Comparison of Aircraft System Using Fuzzy Logic Control and Traditional Control Scheme

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Abstract-Sinusoidal Current Control technique for extracting reference currents for shunt active power filters has been assessed for 400Hz aircraft electric power system. From that point forward, its performance has been compared when optimized using fuzzy logic control. Critical analysis of Comparisons of the compensation ability of these two techniques based on THD and compensation time will be done, and suggestions will be given for the selection of the best method to be used. The simulated results are presented. That will prove the importance of the proposed control method of aircraft shunt SAF in the aviation industry.

Keywords-aircraft electrical system; shunt Active Filter (SAF); sinusoidal current control strategy; fuzzy logic control; total harmonic distortion.

I. Introduction

More advanced aircraft power system [1]–[3] are now day requirement due to the vast application of electrical power in place of different other alternate power sources. The subsystems like flight control, passenger entertainment, flight surface actuators, are driven using electric power that consecutively increased the demand for creating aircraft power system much more advanced and intelligent. These subsystems have considerable issues of stability and power quality problems.

Aircraft AC power system uses source frequency and source voltage of 400 Hz and 115/200V respectively [1]–[3]. The loads with the aircraft ac system are quite dissimilar from the normal loads used in general 50 Hz supply system [1]. Whenever we consider it as the generation portion; aircraft system will be AC driven from the engine for general aircraft primary power. However, when considering the distribution of general primary power, whether AC or DC; each approach has its merits. In DC distribution, HVDC power distribution systems permit the most resourcefulemploy of generated power by antithetical loss from skin effect. It allows paralleling and load sharing among the generators. In AC distribution, Switching of AC is very clear-cut even at high levels as it logically has a zero crossing point. Due to its high reliability over HVDC system, the full range of Contactors, Relays can be exploited.

While talking about Aircraft Power Systems we also need to consider increased power electronics application in aircraft. It creates harmonics, mainly neutral currents, waveform distortion of both supply voltage and current, poor power factor and excessive current demand. Besides if a number of non-linear loads are impressed upon a supply their effects are additive. Due to these troubles, there may be nuisance tripping of circuit breakers or increased loss and thermal heating effects that may provoke early component failure.

Today, advanced computing techniques are used very popularly in automatic control system and also for optimization of the system.

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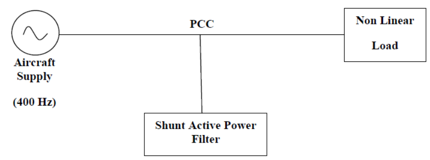

Fig. 1: Aircraft system using Shunt Active Power Filter

Some of them are GA used optimization of active power filter [9]–[12], fuzzy logic [4]–[8], neural network control [14]–[18], power loss minimization using PSO (Particle swarm optimization) [13], applied in machinery and filter devices.

Fuzzy logic controller has been used to improve the overall performance of active filter for reduction of harmonics and other related problems generated by the aircraft electrical system due to the non-linear loads [1]. The simulation results clearly show their effectiveness. The simulation results obtained with a novel optimized model will prove its superiority over traditional sinusoidal current control technique.

The paper has been designed in the following steps. The SAF configuration and the loads under consideration are discussed in Section II. The control algorithm for SAF is discussed in Section III. MATLAB/ Simulink based simulation results are presented in Section IV, and finally Section V concludes the paper.

II. System Information

The aircraft system is a 3-phase power system using source frequency of 400 Hz. From Figure 1, we can see that Shunt Active Power Filter specifically improves the power quality and compensates the most of the harmonic currents in the system [22], [24], [25], [27], [28]. The SAF is uses one voltage source inverters (VSIs) connected at PCC with a DC link voltage [20]–[23].

The set of loads for aircraft system consist of three loads. First load is a three-phase rectifier in parallel with inductive load and an unbalanced load connected in a phase with midpoint (Load 1). Second one is a three-phase rectifier connects a pure resistance directly (Load 2). Third one is a three-phase inductive load linked with the ground point (Load 3). A combination of all three loads connected with the system together at different time interval has been done. So, that we can study the effectiveness of the control schemes used. That, in turn, verifies the functionality of the SAF and its ability to harmonics compensation. For the case, 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 values are given in Appendix.

III. Control Theory

The proposed control of SAF depends on Sinusoidal Current Control strategy. It has also been optimized for artificially intelligent technique i.e. fuzzy logic control. Sinusoidal Current Control strategy has been discussed in brief in this section. The following section also deals with primary application of fuzzy logic in control scheme on Sinusoidal Current Control strategy [19], [20].

A. *Sinusoidal Current Control Strategy (SCC)*

With some modification in Constant Instantaneous Power Control strategy [19], the new approach can be used under unbalanced conditions too. The new strategy has been named as Sinusoidal current control strategy.

Fig. 2 shows the control diagram of shunt active filter using sinusoidal current control strategy that is modified a version of Constant Instantaneous Power Control strategy and under unbalanced conditions able to compensate load currents too. The modification uses a positive sequence detector that replaced the 6.4 KHz cutoff frequency LPFs and found the correct phase angle, as well as the frequency, of the component of fundamental positive sequence voltage. Thus, SAF compensates the most 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 $\alpha-\beta-0$ transformation block and send to the $\alpha-\beta$ voltage reference block, which calculates v_α and v_β.

Finally, $\alpha-\beta-0$ inverse transformation block calculates the V_a',, V_b', and V_c'. In place of the filtered voltages used previously, V_a',, V_b', and V_c', are inputs to the main control circuit. Now fundamental negative sequence power, harmonic power, and the fundamental reactive power, are also included in the compensating powers.

The sinusoidal current control strategy makes the active filer to compensate the current of a nonlinear load to guarantee balanced, sinusoidal current drawn from the network, even under an unbalanced and/or distorted system voltage. We know that neutral current is a big problem for aircraft system and this strategy compensates also the neural current of the load.

Fig. 2 shows the complete control block diagram of the shunt active filter that realizes the sinusoidal current control strategy for aircraft systems. One simplification was done in the positive-sequence detector shown in Fig. 3, and included as part of the controller of the aircraft shunt active filter. Fig. 4 presents the MATLAB/Simulink model of control block diagram of shunt active filter.

It is important to remark that the voltage regulator of Fig. 2 that generates the signal p_{loss} has received an additional ask besides those listed in the last sections: to correct errors in power compensation. This occurs because the feed forward control circuit is now unable to supervise the zero-sequence power. Since the active filer compensates the whole neural current of the load in the presence of zero-sequence voltages, the shunt active filter eventually supplies. pis replaced simply by $p_{\bar{loss}}$. Therefore, if t-he active filer supplies $\bar{p_0}$ to the load, this causes dc voltage variations, which are sensed by the PI controller of the dc voltage regulator. Hence, an additional amount of average real power, numerically equal $\bar{p_0}$, is automatically added to the signal plot that is mainly used to provide energy to cover for losses in the power circuit of the SAF.

B. *Fuzzy Logic Control Application inSinusoidal Current Control Strategy (FUZZY-SCC)*

The fuzzy logic control is generally used in the dc voltage control loop of the SAF. In fuzzy logic, the design uses standard centrifugal de-fuzzification method. The steps involved in the design of a controller using the fuzzy logic require a particular set of information. The algorithm is simple once the design problem is identified i.e. number of input and output variables required and the kind of output desired.

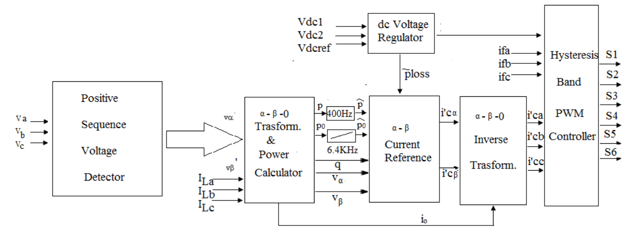

Fig. 2: Control Diagram for Shunt Active Filter Controller using Sinusoidal Current Control Strategy

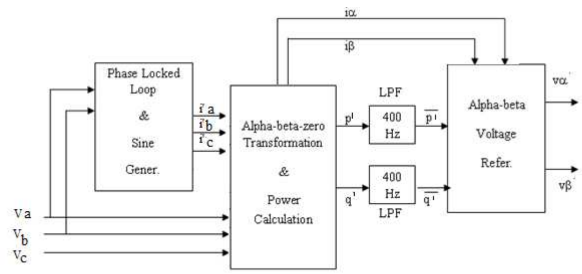

Fig. 3: Block Diagram of the Fundamental Positive-Sequence Voltage Detector for Sinusoidal Current Control Strategy

TABLE I: Fuzzy Control Rule

Errorde/dt	Negative	Zero	Positive
Negative	Big Negative	Positive	Big Positive
Zero	Big Negative	Zero	Big Positive
Positive	Big Negative	Negative	Big Positive

Two inputs; error (e)& its derivative (de/dt) and one output, which are the command signal are applied. The inputs are normalized values of capacitor voltage deviation as e and its derivative (de/dt). The two inputs uses familiar Gaussian membership functions. The output uses the triangle membership function. Tab. I shows the fuzzy control rule. Fig. 4 displays the membership functions used.

IV. Simulation Results and Discussions

The proposed scheme of SAF is simulated to estimate its performance. The load applied with the aircraft system consists of three-phase rectifier connected a pure resistance directly. To make an active compensation by SAF, a small inductance is connected at the terminals of the load. The simulation results reveal that the control scheme is comfortably able to reduce the considerable amount of THD in source voltage and source current within limits.

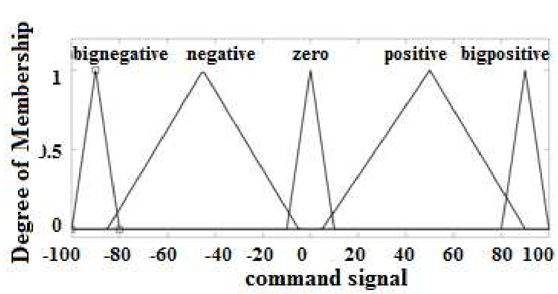

Fig. 4: Membership functions

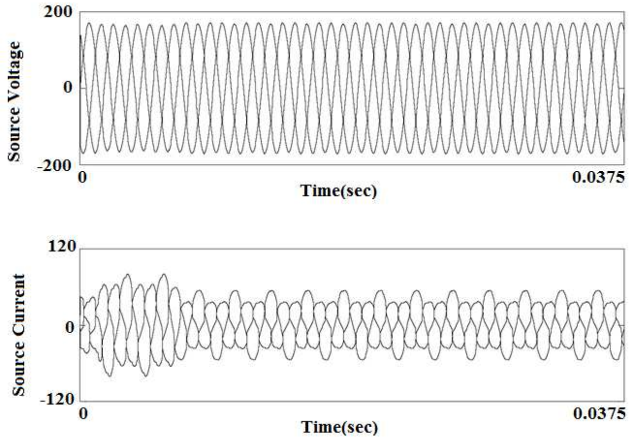

Fig. 5: Waveforms of source voltage and source current for load 1, 2 and 3 connected together at different time interval

A. Uncompensated system

From the simulation results shown in Fig. 5, it has been observed that that the THD of source current & source voltage was 9.5% and 1.55% respectively, which is obviously not within the limit of the international standard.

B. Performance of SAF

In this section, performance of SAF has been discussed for Sinusoidal Current Control Strategy alone and along with Fuzzy Logic Control. Simulation results using MATLAB show the affectivity of control schemes.

1) For Sinusoidal Current Control Strategy : The results from simulation are shown in fig. 6. THD block available in MATLAB has been used to calculate the THD of source current and voltage. From the MATLAB simulation results, THDs of source current & source voltage were 2.72% and 1.65% respectively. At t=0.01 sec, we can see that the waveforms for source voltage and source current have become sinusoidal. The observed compensation time was 0.01 sec.

The waveforms of compensation current, dc capacitor voltage and load current can be seen from Fig. 6. There is variation in dc voltage which can be seen clearly in the waveforms. If there is a need for increasing the compensation current for fulfilling the demand of load current, it releases the energy and after that it charges and tries to regain its set value.

After close observation, we can find out that the compensation current is completing the demand of load current. After using SAF, the source current, and voltage forcefully becomes sinusoidal. Comparative performance of compensation current, source current and source voltage for various loads used for different control strategies are discussed in further chapters. After the comparison with the uncompensated system, it has been observed that the system using active filter has compensated the supply system. The results are within the limit of IEEE 519-1992 standard defined for voltage and current harmonics.

2) For Sinusoidal Current Control techniquesusing Fuzzy Controller (SCC-Fuzzy): The results from simulation are shown in Fig. 7. From the MATLAB Simulation results,THDs of source current & source voltage were 2.22% and 1.01% respectively. At t=0.0066 sec, we can see that the waveforms for source voltage and source current have become sinusoidal. The observed compensation time was 0.0066 sec.

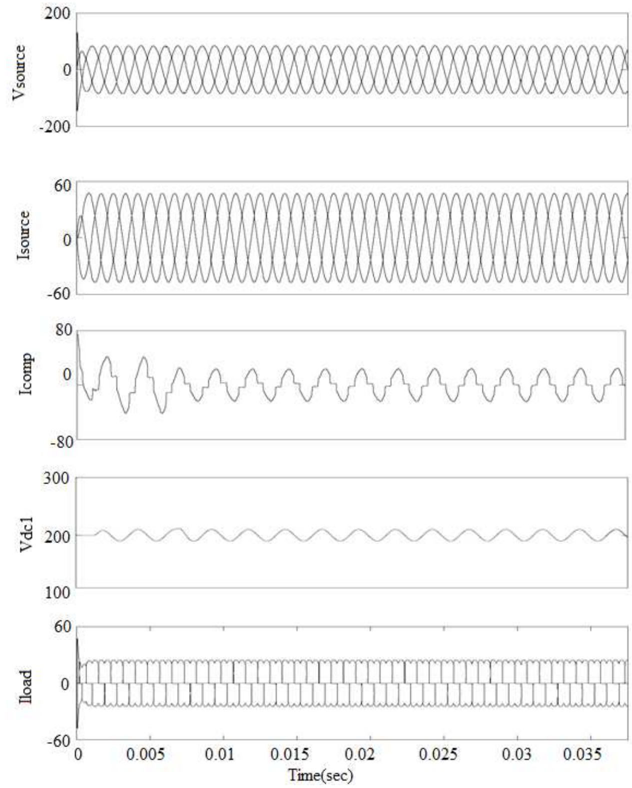

Fig. 6: Source Voltage, Source Current, Compensation Current, DC Link Voltage and Load Current Waveforms of Active Power Filter using SCC Strategy for Aircraft System

TABLE II: Summaries of Simulation Results Using SAF

Strategy Used Compensation Time(sec)	THD-I (%)	THD-V (%)
SCC 0.0100	2.72	1.65
SCC-FUZZY 0.0066	2.22	1.01

The waveforms of compensation current, dc capacitor voltage, and load current can be seen from Fig. 7. There is variation in dc voltage which can be seen clearly in the waveforms. If there is a need for increasing the compensation current for fulfilling the demand of load current, it releases the energy and after that it charges and tries to regain its set value.

After close observation, we can find out that the compensation current is completing the demand of load current and after applying the SAF, the source current and voltage forcefully becomes sinusoidal. Comparative performance of compensation current, source current and source voltage for various loads used for different control strategies are discussed in further chapters. After the comparison with the uncompensated system, it has been observed that the system using active filter has compensated the supply system. The results are within the limit of IEEE 519-1992 standard defined for voltage and current harmonics.

C. Comparative Analysis of the Simulation Results

Simulation results, shown in Fig. 6 and Fig. 7, have been tabulated in Tab. II. From the table, we can conclude that SCC-Fuzzy strategy is better than conventional SCC approach.

Figure 8 presents the bar chart for total harmonic distortion calculated for source current and source voltage. We can clearly

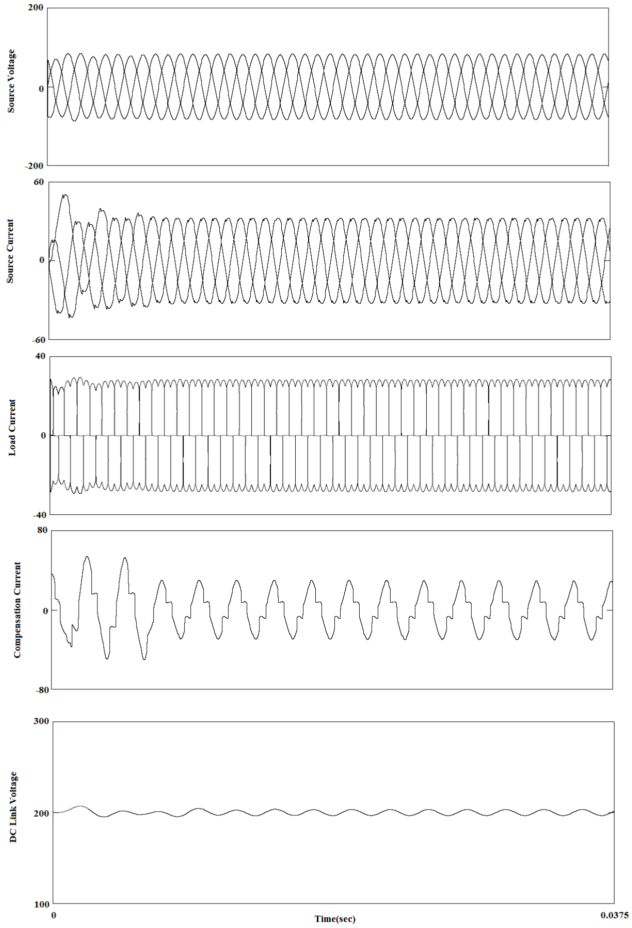

Fig. 7: Source Voltage, Source Current, Load Current, Comp Current and DC Link Voltage Waveforms of Active Power Filter using SCC Strategy using Fuzzy Logic Control for Aircraft System

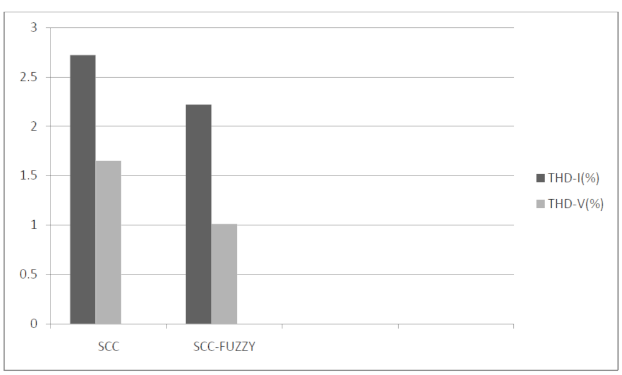

Fig. 8: THD of Source Current and Source voltage for SCC and SCC-Fuzzy strategy

observe the significant reduction in THD of both source voltage and source current for SCC-Fuzzy from SCC strategy. Current THD is reduced from 2.72% to 2.22%. Voltage THD is reduced from 1.65% to 1.01%. The compensation time for SCC-Fuzzy is less than SCC strategy, which clearly proves that SCC-Fuzzy is fast and overall better than traditional SCC strategy.

V. Conclusion

This paper has done a critical analysis of traditional (SCC) and soft computing control strategies (SCC-Fuzzy) for shunt SAFs installed in aircraft power utility of 400 HZ. The ideas have been given for the optimum selection of strategy based on compensation time and THDs of source current and voltage. Sinusoidal Current Control Strategys performance has been improved like anything when modified using Fuzzy Logic control. SCC-Fuzzy has been observed better and fast as compare to SCC control strategy discussed.

VI. Appendix

The system parameters used are as follows [1]:

Three-phase source voltage: $110V/400Hz$
Filter capacitor= $5F$
Filter inductor=$0.25mH$
Dc voltage reference: $400V$
Dc capacitor: $4700F$

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