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Comparison of Constant Source Instantaneous Power & Sinusoidal Current Control Strategy for Total Harmonic Reduction for Power Electronic Converters in High Frequency Aircraft System

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Abstract: Two different control strategies i.e. Constant source instantaneous power strategy and Sinusoidal Current Control Strategy for taking out reference currents for shunt active power filters have been assessed and their recital have been compared under variety of non linear loads. Comparative analysis of control strategies will be done on the basis of THD & response time and suggestion will be made for optimum filter configuration. The simulation has been done using MATLAB/Simulink.

Keywords: Active power filter (APF), constant source instantaneous power strategy, Sinusoidal Current Control Strategy, harmonic compensation.

I. INTRODUCTION

Need of improved aircraft power systems [1]-[3] have been increased significantly due to unavailability of other alternate power sources except than electrical power source

New advanced concepts based aircraft uses electric power to drive its subsystem such as flight surface actuators, flight control, passenger entertainment, etc. These new additive subsystems has significantly increased electrical loads i.e. power electronic devices, more consumption of electrical energy, great demand for generated power, and much more power quality and stability problems.

Aircraft ac power system uses three phase system of source frequency of 400 Hz [1]-[3]. Due to the increased power electronics application in aircraft, unbalances and the harmonics creates more losses and bad power supply performances. These harmonics may interfere with communication circuits and change the response of the sensitive equipment in such a bad manner that the power supply quality will degrade and the generation system may be polluted.
By the application of shunt active power filters in aircraft can eliminate harmonic, reactive and unbalanced currents, improve the power supply performance and the stability of systemNow a days, the intelligent algorithms are used widely in control system or for optimization of the system applied. Some of them are such as adaptive tabu search [4]-[8] used for finding the optimized values of the controllers variables[4]-[12], optimization of active power filter using GA[9]-[12], power loss minimization using particle swarm optimization[13], neural network control [14]-[18].
This paper presents simulation of two different popular control strategies (Constant source instantaneous power strategy and Sinusoidal Current Control 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 modeling. Section IV show the performance of proposed technique and the last section V concludes the paper and followed by the references.

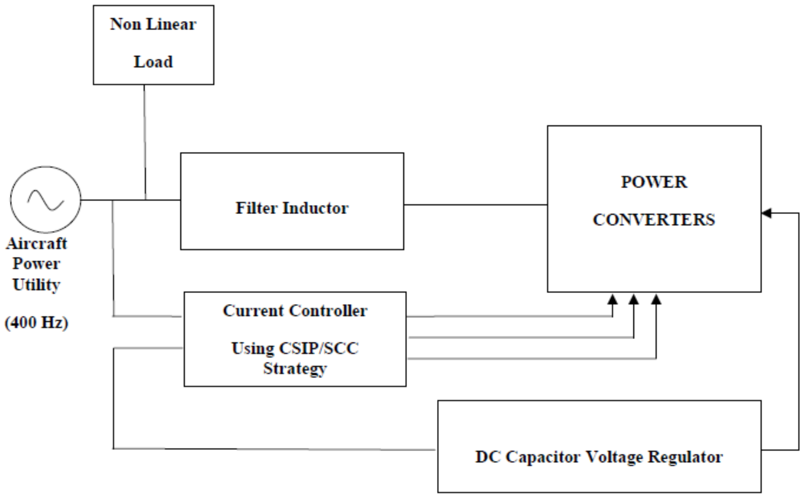

Figure 1 Block diagram of the system using different control strategies

II. CONSTANT SOURCE INSTANTANEOUS POWER STRATEGY (C.S.I.P)

Figure 2 presents the control diagram of the shunt active filter using constant source instantaneous power strategy We can observed that four low pass filters have been shown in the control block; in which, three with cut off of 6.4 KHz has been applied to filter the voltages and one for the power p_0. Direct application of the phase voltages cannot be used in the control due to instability problem. There may be resonance between source impedance and the small passive filter. Low pass filters have been applied to the system to attenuate the voltage harmonics at the resonance frequency which are higher than 6.4 KHz. p, q ,p_0 ,v_α and v_β are obtained after the calculation from α-β-0 transformation and send to the α-β current reference block, which calculates $i'_{c\alpha}$ and $i'_{c\beta}$. Finally, α-β-0 inverse transformation block calculates the current references and applied to the PWM current control i.e. hysteresis band controller.

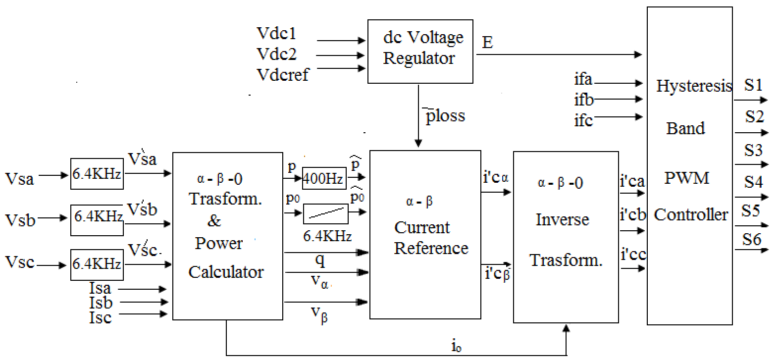

Figure 2 Control block diagram of the shunt active filter using constant source instantaneous power strategy

III. 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_α ,i_β , p' and q' are obtained after the calculation from α-β-0 transformation block and send to the α-β voltage reference block, which calculates $v_{\alpha'}$ and $v_{\beta'}$. Finally, α-β-0 inverse transformation block calculates the V'sa, V'sb and

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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.

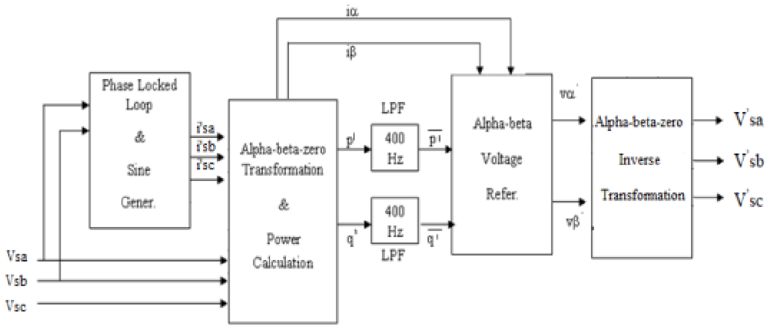

Figure 3 Block diagram of the fundamental positive-sequence voltage detector for sinusoidal current control strategy

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, Sinusoidal Current Control Strategy and Synchronous Reference Frame Strategy

1) *For Constant Source Instantaneous Power Strategy*

From the simulation results shown in figure 4, it has been observed that that the THD of source current & source voltage was 2.48% and 1.53% respectively. The response time for compensation was 0.01 sec.

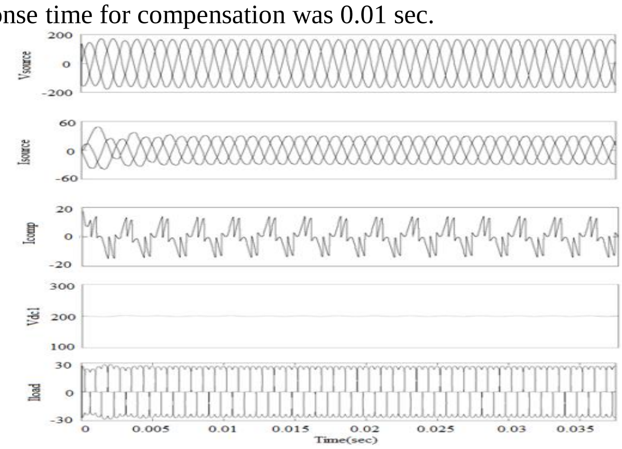

Figure 4 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using constant source instantaneous power strategy with three-phase symmetrical nonlinear load condition for aircraft power utility

2) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 5, 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.

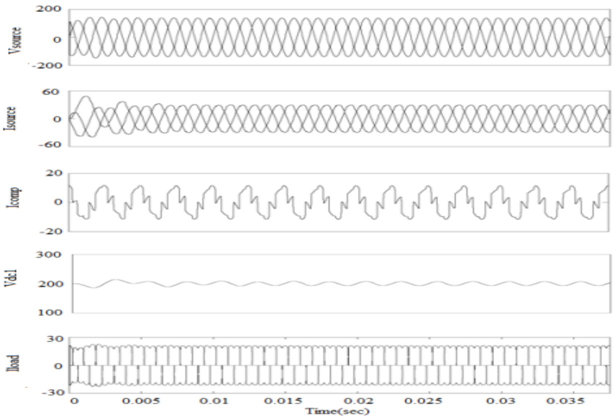

Figure 5 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase symmetrical nonlinear load condition for aircraft power utility

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, Sinusoidal Current Control Strategy and Synchronous Reference Frame Strategy

1) For Constant Source Instantaneous Power 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 1.48% respectively. The response time for compensation was 0.016 sec.

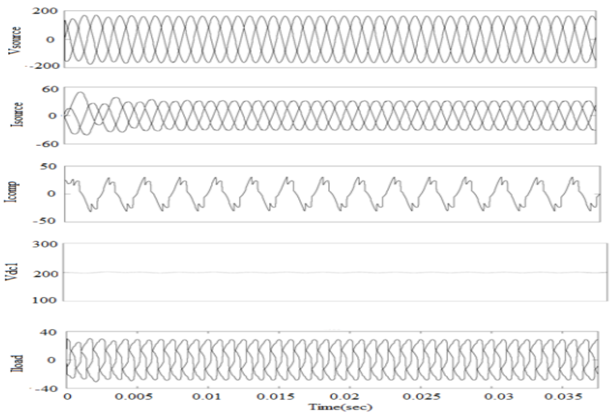

Figure 6 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using constant source instantaneous power strategy with three-phase symmetrical nonlinear and inductive load condition for aircraft power utility

2) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 7, 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.

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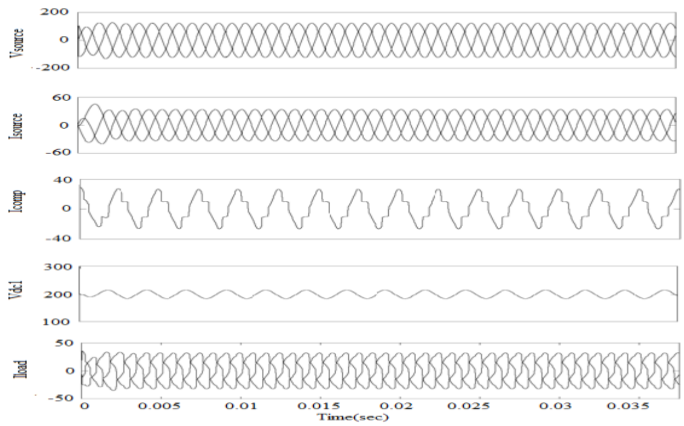

Figure 7 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase symmetrical nonlinear and inductive load condition for aircraft power utility

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 Constant Source Instantaneous Power Strategy*

From the simulation results shown in figure 8, it has been observed that that the THD of source current & source voltage was 0.72% and 0.71% respectively. The response time for compensation was 0.0074 sec.

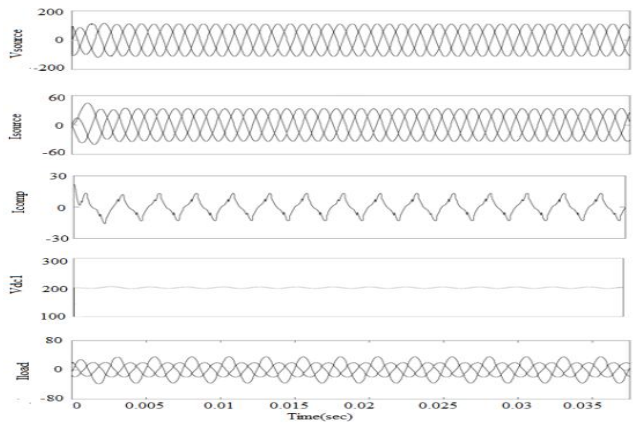

Figure 8 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using constant source instantaneous power strategy with three-phase unbalanced nonlinear, inductive load condition for aircraft power utility

2) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 9, 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.

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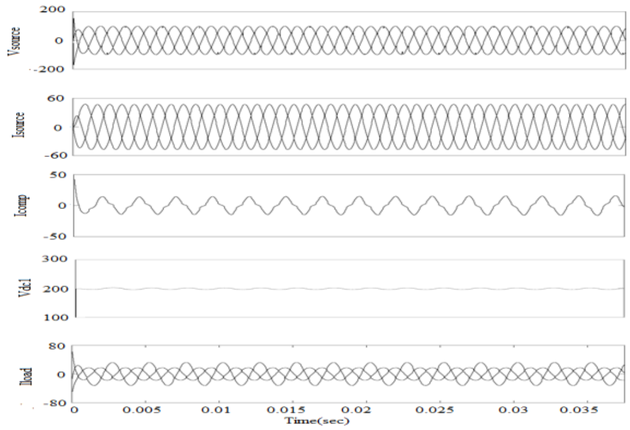

Figure 9 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with three-phase unbalanced nonlinear, inductive load condition for aircraft power utility

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, Sinusoidal Current Control Strategy and Synchronous Reference Frame Strategy

1) For constant source instantaneous power strategy

From the simulation results shown in figure 10, it has been observed that that the THD of source current & source voltage was 2.84% and 1.88% respectively. The response time for compensation was 0.0147 sec.

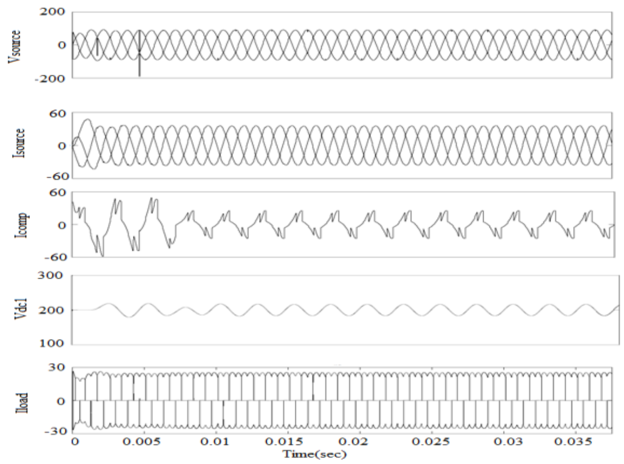

Figure 10 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using constant source instantaneous power strategy with all three loads connected for aircraft power utility

2) For Sinusoidal Current Control Strategy

From the simulation results shown in figure 11, 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.

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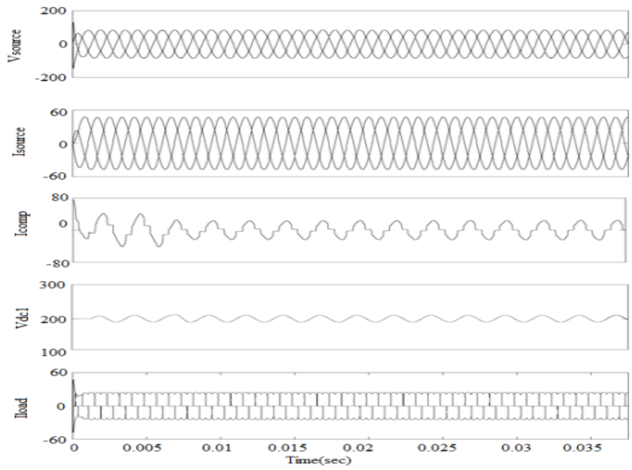

Figure 11 Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using sinusoidal current control strategy with all three loads connected for aircraft power utility

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 as well as fasted among both schemes.
2) *For Load 2:* Constant source instantaneous power strategy (CSIP) and Sinusoidal current control strategy (SCC) have been found best for least THD of source current, whereas for least THD of source voltage, Sinusoidal current control strategy (SCC) was best as well as SCC is fastest among both the strategy.
3) *For Load 3:* Sinusoidal current control strategy (SCC) has been found best for least THD of source current and source voltage. SCC and CSIP, both strategies are having equal response time for this case.
4) *For all three loads connected:* Sinusoidal current control strategy (SCC) has been found best for least THD of source current and source voltage as well as fasted among both schemes.

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

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TABLE 2

Summary of Simulation Results Using APF

Strategy& load details	THD-I (%)	THD-V (%)	Response Time(sec)
Load 1 (using CSIP Strategy)	2.48	1.53	0.01
Load 1 (using SCC Strategy)	2.43	1.44	0.0074
Load 2 (using CSIP Strategy)	2.30	1.48	0.016
Load 2 (using SCC Strategy)	2.30	1.29	0.0085
Load 3 (using CSIP Strategy)	0.72	0.71	0.0074
Load 3 (using SCC Strategy)	0.44	0.32	0.0074
All three loads at different time interval (using CSIP Strategy)	2.84	1.88	0.0147
All three loads at different time interval (using SCC Strategy)	2.72	1.65	0.01

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
With Load 2	CSIP/SCC	SCC	SCC
With Load 3	SCC	SCC	SCC/CSIP
All three loads connected	SCC	SCC	SCC

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 Strategy has been observed as most fit for all loads discussed , which is the modified version of Constant Source Instantaneous Power strategy.

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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