMCC-SDBC)

AUTHORS: M. Hagiwara, R. Maeda, and H. Akagi

PUBLICATION: IEEE Trans. Ind. Appl., vol. 48, no. 2, pp. 720–729, 2012.

This paper presents the application of a modular multilevel cascade converter based on single-delta bridge cells (SDBCs) to a STATic synchronous COMpensator (STATCOM), particularly for negative-sequence reactive-power control. The SDBC is characterized by cascade connection of multiple single-phase H-bridge (or full bridge) converter cells per leg, thus facilitating flexible circuit design, low-voltage steps, and low-electromagnetic-interference emissions. This paper designs, constructs, and tests a 100-V 5-kVA pulsewidth-modulated STATCOM based on the SDBC, with focus on the operating principle and performance. Experimental results verify that it can control not only positive-sequence reactive power but also negative-sequence reactive power and low-frequency active power intended for flicker compensation of arc furnaces.

TITLE: An improved hybrid DSATCOM topology to compensate reactive and nonlinear loads

AUTHORS: C. Kumar and M. Mishra

PUBLICATION: IEEE Trans. Ind. Electron., vol. 61,no. 12, pp. 6517–6527, Dec. 2014

This paper proposes an improved hybrid distribution static compensator (DSTATCOM) topology to address some practical issues such as power rating, filter size, compensation performance, and power loss. An LCL filter has been used at the front end of a voltage source inverter (VSI), which provides better switching harmonics elimination while using much smaller value of an inductor as compared with the traditional L filter. A capacitor is used in series with an LCL filter to reduce the dc-link voltage of the DSTATCOM. This consequently reduces the power rating of the VSI. With reduced dc-link voltage, the voltage across the shunt capacitor of the LCL filter will be also less. It will reduce the power losses in the damping resistor as compared with the traditional LCL filter with passive damping. Therefore, the proposed DSTATCOM topology will have reduced weight, cost, rating, and size with improved efficiency and current compensation capability compared with the traditional topology. A systematic procedure to design the components of the passive filter has been presented. The effectiveness of the proposed DSTATCOM topology over traditional topologies is validated through both simulation and experimental studies.

IMPLEMENTATION:

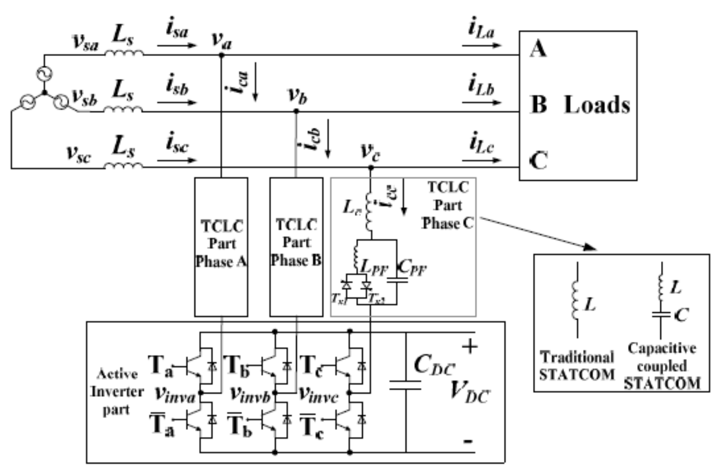

Fig. 1. Circuit configuration of the hybrid-STATCOM.

Fig. 1 shows the circuit configuration of hybrid-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 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 ax of the thyristors. The active inverter part is composed of a voltage source inverter with a DC-link capacitor Cdc, 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 Fig. 1. 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. Specifically, with the proposed controller, the response time of hybrid-STATCOM can be faster than SVCs, and the active inverter part can operate at lower dc-link operating voltage than the traditional STATCOMs. The control strategy of hybrid-STATCOM is separated into two parts for discussion: A. TCLC part control and B. Active inverter part control. The response time of hybrid-STATCOM is discussed in part C. The control block diagram of hybrid-STATCOM is shown in Fig. 5.

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 XTCLC. Referring to (3), to obtain the minimum inverter voltage Vinvx»0, XTCLC can be calculated with Ohm's law in terms of the RMS values of the load voltage (Vx) and the load reactive current (ILqx).

$$\|v\| = \sqrt{v_a^2 + v_b^2 + v_c^2}$$

$$\begin{bmatrix} q_{La} \\ q_{Lb} \\ q_{Lc} \end{bmatrix} = \begin{bmatrix} v_b \cdot i_{Lc} - v_c \cdot i_{Lb} \\ v_c \cdot i_{La} - v_a \cdot i_{Lc} \\ v_a \cdot i_{Lb} - v_b \cdot i_{La} \end{bmatrix}$$

In (21) and (22), *vx* and *qLx* are the instantaneous load voltage and the load reactive power, respectively. As shown in Fig. 5, a limiter is applied to limit the calculated *XTCLC* in (9) within the range of *XTCLC*>*Xind(min)* and *XTCLC*<*XCap(min)* (*XCap(min)*<0). With the calculated *TCLC*, the firing angle _*x* can be determined by solving (4). Because (4) is complicated, a look-up table (LUT) is installed inside the controller. The trigger signals to control the TCLC part can then be generated by comparing the firing angle _*x* with _*x*, which is the phase angle of the load voltage *vx*. _*x* can be obtained by using a phase lock loop (PLL). Note that the firing angle of each phase can differ if the unbalanced loads are connected (see (4) and (20)). With the proposed control algorithm, the reactive power of each phase can be compensated and the active power can be basically balanced, so that DC-link voltage can be maintained at a low level even under unbalanced load compensation.

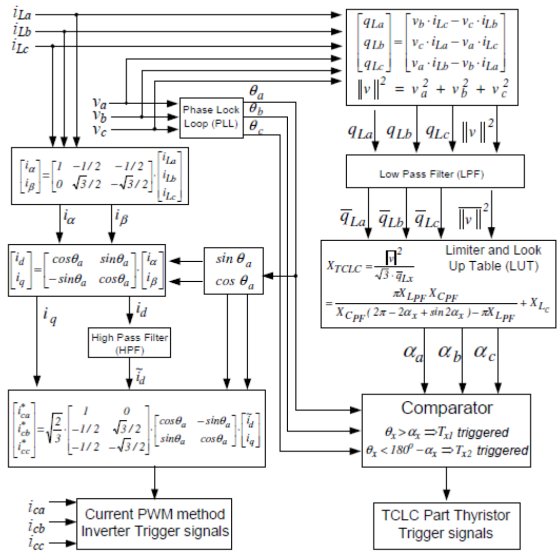

Fig. 5. The control block diagram of hybrid-STATCOM.

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 icx * so that the Mistuning problem, the resonance problem, and the harmonic injection problem can be avoided. The icx * is calculated by applying the id-iq method [7] because it is valid for different voltage and current conditions. The calculated icx * contains reactive power, unbalanced power, and current harmonic components. By controlling the compensating current icx to track its reference icx *, the active inverter part can compensate for the load harmonic currents and improve the reactive power compensation ability and dynamic performance of the TCLC part under different voltage conditions. The icx * can be calculated as

$$\begin{bmatrix} i_{ca}^{*} \\ i_{cb}^{*} \\ i_{cc}^{*} \end{bmatrix} = \sqrt{\frac{2}{3}} \cdot \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} cos\theta_a & -sin\theta_a \\ sin\theta_a & cos\theta_a \end{bmatrix} \cdot \begin{bmatrix} \tilde{i}_d \\ i_q \end{bmatrix} \quad (23)$$

Response time of hybrid-STATCOM

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). However, the proposed hybrid-STATCOM structure connects the TCLC part in series with an instantaneous operated active inverter part, which can significantly improve its overall response time. With the proposed controller, the active inverter part can limit the compensating current *icx* to its reference value *icx** via pulse width modulation (PWM) control, and the PWM control frequency is set to be 12.5 kHz. During the transient state, the response time of hybrid-STATCOM can be separately discussed in the following two cases. a) If the load reactive power is dynamically changing within the inductive range (or within the capacitive range), the response time of hybrid-STATCOM can be as fast as traditional STATCOM. b) In contrast, when the load reactive power suddenly changes from capacitive to inductive or vice versa, the hybrid-STATCOM may take approximately one cycle to settle down. However, in practical application, case b) described above seldom happens. Therefore, based on the above discussion, the proposed hybrid-STATCOM can be considered as a fast-response reactive power compensator in which the dynamic performances of hybrid-STATCOM are proved by the simulation result (Fig. 6) and the experimental results (Fig. 7, Fig. 8, Fig. 10, and Fig. 12).

Inductive and light loading

For the proposed hybrid-STATCOM, the isx, DPF, and THDisx are compensated to 5.48A, unity, and 1.98%, respectively. As discussed in the previous section, a low DC-link voltage (Vdc=50V) of hybrid-STATCOM is used to avoid mistuning of firing angles, prevent resonance problems, and reduce the injected harmonic currents.

Capacitive loading:

With the lowest DC-link voltage (Vdc=50V) of the three STATCOMs, hybrid-STATCOM can still obtain the best compensation results with DPF=1.00 and THDisx= 3.01%. In addition, the isx is reduced to 3.41A from 4.34A after compensation.

Inductive and heavy loading

On the other hand, the proposed hybrid-STATCOM can still obtain acceptable compensation results (DPF = 1.00 and *THDisx* = 3.01%) with a low DC-link voltage of *Vdc*=50V. The *isx* is reduced to 5.89A from 8.40A after compensation

In this paper, a hybrid-STATCOM in three-phase power system is proposed and discussed as a cost-effective reactive power compensator for medium voltage level application. The system configuration and V-I characteristic of the hybrid-STATCOM are analyzed, discussed, and compared with traditional STATCOM and C-STATCOM. In addition, its parameter design method is proposed on the basis of consideration of the reactive power compensation range and prevention of a potential resonance problem. Moreover, the control strategy of the hybrid-STATCOM is developed under different voltage and current conditions. Finally, the wide compensation range and low DC-link voltage characteristics with good dynamic performance of the hybrid-STATCOM are proved by both simulation and experimental results

REFERENCES:

[1] J. Dixon, L. Moran, J. Rodriguez, and R. Domke, "Reactive power compensation technologies: State-of-the-art review," Proc. IEEE, vol. 93, no. 12, pp. 2144–2164, Dec. 2005.

[2] L. Gyugyi, R. A. Otto, and T. H. Putman, "Principles and applications of static thyristor-controlled shunt compensators," IEEE Trans. Power App. Syst., vol. PAS-97, no. 5, pp. 1935–1945, Sep./Oct. 1978.

[3] T. J. Dionise, "Assessing the performance of a static var compensator for an electric arc furnace," IEEE Trans. Ind. Appl., vol. 50, no. 3, pp. 1619–1629, Jun. 2014.a

[4] F. Z. Peng and J. S. Lai, "Generalized instantaneous reactive power theory for three-phase power systems," IEEE Trans. Instrum. Meas., vol. 45, no. 1, pp. 293–297, Feb. 1996.

[5] L. K. Haw, M. S. Dahidah, and H. A. F. Almurib, "A new reactive current reference algorithm for the STATCOM system based on cascaded multilevel inverters," IEEE Trans. Power Electron., vol. 30, no. 7, pp. 3577–3588, Jul. 2015.

[6] J. A. Munoz, J. R. Espinoza, C. R. Baier, L. A. Moran, J. I. Guzman, and V. M. Cardenas, "Decoupled and modular harmonic compensation for multilevel STATCOMs," IEEE Trans. Ind. Electron., vol. 61, no. 6, pp. 2743–2753, Jun. 2014.

[7] V. Soares and P. Verdelho, "An instantaneous active and reactive current component method for active filters," IEEE Trans. Power Electron., vol. 15, no. 4, pp. 660–669, Jul. 2000.