

# A Novel ANPCI-DSTATCOM for Power Quality Improvement in Distribution System

Jibin Joseph, Divya S

**Abstract** - This paper deals with power quality problems in distribution system and its solution by implementing a new system which is ANPCI-DSTATCOM. The improvement of power quality is a frequently discussed issue, which still requires a considerable research effort to be devoted to the study of the problem. Due the intensive use of power converters and other non-linear loads in industry and by consumers, an increasing deterioration of the power systems voltage and current waveforms are observed. The DSTATCOM is one of the efficient custom power device, which is used to compensate current quality problems of sensitive loads. Here the DSTATCOM consists of a shunt converter which is derived from ANPC inverter, having a dc link. A control strategy known as PLL reference control is used to produce the gate signals for ANPC inverter to balance the unbalanced current present in the load currents. In this paper, ANPCI-DSTATCOM is developed using Simulink in MATLAB.

**Index Terms** – Active Neutral Point Clamping Inverter (ANPCI), Harmonics, Power quality, Distribution Static Compensator (DSTATCOM), Phase locked loop (PLL).

## I. INTRODUCTION

Recently, power quality problems have become an important issues for electricity consumers at all the level of usage. The deregulation of electric power energy has boosted the public awareness toward power quality among the different categories of users. To provide an active & flexible solution for power quality problems, various efforts have been taken from time to time. Among these power quality solutions, the lossless passive filters consisting of L-C tuned component have been widely used to suppress harmonic [1,2]. Passive filters are advantageous as its initial cost is low and high efficiency, on the other hand it have various drawbacks of instability, fixed compensation, resonance with supply as well as loads and utility impedance. To overcome these limitations active power filters [3] have been used. The concept of the custom power is tools of application of power electronics controller devices into power distribution system to supply a quality of power, demanded by the sensitive users. They have good performance at medium distribution levels and most are available as commercial products

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VSI are generally used For the generation of custom power devices, due to self-supporting of dc bus voltage with a large dc capacitor[4]. DSTATCOM (Distribution Static Compensator) is an important device for correcting power factor, to maintaining constant distribution voltage and to mitigate harmonics in a distribution network. There are many industrial applications where a DSTATCOM offers very fast response to reactive power demand. Therefore it can be used for power factor correction and voltage regulation. A DSTATCOM is a controlled reactive source which includes a Voltage Source Inverter (VSI) and a DC link capacitor connected in shunt, capable of generating and /or absorbing reactive power. It is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle[5,6]. The VSI connected in shunt with the ac system provides a multifunctional topology which can be used for up to four quite distinct purposes:

- Power factor improvement
- Current Harmonic compensation
- Load current balancing
- Flicker effect compensation

Here a three-phase five-level inverter using coupled inductors (ANPCI) is working as shunt inverter. With the proposed inverter, one dc voltage source is needed and which eliminates the problem of dc capacitor voltage balancing with the conventional topologies [7-10]. Eight power switches with the same voltage stress and only one set of coupled inductors are adopted [11]. It is, in fact, the adoption of the coupled inductors that makes it possible to generate an output of five-level voltage with only one dc voltage source. The presented topology is very suitable for low to medium power applications and also for high-current cases [12-15].

## II. STRUCTURE AND WORKING OF ANPC INVERTER

The figure 1 represents the circuit diagram of the inverter using coupled inductors. It needs a dc input voltage and  $L_1$  and  $L_2$  are the two coupled inductors. The mutual inductance of the two inductors is  $M$  and the output terminals of this inverter are A, B and C. Obviously, this topology is very simple and can be constructed simply by the addition of a coupled inductor to a conventional three-arm inverter bridge. It is the adoption of the coupled inductors that makes it possible to output five-level voltage with only one dc voltage source. Suppose that the two coupled inductors are with the same number of turns or

obtained by a center-tapped inductor. Actually the coupled inductors will perform as an adder of the two input voltage at the non-common-connected terminals with the common-connected terminal as the output. Actually, without the help of the coupled inductors, the proposed inverter will not be able to output five-level voltage. The power switches in one arm are assumed to switch complementarily. For instance,  $S_2$  must be turned OFF if  $S_1$  is turned ON and vice versa.

The coupled inductors also carry half the load current besides the ripple current and thus the switch  $S_3/S_4$  carries about half the load current if the ripple component is low. The high-switching frequency devices ( $S_3, S_6$ ) take only half the load current while the low-switching frequency devices ( $S_1, S_2, S_7, S_8$ ) carry the whole load current. Thereby, the switching and conduction losses of  $S_3, S_6$  will not be very high because they only carry half of the load current. This characteristic of the proposed inverter makes it very suitable for high-current applications.

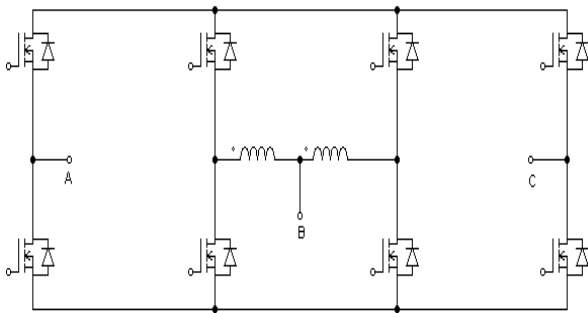


Figure.1 Proposed Three Phase ANPC Inverter

A. Implementation of Shunt Connected ANPCI-DSTATCOM

The active filter concept uses power electronics to produce harmonic current components that cancel the harmonic current components from the non-linear loads. The active filter uses Power electronic switching to generate harmonic currents that cancel the harmonic currents from a non-linear load. In this configuration, the filter is connected in parallel with the load being compensated. Therefore the configuration is often referred to as an active parallel or shunt filter. Figure.2 illustrates the concept of the harmonic current cancellation so that the current being supplied from the source is sinusoidal. The ANPC inverter used in the active filter makes the harmonic control possible. This inverter uses dc capacitors as the supply and can switch at a high frequency to generate a signal that will cancel the harmonics from the non-linear load.

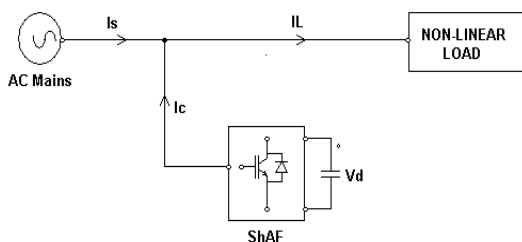


Figure.2 Line diagram of Shunt ANPCI-DSTATCOM.

III. DISTRIBUTION SYSTEM UTILIZING ANPCI-DSTATCOM

Recently, the utility service providers are putting more and more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads, to control the power distribution system harmonics pollution. At the same time, the use of sophisticated equipment or load has increases significantly, and it needs clean power for its proper operation. Fig.3 shows the novel ANPCI-DSTATCOM topology. As shown in Figure.3, the DSTATCOM should be connected in shunt with the line to function as a controlled voltage source.

If we could use the neutral of three-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system. The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology or a four leg voltage source inverter (VSI) topology for a shunt inverter. The four-leg VSI topology requires one additional leg as compared to the split capacitor topology. VSI structure is much easier than that of the split capacitor. But here the UPQC design by using IARC control and it is connected to 3P4W system.

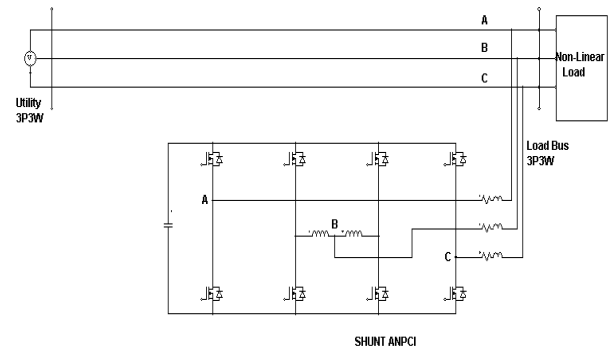


Figure.3 ANPCI-DSTATCOM Connected Three Phase Distribution System

IV. DESIGN OF ANPCI-DSTATCOM CONTROLLER

A. Controller for Shunt Active Filter

The control algorithm for shunt VSI is based on PLL reference control generation scheme. The reference signals extracted for shunt inverter from actual load current. The reference voltage signals for phase a, b, c can be represented as:

$$\begin{bmatrix} V_{la} \\ V_{lb} \\ V_{lc} \end{bmatrix} = \begin{bmatrix} V_l \sin \omega t \\ V_l \sin(\omega t - 120) \\ V_l \sin(\omega t + 120) \end{bmatrix} \quad (1)$$

Here a PLL is used to generate the reference voltages. This Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. If the Automatic Gain Control is enabled, the input (phase error) of the PLL regulator is scaled according to the input signal magnitude. These reference voltage signals are then compared with the voltage at the point of common coupling (PCC). The resulting signal is

used to generate the gate pulses for shunt filter, by using a relay. The relay will output the specified 'on' or 'off' value by comparing the input to the specified thresholds. The on/off state of the relay is not affected by input between the upper and lower limits.

V. SIMULATION RESULT ANALYSIS OF PROPOSED ANPCI-STATCOM

The simulation results for the proposed distribution system utilizing ANPCI-DSTATCOM are shown in below figures. The proposed ANPCI-DSTATCOM should maintain the system current at a desired value and free from distortion and also it maintains the dc-link voltage at a set reference value. The shunt inverter injects the required compensating current through series transformer, making the load current free from distortion and at a desired level. The simulation result shows that the proposed ANPCI-DSTATCOM topology is an effective solution for a three phase distribution system which feeds non-linear loads. In this paper a three phase diode rectifier is connected to load side for representing non-linear load.

Table No.1 simulation parameters

Source	Voltage	440V, 50Hz
	Impedance	R=1Ω, L=1μH
DC link	Capacitor	C=500mF
Neutral Point	Coupled inductors	L= 1mH
Shunt active filter	MOSFET	Rs=100kΩ, Cs=∞
Load	Non-linear load	10KW

The following typical studies have been simulated and the results are presented.

- Compensation of unbalanced current.
- Power factor correction
- Harmonic compensation

A. Simulation Results without Compensator

In AC power distribution systems, harmonics occur when the normal electric current waveform is distorted by non-linear loads. When a three phase distribution system is connected with highly non-linear loads, it will affect the total system parameters. In the below figures, we can see the distorted wave forms of current and power factor of the system without ANPCI-DSTATCOM. In a balanced distribution system, where each phase carries an equal amount of current, the currents cancel each other out when they combine at the common neutral conductor to return to the source, causing the neutral current to be zero.

With non-linear loads, the third harmonic on all three phases is exactly in phase and adds, rather than cancels, thus creating current and heat on the neutral conductor. Left untreated, harmonic loads can reduce the distribution capacity and degrade the quality of the power of public utility power systems and result in equipment malfunctions such as communication errors and data loss.

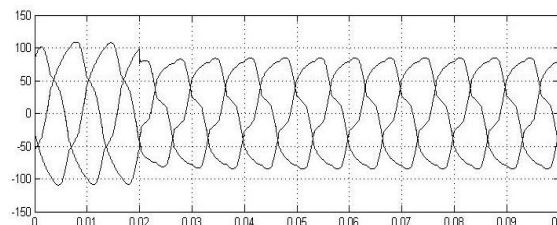


Figure.4 System Current without ANPCI-DSTATCOM

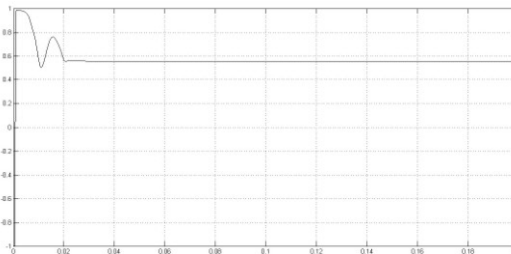


Figure.5 Power Factor without ANPCI-DSTATCOM

B. Simulation Results with Proposed ANPCI-DSTATCOM

Current Compensation: Figure 6 shows the unbalanced and distorted load current due to the effect of non-linear loads. The amplitude of the wave form increased and distorted, which may cause undesired operation of other systems connected to the main system. Figure 8 shows the balanced and maintained system current. Current compensation is successfully done by proposed ANPCI-DSTATCOM. Figure 7 shows the shunt injected current by the device.

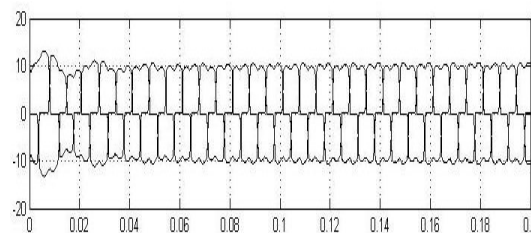


Figure.6 Unbalanced Load Current

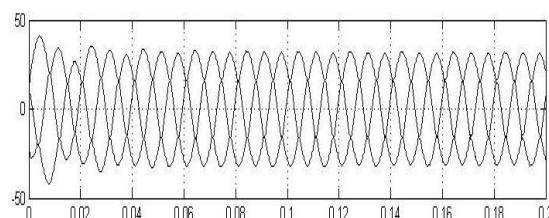


Figure.7 Injected Current

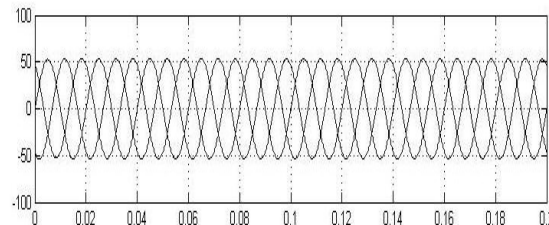


Figure.8 Maintained Source Current

Power Factor Improvement: In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires and

other equipment. Because of the costs of larger equipment and wasted energy, electrical utilities will usually charge a higher cost to industrial or commercial customers where there is a low power factor. A high power factor is generally desirable in a transmission system to reduce transmission losses and improve voltage regulation at the load. It is often desirable to adjust the power factor of the system above 0.9, as in figure 9. When reactive elements supply or absorb reactive power near the load, the apparent power is reduced. DSTATCOM is one of the effective custom power devices, which improves the power factor of the overall system.

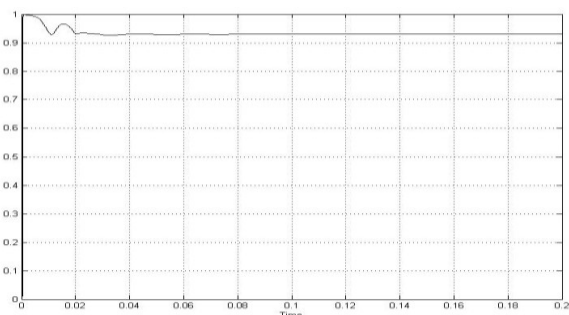


Figure.9 Improved System Power Factor

THD Analysis: Non-linear load draws harmonic currents, there for the system may get distorted. The dynamic behaviour of industrial loads such as rolling mills, arc furnaces, traction loads and large fluctuating single-phase and three phase rectifier loads draw wildly fluctuating amounts of reactive power from the supply systems. Harmonics are sinusoidal voltages or current having frequency that are integer multiples of the fundamental frequency. These loads cause fluctuations in the supply voltages and currents.

The FFT analysis of the proposed ANPCI-DSTATCOM System is shown in below figure 10. The compensated system current having a THD of 0.62%. Thus the proposed ANPCI-DSTATCOM system should maintain the system current at a desired value and free from distortion.

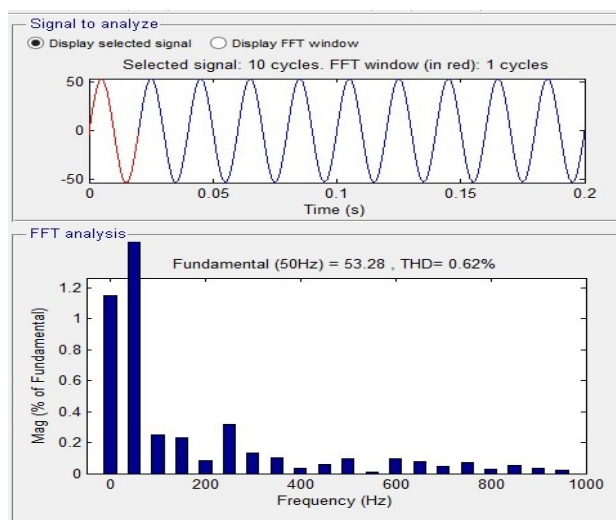


Figure.10 System Current Harmonic Analysis of ANPCI-DSTATCOM System

## VI. CONCLUSION

The proposed model is feasible and will be helpful to improve the power quality. Shunt converters allow the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than the conventional approaches. In the present paper, we have observed that application of the five-level converter provides quality compensation compared with that of the conventional converters. The objective of this work is to study the performance of ANPCI-DSTATCOM for improve the power quality in distribution network with non-linear loads. The proposed three-phase five-level inverter is based on coupled inductors. Meanwhile, the voltage stresses on all the power switches are the same and only four switches are operated at high frequency. The FFT analysis of the proposed circuit shows the THD value is only about 0.62% and hence it is proven that the proposed system is more efficient. The simulation results show that perfectly balanced system current and are free from distortion. Here we are absorbing current unbalance and reduced the total harmonic distortion (THD). It is concluded that ANPCI-DSTATCOM has a huge scope in improving power quality in distribution systems.

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