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SIMULATION OF FUZZY LOGIC CONTROLLER BASED MLI-STATCOM WITH SYNCHRONOUS REFERENCE FRAME IN POWER DISTRIBUTION NETWORK

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Abstract: In this Project Fuzzy based MLI-STATCOM with Synchronous reference frame in Distribution network is presented. In Modern distribution systems have very complex networks connected with linear and Nonlinear loads. The presence of harmonics in system it will effected with power quality problems. Due to this high amount of power losses and disoperation of power electronics devices is caused, along with this Harmonics have a number of undesirable effects like Voltage disturbances. These harmonics are needed to mitigate for Power Quality Enhancement in distributed system. To suppress harmonics and other power quality issues related to current, Distribution Static Compensator (DSTATCOM) connected across load is proved to be effective. DSTATCOM is one of the FACTS Devices which can be used to mitigate the harmonics. This paper proposes a five-level diode clamped Multilevel Inverter based Distribution STATCOM (MLI-DSTATCOM) with Synchronous Reference Frame based control for harmonic mitigation. The voltage source converter is core of the DSTATCOM and the hysteresis current control is indirect method of controlling of VSC. In this paper we implement with SRF based DSTATCOM control. SRF theory is implemented for the generation of controlling reference current signals for controller of DSTATCOM. A fuzzy logic control scheme is proposed for the controlling operation of STATCOM. The system performance will analyzed .In extension by implementing fuzzy logic control to the system the harmonics are mitigated in the distribution system and Total harmonic distortion will be reduced.

Keywords—Multilevel Inverter based Distributed STATCOM (MLI-DSTATCOM); Synchronous Reference Frame (SRF); Power Quality (PQ); Harmonic Mitigation; Active Power Filter (APF); Total Harmonic Distortion (THD).

I.INTRODUCTION

The revolution in the digital world and power electronics has a considerable impact on the electricity network. The increasing levels of nonlinear loads and power supplies are polluting electric network more and more with days passing. Low Power factor leads to reduction in energy efficiency and power handling capacity, more losses in electrical machines and appliances, torque pulsations in motor and also creating perilous disturbances to connected devices in electric network [1]-[2]. In distribution system many techniques

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and equipment's are used to mitigate power quality related issues. The most common method employed is a passive filter which suppresses harmonics thereby improving power factor and consequently reducing losses in the network and appliances, but the drawback is bulky size, resonance and limited compensation characteristics [3]. Custom Powered Devices (CPD) later introduced gave improved performance over the passive filters and are very useful for maintaining the present power quality levels [4]-[5]. To suppress harmonics and other power quality issues related to current, Distribution Static Compensator (DSTATCOM) connected across load is widely researched and proved to be effective. Other FACTS devices also have been researched widely to improve power quality, flexibility, controllability and stability. Reactive power control or compensation is of importance for stability, control and quality in power system. DSTATCOM also have a significant role to play for reactive power control in distribution network [6] - [8]. Performance of any CPDs is greatly depending on the gating pulses and the control algorithm to generate estimated reference currents. Few control algorithms mostly employed are feed forward training [6], SRF theory and instantaneous active and reactive power theory [9] –[12], Lyapunov-function control [13] and the non-linear control technique [14] etc. Performance of MLI-DSTATCOM is analyzed in this paper with nonlinear, balanced/unbalanced load. With the proposed control method, load currents, source currents and source voltages are measured. Total Harmonic Distortion (THD) of supply currents with conventional two-level DSTATCOM, three-level diode clamped and five-level diode clamped MLI-DSTATCOM is developed and analyzed in Matlab/Simulink software. This study has been expanded to active and reactive power flow analysis

II. OPERATION OF DSTATCOM

Distribution Static Compensator (DSTATCOM) is connected in parallel like a STATCOM, which is connected at transmission level where as DSTATCOM at distribution level. Its main function is to inject harmonically distorted current in phase opposition to the load current thereby suppressing harmonics in the supply current [7], in addition to this it also supplies required reactive power to the load. A typical block diagram of a DSTATCOM with unbalanced and nonlinear load is depicted in Fig. 1. DSTATCOM equivalent circuit is given in Fig. 2, where *VSabc* is phase voltage of supply; *VSHabc* is a fundamental component of phase output voltage of DSTATCOM and *I SHabc* is a fundamental component of shunt APF current. The operation of DSTATCOM is explained in the following modes.

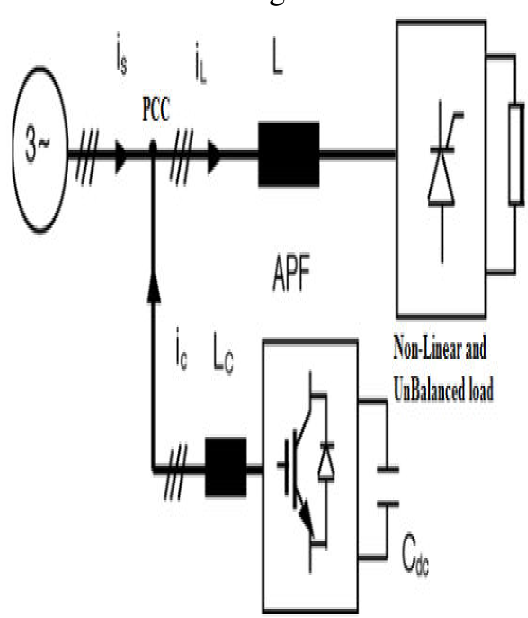

Fig. 1 Block diagram of DSTATCOM

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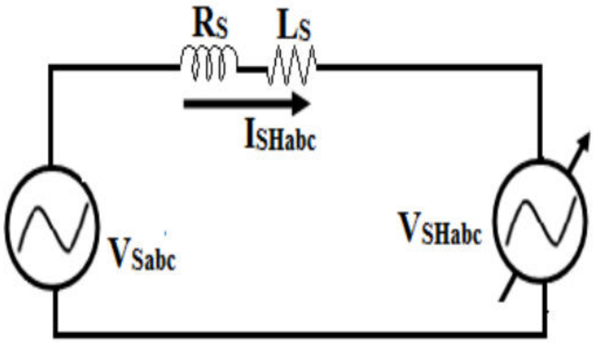

Fig. 2 Equivalent circuit of DSTATCOM

Mode 1: If *VSHabc* is in-phase and equal to *VSabc* then DSTATCOM does not inject and absorb any reactive power

Mode 2: If *VSHabc* is greater than *VSabc* and *I SHabc* leads *VSabc* by some angle, then DSTATCOM will supply the reactive power of the system. This mode can also be called as capacitive mode and its phasor representation is given in Fig. 3(a). Here DSTATCOM supply all required load reactive power thereby making supply currents free from reactive currents.

Mode 3: If *I SHabc* lags *VSabc* then DSTATCOM will take reactive power from the system. This mode can also be called as inductive mode and its phasor representation is shown in Fig. 3(b)

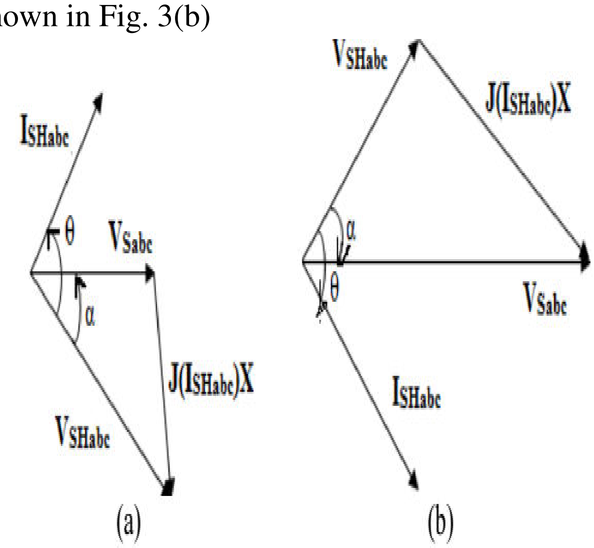

Fig. 3 Phasor representation of DSTATCOM

From the phasor diagrams it is clear that, DSTATCOM either generates or absorbs the reactive power by controlling the phase angle (α) between *VSHabc* and *VSabc* thereby regulating the magnitude of the *VSHabc* and thus DC Link capacitor voltage.

III. SYNCHRONOUS REFERENCE FRAME CONTROL

SRF control is one of the efficient controls to suppress voltage and current harmonics. It referred d-q technique, in which transformations and its inverse transformations of a-b-c to d-q-0 are used [15]. The basic SRF Control technique to generate reference currents from nonlinear balanced/unbalanced load is depicted in Fig. 4. The load currents of ab-c coordinates (*I Labc*) are transformed into d-q-0 coordinates with the help of modified PLL according to the equation (1).These d-q-0 coordinates comprises of an oscillatory component (*I ~oSd* and *I ~oSq*) and averaged component (*I ASd* and *I ASq*) resulting to oscillatory in nature. In order to avoid oscillatory response and maintain only averaged components of d-q-0 coordinates, a 2nd ordered Butterworth LPF is used. These averaged components are stable in nature and are referred to as source current averaged component (*I SdL*).

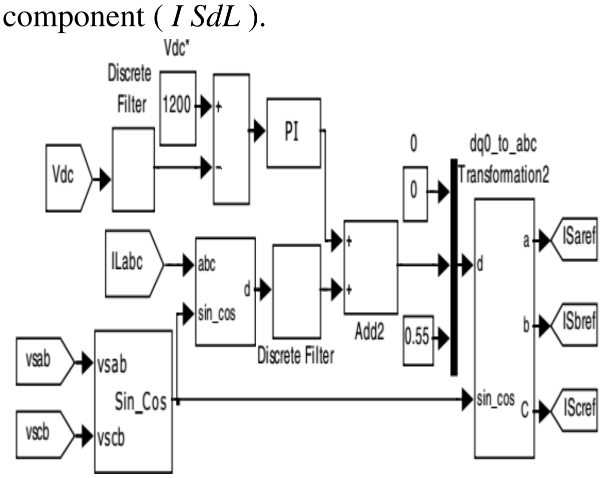

Fig. 4 Shunt Controller using SRF

$$\begin{bmatrix} I_{S0} \\ I_{Sd} \\ I_{Sq} \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ \sin(wt) & \sin(wt - 2\pi/3) & \sin(wt + 2\pi/3) \\ \cos(wt) & \cos(wt - 2\pi/3) & \cos(wt + 2\pi/3) \end{bmatrix} \begin{bmatrix} I_{Loa} \\ I_{Lob} \\ I_{Loc} \end{bmatrix} \quad (1)$$

For proper compensation, voltage of DC link capacitor must be kept constant at rated value (i.e. 1200V in this case).The PI controller is therefore used to compensate the loss component of active current (IDloss). Using Ziegler-Nichols' method, proportional gain (Kp) and Integral gain (Ki) are estimated and are fine tuned to values of 0.003 and 0.0025.The d-axis component of supply current including the active power loss component for capacitor voltage balancing can be represented by

$$I^*_{Sd} = I_{Dloss} + \overline{I}_{SdL} \quad (2)$$

Considering these currents as d-axis component, d-q-0coordinates are transformed into a-b-c coordinates with reference to equation (3) and are taken as reference supply currents.

$$\begin{bmatrix} I_{refSa} \\ I_{refSb} \\ I_{refSc} \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1/\sqrt{2} & \sin(wt) & \cos(wt) \\ 1/\sqrt{2} & \sin(wt - 2\pi/3) & \cos(wt - 2\pi/3) \\ 1/\sqrt{2} & \sin(wt + 2\pi/3) & \cos(wt + 2\pi/3) \end{bmatrix} \begin{bmatrix} I_{S0} \\ I^*_{Sd} \\ I_{Sq} \end{bmatrix} \quad (3)$$

These reference currents (I_{refSa} , I_{refSb} and I_{refSc}) are compared with load currents (I_{La} , $I_{Lb}$and I_{Lc}) to generate DSTATCOM reference currents i_{Shabc_ref}. The currents of the DSTATCOM are maintained at reference values using Hysteresis current controller as shown in Fig.5. The hysteresis current controller is operated with a lower band 0.25A and higher band of 0.5A to generate switching pulses to a five level diode clamped MLI-DSTATCOM.

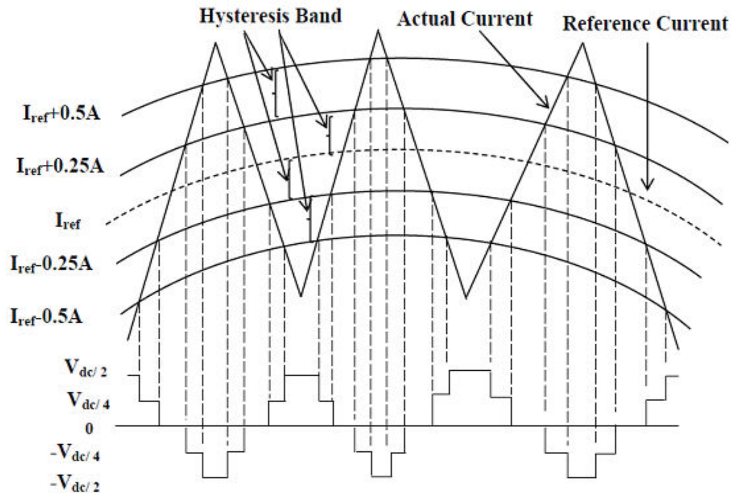

Fig..5: Hysteresis current control scheme for five level MLI-DSTATCOM

IV INTRODUCTION TO FUZZY LOGIC CONTROLLER

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components

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such as: a fuzzification interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

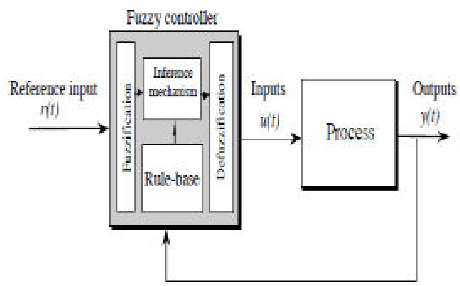

Fig.6. General Structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

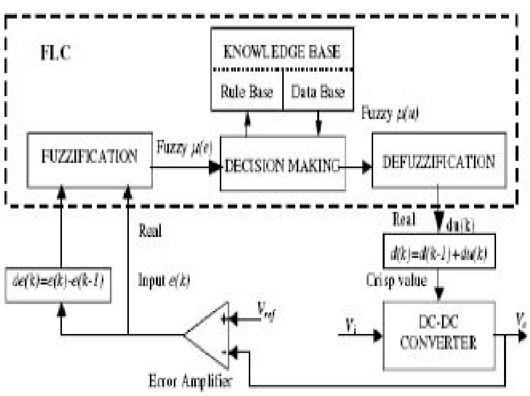

Fig.7. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

A. *Fuzzy Logic Membership Functions:*

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

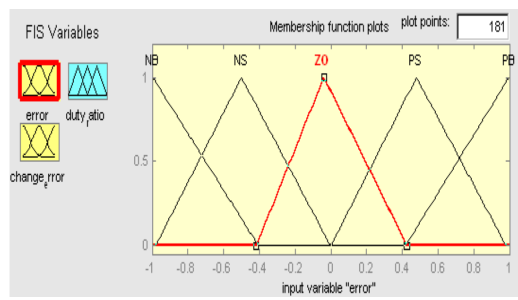

Fig. 8.The Membership Function plots of error

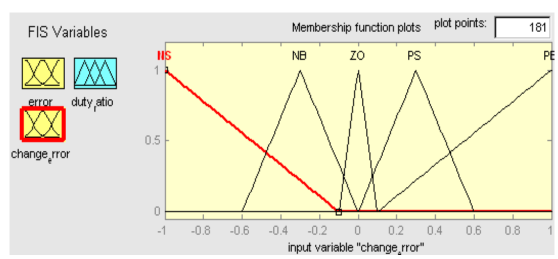

Fig.9. The Membership Function plots of change error

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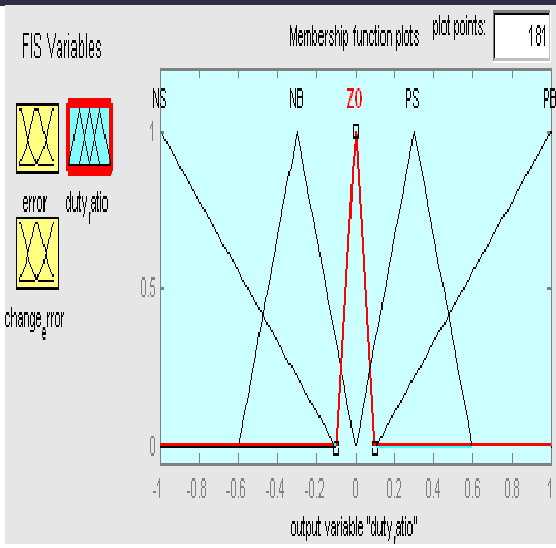

Fig.10. the Membership Function plots of duty ratio

B. Fuzzy Logic Rules:

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table I as per below:

Table I

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

Table rules for error and change of error

V.MATLAB/SIMULATION RESULTS

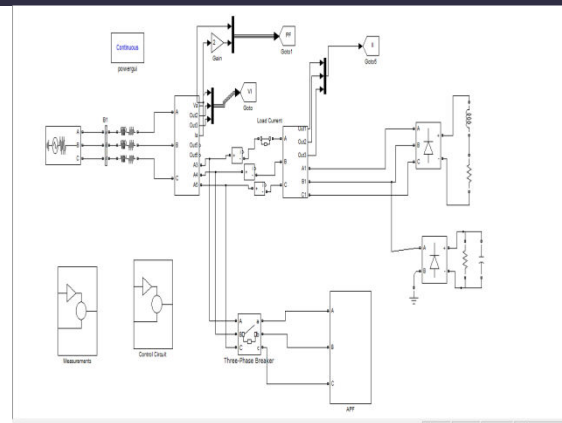

Fig 11 Matlab/simulation circuit of MLI-STATCOM

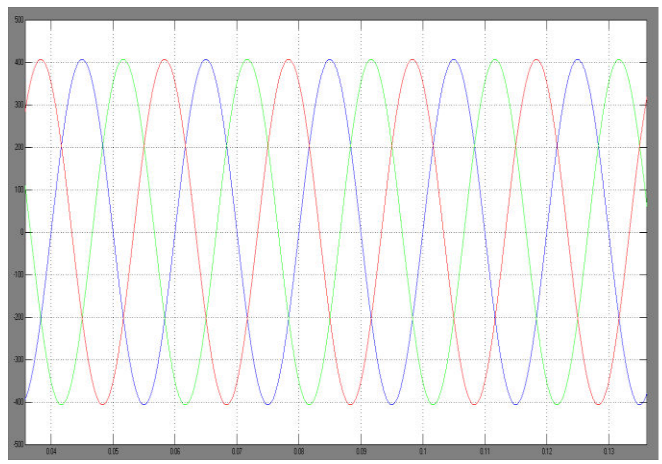

Fig 12 simulation wave form of MLI-STATCOM three phase voltage

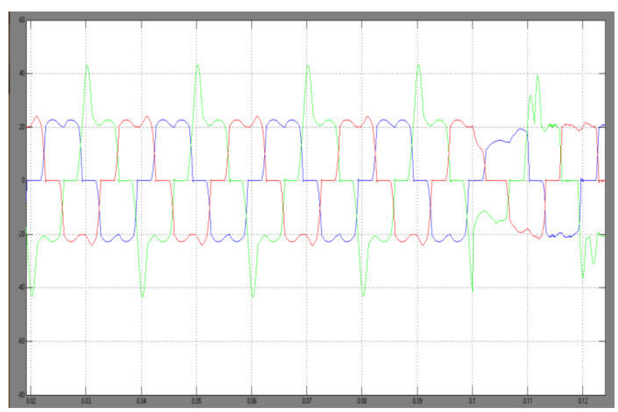

Fig 13 simulation wave form of MLI-STATCOM three phase load current

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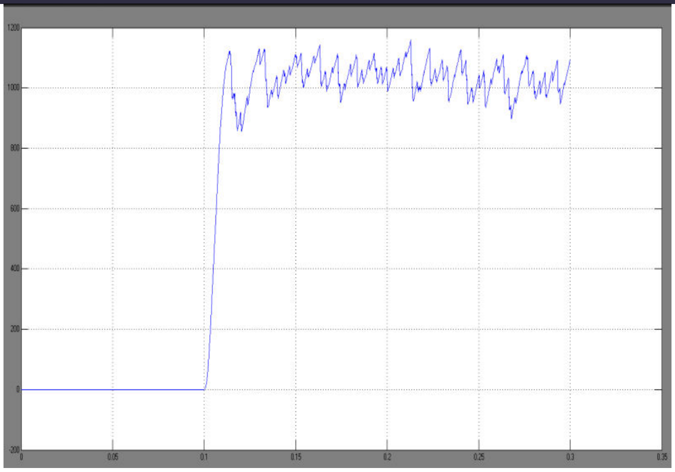
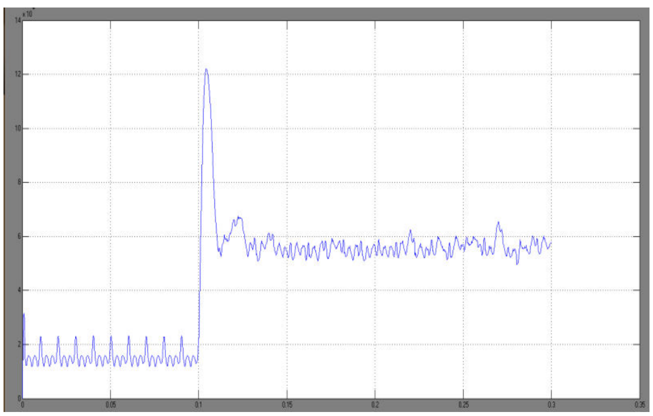
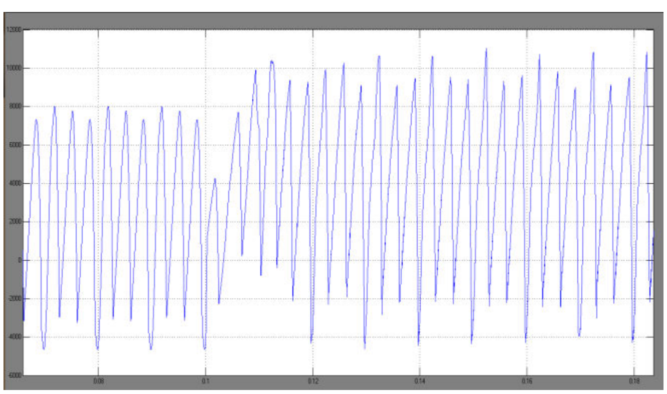


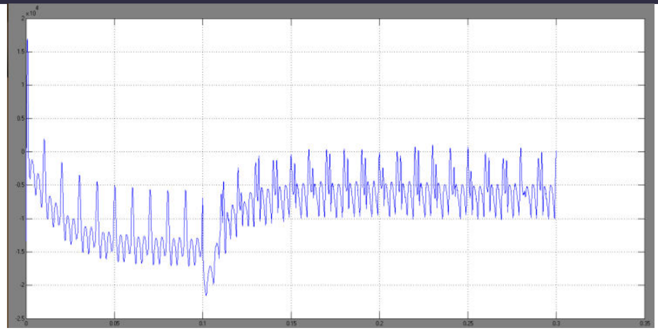
Fig 14 Simulation wave form of DC Link Capacitor voltage



(a)



(b)



(c)

Fig 15 Reactive power at (a) load (b) supply and (c) proposed MLIDSTATCOM

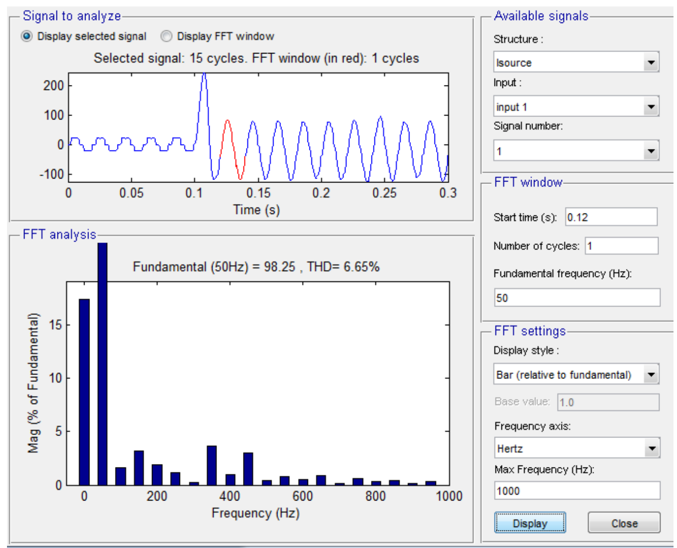
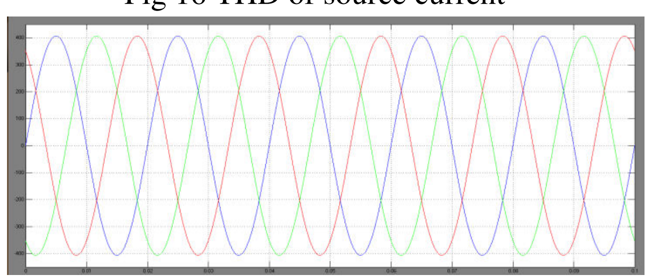
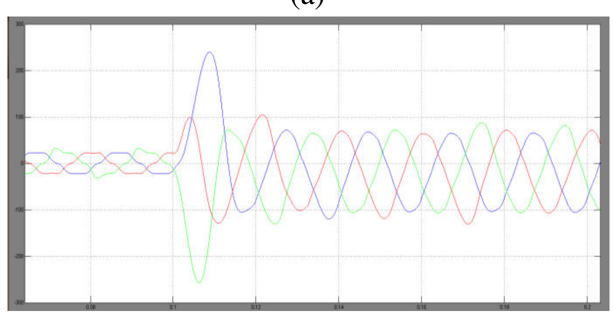


Fig 16 THD of source current



(a)



(b)

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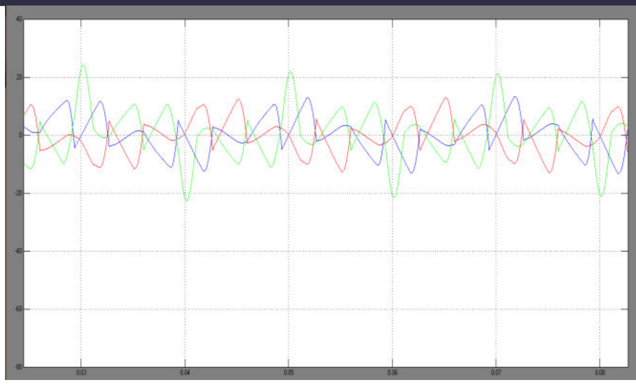
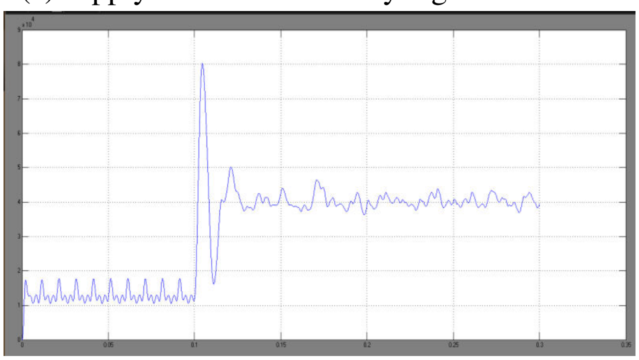
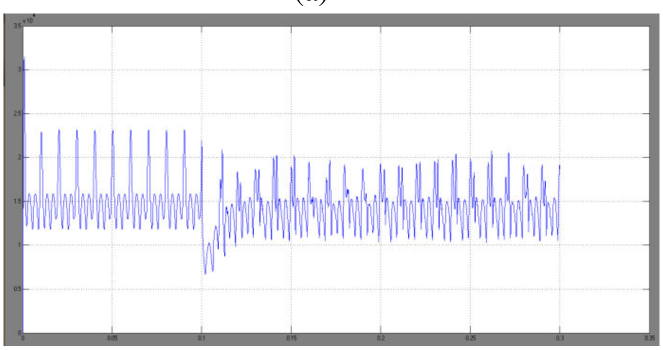


(c)

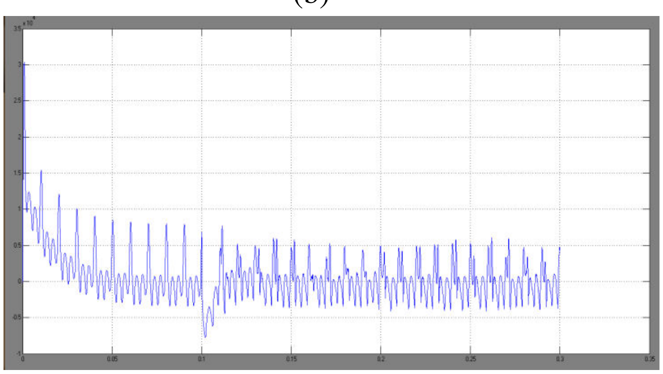
Fig 17 before and after compensation of (a) supply voltage (b) load current (c) supply current with Fuzzy logic controller



(a)



(b)



(c)

Fig 18 Reactive power at (a) load (b) supply and (c) proposed MLIDSTATCOM with fuzzy logic

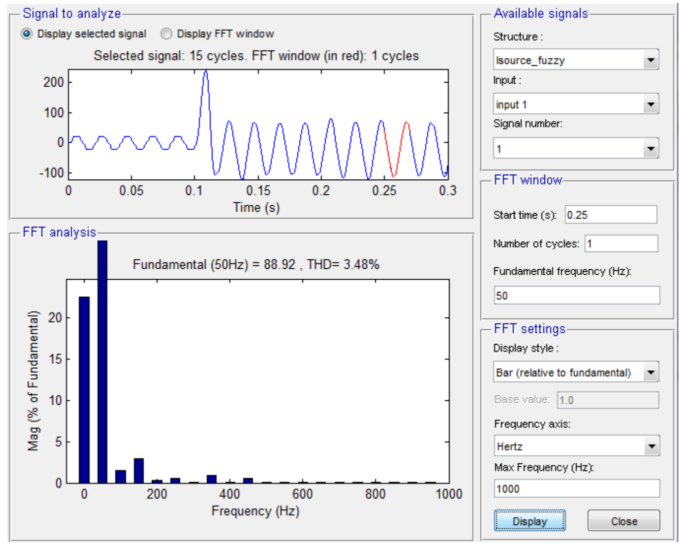


Fig 19 THD of source current with fuzzy logic

CONCLUSION

The performance of a proposed five level diode clamped MLI-DSTATCOM is analyzed using Synchronous Reference Frame based control scheme under nonlinear balanced/unbalanced load. The performance of the proposed MLIDSTATCOM is compared with conventional two-level and three-level diode clamped MLI-DSTATCOM. From simulation results, it can be observed that the proposed five level MLI-DSTATCOM compensates supply harmonics more effectively compared to the two-level and three level diode clamped MLI-DSTATCOM. The %THD of the supply currents observed to be very small after connecting the proposed five-level DSTATCOM. Hence, it can be concluded that the five-level diode clamped MLI-DSTATCOM gives superior performance compared to two-level and three-level DSTATCOM with Fuzzy logic controller the THD Value of source current is decreased

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REFERENCES

[1] Ucar Mehmet, OzdemirEngin, "Control of a 3-phase 4 leg active powerfilter under non-ideal mains voltage condition," Electr Power Syst Res2008:58–73.

[2] Phipps JK, Nelson JP, Sen PK., "Power quality and harmonic distortionon distribution systems," IEEE Trans IndAppl 1994;30:476-84.[3] Lee TL, Hu SH, "Discrete frequency-tuning active filter to suppressharmonic resonances of closed-loop distribution power systems," IEEETrans Power Electr 2011;26(1):137–48.

[4] Ghosh A, Ledwich. G., Power Quality Enhancement Using CustomPower Devices, London, U.K.: Kluwer;2002.

[5] Lee Tzung-Lin, hushang-Hung, chanyu-Hung., "DSTATCOM withpositive- sequence admittance and negative-sequence conductance tomitigate voltage fluctuations in high-level penetration of distributedgeneration systems," IEEE Trans. Ind. Electron. 2013; 60(4):1417–28.

[6] Jing X, Cheng L., "An optimal-PID control algorithm for training feedforward neural networks," IEEE Trans. Ind. Electron2013;60(6):2273-83.

[7] P. Rao, M.L. Crow, Z. Yang, "STATCOM control for system voltagecontrol applications," IEEE Trans. Power Delivery 15 (4) (2000) 1311-1317.

[8] P.S. Sensarma, K.R. Padiyar, V. Ramanarayanan, "Analysis andperformance evaluation of distribution STATCOM for compensatingvoltage fluctuations," IEEE Trans. Power Delivery 16 (2) (2001) 259-264.

[9] BenysekGrzegorz, Pasko Marian., Power theories for improved powerquality, London: Springer-Verlag; 2012.

[10] Benhabib MC, Saadate S., "New control approach for four-wire activepower filter based on the use of synchronous reference frame," Electr.Power. Syst. Res 2005; 73(3):353-62.

[11] Singh B, Solanki J., "A comparison of control algorithms forDSTATCOM," IEEE Trans. Ind. Electron 2009; 56(7):2738-45.

[12] Da Silva CH, Pereira RR, da Silva LEB, Lambert-Torres G, Bose BK,Ahn SU., "A digital PLL scheme for three-phase system using modifiedsynchronous reference frame," IEEE Trans. Ind. Electron2010;57(11):3814-21.

[13] Rahmani Salem, Hamadi Abdel amid, Kamal Al-Haddad A.,"Lyapunov- function-based control for a three-phase shunt hybrid activefilter," IEEE Trans Ind Electron 2012; 59(3):1418-29.

[14] Rahmani S, Mendalek N, Al-Haddad K., "Experimental design of anonlinear control technique for three-phase shunt active power filter,"IEEE Trans Ind Electron 2010;57(10):3364-75.

[15] Kota V.R, Vinnakoti S., "SRF-based control of unified power qualityconditioner for power quality enhancement," IEEE (EESCO), 2015,Pages: 1-6.