THD and Compensation Time Analysis of Three-Phase Shunt Active Power Filter Using Adaptive Spider Net Search Algorithm (ASNS) for Aircraft System

Saifullah Khalid*

Institute of Engineering & Technology, Lucknow, India

Abstract—A novel Adaptive Spider Net Search Algorithm (ASNS) has been presented, which has been used for the optimization of conventional control scheme used in shunt active power filter for aircraft system. The superiority of this algorithm over existing Genetic Algorithm results has been presented by analyzing the THD and compensation time of both the algorithms. The simulation results using MATLAB model ratify that algorithm has optimized the control technique, which unmistakably prove the usefulness of the proposed algorithm in aircraft supply system.

Keywords—Active power filter (APF); Adaptive Spider Net Search Algorithm; Genetic Algorithm; Harmonic Compensation.

I. INTRODUCTION

Non-linear loads cause the unbalancing, harmonics, distortion etc into the power arrangement and these unwanted problems turn out profusely of problems within the system. Whenever application of such loads can increase, source gets distorted and unbalanced. These currents foul the supply purpose of the utility. Therefore, it’s necessary to compensate unbalance, a harmonic and reactive element of the load currents. Whereas once source is unbalanced and distorted, these problems worsen the system [1-3].

Today, the soft computing techniques like Fuzzy algorithms, ATS algorithms, Genetic Algorithm [4-12], particle swarm optimization [13], ANN [14-17] applied in every machinery and filter devices for optimization of the system applied or in the various control system

In this paper, one novel soft computing technique i.e. adaptive Blanket Body cover algorithm is applied for reduction of harmonics and other related drawbacks generated into the balanced, unbalanced and distorted system because of the nonlinear loads [1]. The results obtained with the algorithms are much better than those of typical ways. ABBC algorithmic program has given the higher results as compare to the traditional theme. The effectiveness of the planned scheme has been proven by the simulation results mentioned. The results even their effectiveness. The paper is structured under the following manner. The APF configuration and conjointly the loads used commonly in the industry are talked about in Section two. The actual control algorithm for APF is revealed in Section three. MATLAB/ Simulink primarily based simulation results are shown and discussed in Section four. Section five wraps up the paper.

II. SYSTEM DESCRIPTION

In this paper, the aircraft supply system considered is a 3 phase system having source frequency of four hundred Hertz. The APF limits and reduces the harmonic currents and other related issues among the
system. This, in turn, improves the overall power quality. The shunt APF is completed by the application of VSIs at PCC with a standard DC link voltage. The values of the circuit parameters and the different loads into consideration are given in Appendix.

One three-phase rectifier in parallel with an inductive load and an unbalanced load connected in a phase with the midpoint, one three phase rectifier connects a pure resistance directly, and one three phase rectifier connects a pure resistance directly. These loads have been considered as load 1, 2 and 3 respectively. All three loads are connected to both supply at such interval or together such that ability of APF can be evaluated and it has been tested for 15 cycles. The circuit parameters are given in Appendix.

III. CONTROL THEORY

The projected control of APF which is basically dependent on Sinusoidal Current control (SCC) technique optimized with soft computing techniques i.e. adaptive Spider Net Search algorithm (ASNS and Genetic Algorithm (GA). Overall the control process using SCC technique with the application of ASNS/GA has been explained below in further sections.

A. Adaptive Spider Net Search Algorithm

Adaptive Spider Net Search (ASNS) is proposed and developed by the author for different combinatorial optimization issues. Nonlinear continuous optimization problems require a vigorous search line to decide them. The novel adaptive Blanket Body cover algorithmic (ABBC) has been developed for them. In the ASNS algorithmic, an unremitting search space is discretized. Adaptive radius and backtracking options are added such that the performance of the search technique becomes better. In this paper, the projected ASNS algorithmic rule seeks out the optimum values of Kp and Ki for proportional integral (PI) controller.

Based on the equation using overshoot, rise time and settling time, the objective function (OF) is decided to resemble to provide their optimum values. In the beginning, the Boundary of Kp and Ki along with their maximum and minimum limits are defined. Thereafter, conditions for ASNS backtracking, the radius value, and the objective function are added. Lastly, the stop criteria are given.

Net of spider has been supposed of the shape of the hexagon. We have used 500 hexagons and every corner of the hexagon, we have defined some random values of Kp & Ki which will be within the range of predefined initial values. Best value of each hexagon will be saved as first corner value of next hexagon. The comparison will move in clockwise as well as zigzag direction for the complete check of optimum value. After every comparison, best value will be compared with next value on the next corner and then the best outcome will be saved and will be compared to next one. This process will repeat itself and will stop when stopping criteria fulfills. We have considered 500 hexagons as shown in figure 1. We have observed that comparison of each hexagon corner values goes through nine times as shown in figure 2 and that is the reason for selecting maximum Searching iteration (4500 iterations) for ASNS as the stop criterion. There is a predefined list named as Spider net-list, which contains the values which have been distributed over the corners of the hexagons.

There is a predefined list named as Spider net-list, which contains the values which have been distributed over the corners of the hexagons. The flow chart for finding the optimum parameter values using the Adaptive Spider Net Search (ASNS) Algorithm is given in figure 3. The values of 0.1 and 50 have been used respectively for Kp and Ki. The optimum values of 0.194 and 15.32 come out using the ASNS algorithm. The reduction of THD for current and voltage justifies that the values obtained using ASNS Algorithm are optimum. The time used for computation is few seconds which shows that the algorithm is very fast. Since all the values are being calculated offline, the algorithm proves its stability. Later, the new values did the replacement of present values. The optimization of the controller using algorithm is clearly proved by the simulation results. The objective function has been defined using the equations. The equations are made of settling time (T_{Settling}), rise time (T_{Rise}) and percent overshoot (P.O.). The program will stop when the 4500
iterations are over. This will be done using counter used for counting the iterations.

Objective function (OF) is defined by

\[
\text{OF (settling time, rise time and percent overshoot)} = R + S + P
\]

(1)

\[
R + S + P = 1
\]

(2)

R, S, and P are the priority coefficients of settling time, rise time and percent overshoot respectively.

The values of R, P, and S are set to 0.33, 0.33, and 0.34, respectively. The ASNS will endeavour to find the optimum parameters values to achieve the least OF value.

The algorithm has been explained stepwise for more clarity.

![Figure 3. Flow Chart for Finding the Parameters Using ASNS Algorithm](image)

Step 1: Loading of Spider Net list. The list contains the values of Kp and Ki. The counter has is at zero, that will count the number of iterations.

Step 2: Calculation of objective function for the values of Kp and Ki.

Step 3: The values of OB obtained is being compared with the computed value of OB of Spider Net list i.e. first corner starts from the left side.

Step 4: If the outcome is not superior, it will be added in spider net list. Automatically, the counter will increase by changing the values of Kp and Ki from the spider net list. The previous values will be replaced with these new values. Computation of for these values will be done and then once again, go to step 3.

Step 5: The outcome will be saved as the most excellent solution if those are superior to spider net list solutions.

Step 6: The outcome i.e. the optimum values of the parameters (Kp and Ki) will be displayed only when the count or number of iterations are 4500. Otherwise based on the count values, the parameters will be taken from the spider net list and changed. Later, OF for these values will be computed and then once again go to step 3.

B. Genetic Algorithm (GA)

GA could also be a finding technique that's used from very earlier time for optimization of parameters.

The fittest survives is the basic rule of Genetic Algorithm. The Genetic Algorithm is applied to figure out the optimum value of the parameter i.e. device filter (L_f). A program has been written in MATLAB with the defined boundary & limit conditions of the parameter. The outcome of the program is the optimum value of the filter.

C. Control Scheme

Sinusoidal current control (SCC) technique has been applied for APF with the appliance of novel computing algorithm & GA. The soft computing technique i.e. ABBC is conversant in providing the foremost effective optimized values of the parameters of the PI controller. Whereas, GA is used to find the optimum inductor value.

IV. RESULTS & DISCUSSIONS

In this section, aircraft supply has been simulated in MATLAB/Simulink and its results are mentioned. Three loads have been applied together at a different time interval to check the affectivity of the control schemes for the reduction of harmonics. The compensation has been done more effective using a small amount of inductance. It has been connected to the terminals. Three sorts of loads have been used.

All three loads are connected to both of the supply at such interval or together such that ability of APF can be evaluated. The first load is always connected to the system. Second load switches or disconnects every 2.5 cycles. On the other hand, the third load switches very half cycle.

A. For Uncompensated system

When all three loads are connected as per the configuration discussed in the previous section, Total harmonic distortion (THD) of source (supply) current has been observed as nine point five percent and THD
of source (supply) Voltage were one point five percent. In this duration, the APF is not connected. The results are shown in figure 4. By observant this information, we are going to merely understand that they are not within the limit of the international standard.

![Figure 4. Source Voltage and Source Current Waveforms of Uncompensated System](image)

B. For Compensated System

The enactment of APF connected with different loads, when utilizing ANN & Genetic Algorithm has been discussed below for the control strategy given below.

a. For Sinusoidal Current Control Strategy

Figure 5 presents the results obtained after the simulation, which ascertained that the total harmonic distortion (THD) of supply (source) current & supply (source) voltage was 2.82% and 1.65% severally. The time used for compensation was 0.01 sec. At t=0.01 sec, it is apparent that the waveforms for source voltage and source current have become sinusoidal. Fig. 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.

b. For Sinusoidal Current Control strategy using Genetic Algorithm

Figure 6 presents the results obtained after the simulation, which ascertained that the total harmonic distortion (THD) of supply (source) current & supply (source) voltage was 2.42% and 1.60% severally. The time used for compensation was 0.0066 sec. At t=0.0066 sec, it is apparent that the waveforms for source voltage and source current have become sinusoidal. Fig. 6 shows the waveforms of compensation current, DC capacitor voltage, and load current.

![Figure 5. Waveforms of APF Using SCC Strategy (Source Voltage, Source Current, Compensation Current (Phase b), DC link Voltage and Load Current)](image)

![Figure 6. Waveforms of APF Using SCC Strategy with GA (Source Voltage, Source Current, Compensation Current (Phase b), DC link Voltage and Load Current)](image)
Waveforms show the variations in dc capacitor voltage. Whenever the demand for high load current comes, it releases the energy that in turn increases the compensation current. Later on, it charges and tries to regain its previous set value. By making a simple observation, we can say that compensation current is fulfilling the demand of load current. After the active filtering, the source current and voltage is forced to be sinusoidal.

C. Comparative Analysis

The simulation waveforms are shown above and also the result tabulated in table one confirms that the novel ABBC algorithm primarily based APF can execute fine in aircraft supply system. Its dynamic ability and superiority over typical SCC and GA technique for least THD and less compensation time can be seen in the results. The bar chart (figure 8) proves the superiority of the other two methods.

<table>
<thead>
<tr>
<th>Strategy</th>
<th>THD-I (%)</th>
<th>THD-V (%)</th>
<th>Compensation Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCC</td>
<td>2.83</td>
<td>1.65</td>
<td>0.0100</td>
</tr>
<tr>
<td>SCC-GA</td>
<td>2.42</td>
<td>1.60</td>
<td>0.0066</td>
</tr>
<tr>
<td>SCC-ASNS</td>
<td>1.92</td>
<td>1.06</td>
<td>0.0065</td>
</tr>
</tbody>
</table>

Figure 7 presents the results obtained after the simulation, which ascertained that the total harmonic distortion (THD) of supply (source) current & supply (source) voltage was 1.92% and 1.06% severally. The time used for compensation was 0.0065 sec. At t=0.0065 sec, it is apparent that the waveforms for source voltage and source current have become sinusoidal. Fig. 7 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.

Figure 7. Waveforms of APF using SCC strategy with ASNS Algorithm (Source Voltage, source current, compensation current (phase b), DC link Voltage and load current)

Figure 8. Bar Chart for Different Control Techniques Applied for Shunt Active Power Filter for Aircraft System

V. CONCLUSIONS

A novel advanced algorithm i.e. adaptive Blanket Body cover (ASNS) algorithm applied in APF has been conferred, that performs successfully under aircraft supply System. The optimization of the system by using Adaptive Spider Net Search algorithm has acted upon excellent for traditional Sinusoidal Current Control Technique. ASNS has effectually reduced the harmonics & other related drawbacks and issues. THD has been lessened noteworthy within the very short duration of few seconds. So, it is obvious that ABBC is superior as well as quicker.

PARAMETERS

The aircraft system parameters are [1]:

- Three-phase source voltage: 115V/400 Hz
- Filter capacitor: 5 µF,
- Filter inductor=0.25m H
- Dc capacitor: 4700µF
- Dc voltage reference: 400 V
REFERENCES


