HARMONIC REDUCTION IN HIGH FREQUENCY (400HZ) AIRCRAFT POWER SYSTEM APPLYING ARTIFICIAL INTELLIGENCE TECHNIQUES IN SHUNT ACTIVE POWER FILTER

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Abstract: A novel ANN controlled shunt filter designed for aircraft power system has been proposed in this paper. The conventional shunt Active Power Filter (APF) model has been improved using Genetic Algorithm and Fuzzy Logic tools. Genetic Algorithm has been used to determine the optimum value of filter inductor; whereas Fuzzy Logic controller has been used in voltage control loop of the filter. The improvement in the control scheme using ANN control makes APF versatile for compensation of reactive power, harmonic currents, and unbalance in source voltage. Proposed aircraft shunt filter also provides proper solution to the neutral current in the system. The simulated results clearly bring out the effectiveness of the proposed control method of aircraft shunt APF.

Key words: Active power filter, Artificial Neural Network, Fuzzy Logic controller, Genetic algorithm.

I. INTRODUCTION

More advancement in aircraft power systems [1]-[3] is required due to increased sensitivity of applications of electrical power as against conventional applications. The subsystems like flight control, flight surface actuators, passenger entertainment, etc. are driven using electric power, which in turn has increased the demand for creating aircraft power systems to be more intelligent and advanced. These subsystems have significantly increased electrical loads deploying power electronic devices, increasing consumption of electrical energy etc. Above all the concern for stability and power quality problems has also risen up.

In contrast to normal supply system source frequency of 50 Hz, the aircraft ac power system uses source frequency of 400 Hz [1]-[3]. Aircraft power utility has source voltage of 115/200V. The loads associated with the aircraft ac system are different from the normal loads used in 50 Hz supply system [1]. When we consider the generation portion; aircraft system remains AC driven from the engine for aircraft primary power. Fuel cell technology can be used to produce a DC output for ground power where its silent operation matches up satisfactorily with the Auxiliary Power Unit (APU). While discussing Aircraft Power Systems we also need to consider increased power electronics application in aircraft which creates harmonics, large neutral currents, waveform distortions in both supply voltage and the current, poor power factor and excessive current demand. Furthermore, if a number of non linear loads are impressed upon a supply their effects become additive. Due to these problems, there may be nuisance tripping of circuit breakers or increased loss and thermal heating effects which may incite early component failure. This is a big problem to any sophisticated motor loads on the system. Therefore good power quality of the generation system is of particular interest to the Aircraft manufacturer. We know that aircraft systems work on high frequency so even on the higher frequencies in the range of 360 to 900Hz; these components would still remain very important Now a-days, advance soft computing techniques are widely used in automatic control system or in optimization of the system parameters. Some of them are such as Fuzzy Logic controllers [4]-[8], optimized active power filters using GA[9]-[12], power loss minimization using particle swarm optimization[13], neural network control [14]-[18] applied both in machinery as well as in filter devices. In this paper, three different AI techniques i.e. GA, Fuzzy and ANN have been used to make a complete optimized active power filter for reduction of harmonics and others problem created into the aircraft electrical system due to the non linear loads [1]. The simulation results clearly show their effectiveness. The simulation results obtained with new model are much better than those of traditional methods.

The paper has been organized in the following manner. The APF configuration and the load under consideration are discussed in Section II. The control algorithm for APF is discussed in Section III. Simulation results are discussed in Section IV and finally Section V concludes the paper.

II. SYSTEM DESCRIPTION

The aircraft electrical system is a three-phase power system with source frequency of 400 Hz as shown in Fig.1. The shunt Active Power filter improves the power quality and compensates the harmonic currents in the system [22], [24]-[25], [27]-[28], [30]. The shunt APF is realized by using one voltage source inverter (VSI) connected at point of common
coupling (PCC) with a common DC link voltage [20]-[23]. In order to realize a real aircraft load, the loads used in this paper are a combination of unbalanced and balanced non-linear loads. The load used is three-phase rectifier parallel with inductive load and an unbalanced load. The values of the circuit parameters and load under consideration are given in Appendix.

III. CONTROL THEORY

The proposed control of APF depends on Constant instantaneous power control strategy applied with artificial intelligent techniques such as Genetic algorithm, Fuzzy Logic and ANN [4]-[18]. The following section deals with basic application of Genetic algorithm, Fuzzy Logic and overall control scheme using ANN based on constant source current control strategy [19], [20], [29].

3.1 Design Using Genetic Algorithm

Genetic Algorithms work on principles of natural evolution and genetic laws and used as new search techniques. GA can be used online or offline in the system for the selection of the parameters used in controller, the evaluation process includes a test, which gives the result in a format of number representatives of the performance of each individual. Using any mean; either online or offline, will be associated with both the advantages and disadvantages. The major advantage comes out of the on-line approach is the steadiness of the ultimate solution, because it is selected on the basis of its real performances. We know that GAs typically involve lots of tests to reach a perfect result. This means that this optimization process takes much larger time for experiments to run on the real system. The off-line optimization can be based on a much precise model of the system including all components, all non-linearities and limits of the controllers. It should, however, be understood that a compromise is required to be met with in terms of simulation accuracy and optimization time.

In this paper, GA is applied to the system simulated and has been used to search the optimum value inductor filter (Lf). The boundary and limits of parameters in the filter has been defined and a program using genetic algorithm has been written to give the best value of the filter inductor.

3.2 Fuzzy Logic control

The Fuzzy Logic control has been used in the dc voltage control loop of the active power filter. In fuzzy, the design uses centrifugal defuzzification method. There are two inputs; error and its derivative and one output, which is the command signal. The two inputs uses Gaussian membership functions while the output uses triangle membership function. Table 1 presents the fuzzy control rule and Fig. 2 shows the membership functions used.

3.3 Artificial Neural Network Control

In this paper, the Constant source current control strategy based current controller has been modeled, by an artificial neural network (ANN) using two hidden layers with 12 neurons each, and one output layer with 3 neurons. As seen in the Constant instantaneous power control strategy theory, the current controller has seven inputs and three outputs. The network type used is feed forward back prop. TRAINLM has been used as a training function and LEARNGDM has been used as adaptive linear function. In this model each neurons of the hidden layers has n inputs and it varies based on the function of chosen hidden layer. The adaptation of the weights (W) and bias (b) in the ANN, is based, initially, on the calculation of the mean square error (MSE) between the outputs of the Constant instantaneous power control technique and those of the ANN, and secondly, on TRAINLM algorithm.

3.4 Control Scheme
In this paper Constant instantaneous power control strategy [19], [20], [23] has been used for active power filter with the application of artificial intelligent techniques as shown in the Fig. 3. The intelligent techniques like Fuzzy Logic; genetic algorithm and ANN technique have been used to optimize the system so that the system will give the best performance under all conditions. We know that, the hysteresis controllers produce high switching frequency, which is very harmful for aircraft power utility of 400 Hz. So, we have applied the space vector modulation technique to this HB controller so that the disadvantages of the hysteresis controller can be reduced. SVM technique treats the inverter as a whole unit, which is different when compared to normal PWM technique. This technique is based on the decomposition of a reference voltage vector into voltage vector. However, when using this concept eight possible outputs are available out of them; two of the outputs are the null voltage vectors while the remaining six vectors are 60° apart of each other. The inverter will be driven to one of the eight unique switching states, where each state corresponds to a space vector. The eight space voltage vectors of the inverter are shown in Fig. 4. Each state corresponds to a space vector. V0 is the null voltage vector, and it generally has two switching patterns V0 (000) and V0 (111). The others six voltage vectors are labeled from V1 to V6 and are divided into six regions. This configuration can produce a better current shape by using a significant bandwidth of the hysteresis control [8], [31].

The whole system based on Constant instantaneous power control strategy [24], [29] utilizing SVM based HB [31] has been implemented to give the filter currents which will compensate the harmonics and make the system clean and well within standard limit [26].

### IV. SIMULATION RESULTS & DISCUSSIONS

The proposed scheme of APF is simulated to estimate its performance. The set of load consists of three-phase rectifier parallel with inductive load and an unbalanced load connected a phase with midpoint. The proposed control scheme has been simulated to compute the performance of APF and analysis through THD of source and load current. To realize compensation by APF, a small inductance is connected at the terminals of the load. The simulation results clearly demonstrate that the scheme is able to successfully reduce the significant amount of THD in source current and voltage within limits. Simulation results have been analyzed on the basis of THD and response time obtained. Simulation has been done for 15 cycles.

#### 4.1 Uncompensated system with three-phase rectifier parallel with inductive load and an unbalanced load connected a phase with midpoint

After doing simulation without using any filter (Figure 5) i.e. for Uncompensated System, it has been observed that the THD of source current found when load connected with the system is 4.03% and THD of source Voltage were 30%. By observing these data, we can easily understand supply has been polluted when loads has been connected.

#### 4.2 Performance of APF under three-phase rectifier parallel with inductive load and an unbalanced load.

During the analysis of simulation results based on THD, this has been observed (Figure 6) that while doing simulation of Shunt Active power based on Conventional constant source instantaneous power strategy that the THD of source current found was 2.49% and THD of source Voltage were 1.66%; whereas when model has been optimized using Genetic Algorithm, Fuzzy Logic and current controller developed using ANN control techniques...
has been used, it has been observed that the THD of source current reduces to an amazing 1.12%, and THD of source voltage reduces to 1.63% which is absolutely the improvement from conventional one. During the analysis of simulation results based on response time for compensation, this has been observed that after the comparison of both model i.e. conventional constant source instantaneous power strategy model and improved model using Genetic Algorithm, Fuzzy Logic and current controller developed using ANN control techniques, the response time of new improved model was only 0.0058 sec; as comparison from old simple conventional model 0.0082 sec, we found that new model is better than old conventional model.

From figure 7, we can clearly observe that THD for current and voltage are the least for AI(GA-FL-ANN) technique and figure 8 shows that AI technique applied is fast as compared to conventional technique.

CONCLUSION

A novel GA-FL-ANN control aircraft shunt active filter has been reported which clearly demonstrates its fast compensation ability. This also has been observed that Genetic Algorithm, Fuzzy Logic and ANN have well optimized the model and increased the ability of conventional model. From the simulation results, this can be easily seen that the proposed novel active filter can be effectively applied in higher frequency systems like aircraft systems.

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

REFERENCES


Table 2 THDs & Response Time of Compensated System

<table>
<thead>
<tr>
<th>Techniques</th>
<th>THD-I (%)</th>
<th>THD-V (%)</th>
<th>Compensation Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>2.49</td>
<td>1.66</td>
<td>0.0082</td>
</tr>
<tr>
<td>GA-FL-ANN</td>
<td>1.12</td>
<td>1.63</td>
<td>0.0058</td>
</tr>
</tbody>
</table>

Fig. 6. Source Voltage, source current, compensation current (phase b), load current and DC link Voltage waveforms of Active power filter using GA-FL with neural network controller with three-phase symmetrical nonlinear load condition for aircraft power utility.

The simulation waveforms shown and the result tabulated in table 2 confirm that the new improved GA-FL-ANN control based Shunt APF is able to compensate the system efficiently.

Fig. 7. Graphical representation of THD-I and THD-V for uncompensated system, conventional and GA-FL-ANN control strategy.