Harmonics Reduction using Active Power Filter with HBCC Approach

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***ABSTRACT*-This paper presents harmonics reduction using active power filter based on synchronous reference frame theory. The synchronous reference frame theory is used to recognize and extract harmonic distortion, hysteresis band current control. This approach is used to control load current and determine signal for inverter gates. The proposed method introduces compensating current to eliminate the harmonics generated due to three phase non-linear load. After injecting compensating current at the point of common coupling, input source current becomes pure sinusoidal hence the total harmonic distortion is highly reduced.**

Keywords-Active power filter, Harmonics reduction, SRF, HBCC

I. INTRODUCTION

The main problem due to harmonics is power losses. The active power filter plays a vital role in the harmonics elimination and distortion detections. The basic principle of active power filtering is to synthesize and apply a certain current or voltage waveform at a specified point of a distribution network. Active filters are fundamentally static power converters designed to synthesize a current or voltage source.The common application of active filtering combines the tasks of harmonic filtering and power factor compensation. Murat et *al*. illustrated that the adaptive band current controller for active power filters to eliminate harmonics and compensating the reactive power of three phase rectifier [1].

Sasan *et al*., represented that the hysteresis current control technique based on unipolar pulse width modulation with time and magnitude error control to reduce switching losses and to improve the quality of output current [2]. In the similar manner, Abaali *et al.*, reported the modified synchronous detection for determine the reference compensating currents of the shunt active power filter under non sinusoidal voltage conditions [3].

Routimo *et al.*, describes about the improving active power filter performance with a prediction based reference generation [4]. Recent scenario in the field of active power filters is used to reduce the neutral current and also naturally acceptable total harmonic distortion for each line current [5]. Traditionally active filters was used as a solution used for the problems caused by the following malfunction like reactive power compensation, harmonics and cost effective in power conditioning [6]. The present research paper describes about the compensating current to eliminate the harmonics generated due to three phase non-linear load system. The simulation results explain in detail about the harmonic distortion is highly reduced.

II. SHUNT ACTIVE POWER FILTER

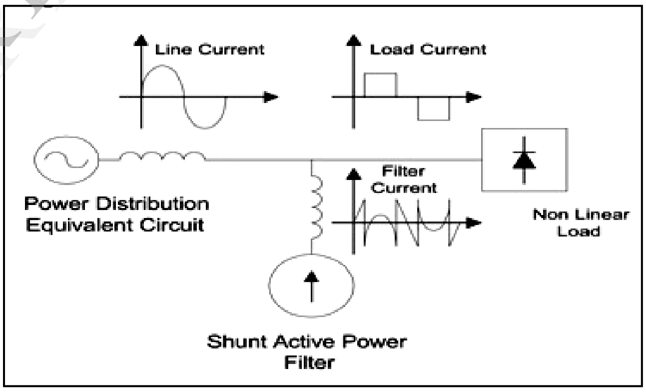

Figure 1: Illustrates the schematic diagram of Shunt active power filter compensation

The shunt active power filter (SAPF) is connected in parallel with the line through a coupling inductor. The main application of SAPF is used for the detection of the harmonic load current. The harmonic load current is injected into the system to compensate distorted current identical with the load harmonic current in the opposite phase. As a result, the net current drawn from the distribution network will be a sinusoidal current. In the overall system by including feedback loops functions like reactive power compensation, Flicker/imbalance compensation can be performed.

III. PROPOSED TEST SYSTEM

1. Synchronous Reference Frame Theory(D-Q-O)

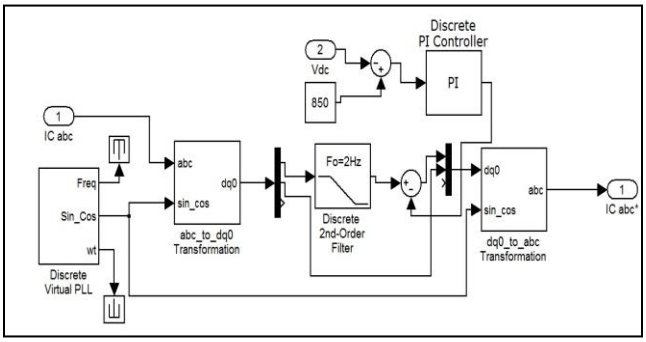

Figure 2: Represents the schematic diagram of Synchronous reference frame theory (D-Q-O)

In current research paper explain about the synchronous frame theory. It is used to extract harmonics by separating DC and AC parts of the current. The time variant current with fundamental frequencies are constant even after transformation and also harmonics with different speed remain time variant in this reference frame. Thus reference frame rotates synchronous with fundamental currents. The voltage ripple in DC link will get increased due to inverter circuit which affects the performance of filter. To rectify the above mentioned problem, the PI regulator is used, where the DC link voltage is compared with reference voltage through which d component of current is extracted.

a. abc to dq0 Transformation

$$i_d = \frac{2}{3}\left[i_a \sin(\omega t) + i_b \sin\left(\omega t - \frac{2\pi}{3}\right) + i_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right] \rightarrow [1]$$

$$i_q = \frac{2}{3}\left[i_a \cos(\omega t) + i_b \cos\left(\omega t - \frac{2\pi}{3}\right) + i_c \cos\left(\omega t + \frac{2\pi}{3}\right)\right] \rightarrow [2]$$

$$i_0 = \frac{1}{3}\left[i_a + i_b + i_c \right] \rightarrow [3]$$

$$\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(\omega t) & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \rightarrow [4]$$

The abc to dq0 transformation shown in the Figure 2 and it has two inputs and one output. The first input is a vectorized sinusoidal phase signal to be converted (Phase a, Phase b, Phase c) and the second input is a vectorized signal conditioning the [sin (ω t), cos (ω t)] values, where w is the rotation speed of the reference frame. The output is a vectorized signal conditioning in the three sequence components (d, q, 0) in the same units as the (a, b, c) input signal.

b. dq0 to abc Transformation

$$i_a = \left[i_d \sin(\omega t) + i_q \cos(\omega t) + i_0 \right] \rightarrow [5]$$

$$i_b = \left[i_d \sin\left(\omega t - \frac{2\pi}{3}\right) + i_q \cos\left(\omega t - \frac{2\pi}{3}\right) + i_0 \right] \rightarrow [6]$$

$$i_b = \left[i_d \sin\left(\omega t + \frac{2\pi}{3}\right) + i_q \cos\left(\omega t + \frac{2\pi}{3}\right) + i_0 \right] \rightarrow [7]$$

$$\begin{bmatrix} i_a^{*} \\ i_b^{*} \\ i_c^{*} \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & \cos(\omega t) & 1 \\ \sin\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) & 1 \\ \sin\left(\omega t + \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) & 1 \end{bmatrix}\begin{bmatrix} i_d \\ i_q \\ i_0 \end{bmatrix} \rightarrow [8]$$

The dq0 to abc transformation shown in the Figure 2 has two inputs and one output. The first input is a vectorized signal containing the sequence components (d, q, 0) to be converted and the second input a vectorized signal conditioning the [sin (ω t), cos (ω t)] values where w is the rotation speed of the reference frame. The output is a vectorized signal conditioning the three sinusoidal quantities (Phase a, Phase b, Phase c) in the same units as the (d, q, 0) input signal.

2. Hysteresis Band Current Control Technique

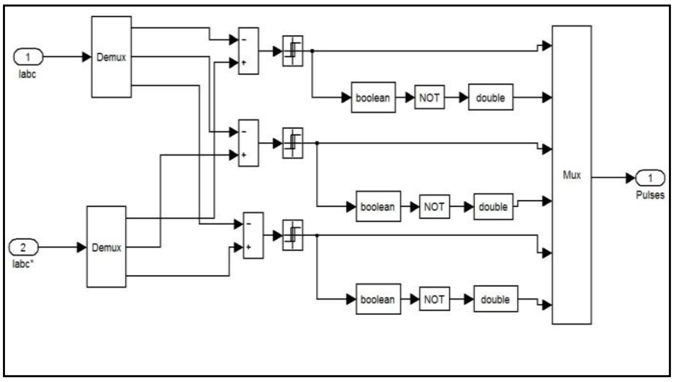

Figure 3: Represents the schematic diagram of Hysteresis band current controller

The hysteresis band current control techniques are used to control load current. It is used to determine the switching signal for inverter gates. The hysteresis modulation is a feedback current control method, where the actual current tracks the reference current within hysteresis band. The reference current used here is obtained using synchronous reference frame theory. The hysteresis band current controller shown in the figure 3 explains the operation of hysteresis current control techniques. The controller compares the sinusoidal current of desired magnitude and frequency with the reference current. If the current exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result the current starts to decompose. If the current crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result the current gets back in to the hysteresis band. Therefore, the actual current is forced to track the reference current within the hysteresis band.

IV. SIMULATION MODEL OF TEST SYSTEM

Design Specification and Circuit Parameters		
S.No	Simulation Parameters	Range
1.	AC supply voltage	200 volt
2.	Fundamental frequency	50 Hz
3.	Load resistance	30 Ω
4.	Load inductance	1 µH
5.	Line inductance	0.35 µH
6.	Inverter inductance	7 µH

Table 1: Represents the Design Specification and Circuit Parameters

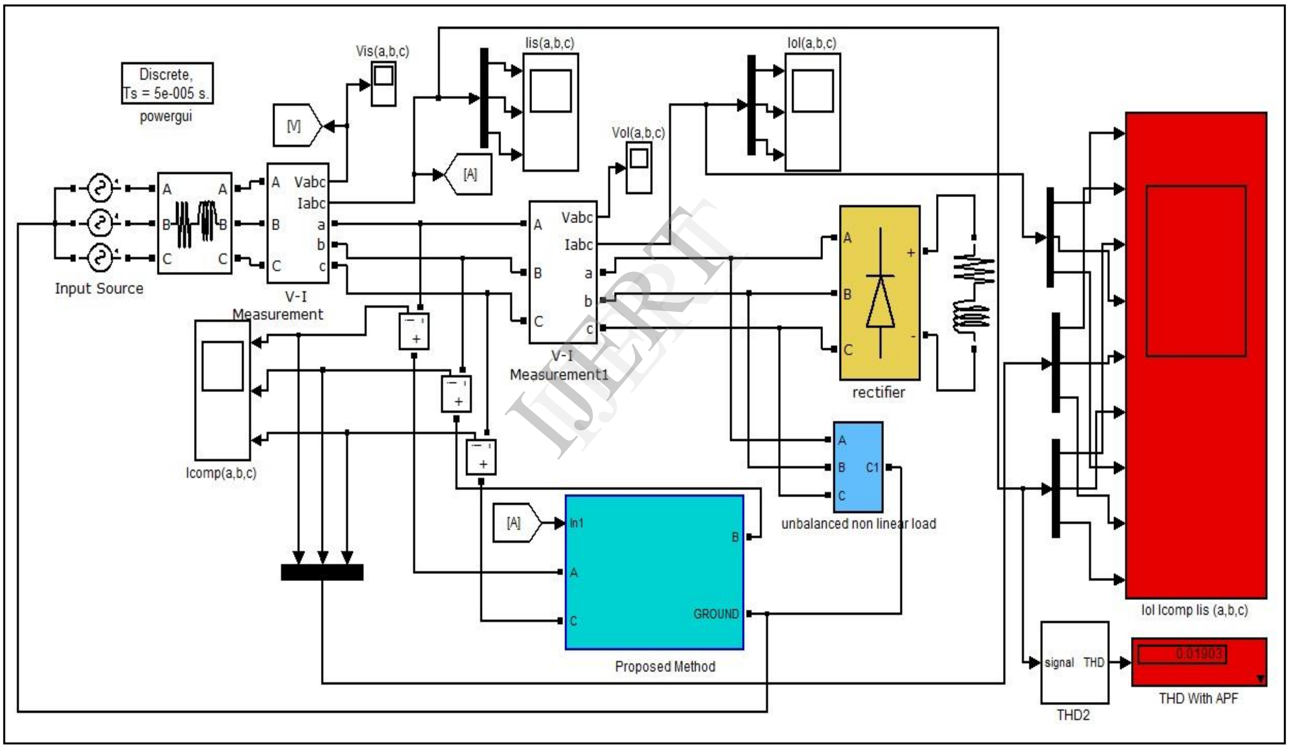

Figure 4: Represents the schematic diagram of Test system with Active Power Filter

V. SIMULATION RESULT AND DISCUSSION

The simulation is performed using MATLAB Simulink platform for three phase nonlinear load and the test system specification are shown in table.1. The synchronous reference frame theory detects the harmonic distortion and the hysteresis current control technique generates the gate pulse for inverter and shunt active power filter eliminates the harmonic by injecting compensating current at point of common coupling.Fig.5 shows the waveform of overall test system with shunt active power filter.

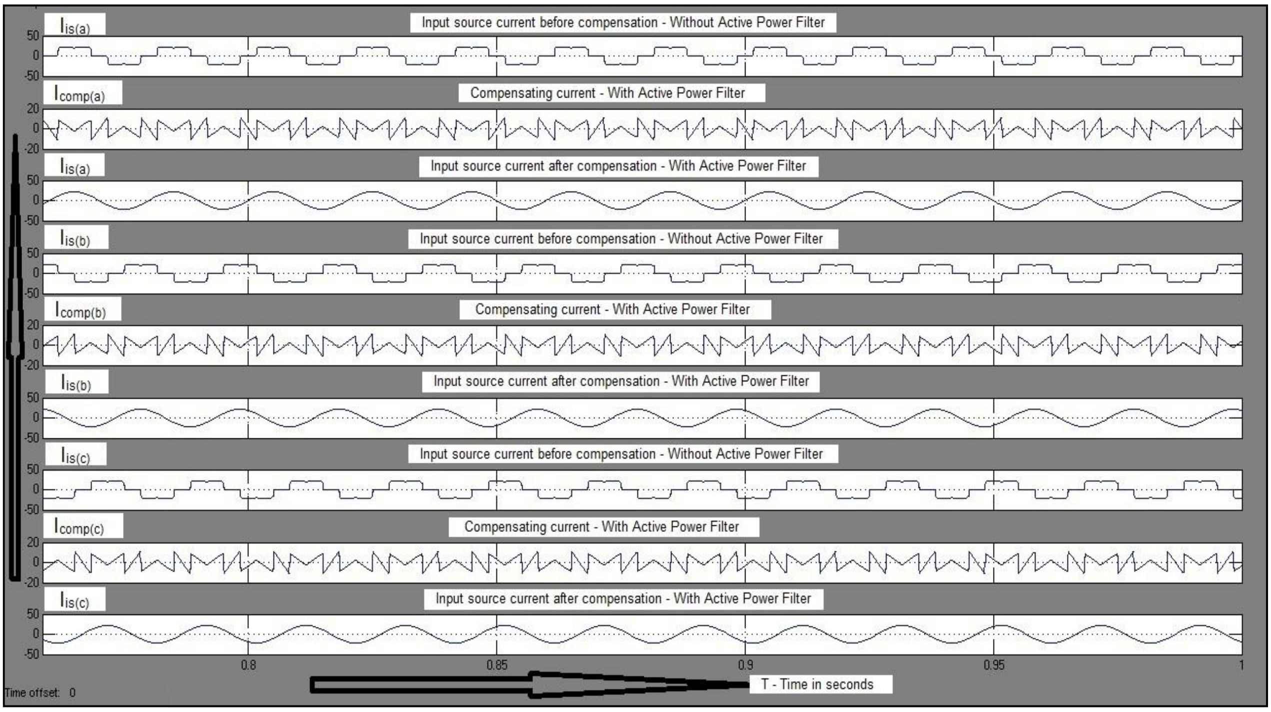

Fig.5. $I_{is\ (a,b,c)}$ Input source current(Without Active Power Filter), $I_{comp\ (a,b,c)}$ Compensating current(With Active Power Filter), $I_{is\ (a,b,c)}$ Input source current(With Active Power Filter)

Total Harmonic Distortion-THD			
S.no	Input Source Current	Without Active Power Filter	With Active Power Filter
1.	Phase-A	33.49	1.903
2.	Phase-B	32.10	1.833
3.	Phase-C	31.09	1.724

Table 2: Represents the Total Harmonic Distortion-THD

The table.2 shows total harmonic distortion reduction after connecting the proposed method with the test system. In phase A Total Harmonic Distortion was reduced from 33.4% to 1.9%, In phase B Total Harmonic Distortion was reduced from 32.1% to 1.8% and in phase C Total Harmonic Distortion was reduced from 31.09% to 1.7%.

VI. CONCLUSION

The synchronous reference frame theory recognizes and extracts harmonic distortion, hysteresis band current control approach controls load current and determine signal for inverter gates. Thus the proposed method introduces compensating current to eliminate the harmonics generated due to three phase non-linear load. The simulation results show that total harmonic distortion is highly reduced and power quality enhancement is achieved using proposed method.

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BIOGRAPHIE

Mr.J.Vikramarajan received his Master degree in Power Electronics and Drives and Bachelor degree in Electrical and Electronics Engineering from VIT University, India. His research interests are power electronic applications, power quality, power electronic converters and power electronic controllers for renewable energy systems.