Improved Dynamic Performance of Power Quality Using 9 - level DSTATCOM with DG Application

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Abstract **- Accrual of electricity demand due to elevate the industrialization and population, energy generation is veritably a challenging in now a days. Improvement of power quality is the greater concern in advanced power system element, it is essential to congregate the need of energy by employ the renewable energy generating sources like pv, fuel cell, biomass, wind, etc and utilizing many more applications like grid interconnected systems, power quality improvement. The situations like harmonic, reactive power exchanging, power factor correction, balancing the load & so on, due to greater effect on highly susceptible loads are to be encouraged in power distribution system. To enhance these circumstances, custom power appliances are used to achieve high grid stability. In that CHB based D-STATCOM is a meticulous power appliance for enhancing harmonic distortions from high power semiconductor switching device, exchanging the both active & reactive power, defend the gird stability by implementing DG technology, to regulate the power quality issues in power distribution network. There are several control strategies used for this operation of D-STATCOM. This paper highlights the improved dynamic performance of 9-level CHB multilevel inverter based DSTATCOM with energy backup scheme and controlled by pwm control technique founded by IRP theory for generation of reference current signals and is also compared with 7-level CHB scheme for the better results in the view of power quality improvement by decreasing THD value. Hence proposed system is dynamically evaluated with Matlab/Simulink.**

Keywords - Cascaded H-Bridge Multilevel Inverter (CHB); Instantaneous Real-Reactive Power Theory (IRP Theory); DGS (Distributed Generation Scheme); Total Harmonic Distortion (THD).

I. INTRODUCTION

Nowadays, value of renewable energy is expand morely and installed worldwide due to contamination of environmental conditions and shortage of energy [1]. A renewable energy source produces energy, and with the importance of high rated power converters are used to interfacing the grid and enhancing the grid stability. Such energy systems transmute energy from renewable sources and exchange low voltage into high voltage with constant nature via a power electronic converter such as grid tied inverter or multilevel inverter. The conveyance of neat power has been forever an outstanding task for utility systems, in previous days the innocence of power system with virtually pure linear load, now present situation the increased growth of high rated power electronics technology (e.g. diodes, transistors, thyristors) and the implementing this way of technology in industrial and domestic applications to become the generation of qualitated power is a actually very big deal, mostly in distribution systems [2].

By the reason of these power quality issues, many of the industrial consumers are durably affected. With present scenario the development running towards the competition and deregulation in between utility systems, now the present situation of power quality problems are conclusive very important [3]. This harmonic current is more responsible for distorting the currents & voltages, increasing the power loss and generates heat on transformers and networks, and causing mis-operation of electronic equipment, minimize the life expectancy. In order to enrich these power quality issues in distribution system as well as to enhance these restriction values, two important solutions have been implemented: *LC* passive resonant compensators and power custom devices.

The attention of custom power devices (CPD) distinguishes with utilization of power electronic controllers for increasing dynamic stability in power distribution network. Moreover, there are many number of custom power devices in that CHB based distributed compensator (MLI-DSTATCOM) with integration of energy generation scheme is highly preferred for universal operation and better results. In presence of multilevel inverters (MLI) are offering to procreate helpful resolution to high range of power applications as well as power quality improvement techniques and motor drive control techniques. High efficient MLI's are used increasingly when

employing low switching frequency are proposed [4] and support of staircase output voltage is acquired by merging the various input dc voltage sources .This input dc voltage source can be obtained from distributed energy source like PV cells, fuel cells, ultra -capacitors and lithium batteries etc. Moreover the 3-level VSI have very high switching strategy; it may suffer from high switching losses, noise and EMI. Refining that output waveform with reduction of those problems and harmonic distortion values prefer multilevel inverter modules and it also minimizes the variation of common mode voltage in comparison of a normal 3-level inverter evaluated in [5]. That's why it is high suitable for many applications which requires high ampere/volt ratings.

High range multilevel inverters are separated based on design such as flying capacitor (FC), diode clamped (DC), and (CHB) cascaded H-bridge. In that CHB MLI approach has intensify output voltage with low distortion with increasing the number levels and main advantage is, needless of any clamping diodes & balanced capacitors [6]. In composition of the preferred range of output values are ascertain by modulation scheme (PWM). Therefore by the manner of governing the modulation scheme then harmonic distortions are gradually minimizes. The MLI DSTATCOM is certified as prosperous sort of advanced custom power device have following advantages,

1. It has very high range of capacity to exchange & control the flow of active power.
2. It need low maintenance and have maximized energy capacity.

This paper highlight, the integration of PV energy source with shunt compensator for enhancing the power quality issues, moreover implementation of DSTATCOM with CHB MLI has great opportunity as well as generation of reference currents by utilizing PWM based IRP theory is more preferred for shunt devices [7], it can contribute fast transient response without any loop compensation scheme. With the advance of very low cost and ease of design, it's very approved for power quality enhancing methods and improves maintenance of high grid stability.

II. PROPOSED MULTILEVEL BASED D-STATCOM WITH ENERGY SOURCE

The advancement of variant energy generating sources has turned to a global priority, arises to intensive innovation about low environmental impact of renewable energy generation schemes.

The inauguration of minor & distributed energy system has been possible because of many manipulations in economy variations and power system units. The contiguity in between consumption and production centers has retrieve importance, and high priority DG's (distributed generation) technology have great approach in recent years. DG appliances are predictable to comprehend the distribution network within the future decades. In spite of many vantage of DG can accommodate, and have lot of contradicts that demand of addressing the fully arrangement of DG into main grid system which has adequate nature of flexibility and assimilate to regulate environment economical conditions due to importance of small range of size and inferior construction lead time. Now the trend is increased, due to many benefits of utilizing RES in distributed energy generation framework (DEG). As Fig.1 depicts the sketch of proposed three phased MLI based D-STATCOM with PV source act as DG with high step up DC/DC conversion technology [8],[9]. Additionally, DG introduce identical attractive characteristics in utility systems such as increase of system security with the help of expanding the energy generation sources, improved power quality by exchanging the governable active/reactive power, ancillary benefits of economics by furnishing these permissible services and also cost saving by minimizing peak demand power.

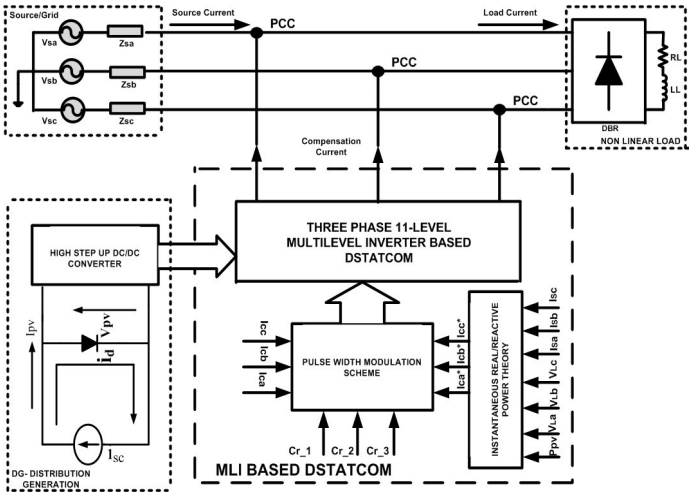


Figure 1. Sketch of Proposed Three Phase MLI Based D-STATCOM with PV Source

In utility systems, three phase diode bridge rectifier topologies are extensively used as front end conversion in many industrial drive control configurations. These types of loads acquaint more distorted harmonic currents at PCC, and it has odd range of fundamental frequency, this type of harmonic distorted currents may cause critical problems and aggravate the power quality in distribution side level networks, the shunt device was implemented to enhance those harmonic distorted currents and accordingly to ameliorate the power quality [10]. As elucidate in Figure 1., a DSTATCOM is essentially a three phased multilevel inverter (MLI) interacted as shunt/parallel at (PCC) point of common coupling through an interfacing inductor, energy generation of that DSTATCOM is implemented with large rated

dc link capacitor and support with novel DG methodology with proposed instantaneous strategy.

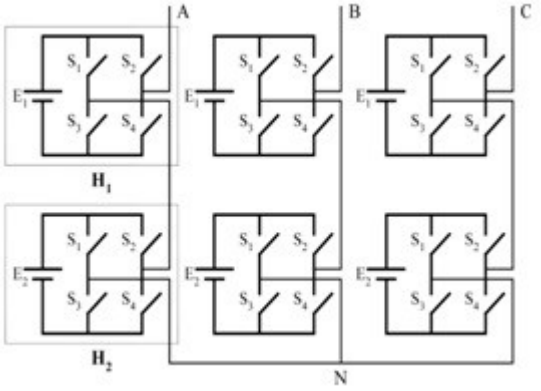


Figure 2. Sketch of Cascaded H-Bridge Based Multilevel Inverter

Most of the DG systems PV modules are more preferred because of their allied small size, low operational noise, installation to be simple, and installing them closer to users. The outcome of PV module is very low voltage the output voltage amplitude value. In order to interact the grid, need converted & boosted into an ac grid connected system. This particular task can be achieved by using multi stage conversion systems, nothing but dc/dc converter with a high frequency range transformer that amend the inverter input dc voltage [11]. Moreover, this conversion stages minimizes the system overall efficiency and makes the system to be more complex.

Inspite of above problems, multilevel converter (MLI) have better features, increases the power range getting from the PV arrays and attenuate the devices voltage stress, and produces output voltage with lower distortion values. On the other way, power semiconductor converter can also be integrating the grid for improving system power quality features. Working as active shunt compensator, they can fulfil the harmonic elimination and compensating reactive power, improving power factor with the principle of in phase opposition. For this condition, it is more convenient to incorporate both functional operation of generation of power and improving power quality using the same proposed structure presented in distributed generation scheme. A theory for the control action of DSTATCOM in three phase power distribution systems is called instantaneous p–q theory was highlighted.

III. INSTANTANEOUS P-Q POWER THEORY

The compensation proposition of this DSTATCOM belongs to two leading parts. One is the estimation of an instantaneous reference current value to counteract the harmonics or both harmonic elimination as well as reactive power simultaneously [12]. Other is procreate the pwm pulses with phase shift & level shifted pwm methods to propagate the compensation of current as a replaceable harmonic distortion level immolate in the main grid voltage. The main intension of this proposed terminology is to govern the power at point of common coupling. While achieving the energy administration operation, the DSTATCOM is indispensably controlled such a way that it always generates or absorbs active power from grid with fundamental nature.

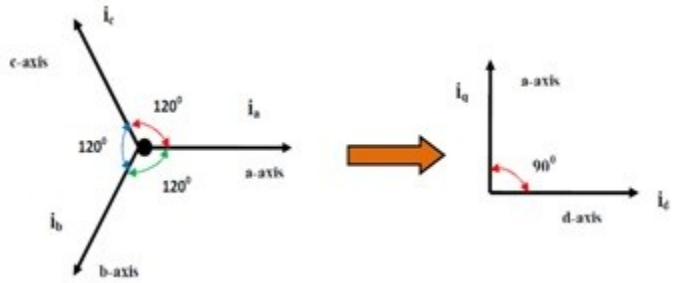


Figure 3. Transformation System (abc to 0αβ)

In this partition, the regular equations relate the instantaneous real & reactive power and symmetrical nature of theories has been evaluated & presented. Fig.2 depicts the transformation of three phase system to instantaneous phases in voltage and current, current & voltage vectors can be conceived by

$$v = [v_a \quad v_b \quad v_c]^T \quad i = [i_a \quad i_b \quad i_c]^T \tag{1}$$

The transformation of this vector from the a-b-c phases to αβ0 coordinates values can be appeared, then

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3/2} & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{3}$$

The projected instantaneous real (P) power in α-β-0 frame is extensively adjudge as follows:

$$P_{3\emptyset}(t) = v_\alpha i_\alpha + v_\beta i_\beta + v_0 i_0 \tag{4}$$

The intended instantaneous power can be estimate with the nature of zero sequence components

$$P_{3\emptyset}(t) = p + p_0 \tag{5}$$

The projected instantaneous real power lacking of no need of zero sequence components is

$$p = v_\alpha i_\alpha + v_\beta i_\beta \tag{6}$$

The intended instantaneous imaginary power (Q) is evaluated by the equation

$$q \triangleq v_\alpha i_\beta - v_\beta i_\alpha \tag{7}$$

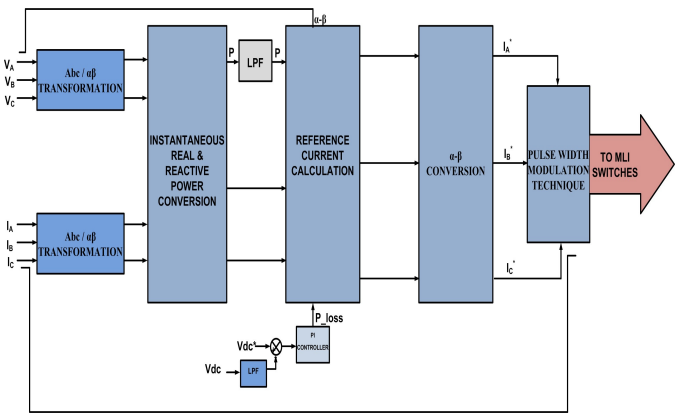


Figure 4. Schematic Diagram of Reference Current Calculation using Instantaneous P-Q Theory

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{7}$$

Separation of active & reactive power into two parts like, DC part and AC part as depicted in eq. (8) and eq. (9). Getting the DC value of active & reactive power, the signals demand of filtered using low pass filter, because of getting fundamental component & abstract the high frequency component.

$$p = \bar{p} + \tilde{p} \tag{8}$$

$$q = \bar{q} + \tilde{q} \tag{9}$$

According to instantaneous real & reactive power theory, the importance of active power (P) is delineating by DC part of reference α-β current, which is arranged as depict in eq. (10).

$$i^*_{\alpha\beta} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \tag{10}$$

Moreover the three phased absolute reference current for MLI based DSTATCOM might be supported as depicted in eq. (11)

$$i^*_{abc} = \sqrt{2/3} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3/2} \\ -1/2 & -\sqrt{3/2} \end{bmatrix} i^*_{\alpha\beta} \tag{11}$$

The load & proposed DSTATCOM acquitted and act as highly resistive load, when compensator produces the compensation currents. Reference currents are getting from reference frame calculator by evaluating proposed instantaneous power theory as depicts in Fig. 3, then after correlate the reference signals from actual signals [13], [14]. These signals are consign to pwm it generate the pulses & take over the controlling the switches the MLI DSTATCOM such that comply by a set of reference values to dampen the harmonics distortions and enhancing reactive power.

IV. EVALUATION OF MATLAB/SIMULINK MODELING & RESULTS

Simulations test is evaluated to assure the certainty of proposed system. The projected MLI based DSTATCOM was implemented to compensate harmonics distortions entail by electronic loads, and regulation of voltage profile and improves the flexibility and stability at PCC and simulated results were coming by using pwm scheme is contemplate through Matlab/Simulink software platform. All harmonic spectrum analysis is presented, should be bounded in terms of THD, and resembles to the harmonic limits constrained by international IEEE/IEC standards.

Table 1. Parameters of Proposed Improved Performance of Shunt Compensator

S.No	Parameters	Values
01	System Voltage (Ph to Ph)	11Kv
02	System Frequency	50 Hz
03	Source Impedance	0.1Ω, 0.9mH
04	Parallel LC Values	0.01 Ω, 10mH
05	Non-Linear Load	3-Phase Diode Bridge Rectifier with Resistor of 25 Ω Connected across DC side.
06	Dc link Capacitor Value (C_{DC})	8000 µF

The proposed compensator comprises of a multilevel based DSTATCOM using IGBT power device in bridge configuration, a PV based DG is enormously supports for grid

conditioning operations & maintain high stability as table I represents the parameters for entire proposed compensation principle.

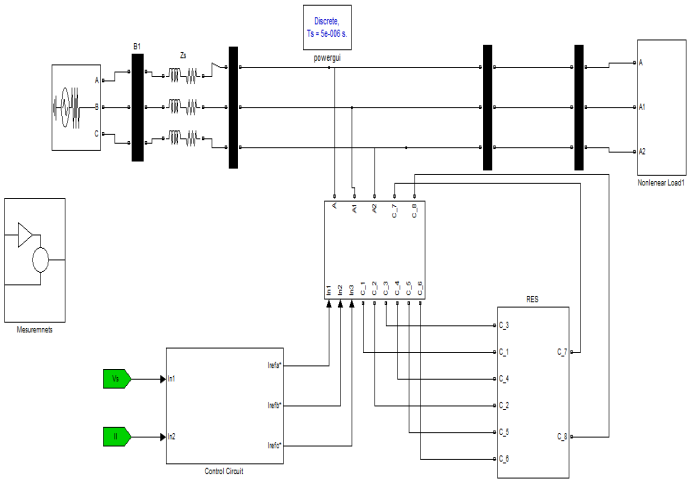
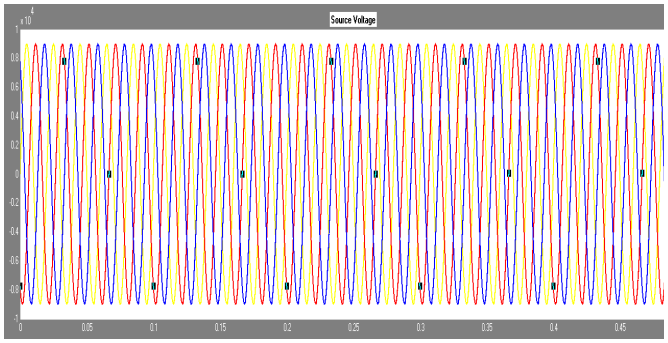
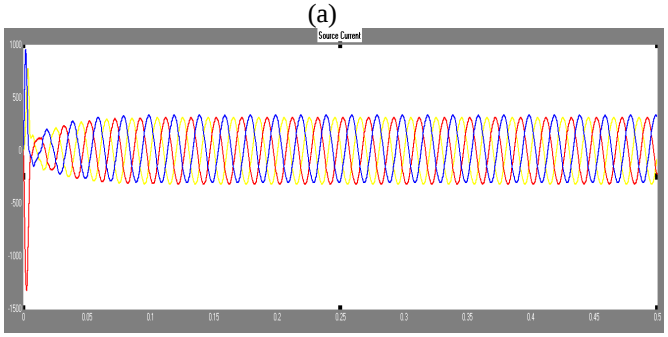


Figure 5. Matlab/Simulink Overall Configuration of Proposed Improved Dynamic Performance of MLI-DSTATCOM with DG Integrating Scheme

Figure5 depicts the matlab/simulink overall configuration of proposed improved dynamic performance of MLI-DSTATCOM with DG integrating scheme using matlab/simulink sim-power system environment.



(a)



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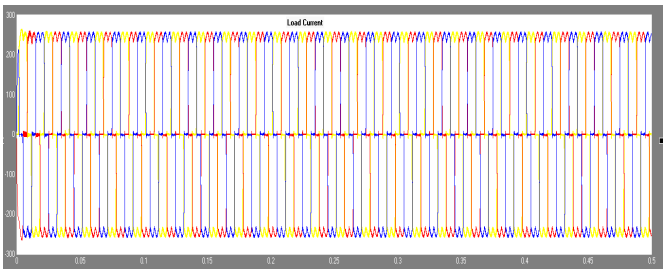

(c)

Figure 6. (a) Source Voltage (Vsabc), (b) Source Current (Isabc), (c) Load Current (Ilabc)

As above Figure 6. depicts the source voltage, source current and load current, with presence of improved dynamic behaviour of MLI D-Statcom with DG interfacing scheme.

Figure 7.shows the 9-level output voltage of improved dynamic behaviour of MLI-D-STATCOM with DG interfacing scheme, based on the H-bridges offered many levels, in this way implemented by using 3 bridge MLI for getting 9 levels.

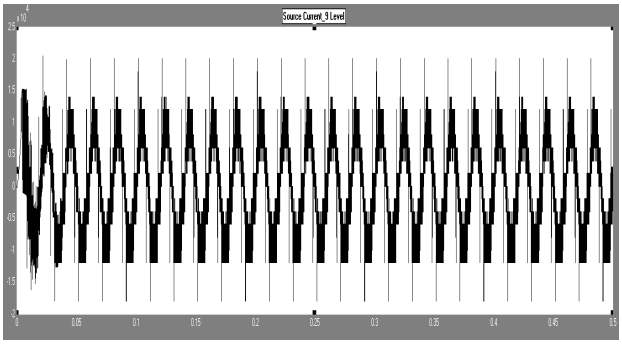

Figure 7. 9-Level Output Voltage

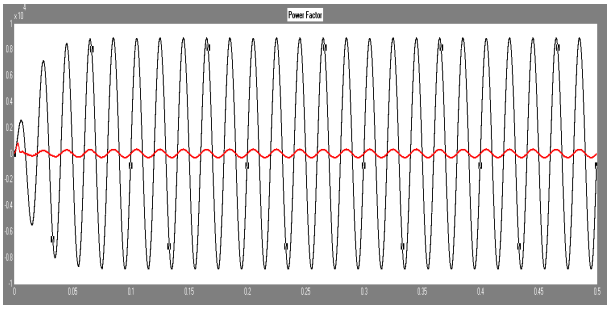

Figure 8. Power Factor at Source Side

Figure 8. shows the power factor at source side of improved dynamic behaviour of MLI-DSTATCOM with DG interfacing scheme, due to the DSTATCOM correct the power factor values with in standard range of values.

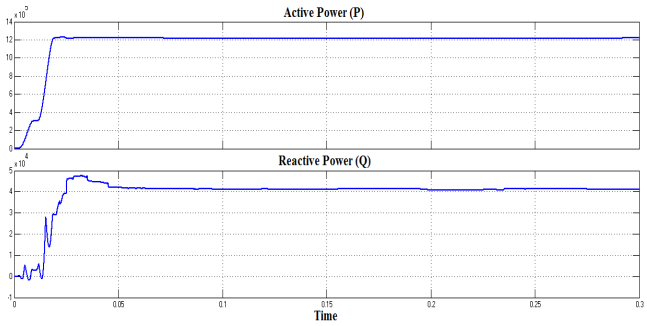

Figure 9. Load Side Active & Reactive Power

Figure 9. shows the Load Side Active & Reactive Power of improved dynamic behaviour of MLI-D-STATCOM with DG interfacing scheme, with DG the load power maintains constant and also regulate the voltage within the tolerance values and maintain high grid stability.

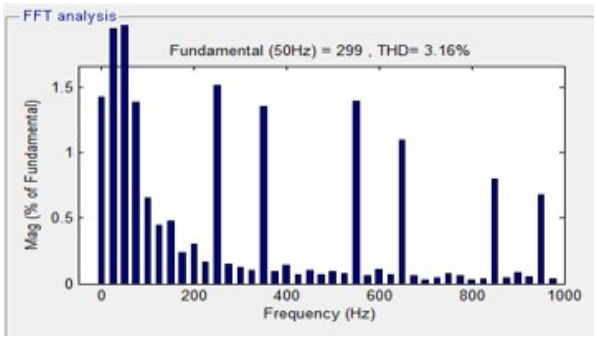

Figure 10. FFT Analysis of source current of 7-Level MLI-DSTATCOM with DG's

Figure 10. shows the FFT Analysis of source current of 7 level MLI-DSTATCOM with DG interfacing scheme and the THD value of source current is 3.16%.

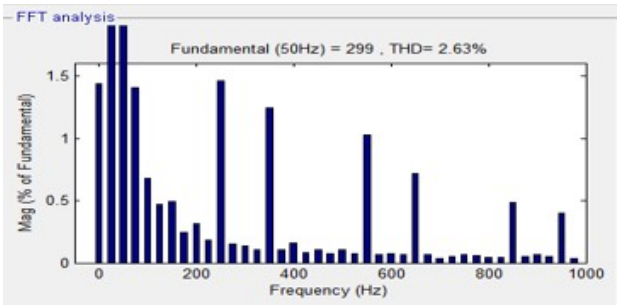

Figure 11. FFT Analysis of source current of 9-Level MLI-DSTATCOM with DG's

Figure 11. Shows the FFT Analysis of source current with improved dynamic behaviour of 9-Level MLI D-STATCOM with DG interfacing scheme, then THD of source current is 2.63%.

V. COMPARISON BETWEEN 7 AND 9 LEVEL SCHEMES

The dynamic performance of power quality improvement using MLI-DSTATCOM with DG has been implemented by MATLAB/SIMULINK for 7 and 9 levels. From the above two figures 10 and 11, the THD values are observed. In the 7-level scheme we got 3.16% and with 9-level scheme is of 2.63%. As levels increases THD value getting decreases, so that improving the power quality. Hence 9-level DSTATCOM with DG scheme will give better dynamic performance compared to 7-level DSTATCOM with DG scheme.

VI. CONCLUSION

The main intention of this paper is to accomplish a CHB based multilevel DSTATCOM for distribution generation application for enhancing power quality features with intended control strategy for generation of reference currents & directly fed to modulation method for production of pulses, based on these pulses MLI based DSTATCOM counteract the harmonic distorted s production from very high switching semi conductor devices and maintain load reactive power as a constant with the use of distribution generation concept based on load variations and also voltage detection and enhancing entire in the power distribution system. The control strategy makes DSTATCOM should be reduced the distortions in current and maintain voltage stability in line and improve the grid stability at the PCC and balance the distribution line parameters with respective to the system conditions. At last the comparative evaluation of proposed 7-level & 9-level based DSTATCOM were presented. In the 7-level scheme the THD value is 3.16% and with 9-level scheme is of 2.63%. As the number of levels increases THD value getting decreases leads to better dynamic performance, so that improving the power quality. Hence 9-level DSTATCOM with DG scheme giving better dynamic performance as compared to 7-level DSTATCOM with DG scheme.

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