# Performance Analysis Of Dstatcom With Icosφ Algorithm Using Adaptive Hysteresis Current Controller

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***Abstract :*** With the development in power system the biggest challenge facing the electrical industry is power quality (PQ) issues. One of the most common power quality problem is current based issues. In order to get good quality of power these current based PQ issues have to be mitigated. In this paper DSTATCOM (Distributed Static Compensator) is used to mitigate current based power quality issues with IcosΦ control approach. The switching pulses for the Voltage Source Inverter (VSI) are generated from Adaptive Hysteresis Current Controller (AHCC) method. The simulation results in MATLAB/SIMULINK are used to show the effectiveness of the proposed structure and its controlling approach on the current disturbances.

***IndexTerms* - Power quality, DSTATCOM, IcosΦ, AHCC**

## I. INTRODUCTION

Today the most important material used by residential and industrial areas is electrical power. So electrical power became very important part of everyones life. It is important to provide uninterrupted and undistorted power supply. Earlier the loads were only linear loads.

But by the introduction of power electronic devices like silicon controlled rectifier (SCR), Insulated gate bipolar transistor (IGBT), power diode, Metal oxide semiconductor field effect transistor (MOSFET) ,most of the loads used are non linear and are very sensitive. The current drawn by these non linear loads like variable speed drives, uninterrupted power supplies and all kind of rectifier draw a non sinusoidal current from the network. Therefore they can be considered to be harmonic current sources. This may also distort the source current too. It will be a cause for low power factor, harmonic and reactive disturbances and reduces the efficiency of power system. And this may affect all other linear and non linear loads which are connected.

In order to eliminate this power quality issues filters are used. The filters may be passive or active. Passive filters use resistors inductors and capacitors and they do not depend upon any type of external power source. Due to some drawbacks in passive filters they are not commonly used. Active power filters (APF) has been proved to be most prominent one of different technical option available to eliminate harmonics and compensate reactive power. APF are constructed using both passive and active elements. Active power filters can be classified into shunt active power filter (SAPF), series active power filters, hybrid active power filters.

SAPFs are widely used in power system to compensate reactive power and current harmonics. SAPF act as a current source by introducing harmonic component created by the load. It supplies a compensating current at the point of common coupling (PCC). The performance of SAPF largely depends on control strategy which is used to generate complementary harmonic current to cancel the harmonic current to cancel the harmonics present in the load current.

The different control algorithms used in DSTATCOM (distribution static compensator) are Instantaneous Reactive Power Theory (IRPT), Synchronous Reference Theory (SRF), Synchronous Detection Method, Simple Peak Detection method. The IcosΦ algorithm is one such algorithm used in DSTATCOM. This makes the controller simple, effective and ease of implementation in real time applications.

The SAPF performance in terms of mitigating harmonics from source to Point of Common Coupling (PCC) is achieved using Adaptive Hysteresis Current Controller (AHCC). In AHCC the bandwidth is changing as a function of reference current and voltage.

## II. IcosΦ CONTROL

Figure1 shows the general block diagram of IcosΦ control algorithm used for the estimation of reference supply current. In this load current $i_{La}.i_{Lb},i_{Lc}$, PCC voltages $v_{sa},v_{sb},v_{sc}$, supply currents and DC voltage $v_{DC}$ of VSC of DSTATCOM are sensed as feedback control signals.

The magnitude IcosΦ is the active portion of fundamental load current. A second order low pass filter (LPF) is used to extract the fundamental load current with a phase shift of $+90^0$ . A zero crossing detector (ZCD) is used to detect the negative going zero crossing of corresponding phase voltage. The fundamental phase voltage is extracted using LPF before being fed to ZCD. The phase shifted current goes as sample input of ZCD, output pulse goes as the hold input of the sample and hold circuit whose output is IcosΦ magnitude. The average of these values in three phase is then derived using summing amplifier with gain of 1/3.

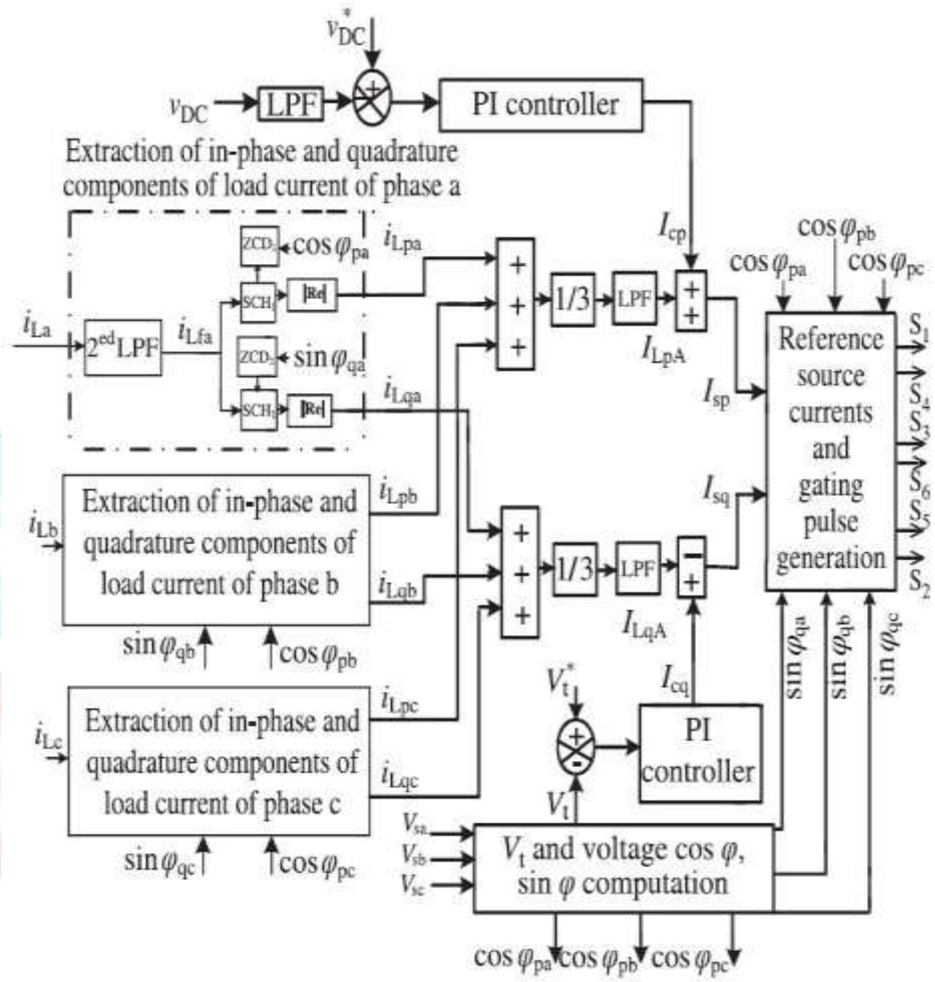


**Fig.1 Block diagram of IcosΦ algorithm**

The three phase instantaneous voltages for phase are specified in the following equation

$$v_a = V_m Sin(\omega t) \tag{1}$$

When the system is supplied by a non linear load the harmonics will be present in load current for phase a, it can be expressed as,

$$i_{La} = \mathrm{Re}(I_{La1}) + I_m(I_{La1}) + I_h \tag{2}$$

Real component of fundamental load current of phase a is

$$\mathrm{Re}(I_{La1}) = |I_{La}| \times \cos\phi_a \tag{3}$$

Magnitude of desired source current of phase a is the average of magnitude of fundamental load component

$$I_s(ref) = \frac{\mathrm{Re}(I_{La1}) + \mathrm{Re}(I_{Lb1}) + \mathrm{Re}(I_{Lc1})}{3} \tag{4}$$

Ua is the amplitude of phase to ground voltage of phase a

$$U_a = 1 \times \sin(\omega t) \quad (5)$$

The desired source current for phase a is

$$i_{sa}ref = |I_s(ref)| \times U_a = I_s(ref) \times \sin(\omega t) \quad (6)$$

The reference compensation current for SAPF is the difference between actual load current and desired source current

$$i_a(comp) = i_{La} - i_{sa}(ref) \quad (7)$$

## III. ADAPTIVE HYSTERISIS CURRENT CONTROLLER

Due to the unconditional stability, fast response the hysteresis current controller is most commonly used in Voltage Source Inverter (VSI) in SAPF. But it has the disadvantage of uncontrollable high switching frequency and this may induce high switching losses. Adaptive hysteresis current controller (AHCC) changes the hysteresis bandwidth based on instantaneous compensation current variation to get the required switching frequency.

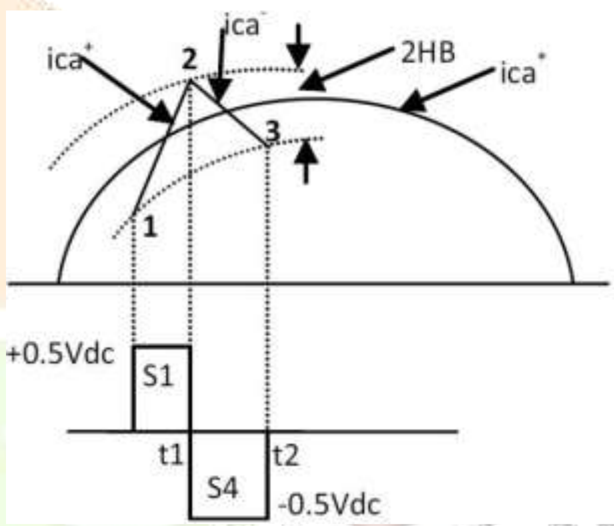


**Figure 2. current and voltage waves with AHCC**

Figure2 shows the inverter current and voltage for phase a. Current crosses the lower hysteresis band at point 1 then the upper switch of the inverter is turned ON. When the current touches band at point 2 then the lower switch of the inverter is turned ON

The following equations can be written in switching intervals $t_1$ and $t_2$ ,

$$di_a^+ = \frac{1}{L}(.5V_{DC} - V_a) \quad (8)$$

$$di_a^- = -\frac{1}{L}(.5V_{DC} + V_a) \quad (9)$$

The following equations are written in switching intervals $t_1$ and $t_2$. L is the phase inductance. $i_a^+$ and $i_a^-$ are the rising and falling current segments respectively. From the geometry of figure following equations are written.

$$\frac{di_a^+}{dt} t_1 - \frac{di_{ref}}{dt} t_1 = 2HB \quad (10)$$

$$\frac{di_a^-}{dt} t_2 - \frac{di_{ref}}{dt} t_2 = -2HB \quad (11)$$

(12)

$$t_1 + t_2 = T_c = \frac{1}{f_c}$$

$t_1$ and $t_2$ are the switching intervals, $f_c$ is the modulation frequency.

$$\frac{di_a^+}{dt}t_1 + \frac{di_a^-}{dt}t_2 - \frac{1}{f_c}\frac{di_{aref}}{dt} = 0 \quad (13)$$

Subtracting (11) from (10)

$$\frac{di_a^+}{dt}t_1 - \frac{di_a^-}{dt}t_2 - (t_1 - t_2)\frac{di_{aref}}{dt} = 4HB \quad (14)$$

$$(t_1 + t_2)\frac{di_a^+}{dt} - \frac{di_a^-}{dt}t_2 - (t_1 - t_2)\frac{di_{aref}}{dt} = 4HB \quad (15)$$

Substituting (9) in (14)

$$(t_1 - t_2) = \frac{\frac{di_{aref}}{dt}}{f_c\left(\frac{di_a^+}{dt}\right)} \quad (16)$$

Substituting (16) in (15)

$$HB = \frac{0.125V_{DC}}{f_c L}\left[1 - \frac{4L^2}{V_{DC}^2}\left[\frac{V_a}{L} + m\right]^2\right] \quad (17)$$

m is the slope of reference current signals. The hysteresis band (HB) can be modulated at different points of fundamental frequency cycle to control the switching pattern of the inverter.

## IV. SIMULATION RESULTS AND ANALYSIS

Software simulation of SAPF with three phase diode rectifier with RL load is done in MATLAB/SIMULINK. The following waveforms shows the source current before and after compensation.

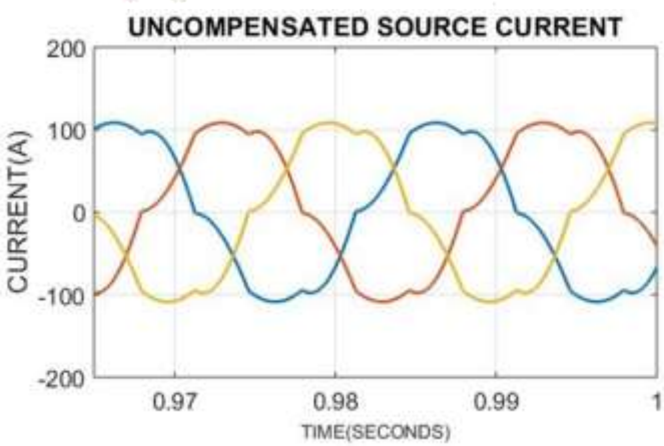


**Figure 3: source current before compensation**

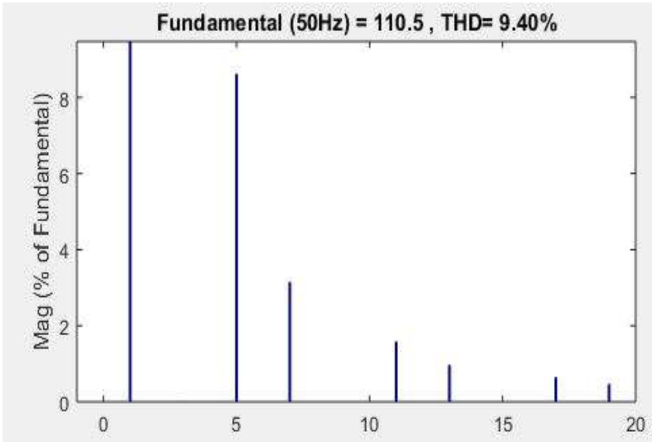


**Figure 4: THD before compensation**

When the non linear load (consist of 6 diodes with RL impedance) is given to a power system, it will generate 6-pulse rectifier waveform

The rectifier source current is shown in figure 3 and it is distorted because of non linear load. And its THD value is 9.4% in figure4.

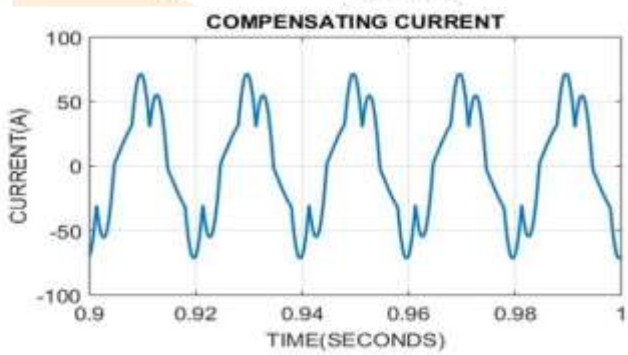


**Figure 5: Compensating current for phase A**

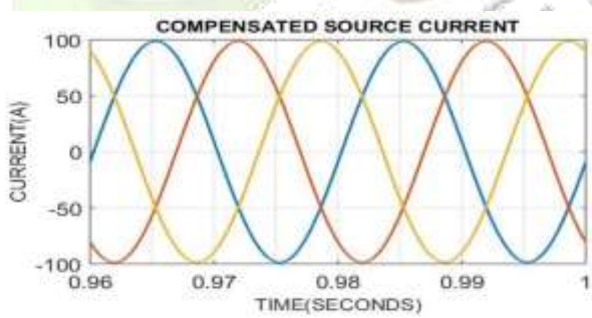


**Figure 6: compensated source current**

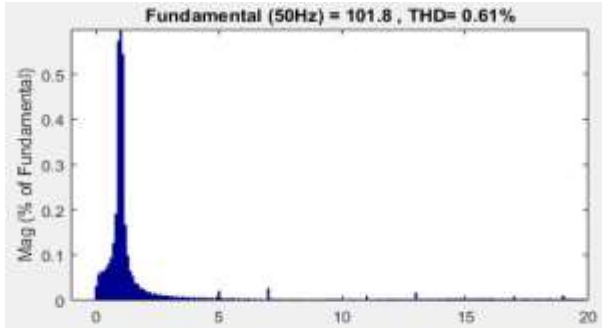


**Figure 7: THD after compensation**

Figure 5 shows the waveform of compensating current that was injected by SAPF using IcosΦ AHCC algorithm. The source current becomes purely sinusoidal shown in figure 6. And its THD value is 0.6%.

**Table.1 THD and Power Factor analysis**

| THD AND POWER FACTOR BEFORE AND AFTER COMPENSATION FOR DIODE RECTIFIER WITH RL LOAD | | | |
|---|---|---|---|
| BEFORE COMPENSATION | | AFTER COMPENSATION | |
| THD | PF | THD | PF |
| 9.4 | 0.871 | 0.6 | 0.9621 |

The table.1 shows that THD value is reduced to 0.6% after compensation. And power factor is also improved.

## V. CONCLUSION

In this work a Shunt active power filter with IcosΦ with AHCC algorithm is designed and simulated for compensation of three phase non linear load. The results shows that the source current is compensated and its THD is 0.6% and it is within IEEE 519-1992 standard limit of 5%. The power factor is also improved.

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