# A NOVEL SHUNT ACTIVE POWER FILTER FOR EPS SYSTEM TO IMPROVE POWER QUALITY

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## ABSTRACT

With the increasing use of electrical power in place of hydraulic, pneumatic, and mechanical power is demanding more advanced aircraft power systems to improve its quality and reliability catches growing interest. In this paper, based on the analysis and modeling of the shunt APF with close-loop control, a feed forward compensation path of load current is proposed to improve the dynamic performance of the APF. The two H-bridge cascaded inverter is used for the aeronautical APF (AAPF). Justifications for topology choosing and corresponding system control method are given. Furthermore, the global framework and operation principle of the proposed AAPF are presented in detail. Simulated waveforms in different load conditions indicate the good performance of the AAPF.

***Index Terms: Active power filter (APF), cascaded multilevel inverter, close-loop control, feed forward of fundamental load current***

## I INTRODUCTION

With the increasing use of electrical power in place of hydraulic, pneumatic, and mechanical power is demanding more advanced aircraft power systems. The concept of the "all-electric aircraft" and the "more electric aircraft" (MEA) have been introduced to overcome some of the drawbacks found in conventional architectures and bring more attractive advantages, such as improved fuel consumption and lower maintenance and operation costs [1]. This implies an increase of the electrical load and power electronic equipment, higher consumption of electrical energy, more demand for generated power, power quality, and stability problems. The concept of multilevel inverters, introduced about 20 years ago entails performing power conversion in multiple voltage steps to obtain improved power quality, lower switching losses, better electromagnetic compatibility, and higher voltage capability. Several topologies for multilevel inverters have been proposed over the years; the most popular cascaded H-bridge apart from other multilevel inverters is the capability of utilizing different dc voltages on the individual H-bridge cells which results in splitting the power conversion amongst higher-voltage lower-frequency and lower-voltage higher-frequency inverters. The total harmonic distortion (THD) is reduced with more number of steps in output voltage without using pulse width modulation techniques. In this paper a novel topology is proposed to get high 31 levels.

Nowadays, the increase in the usage of non-linear loads especially the power electronic equipment's leads to deterioration of the quality of voltage waveforms at the point of common coupling (PCC) of various consumers.

Active power Filter (APF) has been used to mitigate the harmonic pollution in electrical networks. APF acts as an ideal current source and inject the compensating current into the ac lines by selective harmonic compensation in order to cancel the line current harmonics. To improve the power quality traditional compensation methods such as passive filters used have many disadvantages such as fixed compensation, bulkiness, electromagnetic interference and possible resonance etc., Active power filters (APF) have proved to be an attractive alternative to compensate for current and voltage disturbances in power distribution systems [2].

Two fundamental configurations of stand-alone APFs, either active or passive, have evolved: the series and the shunt filter. The shunt active filter shown in Fig. 1 is recognized as a cost effective solution for harmonic compensation in low and medium power systems [3]. It has simple structure and construction, similar to a PWM voltage source inverter, with a large dc link capacitor, and connected to the line by means of an inductor.

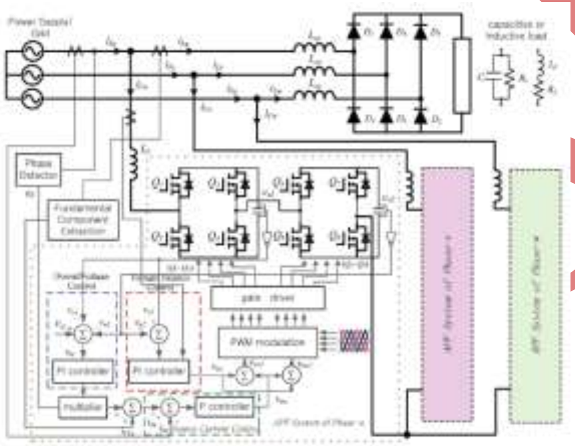


**Fig. 1 Block diagram of shunt active power filter**

Harmonic current compensation by means of active power filter (APF) is a well-known effective solution for the reduction of current distortion and for power quality improvement in electrical systems. The shunt compensator behaves as a controlled current source that can draw any chosen current references which is usually the harmonic components of the load currents. Meanwhile, more and more APFs are applied not only in harmonic current and reactive power compensation but also in the neutral line current compensation, harmonic damping application, and power flow control. As Fig. 1 shows, in the aircraft EPS, the APF could be installed in the source side (such as the aircraft generator) or near the load side, and it could even be integrated into the load-front converter (such as the input stage converter of variable-speed drives).

In this paper, a high-performance aircraft APF is proposed. Differently from traditional open-loop control strategy, the proposed aeronautical APF (AAPF) works in a close-loop way. Good power quality of the EPS is achieved by using the novel AAPF. Furthermore, in order to improve the dynamic performance of the load response, a feed forward path of the load current is added. Based on the modeling and analysis of the close-loop system, the operation principle of the feed forward compensation path is revealed. Meanwhile, in this paper also a new control method for cascaded-inverter-based AAPF is proposed. Simulation results are observed under different fundamental frequencies and load conditions.

## II CONTROL STRATEGY FOR APF

In the traditional control of APF, the current reference is usually the harmonic and reactive components of the load currents. However, the approach, essentially based on feed forward open loop control, is sensitive to the parameter mismatches and relies on the ability to accurately predict the voltage-source inverter current reference and its control performance. I n the close-loop control, detection and control target is the source current. In the aircraft EPS, the fundamental frequency is much higher than 50-Hz power system. Furthermore, measure errors, analog to digital conversion time, digital delay, and other non-ideal factors will deteriorate the open-loop compensation effect to a worse degree. As we known, feedback control has the following merits: It could reduce the transfer function from disturbances to the output, and it causes the transfer function from the reference input to the output to be insensitive to Variations in the gains in the forward path.

The closed loop control scheme for extracting the reference current using synchronous reference frame method is depicted in Fig.2. The function of the harmonic detection block is separately highlighted in Fig 3. The SRF method [14] is based on Park's transformation whereby the 3-phase line currents are transformed into 2-phase quantities using Park's transformation.

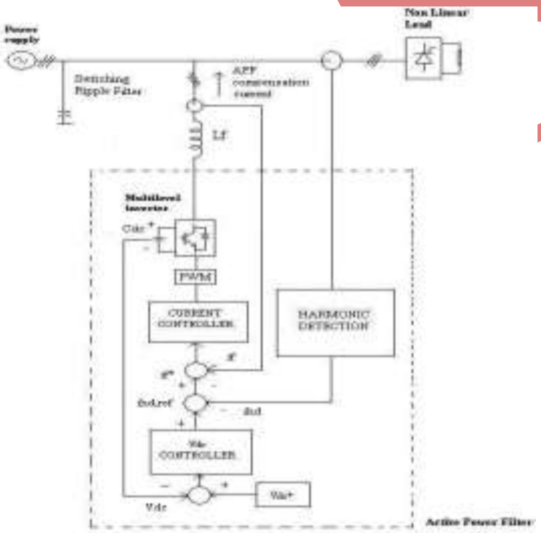


**Fig.2 Closed loop circuit of shunt active power filter**

There are mainly two blocks corresponding to positive and negative sequence components. The positive sequence component of load current is transformed to de–qe axes by generating positive sequence phase information +_ from PLL circuit. The details of mathematical implementation of PLL software in the synchronization of three-phase system is given in [15] and its application in Matlab simulations can be found in package program. AC quantities in positive sequence waveform include all harmonic components while dc quantity is the fundamental component of line current. The negative sequence component of the current is also transformed to de–qe axes by generating negative sequence phase information from the PLL. If voltages and currents in the three-phase system are balanced, the output of this block will be zero. Thus the dominant harmonic component is obtained by comparing the positive and negative sequence controller outputs. The component which is in 2-phase form is converted into 3-phase using inverse transformation. This dominant harmonic component of the current is compared with the reference current derived from the dc voltage controller block.

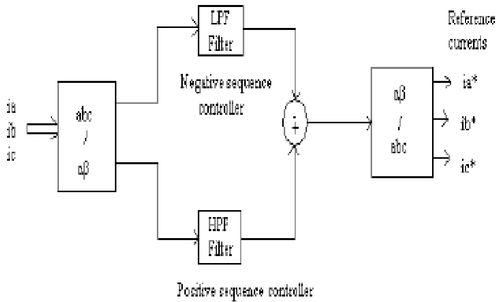


**Fig.3 Scheme of harmonic detection**

In this voltage control loop, sums of the capacitor voltages in each cluster (for example: v for phase-u) are the control target. This control method yields the u-phase overall voltage signal v from the dc capacitor voltage reference v the u-phase is divided into $v_{u1}$, $v_{u2.}$ Furthermore, this voltage control scheme could be expanded to the N H-bridge cascaded inverter topology. Here, N corresponds to the number of cascaded converter units. One obvious advantage of this control scheme is that the final compensation performance would not get worse when one or more cascaded units stop working. The remaining cascaded units would share the dc-link voltage of the fault one. This voltage control scheme can increase the fault toleration and reliability of the AAPF system

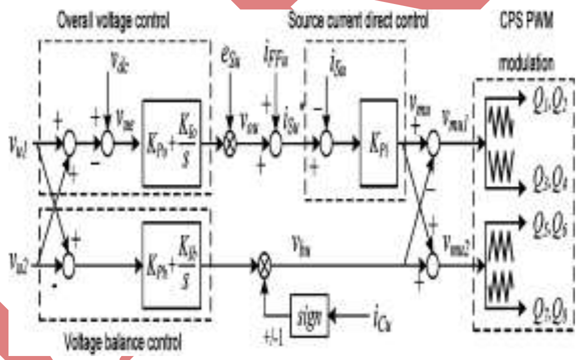
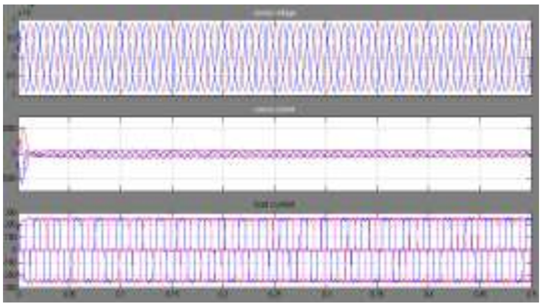


**Fig.4 Control Diagram**

The whole control diagram for phase-u of the proposed u AAPF is given in Fig.4, which contains the overall voltage control, voltage-balance control, load current feed forward compensation, and source current direct control.

## III SIMULATION RESULTS

In order to verify the compensation performance of the proposed AAPF, simulated waveforms using the "Simulink" software package of "Matlab" are given. Fig. 5 shows the simulated results for the 400-Hz EPS SW with inductive load. Nonlinear loads start to work at 0.2 s and are half unloaded at 0.25 s. In fig 5 the first waveform shows source voltage, second waveform shows source current and third waveform shows load current



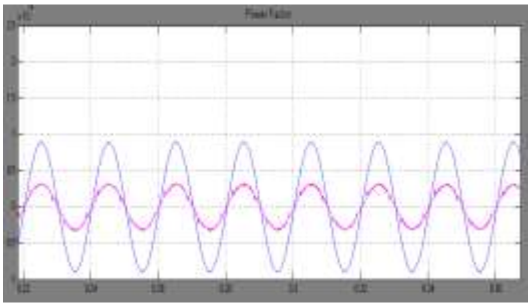
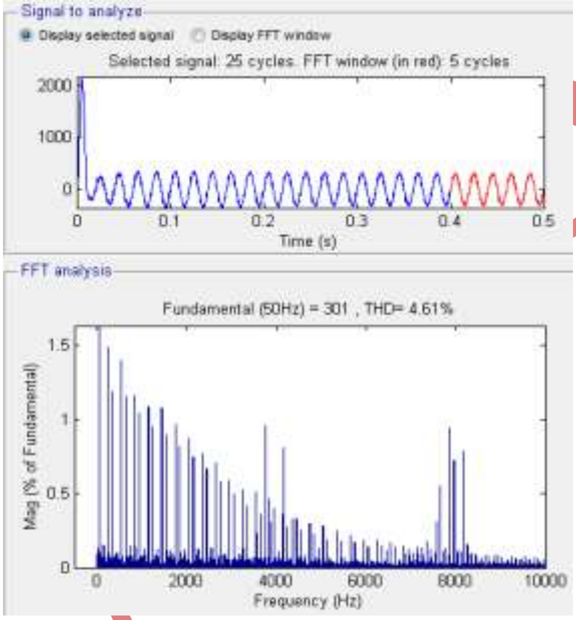


**Fig 5: Simulated results for the given APF converter system Fig 6: Simulation for Power Factor**

As in Fig. 6 the first graph indicates, compensation, and three phase source currents get sinusoidal as in figure two. In Fig the third graph indicates the load current.



Signal to analyze
● Display selected signal ○ Display FFT window
Selected signal: 25 cycles. FFT window (in red): 5 cycles

FFT analysis
Fundamental (50Hz) = 301 , THD= 4.61%

**Fig 7: THD Window**

As Fig. 7 illustrates, after APF's working, the THD of the source current is reduced 4.61%

## IV CONCLUSION

For elimination of power quality problems in modern aircraft EPS systems a new APF is used. In this paper, a load current feed forward compensation method for the source current direct control-based AAPF has been proposed. The corresponding system control strategy of the cascaded-inverter based active filter system is shown. The cascaded H-bridge inverter has been used for active power filter. The deterioration of power quality and increase of harmonic pollution due to the increase in the usage of non-linear loads especially the power electronic equipment's has been highlighted. Then the role of APF in compensating the line current harmonics has been demonstrated by considering certain non-linear loads. Simulation results show that the dominant harmonics in the line current and total harmonic distortion have been reduced significantly. Hence there is an improvement in the power quality.

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