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DESIGN AND IMPLEMENTATION OF 115 V AC POWER SUPPLY FOR USE IN AIRCRAFT

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Abstract- Considering the importance of aviation systems, especially flight simulator systems, we need several power sources, which will be used as a complex in the form of a rack of power sources at the end of this article. One of these power sources is the 115 V 50 Hz and 5.5 A power source, which must have all the characteristics of a sensitive power source, including high protection, fast response, and insensitivity to noise and disturbance. In addition, the power supply should be designed such that it can be operated by the PLC and Control Panel system from any desired point by the command pulse of these systems. In addition, the power supply should have a suitable output for feedback and send it to commanding systems. Additionally, the power supply should have a suitable output for feedback and should be able to send it to the commanding systems. The maximum power of designed power supply is 650 W. also experimental result show the efficiency of proposed power supply is around %96. In this study, the simulation and construction of the device were performed in a laboratory environment and significant results were obtained.

Keywords: SMPS, Good Power, Simulator.

1. INTRODUCTION

Due to the high costs of training flights and increasing safety concerns, the demand for flight simulator systems is rising steadily. In the design of the flight simulator, various power sources need to be considered due to the different voltages used in aircraft systems, one of which is a 115 V AC power source. The power supplies used must have high reliability, fast response, high efficiency, and low maintenance costs. The electrical network of aircraft systems is compared in some studies, and the benefits of using 115 VAC are shown in [1]. Converting this voltage range to higher voltages has certain problems, such as safety issues. However, the distortion that AC and DC voltages produce in aircraft systems should be analyzed because of safety performance [2]. Because of the use of many power converters with different voltage levels in aircraft power systems, the harmonic levels and voltage transients significantly increase.

Harmonic-level passive filters were designed for these systems [3]. To cancel the current ripple and harmonic reduction, a circuit is designed to reveal the relationship between the volt-second imbalance and current distortion [4]. In addition, single-phase PFC converters have been designed to increase the system performance [5-14]. In recent years, new trends have emerged in the aircraft industry. A new matrix-based converter was designed to improve the power density and quality of a system [6]. To meet the EN61000-3-2 class D and RTCA DO-160G standards in aircraft systems, a PFC converter was designed to control the peak current and hysteresis mode of the system, and the experimental results validated them [7]. A soft-switch resonant inverter designed to avoid zero-crossing failures and current can be controlled using this method, and switching losses are reduced [8-15].

A comparison of different AC-AC converters shows that direct and indirect matrix converters are more compact than converters with a capacitive DC link because the input inductor and voltage stress in these converters are less. However, converters with capacitive DC links are easy to control and have low production costs [9]. To modernize the power supply systems of aircraft, an inverter-based power converter with sinusoidal output voltage has been designed [10]. The aim of this converter and control method is to provide harmonic distortion under %5 with a discrete Fourier transform and a self-learning repetitive controller. In the past, small- and medium-sized aircraft used DC voltages such as 28 VDC, but this voltage level in modern aircraft systems has some disadvantages, such as using more wire that increases the weight of the aircraft. Because DC systems are limited to 400 A in the case of current, the size of wires to carry the necessary current becomes prohibitively expensive. Currently, many small aircraft use 28 VDC for emergency voltage and generator starter voltage, but large-scale aircraft such as Airbus A380 use 115 VAC power systems between the AC generator and the AC load [11-12].

A comprehensive analysis of power converters used in aircraft in terms of power density, efficiency, and power quality was provided [13]. The main aim of this research was to reduce EMI, weight, and thermal management. In this paper 115 VAC 5.5 An AC-AC power supply is designed for a flight simulator with overvoltage and overcurrent protection and controllability with a PLC. Also, a 28VDC output is installed for emergency and internal power supply. The simulation and practical results of the manufactured device were consistent.

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2. PROPOSED DESIGN METHOD

The overall goal of this study is to convert 220V single-phase to 115 V 50 Hz and 5.5A. In addition to complying with global power supply standards such as MIL-STD 704F CHG1, MIL-STD 1275E, and MIL-STD 1399, this converter provides overvoltage, overcurrent, and short-circuit protection. In this part, the input power reaches the input of the 50 Hz step-down transformer after passing through the current filters and protections placed on its way. The output of the transformer provides 115V 50 Hz power. Owing to the low frequency of 50 Hz, an E-I 96 silicon core with dimensions 96×55×215 mm^3 was used. Grade 1 wires with a cross-sectional area of 0.8 mm^2 have been used for winding the transformer. The above trans ratio is 0.52. According to the fact that each turn of voltage tolerance of the voltage coil is considered to be 0.39 volts, so the number of initial turns is 560 turns. Considering that we have the ratio and number of primary turns, the ratio of secondary turns was calculated as 280. Figure 1 shows the overall designed circuit of the system.

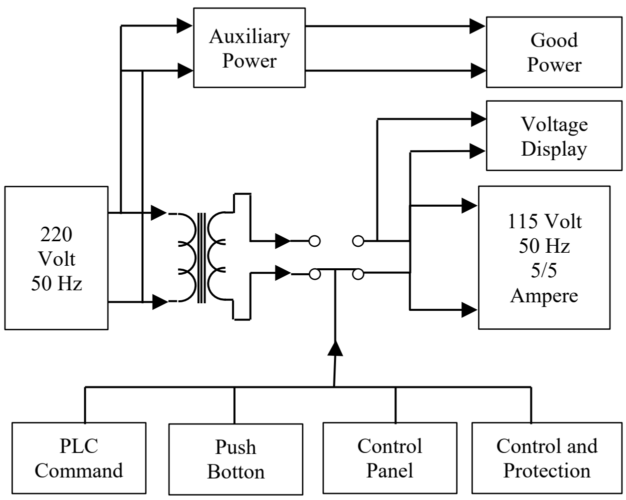

Figure 1. Overall designed circuit of the system

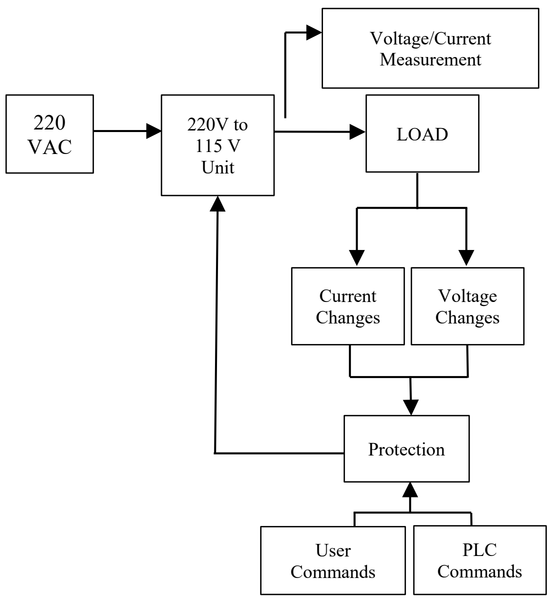

Figure 2. The detailed operation of the system

A 12V power supply is required to support the internal power of the system, the holding circuit, and the commanding circuit, which is supplied by the 220V to 12V DC module. Also, we need a voltage of 28 volts to generate the Power Good signal, for which a DC-DC converter is used. The detailed operation of the system is shown in Figure 2. The protection circuit is designed to disconnect the system if there is a 20% overvoltage and overcurrent at the output. In addition, we expected a maximum ripple of 1% in the output voltage. In this design, we embedded a good power system to show the continuous status of the device and the ability to command the PLC and control panel, as shown in Figure 3.

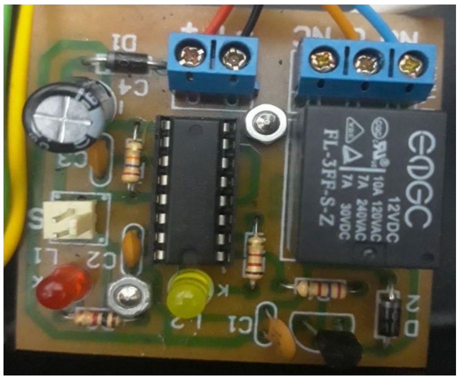

Figure 3. PLC and user command receiver circuit

The characteristics of the designed circuit are listed in Table 1. The system generally has three operating modes. In the on-state, the input switch is connected and the connect command is issued. In this case, the system works. In the off mode, the input switch is off regardless of the status of the command on or off. In the third mode, the input switch is connected, and the system waits to receive the connect command. In this case, the system was ready to operate.

Table 1. Parameters of proposed power supply

	Parameter	Size
General technical specifications	Power	633 W
	Dimensions	12×28×32
Specifications of main product outputs	Output voltage	115 V
	Maximum output current	5.5 A
	Raise Time	40 ms
	Fall Time	40 ms
Specifications of the main product inputs	input voltage	220 volts RMS
	Minimum input current	4 A
	Input frequency	50 Hz
	Input current fuse	5 A

To ensure the correct operation of the device, overvoltage, overcurrent, short circuit and soft start tests were performed, as explained below.

2.1. Overvoltage Test

A DC voltage source set at approximately 195 V DC, which is equal to 120% of the rated voltage of the converter, was applied to the working output, and the protection system quickly cut off the output of the converter. As long as this overvoltage exists, the output of the converter will not connect.

2.2. Overcurrent Test

To perform this test, a resistive load of 17.5 ohms was placed in the output of the converter, which causes a current equivalent to 6.6 amps, which is equal to 120% of the rated current of the converter, and the protection system quickly cuts off the output of the converter; if this overcurrent exists, it will not connect the output.

2.3. Short Circuit Test

To perform this test, the output of the converter, which was working normally, was suddenly short-circuited, and the protection system quickly cut off the output of the converter and did not connect the output of the converter until an error existed.

2.4. Soft Start Test

To perform this test, the output of the converter was shortened before the device was turned on. After the device is turned on, the protection system quickly cuts off the output of the converter and does not connect the output of the converter until this error exists.

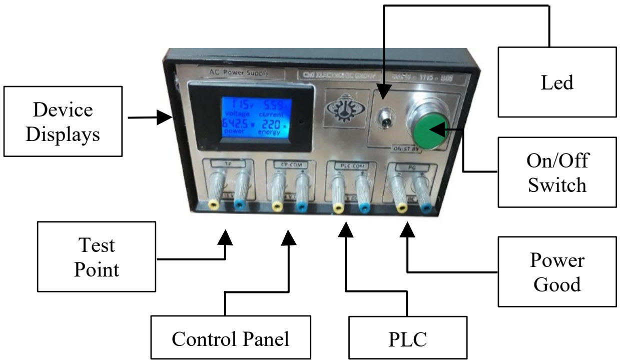

Figure 4. View of the designed device

A view of the designed device is shown in Figure 4. To turn off and turn on the system, we must press the green button of the device for a short moment, which changes its status every time it is pressed. A voltage and current display were used, which shows the voltage with an accuracy of 0.1 and the current with an accuracy of 0.01, respectively. The display also shows the current power and energy consumed by the load. Four pairs of parallel sockets were used from right to left. The first pair of parallel sockets shows a Good Power output, which should be 28 volts if the device is working properly. The second parallel socket pair was also used as a PLC input, which connected and disconnected the device with each pulse of approximately 24 volts sent from the PLC.

The third parallel socket pair is also used as the Control Panel input, which connects and disconnects the device with each 24-volt pulse sent from the Control Panel. The fourth parallel socket pair was used to measure the output, which is called the Test Mode. There is a green LED on the front of the device for easy troubleshooting, which lights up if the converter works properly, as shown in Figure 5.

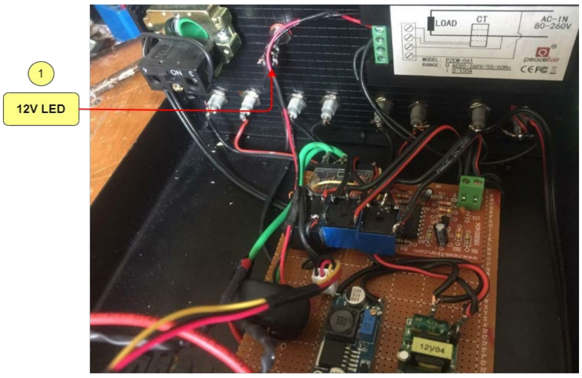

Figure 5. Internal test points of the device

The tests performed on the device in a laboratory environment were as follows: To measure the output voltage of the device, the output load was set to three modes: 50%, 75%, and 100%. The performance of the devices is listed in Table 2. The output frequencies of the devices in the three different load modes are listed in Table 3. The voltage modulations ($V_{\max}$–$V_{\min}$) are presented in Table 4. In addition, we can see the frequency modulation ($f_{\max}$–$f_{\min}$) in Table 5. The load transient recovery times measured during the test are shown in Table 6. The crest factor ratio of output signal was 1.40, as listed in Table 7.

Table 2. Output Voltage

Test item	Measured Value Under Test		
Output Voltage (V)	50%	75%	100%
	117.86	115.60	114.03

Table 3. Output Frequency

Test item	Measured Value Under Test		
Frequency (Hz)	50%	75%	100%
	49.99	50.03	50.07

Table 4. Voltage Modulation

Test item	Measured Value Under Test		
Voltage Modulation (V)	$V_{\max}$	ΔV	$V_{\min}$
	160	1	159

Table 5. Frequency Modulation

Test item	Measured Value Under Test		
Frequency Modulation (Hz)	F_{ax}	ΔF_{mod}	$F_{\min}$
	50	0.01	49.99

Table 6. Load Transient Recovery Time

Test item	Measured Value Under Test	
Load Transient Recovery time (ms)	T_{Rise}	T_{Fall}
	40	40

Table 7. Crest Factor

Test item	Measured Value Under Test		
Crest Factor (V)	V_{PEAK}	V_{RMS}	CF
	160	114	1.40

Figure 6 shows the amplitude, effective value, and frequency of the output voltage. In addition, Figure 7 shows the output values of the device, which are consistent with the values measured on the oscilloscope.

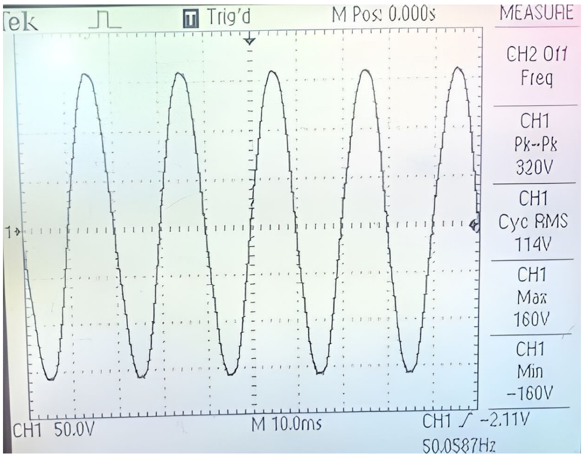

Figure 6. Output waveform of device

115 V voltage	5.59 A current
642.5 W power	220 Wh energy

Figure 7. Output values of device

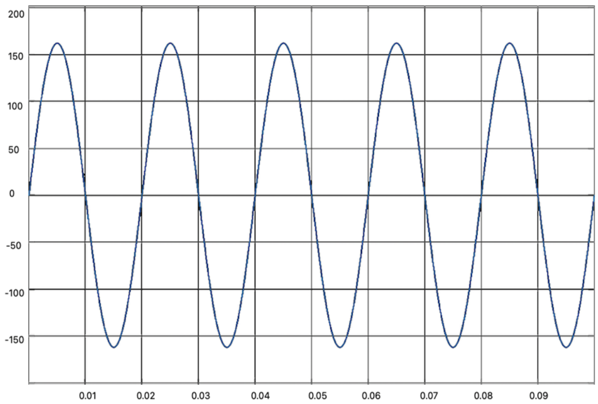

Figure 8. Output voltage

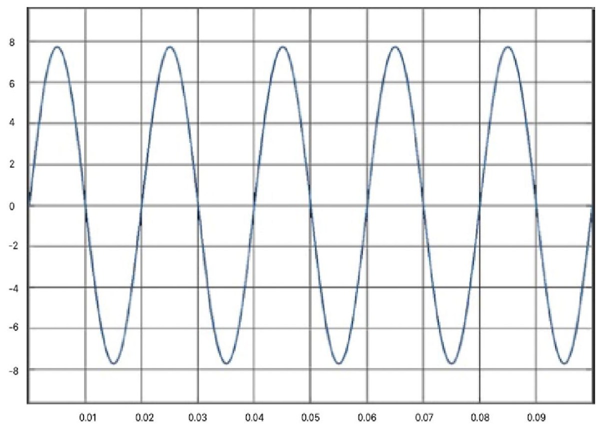

Figure 9. Output current

To demonstrate the performance of the system and the results of the designed circuit and its consistency with the results obtained in the experimental part of the desired system, it was implemented in MATLAB software, as shown in Figure 8 and Figure 9.

3. CONCLUSIONS

In this article, 115V 50 Hz power supply with a maximum current of 5.5 ampere, which is designed and built for use in the flight simulator power supply rack, in addition to complying with global power supply standards such as MIL-STD 704F CHG1, MIL-STD 1275E and MIL STD 1399 has overvoltage, overcurrent and short circuit protections. It also displays voltage, current, power, and energy continuously. In addition, the designed power supply has an embedded power supply system to show the continuous status of the device and the ability to command from the PLC and Control Panel. The designed device was first simulated in MATLAB and then produced and tested in a laboratory to verify its performance; the results obtained were consistent.

Compared to other power supplies, the efficiency of the proposed power supply is approximately 96%, delivering better results. On the other hand, we can see that the proposed power supply has a lower construction cost than the other models. A 28 VDC power point has been integrated into the proposed system to monitor continuous states and the converter’s performance. Because of using most of small and medium sized aircraft systems for emergency voltage or generator start voltage. The output voltage measured under three load mode of %50, %75 and %100. In all modes the maximum output voltage ripple of the designed power supply is about 1%. Load transient recovery time of the designed power supply is 40 ms.

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