

Performance Evaluation of GA optimized Shunt Active Power Filter for Constant Frequency Aircraft Power System

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Abstract

Sinusoidal Current Control strategy for extracting reference currents for shunt active power filters have been modified using Genetic Algorithm and its performances have been compared. The acute analysis of Comparison of the compensation capability based on THD and speedwell be done, and recommendations will be given for the choice of technique to be used. The simulated results using MATLAB model are shown, and they will undoubtedly prove the importance of the proposed control technique of aircraft shunt APF.

Keywords: Aircraft electrical system, Shunt Active Filter (APF), Sinusoidal Current Control strategy, GA, THD

1. Introduction

More advanced aircraft power systems [1]-[3] have been needed due to increased use of electrical power on behalf of other alternate sources of energy. The subsystems like flight control, flight surface actuators, passenger entertainment, are driven by electric power, which flowingly increased the demand for creating aircraft power system more intelligent and advanced. These subsystems have extensive increased electrical loads i.e. power electronic devices, increased feeding of electric power, additional demand for power, and above to all of that great stability problems.

In peculiarity to standard supply system, the source frequency is of 50 Hz, whereas, aircraft AC power system works on the source frequency of 400 Hz [1]-[3]. Aircraft power utility works on source voltage of 115/200V. The loads applicable to the plane a system differs from the loads used in 50 Hz system [1]. When we deliberate the generation portion; aircraft power utility will remain AC driven from the engine for the plane primary power. Novel fuel cell technology can be used to produce a DC output for ground power, and its silence process would match up to suitably with the Auxiliary Power Unit (APU). Though when considering the dissemination of primary power, whether AC or DC; each approach has its merits. In DC distribution, HVDC power distribution systems permit the most resourceful employ of generated power by antithetical loss from skin effect. This allows paralleling and loads sharing amongst the generators. In AC distribution, AC Flogging is very clear-cut at high levels too. Due to its high dependence on HVDC system, a wide range of Contactors, Relays can be exploited.

While talking regarding craft Power Systems we tend to conjointly ought to contemplate increased power electronics application in craft that creates harmonics, massive neutral currents, wave form distortion of each supply voltage and current, poor power issue, and excessive current demand. Besides if some non-linear loads is affected upon a supply, their effects are additive. Due to these troubles, there could also be nuisance tripping of circuit breakers or inflated loss and thermal heating effects which will provoke early element failure. This is a prodigious problem to every motor loads on the system. Hence, decent power quality of the generation system is of scrupulous attention to the Aircraft manufacturer. We discern that aircraft systems work on high frequency so even on the higher frequencies in the range of 360 to 900Hz; these components would remain very significant.

Today, advanced soft computing techniques are used widely in the involuntary control system, and optimization of the system applied. Several of them are such as fuzzy logic [4]-[8], optimization of active power filter using GA [9]-[12], power loss reduction using particle swarm

optimization [13], Artificial neural network control [14]-[18] applied in together machinery and filter devices.

In this paper, GA has been used to mend the complete performance of active filter for the lessening of harmonics and other delinquents created into the aircraft electrical system because of the non-linear loads [1]. The simulation results clearly show their effectiveness. The simulation results acquired with the new model are much improved than those of traditional method.

The paper has been modified in a sequential manner. The APF outline and the load under contemplation are discussed in Section II. The control algorithm for APF converses in Section III. MATLAB/ Simulink based simulation results are presented in Section IV, and finally Section V concludes the paper.

2. System Depiction

The craft power grid may be a three-phase power grid with the frequency of four hundred cycle per second. As exposed in Figure 1, Shunt Active Power Filter improves the power quality and compensates the harmonic currents within the system [22], [24]-[25], [27]-[28]. The shunt APF is understood by using one voltage supply inverters (VSIs) connected at the PCC to a typical DC link voltage [20]-[23].

The set of loads for aircraft system consist of three loads. The first load is a three-phase rectifier in parallel with an inductive load and an unbalanced load connected in a phase with the midpoint (Load 1). The second one is a three phase rectifier connects a pure resistance directly (Load 2). The third one is a three-phase inductive load linked with the ground point (Load 3). Finally, a combination of all three loads connected with system together at a different time interval to study the effectiveness of the control schemes has been used to verify the functionality of the active filter in its ability to compensate for current harmonics. For the case of all three load connected, Load 1 is always connected, Load 2 is initially connected and is disconnected after every 2.5 cycles, Load 3 is connected and disconnected after every half cycle. All the simulations have been done for 15 cycles. The circuit parameters are given in Appendix.

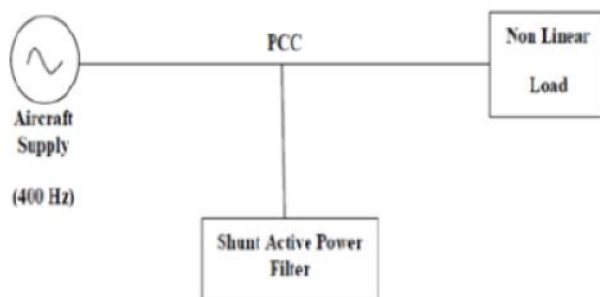


Figure 1. Aircraft system using Shunt Active Power Filter

3. Control Theory

The projected control of APF depends on Sinusoidal Current Control strategy, and it has been optimized for artificial intelligent technique e.g. Genetic Algorithm. Sinusoidal Current control strategy has been mentioned in short during this section. The subsequent section conjointly deals with the basic application of GA in the control schemes [19], [20], [29].

3.1. Sinusoidal Current Control Strategy (S.C.C.)

The sinusoidal current control strategy could be a changed version of constant instantaneous power control strategy, which might compensate load currents underneath unbalanced states too. The modification includes a positive sequence detector that replaces the 6.4 KHz cutoff frequency low-pass filters. It specifically matches the frequency and phase angle of the fundamental component. Thus, APF compensates the load reactive power. The extreme

concern should be taken, while designing this detector, so that shunt active filter produces ac currents orthogonal to the voltage component. Otherwise, it will provide active power. i_{α}, i_{β} , p' and q' are attained after the calculation from α - β -0 transformation block and send to the α - β reference voltage block, which calculates $v_{\alpha'}$ and $v_{\beta'}$. Lastly, α - β -0 inverse transformation block calculates the V_{sa} , V_{sb} , and V_{sc} . Instead of the filtered voltages used previously, V_{sa} , V_{sb} , and V_{sc} are reflected as input to the basic control circuit of figure 2. Now fundamental negative sequence power, harmonic power, and the fundamental reactive power, are also incorporated with the compensating powers.

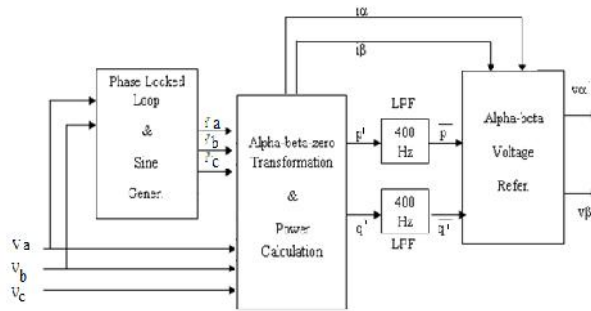


Figure 2. Block diagram of the fundamental positive-sequence voltage detector for sinusoidal current control strategy

3.2. Application of Genetic Algorithm

GA could also be a search technique that's used from generation to generation for optimizing performs. In fact, GA works on the rule of survival of the fittest. For the selecting the parameters used in controller using GA, the analysis methodology want a check, performed on-line on the particular plant or off-line with simulations on computer. Every on-line and offline methodology are having advantages and disadvantages each. If we've got a bent to means on-line approach, the foremost advantage is that the consistency of the final word answer, as a results of it's chosen on the idea of its real performances, whereas if we have a tendency to predict concerning its disadvantage, it always involve thousands of tests to attain an even result i.e. this optimization methodology will take long run for experiments to run on the real system. Simply just in case of the off-line approach, GA improvement relies on a so much plenty of precise model of the system in conjunction with all elements, all non-linearties and limits of the controllers. It has to be compelled to however be well-known that a negotiation must be met in terms of simulation accuracy and optimization time. Offline, computer simulation using MATLAB Simulink has been applied to hunt out the optimum value.

In In this paper, the GA is applied to figure out the appropriate APF parameters i.e. device filter (L_f). The boundary and limits of parameters inside the filter has been outlined and a program using genetic algorithm has been written to return up with the foremost effective value of the filter device.

For the program, the limits, inequality and bounds need to be defined. This paper has attempted to develop a single GA code program for optimizing objective function.

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x0 = [Vdc; Vs; Ic; t; Lf];
lb = [Vdcmin; Vsmin; Icmin; tmin; Lfmin];
ub = [Vdcmax; Vsmax; Icmax; tmax; Lfmax];
Aeq = [];
beq = [];
A = [1 -1 1 -1 1; 1 1 -1 1 -1; 0 0 1 1 1; 1 1 -0 0 -1; 1 1 0 1 0];
b = [Values of Vdc; Vs; Ic; t; Lf depending upon the equations];
[x,fval,exitflag]=fmincon(@myobj,x0,A,b,Aeq,beq,lb,ub)

```

The boundary and limits of parameters in the filter has been defined using the data of ANN model. The data has been collected using MATLAB/Simulink. Finally, a program using genetic

algorithm has been written to generate the best value of the filter inductor. After the calculation, GA generates the value of 0.187mH. After using this inductor value, total harmonic distortion of source current and voltage have been reduced so we can say that inductor value calculated is optimum.

4. Simulation Results & Discussions

The proposed scheme of APF is simulated in MATLAB environment to estimate its performance. Three loads have been applied together at a different time interval to check the affectivity of the control schemes for the reduction of harmonics. A small quantity of inductance is additionally connected to the terminals of the load to urge the foremost effective compensation. The simulation results clearly reveal that the scheme will with success cut back the numerous quantity of THD in supply current and voltage among limits.

4.1. Uncompensated System

Figure 3 shows the waveforms obtained after the simulation of an uncompensated system. It has been observed that the THD of source current calculated when loads connected with the system is 9.5% and THD of source Voltage were 1.55%. By observing these data, we can easily recognize supply has been polluted when loads have been connected and is obviously not within the limit of the international standard.

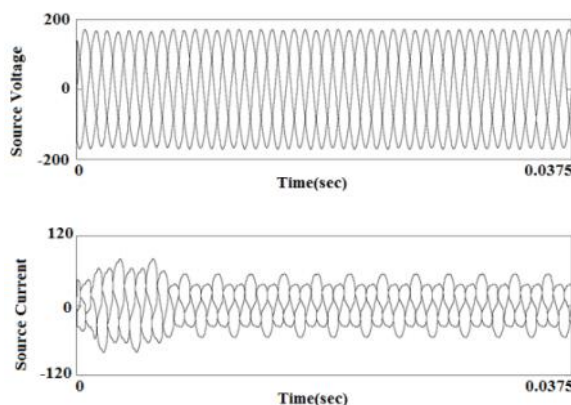


Figure 3. Source Voltage and source current waveforms of uncompensated system

4.2. Compensated System

The performance of APF under different loads connected, when utilizing GA has been discussed below for the control strategy given below.

4.2.1. For Sinusoidal Current Control Strategy

From Figure 4 it has been empiric that that the THDs of source current and source voltage were 2.82% and 1.65% respectively. The compensation time was 0.01 sec. At $t=0.01$ sec, it is apparent that the waveforms for source voltage and source current have become sinusoidal. Figure 5 shows the waveforms of compensation current, DC capacitor voltage, and load current.

The aberration in dc voltage can be acutely apparent in the waveforms. As per claim for accretion the compensation current for accomplishing the load current demand, it releases the energy, and after that it accuses and tries to achieve its set value. If we carefully observe, we can acquisition out that the compensation current is, in fact, accomplishing the appeal of load current, and afterward the active filtering the source current and voltage is affected to be sinusoidal.

4.2.2. For Sinusoidal Current Control Strategy using GA

THDs of source current & source voltage have been found 1.92% and 1.60% respectively after making observations from the simulation results shown in figure 5. The waveforms for source voltage and source current have become sinusoidal at $t=0.0066$ sec. Compensation time is 0.0066 sec. The waveforms of compensation current, dc capacitor Voltage, and load current have been shown in figure 5. The aberration in dc voltage can be acutely apparent in the waveforms. As per claim for accretion the compensation current for accomplishing the load current demand, it releases the energy, and after that it accuses and tries to achieve its set value. If we carefully observe, we can acquisition out that the compensation current is, in fact, accomplishing the appeal of load current, and afterward the active filtering the source current and voltage is affected to be sinusoidal.

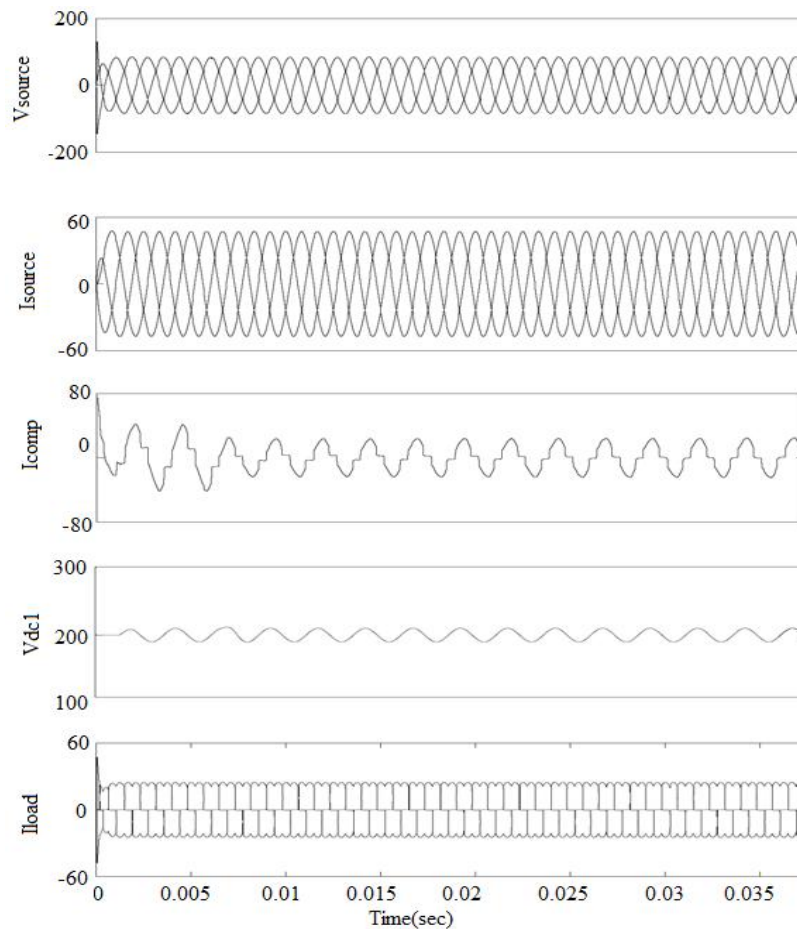


Figure 4. Source Voltage, source current, compensation current (phase b), DC link Voltage and load current waveforms of Active power filter using Sinusoidal Current Control strategy

4.3. Comparative Analysis of the Simulation Results

From the Table 1 we can easily say that Sinusoidal Current Control (SCC-GA) has been found best for current and voltage harmonic reduction. When these results have been compared based on compensation time, it has been also found that SCC-GA strategy is also fastest one.

Table 1. Summary of simulation results

Strategy	THD-I (%)	THD-V (%)	Compensation Time (sec)
SCC	2.83	1.65	0.0100
SCC-GA	1.92	1.60	0.0066

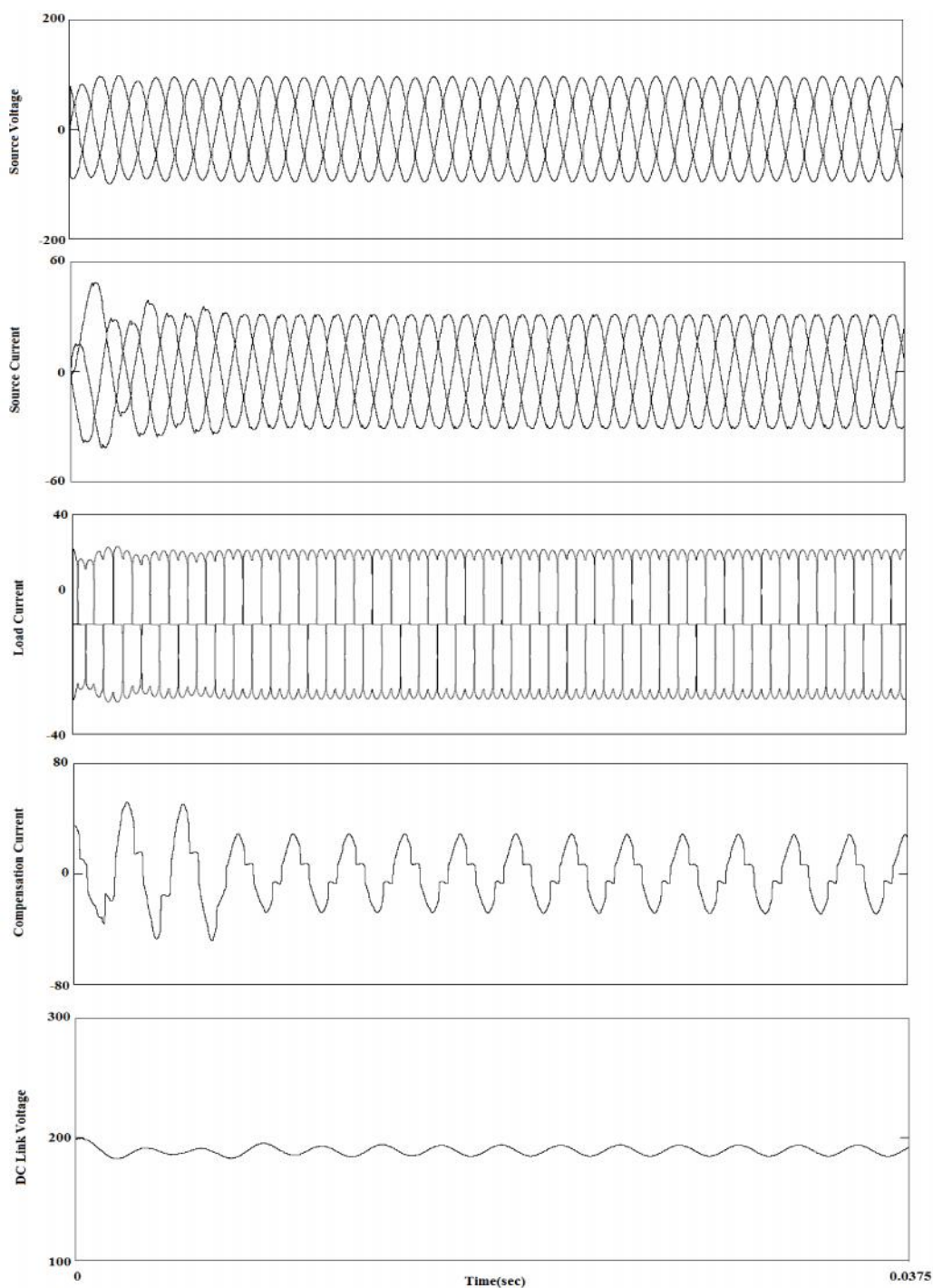


Figure 5. Source Voltage, Source Current, Load Current, Compensation Current (Phase b) and DC Link Voltage Waveforms of Active Power Filter based on *Sinusoidal* Current Control Strategy using Genetic Algorithm with All Three Loads Connected for Aircraft System

5. Conclusion

This paper has done an acute analysis of traditional control and GA applied system for shunt APF in aircraft power utility of 400 HZ. Optimum selection of control strategy based on compensation time and THD has been suggested. Overall Sinusoidal Current Control strategy (SCC-GA) has been observed as an optimum choice. Sinusoidal Current Control Strategy's

performance has been improved, which itself an achievement for the case of optimization in traditional strategies.

Appendix

The aircraft system parameters are [1]:

Three-phase source voltage: 115V/400 Hz

Filter capacitor: 5 μ F,

Filter inductor=0.25m H

Dc capacitor: 4700 μ F

Dc voltage reference: 400 V

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