POWER QUALITY IMPROVEMENT USING CASCADED H-BRIDGE D-STATCOM

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ABSTRACT

The paper presents transformer less cascaded h-bridge distribution static compensator for compensation harmonic, when nonlinear loads connected to the three phase three wire distribution system. The cascaded h-bridge inverter is directly connected to the system and it does not require bulky and expansive injection transformer. The control method used here based on synchronous reference frame theory for generating the compensating reference current. Level shifted carrier pulse width modulation technique is used for switching of h-bridge. Furthermore this topology is compared with and without cascaded h-bridge inverter. The performance of D-STATCOM with and without cascaded h-bridge is simulated using MATLAB/SIMULINK software.

Keywords— DSTATCOM; Srftheory(Synchronous Reference Theory); PI Controller; Cascaded H-Bridge DSTATCOM; Nonlinear Load.

I INTRODUCTION

In most of the industries, the major power quality problems related to harmonics are occurs due to increasing use of nonlinear loads such as power electronic devices, adjustable speed drives, fluorescent lamps, arc furnaces and more[1-2]. The harmonic related power quality problems are compensated using one of the best fact devices such as distribution static compensator (DSTATCOM) [3]. The D-STATCOM is connected in shunt with system and injecting compensating current into the system for compensation of harmonic, reactive power, load balancing and improving the power factor [4-7]. The power rating of the D-STATCOM is increase as the voltage rating of the switching devices is increase. The high voltage switching devices become more costly and they cannot operate with high switching frequency. To overcome this problem multilevel inverter is introduced in STATCOM applications. The conventional D-STATCOM is suitable for low and medium power applications. The cascaded h-bridge D-STATCOM is suitable for high voltage and high power applications. The cascaded h-bridge multilevel inverter first introduced in motor drive applications later is has used for harmonic and reactive power compensation in distribution system. The cascaded h-bridge is the one of the best multi level inverter in multi level inverter topology [8-9]. In multilevel inverter number levels is increase depending upon requirement. It has several advantages over the conventional two-level inverters as they result in reduction of (i) harmonic content of output voltage, (ii) voltage stresses across the semiconductor switching devices, and (iii) switching power loss due to low switching frequency. It also provides lower costs, higher performance, less electromagnetic interference (EMI), and higher efficiency than two-level VSIs power line conditioning applications, both series and shunt compensation [10-12]. The cascaded HB inverter has inherent self-balancing characteristics. The accurate design of D-STATCOM depends on control method. Here synchronous reference control theory with PI controller method is used for extracting the reference current [13-18]. The PI controller is used to balancing the dc-link voltage. The PI controller values are set by using Ziegler-Nichols method. The objective of the paper

- Extracting the reference currents required to mitigate the current harmonic produced by the nonlinear load using synchronous reference frame theory
- Comparing the results without and with cascaded h-bridge distribution static compensator
- Regulating the dc-link voltage with PI controller
- Load balancing
- Harmonic current compensation

In this paper a 5 level cascaded H-bridge D-STATCOM is presented for compensation of harmonic and reactive power in three phase three wire distribution system. Here with and without h-bridge the output voltage and total harmonic distraction also compared. The paper is organised as, Section-II system configuration, Section-III cascaded h-bridge inverter, section IV control strategy section V results & Discussion finally conclusion.

II SYSTEM CONFIGURTION

In Fig-1 shows the Schematic diagram of proposed cascaded H-bridge DSTATCOM connected to the three phase distribution system.

The proposed system configuration as shown in fig-1.the input source voltage of 11Kv is stepped down to 400v by using three phase stepped transformer of 11kv/ 400v for meeting industrial non linear load demand. When nonlinear load is connected to distribution system causes harmonics in source current as well as harmonic introduced at the PCC. It will causes reaming load connected at the PCC is affected. For compensation of harmonic and supplying of required reactive power is obtained by connecting the distribution static compensator at PCC. For reducing harmonic and increasing output voltage the 5 level cascaded h-bridge inverter is used. For non linear load three full bridge rectifiers is used

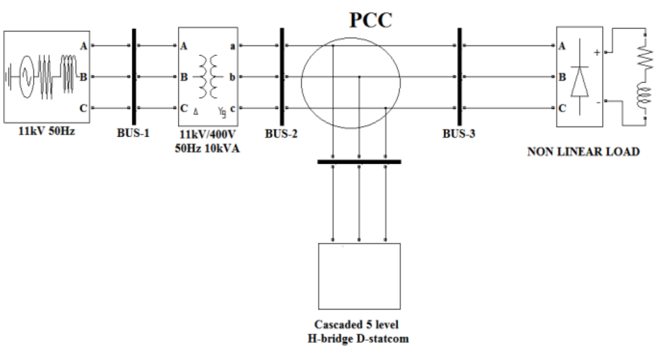

Fig-1. Schematic diagram of proposed cascaded H-bridge DSTATCOM in three phase three wire distribution system.

III FIVE LEVEL CASCADED H-BRIDGE INVERTER

In Fig-2 shows the 5 level cascaded H-bridge inverter .it consist of series combination of two single phase full bridge inverters per phase. Each full bridge inverter has separate DC source. In DSTATCOM the DC source is replaced by dc-link capacitor with suitable voltage rating. Each h-bridge consists of four switches S1, S2, S3 and S4. Each h-bridge inverter produces three levels of output voltages +Vdc,0,-Vdc.when the switches S1 and S2 is turned on than the output voltage is +Vdc. when the switches S3 & S4 is turned on than output voltage is –Vdc. By Turing on all switches S1, S2, S3 and S4 the output voltage is 0.the final resultant three phase ac output voltage is obtain by combined of all individual h-bridge inverter output voltages.

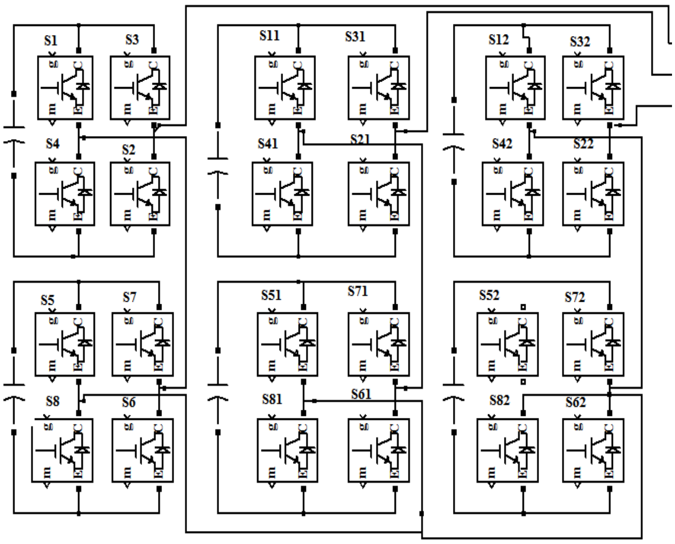

Fig-2. Five level cascaded H-bridge inverter for the proposed system

The switching signals to cascaded h-bridge inverter is obtained using level shifted phase disposition PWM method as shown in Fig-3. The switching signals to the S1 & S2 is obtained comparing the modulated sinusoidal signals with triangular carrier wave. The switching signals to S3 & S4 is obtained by comparing the modulated inverse sinusoidal signal with triangular carrier wave signal.

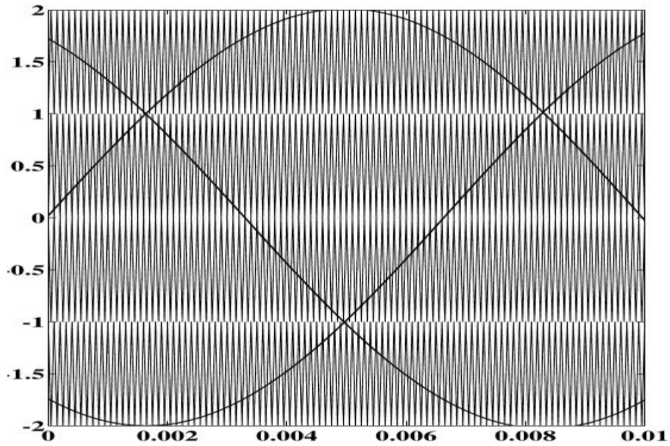

Fig-3. Five level output voltage using Phase disposition Modulation Scheme

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IV CONTROL STRATEGY OF PROPOSED SYSTEM

Fig-4. Shows the control strategy of the proposed system.

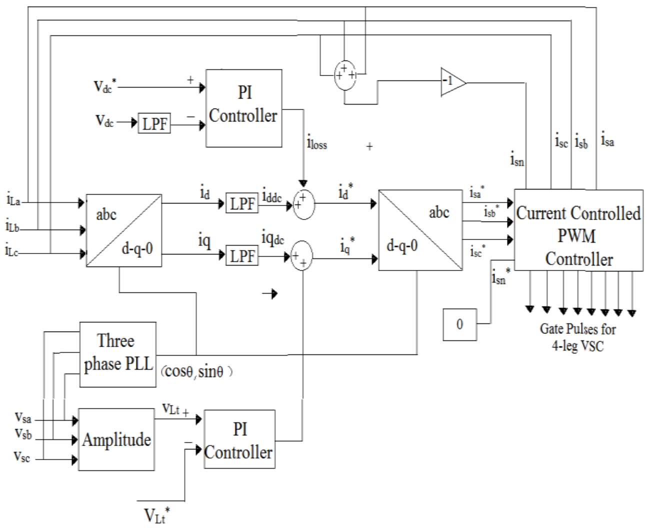

Fig-4. Block diagram of the proposed control scheme for the cascaded H-bridge DSTATCOM

Fig-3 shows the basic control diagram of the synchronous reference frame method (SRF).

In The SRF theorem is also known as i_d-i_q Method. In which a set of voltages and currents can be transformed into α-β frame by using following Eq-(9, 10)

$$\begin{Bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{Bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & 1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{Bmatrix} v_a \\ v_b \\ v_c \end{Bmatrix} \quad (9)$$

$$\begin{Bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{Bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{Bmatrix} i_a \\ i_b \\ i_c \end{Bmatrix} \quad (10)$$

The currents in d-q reference frame can be determined by using angle θ with respect to the α-β frame, and the angle is obtained by using a PLL. The transformation from α-β-0 frame to d-q -0 using following Eq-(11).

$$\begin{Bmatrix} i_0 \\ i_d \\ i_q \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & \sin\theta \\ 0 & -\sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} i_a \\ i_b \\ i_c \end{Bmatrix} \quad (11)$$

Each current component has average valve or dc component and oscillating valve or ac component.

id= iddc+idac (12)

iq= iqdc+iqac (13)

For reactive power compensation, source must deliver the mean value of the direct axis component of the load current along with the active power component of current form maintaining the dc bus and meeting losses (i_{loss}) in DSTATCOM. The output of PI controller at the DC bus voltage of DSTATCOM is considered as the current (i_{loss}) for meeting its losses.

The reference source current is therefore as,

$$I_d^*=i_d dc+i_{loss} \quad (14)$$

Along with direct axis component current, source also delivering quadratuer component current (i_{qdc}).It obtained from the PI controller (i_{qr}) used for regulating the voltage at PCC [11].

The reference supply quadratuer axis source current is therefore as

$$I_q^*=i_q dc+i_{qr} \quad (15)$$

The reference current signals I_d^*, $I_q^*$are transformed in to α-β-0 frame obtained by using following transformation Equation.

$$\begin{Bmatrix} i^*_{s0} \\ i^*_{s\alpha} \\ i^*_{s\beta} \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \begin{Bmatrix} 0 \\ i^*_{d} \\ i^*_{q} \end{Bmatrix} \quad (16)$$

The reference current in a-b-c frame obtained reverse transformation of the above current vector

$$\begin{Bmatrix} i_{s0} \\ i_{s\alpha} \\ i_{s\beta} \end{Bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 0 & 1 & 0 \\ 0 & -1/2 & \sqrt{3}/2 \\ 0 & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{Bmatrix} i^*_{s0} \\ i^*_{s\alpha} \\ i^*_{s\beta} \end{Bmatrix} \quad (17)$$

The obtained reference current in a-b-c frame is compared with triangular reference carrier wave signals using phase disposition PWM control method. The obtained compared switching pulses are applied to cascaded H-bridge D-STATCOM.

V RESULTS AND DISCUSSION

The performance of cascaded H-bridge D-STATCOM for voltage regulation, load voltage balancing and for harmonic reduction is modelled and simulated in MATLAB/SIMULINK software. With increasing number levels in multilevel inverter it produces better quality of output voltage and reduces the total harmonic distortion compare to conventional two level inverter. The model is analysed under nonlinear load conditions. The voltage and current valves are taken in P.U. The simulation run time is 0.3sec. The simulated system model is shown in Fig-1.the simulation is carried out using three cases

Case-A. Nonlinear load without D-STATCOM.

Case-B. Non linear load with D-STATCOM.

Case-C. Non linear load with cascaded H-bridge D- STATCOM.

Case-A: Nonlinear load without D-STATCOM

The When nonlinear load connected the distribution system at bus-3 as shown in fig-1.the nonlinear load causes harmonic in the load voltage ,current wave form and disturbances at the PCC (BUS -2) .it will cause loads connected at the PCC also effected is as shown in fig-5. In fig-5(a)&5(b). Shows that distorted voltage and current waveform at the PCC. Fig -5(c). Shows that distorted current wave form. Fig-5(c) & 5(d). Shows that distorted load voltage and current waveform, when nonlinear load is connected with addition of D-STATCOM.

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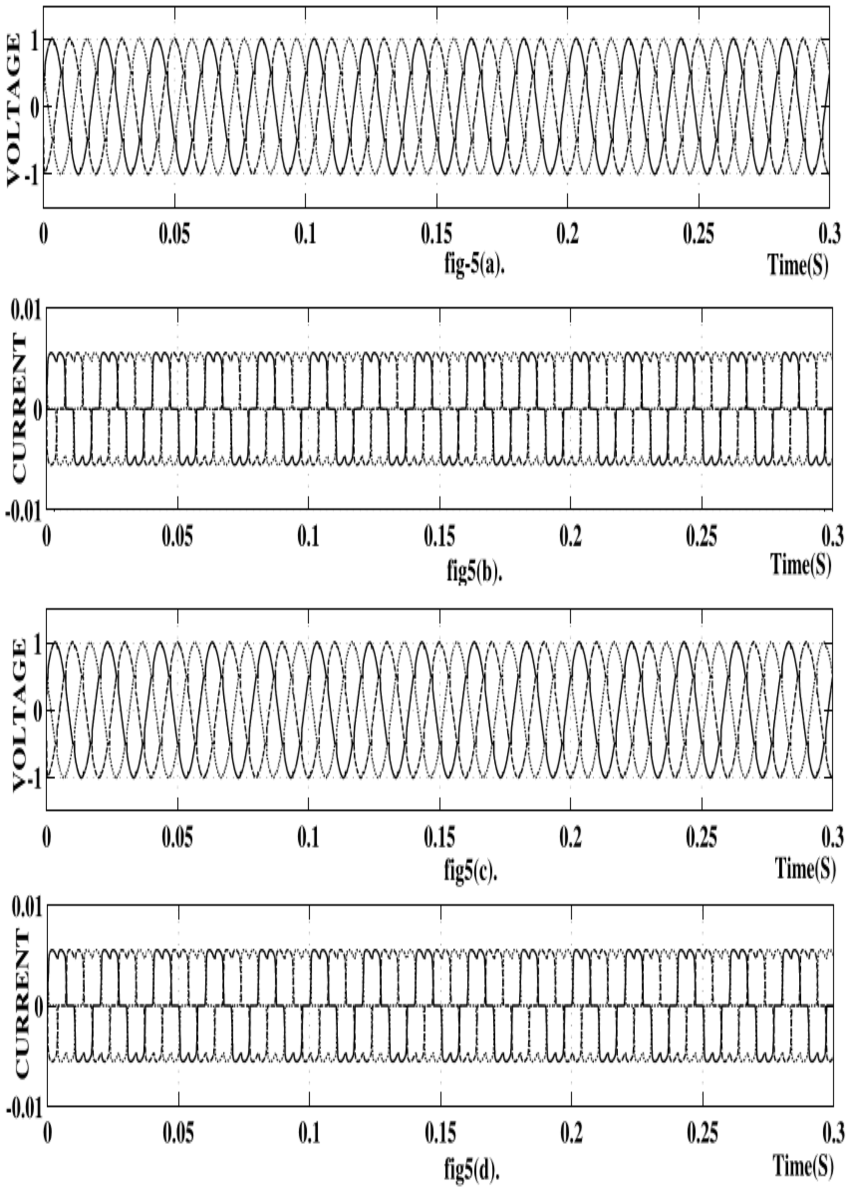

Fig-5 (a).Shows that distorted voltage wave form at the PCC, fig5-(b). Shows the distorted current wave form current waveform at the PCC. Fig -5(c). Shows that distorted load voltage wave form 5(d). Shows that distorted load current waveform, without D-Statcom.

Case-B: Non linear load with D-STATCOM.

When D-STATCOM is connected at the PCC, the voltage and current wave form at the PCC is compensated. The compensated voltage and current wave form at the PCC as shown in fig-6(a) & (b). The load voltage also compensated. The compensated load voltage as shown in fig-6 (c). But the load current is maintain as same as shown in fig-6(d). The regulated DC-link capacitor voltage as shown in fig-6(e).

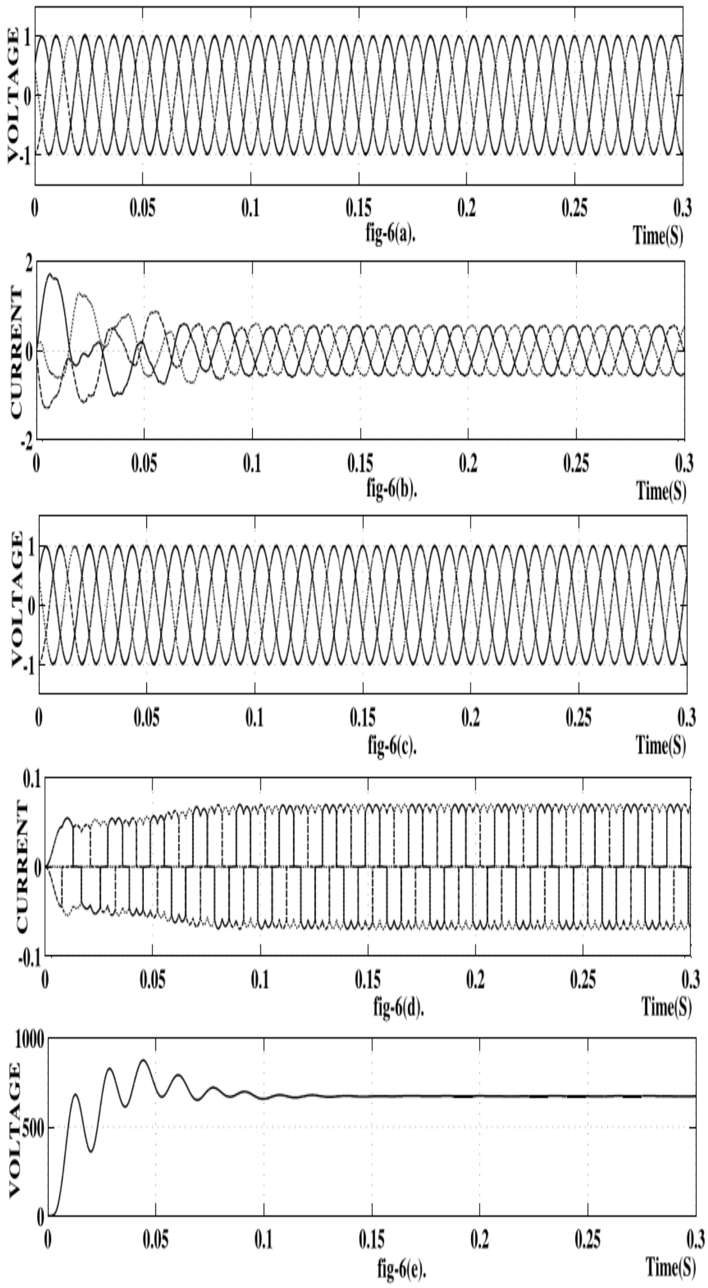

Fig-6(a). Shows that compensated voltage wave form at the PCC, fig6-(b). Shows the compensated current wave form at the PCC. Fig -6(c). Shows that compensated load voltage wave form, Fig-6(d). load current waveform, Fig -6(e).DC-link capacitor voltage waveform ,when D-Statcom is connected.

Case-C: Non linear load with cascaded H-bridge D- STATCOM.

The When cascaded H- bridge D-STATCOM is connected to the system at the PCC, the voltage and current at the PCC is compensated. The compensated voltage and current wave form at the PCC as shown in Fig-7(a) & (b). The load voltage is also compensated the compensated load voltage as shown in Fig-7 (c). But the load current is maintain as same as shown in Fig-7(d). The regulated DC-link capacitor voltage as shown in Fig-7(e).

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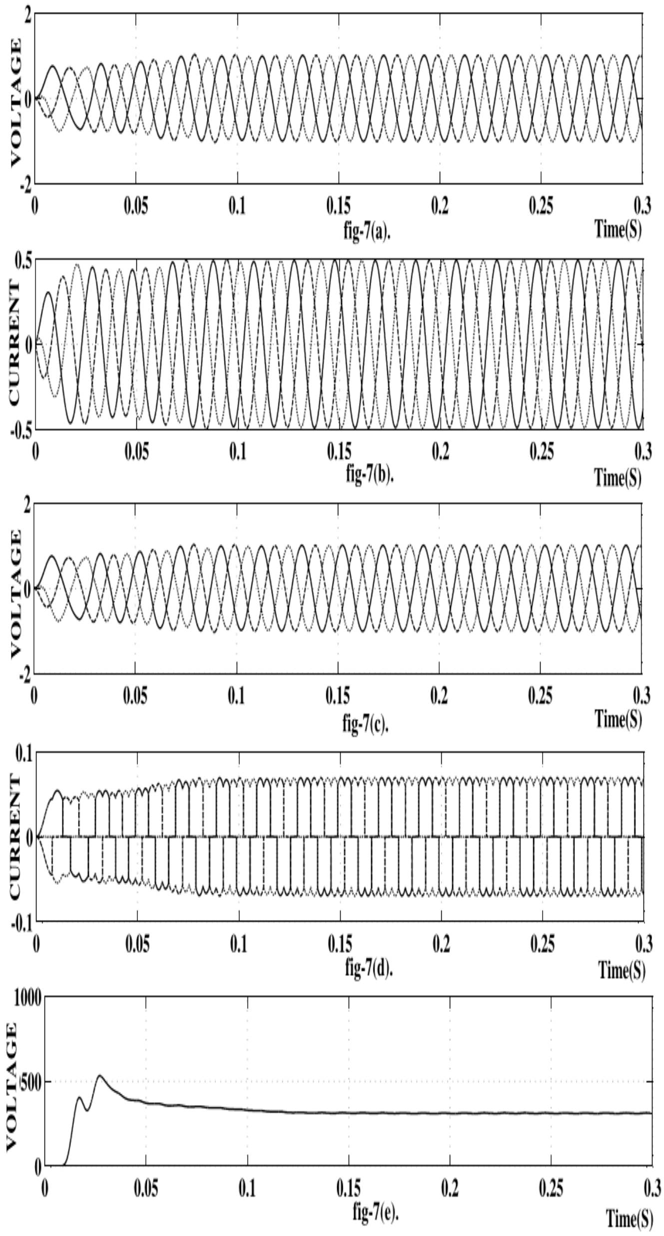

Fig-7(a). Shows that compensated voltage wave form at the PCC, fig7-(b). Shows the compensated current wave form at the PCC. Fig -7(c). Shows that compensated load voltage wave form, Fig-7(d). Load current waveform, Fig -7(e).DC-link capacitor voltage waveform, when cascaded h-bridge D-Statcom is connected at the PCC.

Case-D: THD (Total harmonic distortion) Analysis'

When non linear load connected to the distribution the total harmonic distortions is observed 26.30%. As shown in Fig-8(a).when a D-STATCOM is connected to the system at the PCC the Total harmonic distortion is reduced to 4.09% as shown in Fig-8(b).The proposed cascaded D-STATCOM is connected to the system the Total harmonic distraction is reduced to 1.36% is observed in fig 8(c).

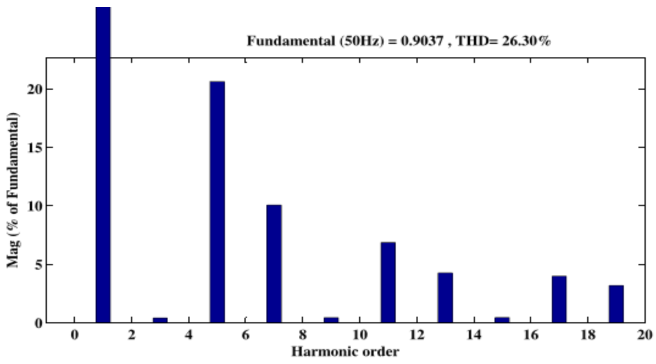

Fig-8(a). Total harmonic distortion analysis, without D-STATCOM

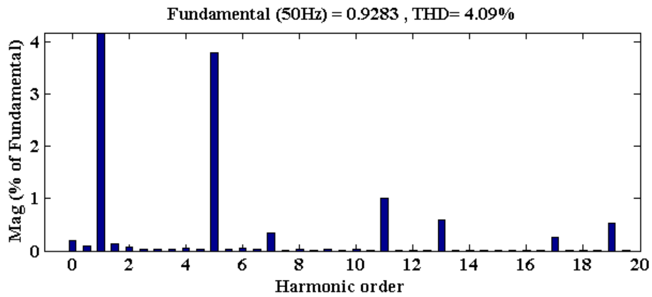

Fig-8(b). Total harmonic distortion analysis, with DSTATCOM

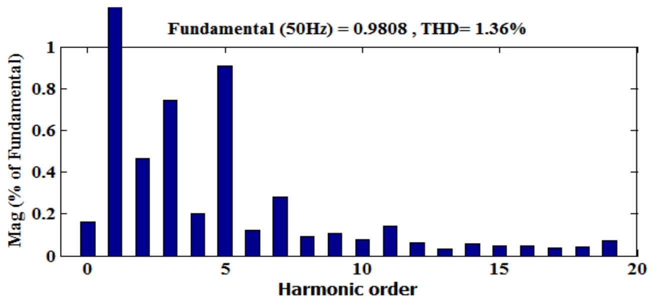

Fig-8(c). Total harmonic distortion analysis, *with cascaded H-bridge D- STATCOM.*

VI CONCLUSIONS

This The performance of cascaded 5-level H-bridge D-STATCOM has been demonstrated for harmonic mitigation in three phase three wire 11Kv distribution system is simulated using MATLAB/SIMULINK software. The following observation are made based on above simulation results

- The dc-link voltage requirement is very low in cascaded h-bridge compared to conventional method of D-STATCOM
- The Filter requirement at the output of the inverter is eliminated
- Effectively maintain the load voltage profile
- The harmonic distortion is of the proposed 5-level H-bridge D-STATCOM very low in compared to conventional method of D-STATCOM operating with same switching frequency.

The Cascaded 5-level H-bridge D-STATCOM well suitable for harmonic mitigation and reactive power compensation during balanced nonlinear load condition.

REFERENCES

[1] IEEE Recommended Practices and Requirements for Harmonics Control in Electric Power Systems, IEEE Std. 519, 1992.

[2] H. Akagi, E H Watanabe and M Aredes, Instantaneous power theory and applications to power conditioning, John Wiley & Sons, New Jersey, USA, 2007.

[3] Chen B, Hsu YA. Minimal harmonic controller for a STATCOM. IEEE Trans Ind Electron 2008; 55(2):655-64.

[4] A. Ghosh and G. Ledwich, Power Quality Enhancement using Custom Power Devices, Kluwer Academic Publisher, Boston, MA, 2002.

[5] A. Ghosh and G. Ledwich, “Load Compensating DSTATCOM in weak AC systems,” IEEE Trans. Power Delivery, vol. 18, No. 4, pp. 1302-1309, Oct. 2003.

[6] G. Ledwich and A. Ghosh, “A flexible DSTATCOM operating in voltage or current control mode,” IEE Proc.-Generation, Trans. & Distrib., vol. 149, No. 2, pp, 215-224, March 2002.

[7] F.Z. Peng, J. S. Lai, J.W. Mckeever, J. Van Coevering, "A Multilevel Voltage-Source inverter with Separate dc sources for Static Var Generation" IEEE Transactions on Industry Applications, Vol. 32, No. 5, Sep 1996, ppl 130-1138.

[8] Muni B.P., Rao S.E., Vithal J.V.R., Saxena S.N., Lakshminarayana S., Das R.L., Lal G., Arunachalam M., "DSTATCOM for Distribution Utility and Industrial Applications", Conference Proceedings, IEEE, Region Tenth Annual Conference, TENCON-03. Page(s): 278-282 Vol. 1.

[9] Bor-Ren Lin and Yuan-An Ou, “Active power filter based on three phase two- leg switch-clamped inverter,” Electric Power Systems Research, vol. 72, no. 1, pp. 63-72, Nov 2004.

[10] María Isabel Milanés, Enrique Romero Cadaval and Fermín Barrero González, “Comparison of Control Strategies for Shunt Active Power Filters in Three- Phase Four-Wire Systems,” IEEE Transactions on Power Electronics, vol. 22, no. 1, pp.229-236, Jan. 2007.

[11] Peng FZ, McKeever JW, Adams DJ. Cascade multilevel inverters for utility applications. In: Proc IEEE IECON. New Orleans, LA; 1997. p. 437–42.

[12] Rodriguez J, Lai JS, Peng FZ. Multilevel inverters: a survey of topologies, controls, and applications. IEEE Trans Ind Electron 2002;49(4):724–38.

[13] Patnaik SS, Panda AK. Cascaded three-level inverter based shunt active filter for power conditioning application. In Proc Annual IEEE India Conf (INDICON); 2013. p. 1–5.

[14] Montero M, Cadaval ER, Gonzalez FB. Comparison of control strategies for shunt active power filters in three-phase four-wire systems. IEEE Trans Power Electron 2007;22(1):229–36.

[15] Vardar K, Akpınar E, Surgevil T. Evaluation of reference current extraction methods for DSP implementation in active power filters. Electr Power Syst Res2009;79:1342–52.

[16] Bhattacharya A, Chakraborty C, Bhattacharya S. Shunt compensation: reviewing traditional methods of reference current generation. IEEE Ind Electron Mag 2009:38–49.

[17] Patnaik SS, Panda AK. Real-time performance analysis and comparison of various control schemes for particle swarm optimization-based shunt active power filters. Electr Power Energy Syst 2013;52:185–97.

[18] Soares V, Verdelho P, Marques GD. An instantaneous active and reactive current component method for active filters. IEEE Trans Power Electron 2000;15(4):660–9.