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Hybrid Inverter DSTATCOM To Compensate Reactive Power For Non-Linear Loads

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Abstract— **This project proposes a hybrid DSTATCOM with LCL filter which is connected at infront of 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 LCL-filter to reduce the dc-link voltage of the D-STATCOM. Hence, reduced the power rating of VSI. Reduced DC- link voltage causes reduced voltage across LCL-filter. Then reduce the power loss. A multi level cascaded – H-bridge is implemented in the VSI operation of a D-STATCOM topology. The effectiveness of the proposed DSTATCOM topology over traditional topologies is validated through MATLAB/SIMULINK software.**

Index Terms— **Distribution static compensator (DSTATCOM), multilevel inverter (MLI), cascaded H-bridge, passive filter, power quality (PQ).**

I. INTRODUCTION

Traditionally static capacitors and passive filters have been utilized to improve power quality (PQ) in a distribution system. However, these usually have problems such as fixed compensation, system-parameter-dependent performance, and possible resonance with line reactance [2]. A distribution static compensator (DSTATCOM) has been proposed in the literature to overcome these drawbacks [3]–[8]. It injects reactive and harmonics component of load currents to make source currents balanced, sinusoidal, and in phase with the load voltages. However, a traditional DSTATCOM requires a high-power rating voltage source inverter (VSI) for load compensation. The power rating of the DSTATCOM is directly proportional to the current to be compensated and the dc-link voltage [10].Generally, the dc-link voltage is maintained at much higher value than the maximum value of the phase-to-neutral voltage in a three-phase four-wire system for satisfactory compensation (in a three-phase three-wire system, it is higher than the phase-to-phase voltage) [2], [10]–[12]. However, a higher dc-link voltage increases the rating of the VSI, makes the VSI heavy, and results in higher voltage rating of insulated gate bipolar transistor (IGBT) switches. It leads to the increase in the cost, size, weight, and power rating of the VSI. In addition, traditional DSTATCOM topologies use an L-type interfacing filter for shaping of the VSI injected currents [13], [14]. The L filter uses a large inductor, has a low slew rate for tracking the reference currents, and produces a large voltage drop across it, which, in turn, requires a higher value of the dc-link voltage for proper compensation. Therefore, the L filter adds in cost, size, and power rating. Some hybrid topologies have been proposed to consider the aforementioned limitations of the traditional DSTATCOM, where a reduced rating active filter is used with the passive components [15]–[21]. In [15] and [16], hybrid filters for motor drive applications have been proposed. In [17], authors have achieved a reduction in the dc-link voltage for reactive load compensation. However, the reduction in voltage is limited due to the use of an L-type interfacing filter. This also makes the filter bigger in size and has a lower slew rate for reference tracking. An LCL filter has been proposed as the front end of the VSI in the literature to overcome the limitations of an L filter [22]–[25]. It provides better reference tracking performance while using much lower value of passive components. This also reduces the cost, weight, and size of the passive component. However, the LCL filter uses a similar dc-link voltage as that of DSTATCOM employing an L filter. Hence, disadvantages due to high dc-link voltage are still present when the LCL filter is used. Another serious issue is resonance damping of the LCL filter, which may push the system toward instability. One solution is to use active damping. This can be achieved using either additional sensors or sensor less schemes. The sensor less active damping scheme is easy to implement by modifying the inverter control structure. It eliminates the need for additional sensors. However, higher order digital filters used in these schemes may require to be tuned for satisfactory performance [26]. Another approach is to go for passive damping. This does not require extra sensor circuitry. However, insertion of a damping resistor in the shunt part of an LCL filter results in extra power loss and reduces the efficiency of the system [26]. This paper proposes an improved hybrid DSTATCOM topology where the LCL filter followed by the series capacitor is used at the front end of the VSI to address the aforementioned issues. This topology reduces the size of the passive components and the rating of the dc-link voltage and provides good reference tracking performance simultaneously. Along with this, a significant reduction in the damping power loss is achieved, which makes this scheme suitable for industrial applications. The performance of the proposed topology is validated through the extensive simulation results.

II. PROPOSED DSTATCOM TOPOLOGY

A three-phase equivalent circuit diagram of the proposed DSTATCOM topology is shown in Fig. 1. It is realized using three-phase four-wire two-level neutral-point-clamped VSI.

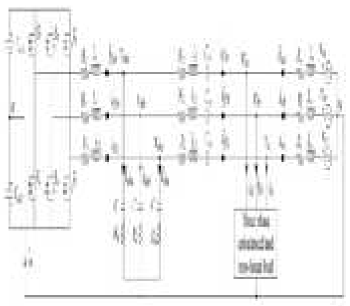

Fig.1. Proposed DSTATCOM topology in the distribution system to compensate unbalanced and nonlinear loads.

The proposed scheme connects an *LCL* filter at the front end of the VSI, which is followed by a series capacitor Cse. Introduction of the *LCL* filter significantly reduces the size of the passive component and improves the reference tracking performance. Addition of the series capacitor reduces the dc-link voltage and, therefore, the power rating of the VSI. Here, *R*1 and *L*1 represent the resistance and inductance, respectively, at the VSI side; *R*2 and *L*2 represent the resistance and inductance, respectively, at the load side; and *C* is the filter capacitance forming the *LCL* filter part in all three phases. A damping resistance Rd is used in series with *C* to damp out resonance and to provide passive damping to the overall system. VSI and filter currents are *i*f1a and *i*f2a, respectively, in phase-*a* and similar for other phases. In addition, voltages across and currents through the shunt branch of the *LCL* filter in phase-are given by *V*sha and *i*sha, respectively, and similarly for the other two phases. The voltages maintained across the dc-link capacitors are *V*dc1 = *V*dc2 = *V*dcref . The DSTATCOM, source, and loads are connected to a common point called the point of common coupling (PCC). Loads used here have both linear and nonlinear elements, which may be balanced or unbalanced. In the traditional DSTATCOM topology considered in this paper, the same VSI is connected to the PCC through an inductor *Lf* [27]. In the *LCL* filter-based DSTATCOM topology, an *LCL* filter is connected between the VSI and the PCC [22].

A) Multilevel Inverter Topolagies

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. Static inverters have no moving parts and are used in a wide range of applications, from small switching power supplies in computers, to large electric utility high-voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panels or batteries. The electrical inverter is a high-power electronic oscillator. It is so named because early mechanical AC to DC converters was made to work in reverse, and thus were "inverted", to convert DC to AC. The inverter performs the opposite function of a rectifier. Types in multilevel inverter are discussed below. There are three types of classical multilevel inverters namely diode clamped, cascaded H-bridge and flying capacitor.

B) Cascaded H-Bridges inverter

A single-phase structure of an m-level cascaded inverter is illustrated in fig.2. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4. To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate dc sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in figure. The phase voltage $v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}$

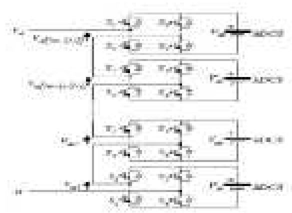

Fig 2 Single-phase structure of a multilevel cascaded H-bridges inverter

III. DSTATCOM CONTROL

The overall control block diagram is shown in Fig. 3. The DSTATCOM is controlled in such a way that the source currents are balanced, sinusoidal,

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and in phase with the respective terminal voltages. In addition, average load power and losses in the VSI are supplied by the source. Since the source considered. here is non stiff, the direct use of terminal voltages to calculate reference filter currents will not provide satisfactory compensation. Therefore, the fundamental positive sequence components of three-phase voltages are extracted to generate reference filter currents. The equations required for the control of a D –Statcom analyzed through SRF theory with PI controller.(1)

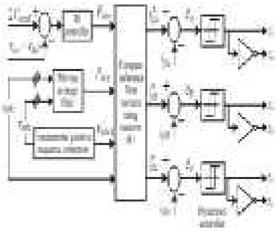


Fig 3 Controller block diagram.

IV. SIMULATION CIRCUITS AND RESULTS D STATCOM/COMPENSATION:

The advantages of the proposed topology are that it uses a lower rating of the VSI, has a smaller value of the filter inductor, reduces the damping power loss, and provides improved current compensation. All these advantages are verified through MATLAB software. System parameters used to validate the performance are given(1). Fig. 3 shows the three phase source currents before compensation which are same as load currents. These currents are unbalanced and distorted due to presence of unbalanced linear and nonlinear loads. Three-phase PCC voltages, as shown in Fig. 4(b), are unbalanced and distorted due to presence of feeder impedance. The performance of the traditional DSTATCOM topology is presented in Fig. 5. The three-phase source currents, which are balanced and sinusoidal, are shown in Fig. 4(a). Fig. 4(b) shows the three-phase PCC voltages. As seen from waveforms, both the source currents and the PCC voltages contain switching frequency components of the VSI. The three-phase filter currents are shown . The waveforms of voltages across upper and lower dc capacitors, as well as the total dc-link voltage, are presented . The voltage across each capacitor is maintained at 520 V, whereas the total dc-link voltage is maintained at 1040 V using the PI controller. The source currents and PCC voltages are balanced and sinusoidal but contain significant switching harmonics ripple. Their percentage total harmonic distortions (THDs) are given (1). To accommodate power losses in the damping resistor, the source currents are slightly increased compared with the traditional topology. Moreover, the total dc-link voltage is maintained at 1040 V (same as the traditional scheme) to achieve load compensation

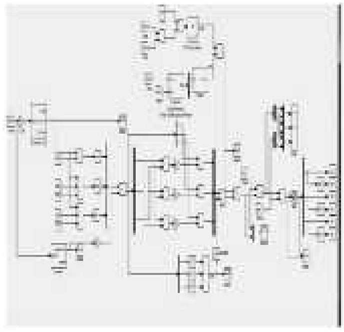
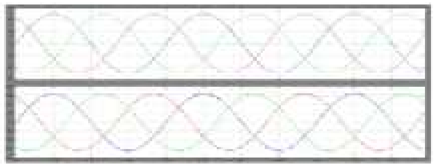
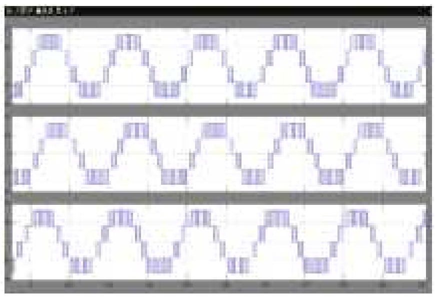


fig 4.3 (b) Control block diagram

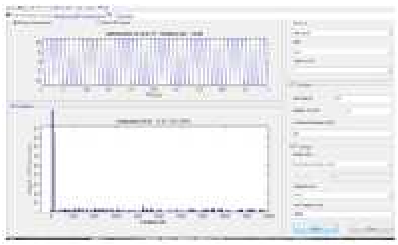
SIMULATION RESULTS:



4.5 Source currents and PCC voltages



4.6 Filter voltages



4.7Reduced Total Harmonic

V. CONCLUSION

In this project, design and operation of an improved hybrid DSTATCOM topology is proposed to compensate reactive and harmonics loads. The hybrid interfacing filter used here consists of an *LCL* filter followed by a series capacitor. This topology provides improved load current compensation capabilities while using reduced dc-link voltage and interfacing filter inductance. Moreover, the current through the shunt capacitor and the damping power losses are significantly reduced compared with the *LCL* filter-based DSTATCOM topology. These contribute significant reduction in cost, weight, size, and power rating of the traditional DSTATCOM topology .A cascaded multilevel inverter D-STATCOM significantly reduces the total harmonic distortion in this project. Effectiveness of the proposed topology has been validated through extensive MATLAB simulation.

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