

# Comparison of Sinusoidal Current Control Strategy & Synchronous Rotating Frame Strategy for Total Harmonic Reduction for Power Electronic Converters in Aircraft System under Different Load Conditions

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**Abstract:** Two dissimilar control strategies for extracting reference currents for shunt active power filters have been evaluated and their performances have been compared under various non linear loads. Comparison of the compensation ability of different control strategies based on THD and speed will be done and suggestions will be given for the selection of strategy to be used under different load. The simulated results using MATLAB model are presented and they will clearly prove the effectiveness of the proposed control method of aircraft shunt APF.

**Keywords:** Active power filter (APF), Sinusoidal current control strategy, Synchronous reference frame strategy, harmonic compensation.

## I. INTRODUCTION

Conventional aircraft power systems has started using more electric power to drive aircraft subsystems which was earlier driven by a combination of mechanical, electrical, hydraulic, and pneumatic systems. The latest power electronics devices have given the momentum in the improvement of the performance of the aircraft electrical systems and this leads to advanced aircraft power system [1]-[3]. In aircraft electrical system, different types of loads require power supplies that are different from those provided by the main generators and also used different source frequency i.e. 400 Hz as compare to normal supply of 50Hz. Due to increased application of power electronic devices in the system, the system suffers from the problem of harmonics, reactive power and flow of neutral current. Shunt active power filter has been applied to aircraft system for the compensation and improvement of power quality[4],[7],[9]-[10],[12]-[13],[15]. The shunt APF is realized by using one voltage source inverters (VSIs) connected at point of common coupling (PCC) with a common DC link voltage [5]-[8].

This paper presents simulation of two different popular control strategies (Sinusoidal current control strategy and Synchronous reference frame strategy) for the extraction of the reference currents for a shunt active power filter connected to aircraft power utility. Block diagram of the system using different control strategies has been shown in Figure 1. Both strategies have been simulated using MATLAB/Simulink and their comparative evaluation has been done under various loads connected alone and together [1].

The organization of the paper has been done in the following manner. Section I gives the Introduction of the Routing Efficient Opportunistic. Section II and Section III is helpful to understand the background of related work and System modelling. Section IV show the performance of proposed technique and the last section V concludes the paper and followed by the references.

## II. SINUSOIDAL CURRENT CONTROL STRATEGY (S.C.C.)

Sinusoidal current control strategy is a modified version of constant source instantaneous power strategy, which can compensate load currents under unbalanced conditions too. The modification includes a positive sequence detector which replaced the 6.4 KHz cutoff frequency low-pass filters and correctly finds the phase angle and frequency of the fundamental positive sequence voltage component and thus shunt active power filter compensates the reactive power of the load. While designing this detector, utmost care should be taken so that shunt active filter produces ac currents orthogonal to the voltage component, otherwise it will produce active power.  $i_{\alpha}$ ,  $i_{\beta}$ ,  $p^*$  and  $q^*$  are obtained after the calculation from  $\alpha$ - $\beta$ -0 transformation block and send to the  $\alpha$ - $\beta$  voltage reference block, which calculates  $v_{\alpha^*}$  and  $v_{\beta^*}$ . Finally,  $\alpha$ - $\beta$ -0 inverse transformation block calculates the  $V^*_{sa}$ ,  $V^*_{sb}$  and  $V^*_{sc}$ . In place of the filtered voltages used previously,  $V^*_{sa}$ ,  $V^*_{sb}$  and  $V^*_{sc}$  are considered as input to the main control circuit of

figure 2. Now fundamental negative sequence power, harmonic power, and the fundamental reactive power, are also included in the compensating powers.

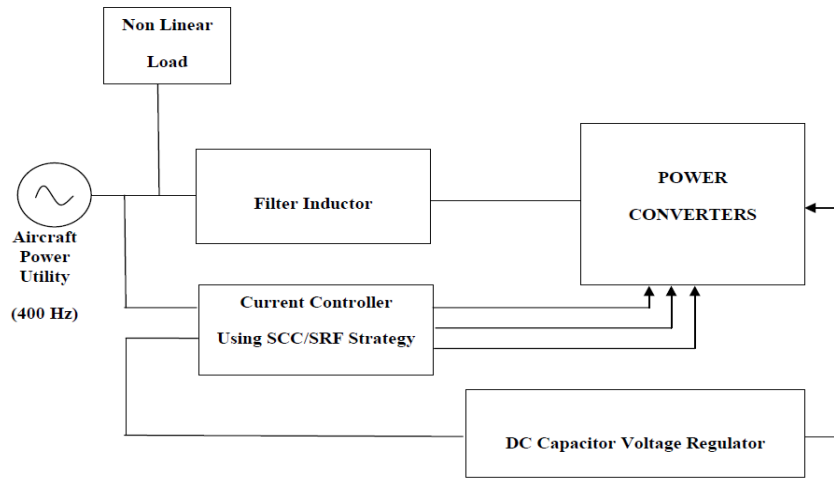


Figure 1 Block diagram of the system using different control strategies

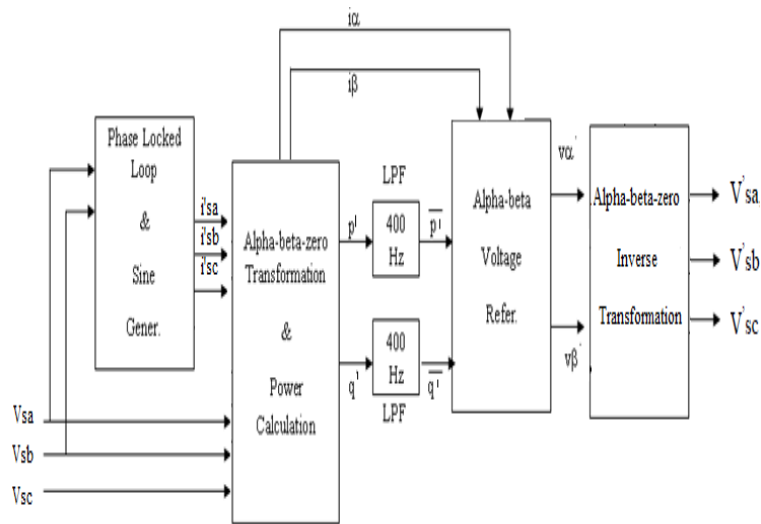


Figure 2 Block diagram of the fundamental positive-sequence voltage detector for sinusoidal current control strategy

### III. SYNCHRONOUS REFERENCE FRAME STRATEGY (S.R.F)

In this strategy, the reference frame d-q is determined by the angle  $\theta$  with respect to the  $\alpha$ - $\beta$  frame applied in the p-q theory. Little modifications are required in the conventional SRF method so that they can be used in aircraft power utility and compensate well the neutral current. For this reasons zero-sequence component of current has not been considered and so, the zero sequence subtract block take away the zero sequence current from the load current and output current comprises of only positive sequence and negative sequence component and after its park transformation, the output current in d-q frame is composed of only instantaneous active and reactive current. A low-pass filter attains the division of the dc and ac component of the active current for compensation of the harmonic and reactive current. This active current passes through a low pass filter and the signal came from dc voltage regulator together through a Park counter-transformation subtracting from the load currents generates the reference current.

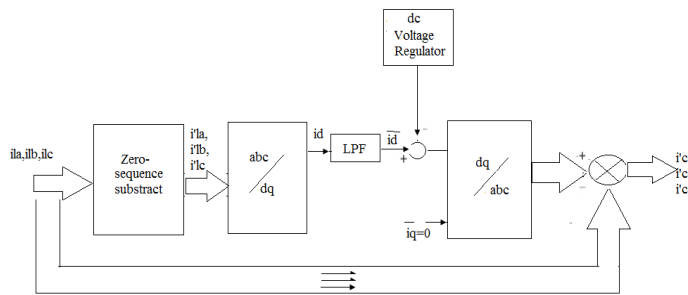


Figure 3 Control block diagram of the shunt active filter using synchronous reference frame strategy

#### IV. COMPARATIVE EVALUATION USING SIMULATION RESULTS

Two different control strategies have been simulated using MATLAB/Simulink to evaluate their performance. Three loads has been used i.e. three-phase rectifier parallel with inductive load and an unbalanced load connected a phase with midpoint, the three-phase rectifier connects a pure resistance directly, three-phase inductive load linked with the ground point and combined all three loads connected with system together at different time interval.

The simulation results clearly demonstrate that the every one of both schemes are proficient to effectively reduce the significant amount of THD in source current and voltage within limits. Simulation has been done for 15 cycles and results have been analyzed on the basis of THD and response time obtained.

##### A. Performance of APF under load 1 (three-phase rectifier parallel with inductive load and an unbalanced load connected a phase with midpoint)

Performance of APF under load 1 has been discussed below for Constant Source Instantaneous Power Strategy and Synchronous Reference Frame Strategy.

##### 1) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 4, it has been observed that that the THD of source current & source voltage was 2.43% and 1.44% respectively. The response time for compensation was 0.0074 sec.

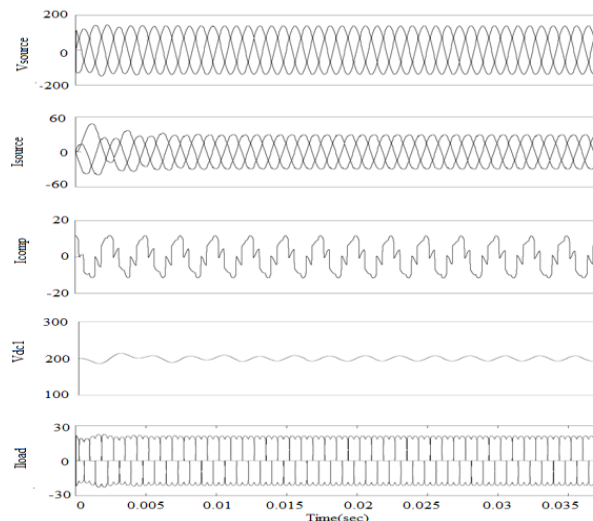


Figure 4 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase symmetrical nonlinear load condition for aircraft power utility

##### 2) For Synchronous Reference Frame Strategy

From the simulation results shown in figure 5, it has been observed that that the THD of source current & source voltage was 2.79% and 1.54% respectively. The response time for compensation was 0.0074 sec.

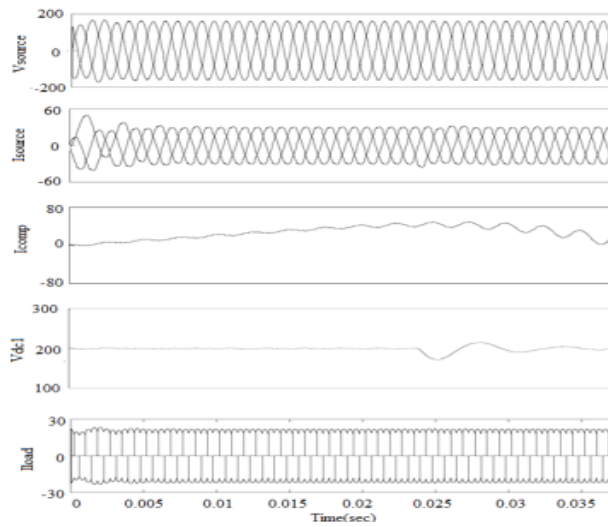


Figure 5 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using synchronous reference frame strategy with three-phase symmetrical nonlinear load condition for aircraft power utility

*B. Performance of APF under load 2(three-phase rectifier connected a pure resistance directly)*

Performance of APF under load 2 has been discussed below for Constant Source Instantaneous Power Strategy and Synchronous Reference Frame Strategy.

*1) For Sinusoidal Current Control Strategy*

From the simulation results shown in figure 6, it has been observed that that the THD of source current & source voltage was 2.30% and 1.29% respectively. The response time for compensation was 0.0085 sec.

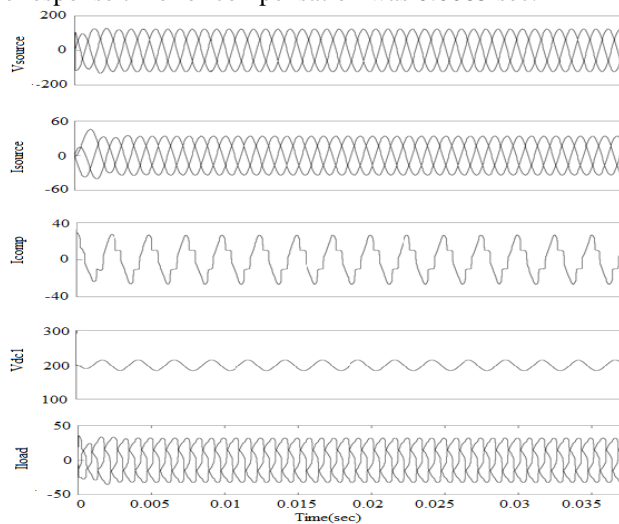


Figure 6 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase symmetrical nonlinear and inductive load condition for aircraft power utility

*2) For Synchronous Reference Frame Strategy*

From the simulation results shown in figure 7, it has been observed that that the THD of source current & source voltage was 2.54% and 1.51% respectively. The response time for compensation was 0.00747 sec.

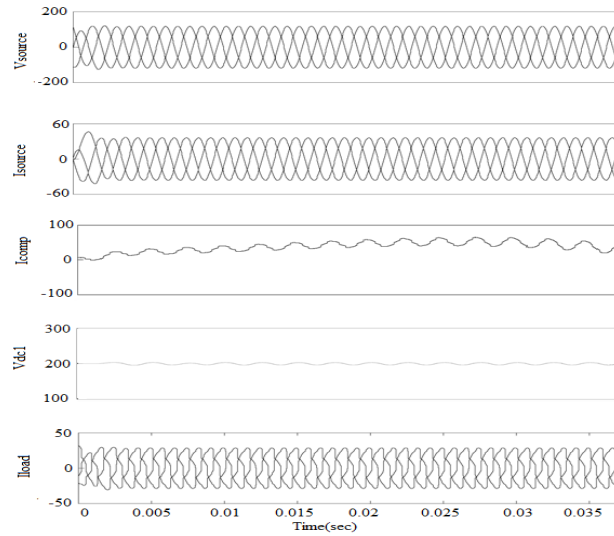


Figure 7 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using synchronous reference frame strategy with three-phase symmetrical nonlinear and inductive load condition for aircraft power utility

C. Performance of APF under load 3 (three-phase inductive load linked with the ground point)

Performance of APF under load 3 has been discussed below for Constant Source Instantaneous Power Strategy, Sinusoidal Current Control Strategy and Synchronous Reference Frame Strategy

1) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 8, it has been observed that that the THD of source current & source voltage was 0.44% and 0.32% respectively. The response time for compensation was 0.0074 sec.

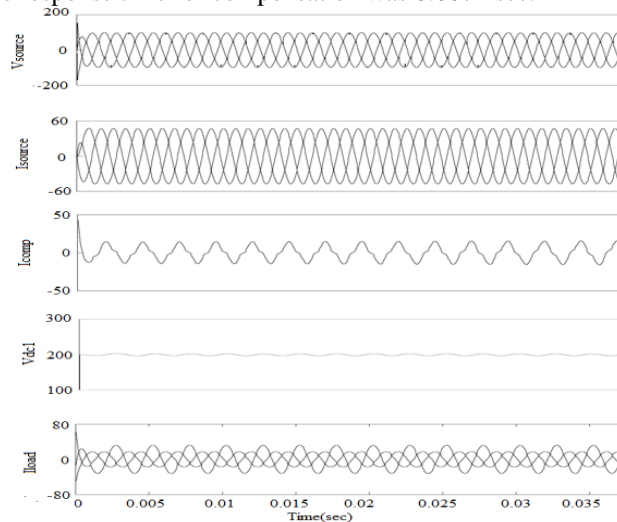


Figure 8 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase unbalanced nonlinear, inductive load condition for aircraft power utility

2) For Synchronous Reference Frame Strategy

From the simulation results shown in figure 9, it has been observed that that the THD of source current & source voltage was 0.52% and 0.68% respectively. The response time for compensation was 0.0073 sec.

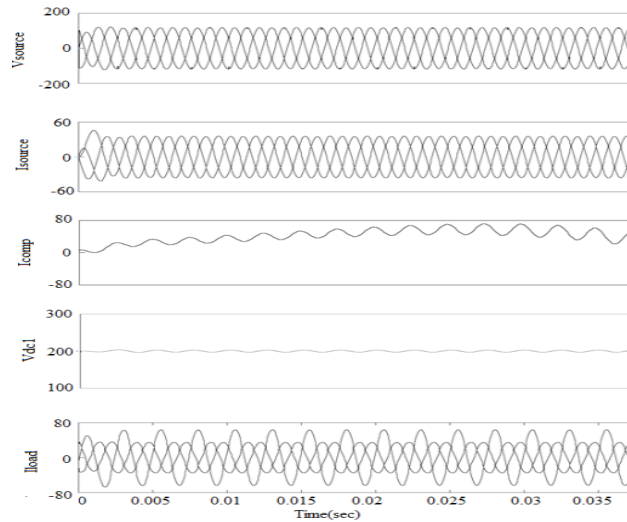


Figure 9 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using synchronous reference frame strategy with three-phase unbalanced nonlinear, inductive load condition for aircraft power utility

*D. Performance of APF under combined all three loads connected at different time interval*

Performance of APF under combined all three loads connected at different time interval has been discussed below for Constant Source Instantaneous Power Strategy and Synchronous Reference Frame Strategy

*1) For Sinusoidal Current Control Strategy*

From the simulation results shown in figure 10, it has been observed that that the THD of source current & source voltage was 2.72% and 1.65% respectively. The response time for compensation was 0.01 sec.

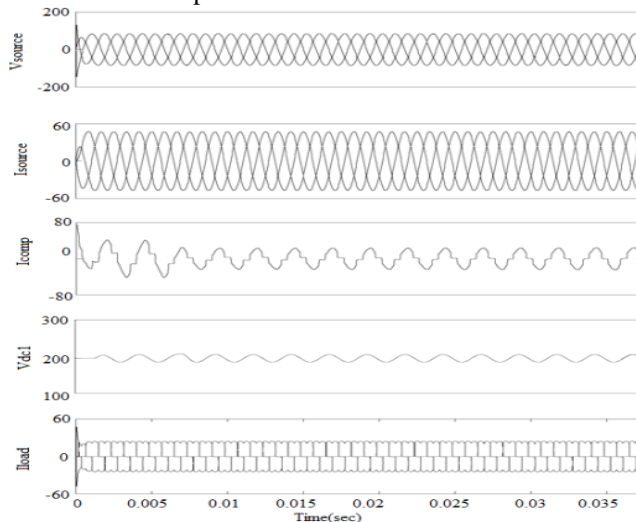


Figure 10 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with all three loads connected for aircraft power utility

*2) For Synchronous Reference Frame Strategy*

From the simulation results shown in figure 11, it has been observed that that the THD of source current & source voltage was 2.78% and 1.91% respectively. The response time for compensation was 0.0072 sec.

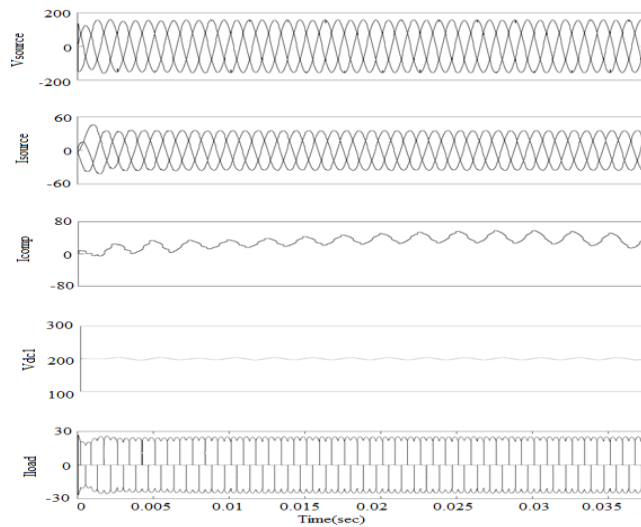


Figure 11 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using synchronous reference frame strategy with all three loads connected for aircraft power utility

E. Comparative Analysis of the Simulation Results

Simulation results has been tabulated in Table 1, Table 2 & Table 3 and from there, following conclusions have been drawn:

- 1) For Load 1: Sinusoidal current control strategy (SCC) has been found best for least THD of source current and source voltage, Sinusoidal current control strategy and Synchronous reference frame strategy, both were equally fast for compensation.
- 2) For Load 2: Sinusoidal current control strategy (SCC) has been found best for least THD of source current and source voltage. Synchronous reference frame strategy was fastest among both control strategies for compensation.
- 3) For Load 3: Sinusoidal current control strategy has been found best for least THD of source current and source voltage whereas Synchronous reference frame strategy was fastest among both control strategies for compensation.
- 4) For all three loads connected: Sinusoidal current control strategy has been found best for least THD of source current and source voltage whereas Synchronous reference frame strategy was fastest among both control strategies for compensation.

These conclusions have been also tabulated in Table 3.

TABLE 1  
THDs of Uncompensated System

Loads connected	THD-I (%)	THD-V (%)
With Load 1	4.03	30
With Load 2	2.07	28.96
With Load 3	1.2	5.45
All three loads connected	9.5	1.55

TABLE 2  
Summary of Simulation Results Using APF

Strategy& load details	THD-I (%)	THD-V (%)	Response Time(sec)
Load 1 (using SCC Strategy)	2.43	1.44	0.0074
Load 1 (using SRF Strategy)	2.79	1.54	0.0074
Load 2 (using SCC Strategy)	2.30	1.29	0.0085
Load 2 (using SRF Strategy)	2.54	1.51	0.00747
Load 3 (using SCC Strategy)	0.44	0.32	0.0074
Load 3 (using SRF Strategy)	0.52	0.68	0.0073
All three loads at different time interval (using SCC Strategy)	2.72	1.65	0.01
All three loads at different time interval (using SRF Strategy)	2.78	1.91	0.0072

TABLE 3  
Comparison of Strategies Used For Aircraft Power Utility

Loads connected	Best Strategy based on Source THD		Best Strategy based on Response time
	THD(Current)	THD(Voltage)	
With Load 1	SCC	SCC	SCC/SRF
With Load 2	SCC	SCC	SRF
With Load 3	SCC	SCC	SRF
All three loads connected	SCC	SCC	SRF

The simulation results shown and the tabulated in table 2 and table 3 undoubtedly explains the choice of different strategy with different load based on THD and response time.

## V. CONCLUSION

This paper has presented a relative study of two control strategies for shunt APFs installed in aircraft power utility of 400 HZ. The ideas have been given for the optimum selection of strategy for three different types of loads alone or together. Overall Sinusoidal Current Control has been observed as most fit for all loads discussed and Synchronous reference frame strategy (SRF) found to be fastest among both control strategies discussed.

## APPENDIX

The system parameters used are as follows [1]:  
 Three-phase source voltage: 115V/400 Hz  
 Filter inductor=0.25m H  
 Filter capacitor: 5 uF,  
 Dc voltage reference: 400 V  
 Dc capacitor: 4700uF



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