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Design and Implementation of 12 pulse AC to DC Converter in Aircraft for Aerospace Applications

Harshitha G B, Sujo Oommen

Abstract: ***Aircraft applications like landing gears, flaps, rudder systems and etc. use actuator systems which includes combination of motor, actuators and auto transformer rectifier units. These systems work at a frequency of 400Hz. These are AC to DC converters used in aircraft's system to supply constant DC power to the motors which in turn operates actuators. These converters varies with the pulses like 12 pulse, 24 pulse etc. For the systems like this harmonics too play a major role. Less the harmonics more efficient and reliable the system will be. In this paper, a 12 pulse AC to DC converter was designed for 400Hz and 50Hz and the actual model was built for 50Hz of 1KW power. The design of 400Hz and 50Hz was done in MATLAB/Simulink and the prototype was built for 50Hz. Total harmonic distortion was obtained and compared for the two systems. All the results the simulation and the prototype are shown in this paper.***

Index Terms*: Autotransformer Rectifier Unit, Actuators, Aircraft systems and Total Harmonic Distortion*

I. INTRODUCTION

An aircraft system mainly consists of three parts which are source (AC Generator or the DC Generator – battery source), conversion units (AC to DC converters which are also called as ATRU system) and the load (which are usually an AC or DC load). In the conventional type of aircraft's, the system used to work on 28V DC power but nowadays in the recent technological systems the aircraft systems are working on 115V of AC voltage of 400HZ.When conventional type. Fig. 1 represents the block diagram of the aircraft system which consists of three main units The power is generated from the source unit of 115V AC 400Hz. This is supplied to the conversion unit which converts the input AC power to the 270V DC power output. compared to conventional type systems, the 115V three phase AC voltages requires less winding making it compact by producing same energy as that of 400V with more efficiency. Since the weight impacts a lot in the aircraft, these systems are being considered more reliable compared to the

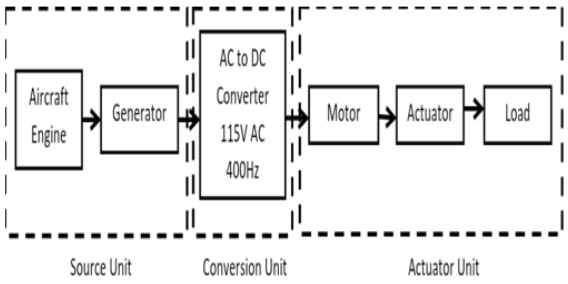

Fig. 1. Block diagram of Aircraft system

This is supplied to the motor which operated the actuator system connected to the load. The actuator systems were of hydraulic or pneumatic in conventional type aircrafts, but in the present world the aircrafts have actuator systems that of Electro-hydrostatic actuators (EHA) or Electromechanical Actuators (EMA) which combine functions of motor and hydraulic or mechanical actuators.

II. 12 PULSE AC TO DC CONVERTER

A. 12 Pulse AC to DC Converter

Fig. 2 represents the block diagram of the 12 pulse AC to DC converter. It will have two transformers placed in parallel where second transformer has phase shift of 30^0 because one will have Δ-Y connection while the other will have Y-Y connection producing 12 pulse rectification where each transformer rectifier will produce 6 pulses each of phase shift 30^0.

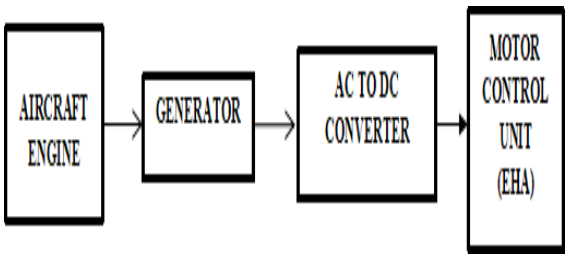

Fig. 2. Block diagram of 12 pulse AC to DC converter

The outputs of the transformers are given to the rectifier units and are combined through an inter-phase reactor to get an output voltage of 270V DC. Fig. 3 represents the phasor diagram of the transformer phase shifted by 30^0 each.

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When the 6 pulse rectifications generated by the rectifiers are equal the harmonic order of 5^{th} and 7^{th} gets canceled with each other, resulting in generation of low THD.

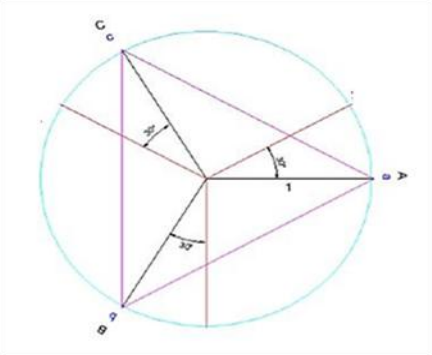

Fig. 3. Phasor diagram of 12 pulse Autotransformer

B. Simulation of 12 pulse AC to DC converter with 400Hz, 50Hz

Simulation of 12 pulse AC to DC converter was done in MATLAB/Simulink for 400Hz and 50Hz of 115V AC voltage.

Table I: Parameters for the 12pulse AC to DC converter

Parameters	Value
Power	150 KW
Input voltage	115 V rms
Frequency	400 Hz
Output voltage	270V

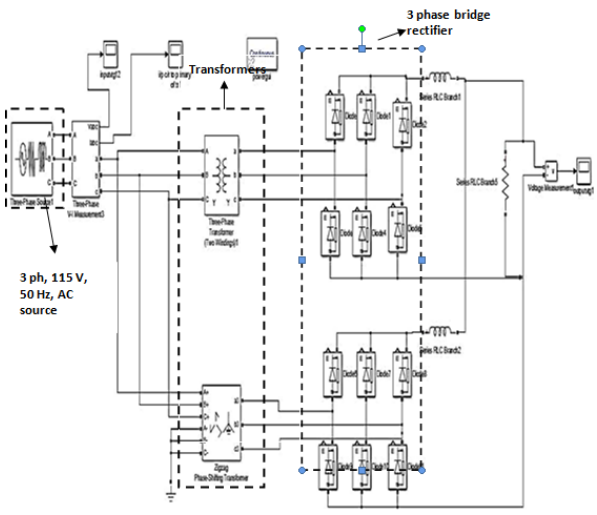

Fig. 4. Simulink model of 12 pulse 400Hz converter

In the fig, the transformers are phase shifted by 30^0 each. The VI measurement block is used to measure the input voltages and the currents where THD can be detected for the system. For the rectifier unit, six diodes rectifier of three phases is used to convert the AC to DC power. The load is a resistive load in this case. Likewise, 12 pulse AC to DC converter of 50Hz was designed in MATLAB/Simulink which is shown in Fig. 5. It holds the same function as that of 400Hz converter making it only different with respect to the frequency. Table II represents the parameters of the 50Hz 12 pulse converter which are also used in implementing the prototype of the same. The parameters are all based on the calculations related to the 12 pulse converter.

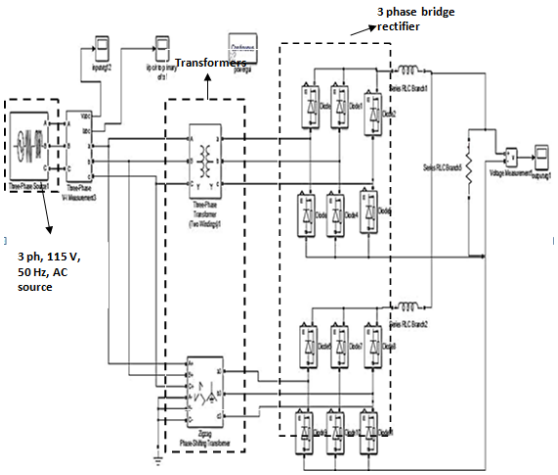

Fig. 5. Simulink model of 12 pulse 50Hz converter

Table II: System parameters for the 12 pulse 50Hz converter

Parameters	Value
Power	1KVA
Input voltage (Y-connected)	115 V rms
Output voltage (Y-connected)	115Vrms
Output voltage (▲-connected)	115 V rms
Resistance (L-L) (Y-connected) (Input side) (Y-connected) (Output side) (▲-connected) (Output side)	4 Ω 5.9 Ω 7 Ω
Inductance (L-L) (Y-connected) (Input side) (Y-connected) (Output side) (▲-connected) (Output side)	113 mH 120 mH 125 mH
Inter phase reactors	100 µH
Load	100 Ω

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C. Simulation Results for 12 Pulse Converter for 400Hz and 50Hz

For the system done in simulation and hardware the input and the output voltages were noted down for the system of 400Hz and 50Hz respectively. Fig. 6, 7, 8 and 9 represents the input currents and voltages for the transformer in 400Hz system and 50Hz system in simulation. The input voltages and the currents are used detect the THD of the system too. The input voltage in the simulated system is shown for three phases.

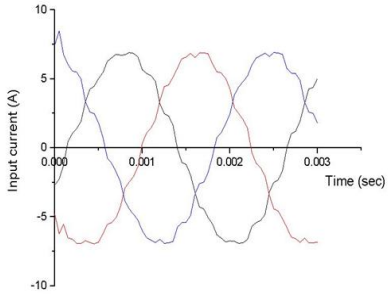

Fig. 6. Input Current for 12 Pulse 400Hz

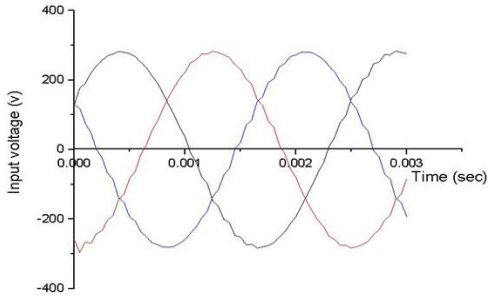

Fig. 7. Input Voltage for 12 Pulse 400Hz

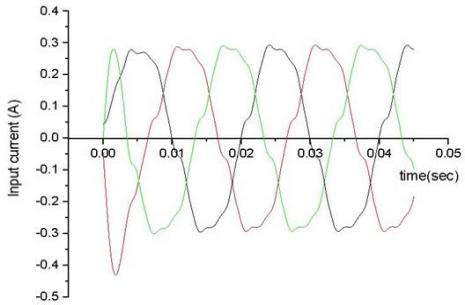

Fig. 8. Input current of 12 Pulse 50Hz

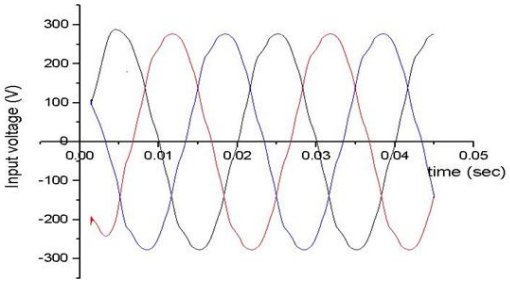

Fig. 9. Input Voltage of 12 pulse 400Hz

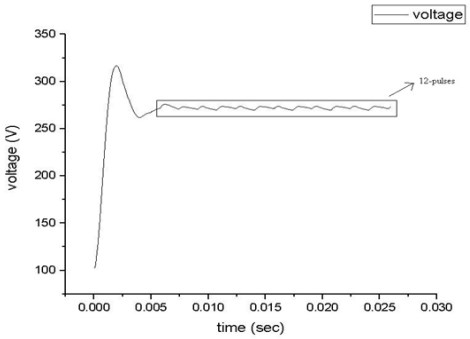

Fig. 10. Output Voltage of 12 Pulse 400Hz

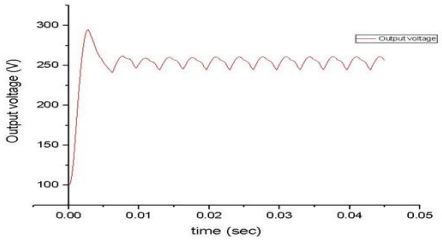

Fig. 11. Output Voltage of 12 Pulse 50Hz

III. ANALYSIS OF TOTAL HARMONIC DISTORTION (THD)

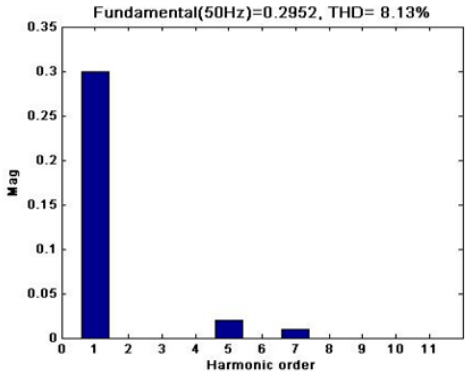

Fig. 12. Current harmonic spectra of 12 Pulse 50Hz Converter

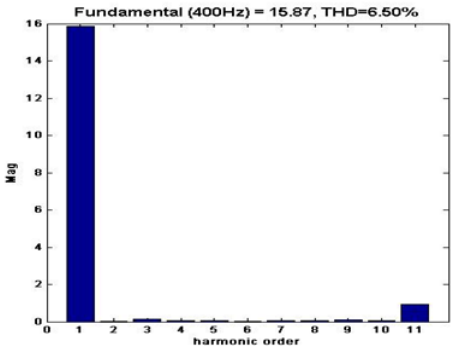

Fig. 13. Current harmonic spectra of 12 Pulse 400 Hz Converter

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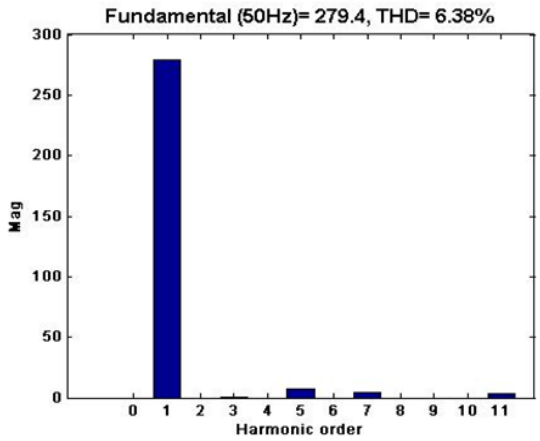

Fig. 14. Voltage harmonic spectra of 12 Pulse 50Hz Converter

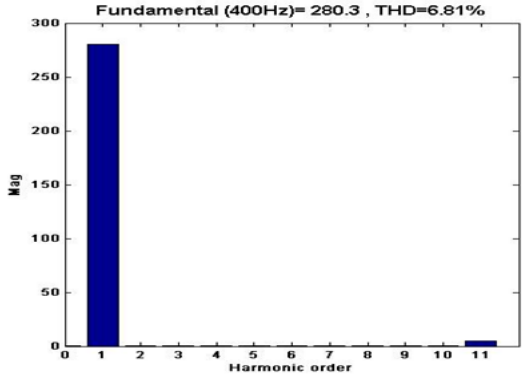

Fig. 15. Voltage harmonic spectra of 12 Pulse 400Hz Converter

For the system designed, all the harmonics of the order below 11th order harmonic are reduced and eliminated thereby reducing harmonics of the AC mains. Table IV represents the comparison of the THD between the simulated 50Hz 12 pulse converter with the hardware prototype of the system.

IV. HARDWARE IMPLEMENTATION OF 12 PULSE AC TO DC CONVERTER

A. Hardware implementation of 12 pulse AC to DC Converter for 50Hz

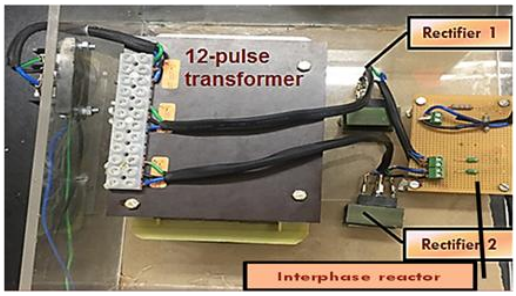

Fig. 16.**Hardware prototype of 12 pulse 50Hz converter**

Fig. 17. Hardware setup of 12 Pulse 50Hz Converter

The hardware for the system was designed and constructed using the parameters shown in Table II. In Fig. 16, shown the transformer is phase shifted with 30^0, since one of the transformers has Y-Y connection while the other has Y-▲ transformer. Two rectifiers are used in prototype. As shown in Fig.18, the DC output is shown on screen using the instruments of Lab View.

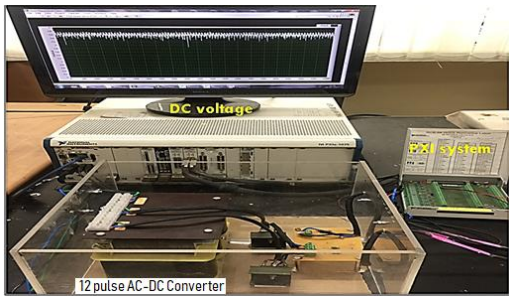

Fig. 18. 12 pulse 50Hz converter with NI Lab View

Since the DC output voltage of 270V cannot be presented in oscilloscope, the pout put voltage of the system was scaled down to certain value to look up in Lab View software using the voltage sensor. Voltage divider or the voltage sensor is used generally to scale down the voltage (which can be scaled down with respect to the ratio) which can be measured easily. Table III represents the parameters selected for voltage divider.

Table III: Parameters for Voltage Divider

Parameter	Value
Resistance (R1)	3.3KΩ
Resistance (R2)	330 Ω

For recording the values and to get output, National Instruments Lab View software was used. Lab View software was used to collect the output data values coming out of the rectifiers of the system. The output was received on the screen using the NI Lab View.

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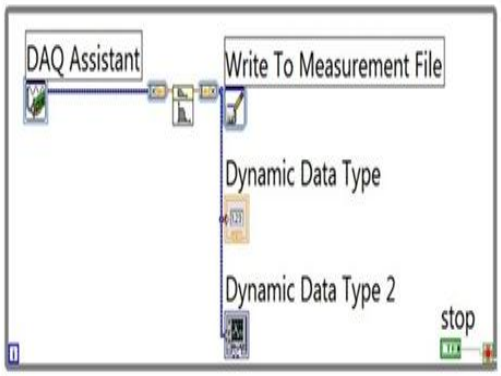

Fig. 19. Measurement of output through NI Lab View

B. Hardware implementation result of 12 pulse AC to DC Converter for 50Hz

Following figures shows the results of 12 pulse AC to DC Converter for 50Hz

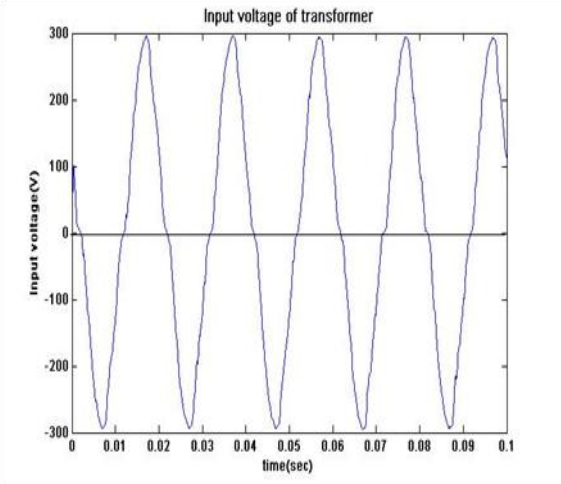

Fig. 20. Input voltage for 50Hz hardware prototype 12 pulse converter

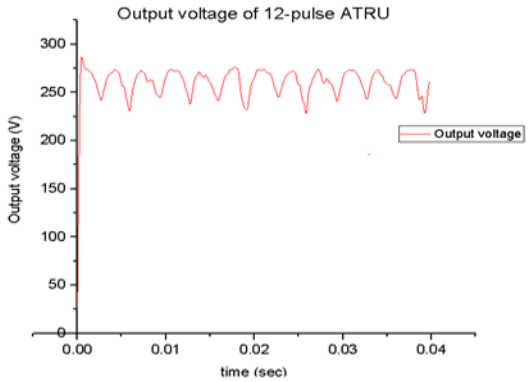

Fig. 21. Output voltage for 50Hz hardware prototype 12 pulse converter

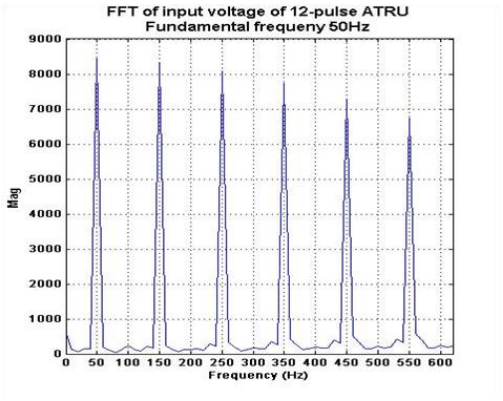

Fig. 22. THD of the hardware prototype input voltage of 12 pulse converter for 50Hz

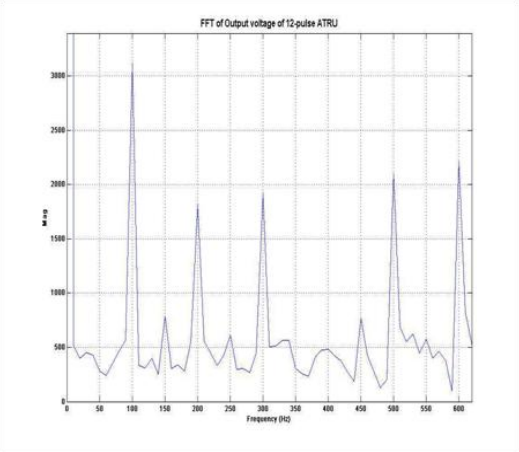

Fig. 23. THD of the hardware prototype output voltage of 12 pulse converter for 50Hz

Table IV: Voltage THD analysis for 12 pulse converter for 50Hz

Voltage	% THD
Input Voltage	7.8
Output Voltage	12.58

Table V. Comparative THD analysis of 12 pulse converter for 50Hz

Analysis	% THD for input voltage	% THD for output voltage
Simulation results	6.17	10.17
Hardware results	7.8	12.58

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V. CONCLUSION

In this paper, a 12 pulse AC to DC converter was designed for 400Hz and 50Hz (in simulation) and the actual model was built for 50Hz of 1KW power.

The design of 400Hz and 50Hz was done in MATLAB/Simulink and the prototype was built for 50Hz. The results of the input voltages and the output voltage of the simulated system and the modeled system match with each other, making it an efficient and reliable model for the applications. According to the standard of the IEC, the THD value of the system simulated and the hardware model are compared and are within the specified limits. Models for the 18 pulse and the 24 pulse can be built and tested for the future purposes.

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