International Journal of Electrical, Electronics and Data Communication, ISSN(p): 2320-2084, ISSN(e): 2321-2950
Volume-6, Issue-7, Jul.-2018, http://iraj.in

# DESIGN AND IMPLEMENTATION OF POWER ELECTRONIC TRANSFORMER FOR INERTIAL MEASUREMENTS OF CIVIL AIRCRAFTS

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**Abstract** - The services that the aircraft supply has to satisfy increases with increase in size of the aircrafts. Most aircrafts use 120V, 400Hz AC supply, but the aircrafts may have multiple voltage requirements in order to power various components in aircrafts. Usually transformers, rectifiers and inverters are used to modify the supply voltage according to the requirement. The main objective of implementing the power electronic transformer (PET) is to replace the ordinary low frequency transformers as it offers several benefits like reduction in size and weight. So that only less energy needs to be stored in the transformer core per cycle, so the core can be made smaller. Reduction in size is always ideal for aircrafts considering safer operation of aircrafts. Implementation of PETs for inertial measurements of civil aircrafts helps in solving low power factor problems and size reduction. In this paper, the practical design and application of a power electronic transformer for inertial measurement of civil aircrafts is done.

**Keywords** - PET, Rectifier, Inverter, Cycloconverter

## I. INTRODUCTION

Most of the aircraft systems use 115V-120V AC at 400Hz or 28V DC.As running at 400Hz supply allows the usage of lighter transformer. In aircrafts, multiple voltage systems are required in order to power various aircraft components. The 120V /400Hz supply can be modified with the use of transformers, rectifiers and inverters. An ordinary transformer used for this purpose may have large size and weight which is not ideal as reduction in weight is always ideal for an aircraft for its safer operation. Considering the fact that, Power electronic transformer (PETs) can be made use for several applications as it offers several advantages when compared to other low frequency transformers including light weight and power factor improvements. PETs can find their applications in power distribution systems with many features like power factor correction, output voltage regulation under load dynamics and harmonic suppression [5]. PETs can be implemented in traction chains, as the low frequency transformers in traction chains are heavy [1].

Implementation of PETs for inertial measurements of civil aircrafts helps in solving low power factor problems and size reduction which is very essential. The size reduction is achieved by operating the transformer at a high frequency level [10]. This is based on the fact that the size of the transformer is inversely proportional to its frequency of operation. For higher frequencies, only less energy needs to be stored in the transformer core per cycle, so the core can be made smaller. A small core means a lighter transformer and reduced weight. Size reduction achieved through increased frequency is often limited by increased core losses but nowadays there is advancement in miniaturized power converters operating in high frequency and very high frequency ranges [12].

Since PET uses power electronic components, it is relatively cheaper and can be easily implemented in civil aircrafts for inertial measurements, where there is a requirement of 15V/400Hz supply.

## II. POWER ELECTRONIC TRANSFORMER

Power electronic transformer consists of power converters on either side of the transformer. The PET demonstrator developed for inertial measurements is composed of rectifier, inverter and cycloconverter part. The rectifier module converts the 120V, 400Hz AC supply available to dc. The purpose of the inverter module is to convert the rectified output from the rectifier to ac of desirable high frequency [9]. The frequency of the ac given to the transformer is made high with the help of inverter module, as the size of the transformer greatly depends on its frequency of operation.

$$E=4.44fNAB \tag{1}$$

According to the above equation, for constant value of B, N, E by increasing f, size of transformer decreases. This concept is utilized in PET for reducing the size of transformer.

The transformer output is given to the cycloconverter which can convert the AC of higher frequency to AC of lower frequency that is required.

## III. DESIGN AND IMPLEMENTATION OF PET

The developed PET consists of rectifier, inverter and cycloconverter part. The rectifier rectifies the AC and

the resultant DC produced is given as input to the inverter. The inverter has the capability to convert DC to AC of higher frequency so that transformer can be operated at a higher frequency level [10]. Inverter output is connected to the transformer which steps down the voltage to the required value that the output demands. Now the output obtained from transformer is at a relatively high frequency that needs to be reduced to 400 Hz .This is done with the use of cycloconverter connected to the output of transformer.
The block diagram for the developed PET demonstrator for 50Hz supply is as shown in Fig.1.

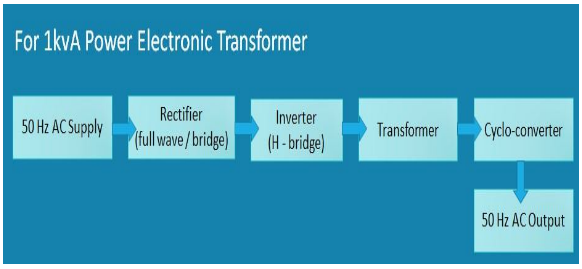


**Fig.1 Block diagram of PET for 50Hz supply**

The PET developed is designed for supplying 15V, 400Hz AC supply considering 120V, 400Hz AC as the input.

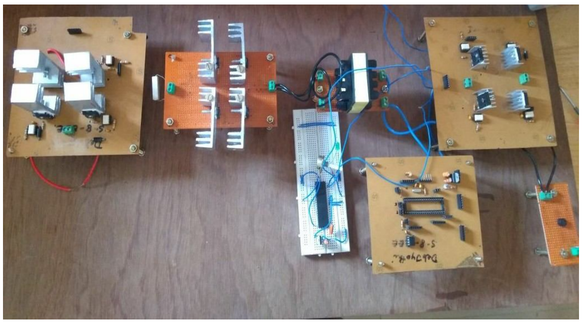

**Fig.2 Developed PET demonstrator**

## A. RECTIFIER

A full bridge rectifier is placed at the supply side. The input to the rectifier is 120V/400Hz AC supply which is rectified and DC obtained at the output. The current flowing through the rectifier which is at the primary side of the transformer is relatively smaller value, around the range of 0.5A.

W10 bridge rectifier module, which is capable of handling 1000V, 1.5A is used. A fuse of 0.5A is also connected at the input circuit to ensure that the current flowing through the rectifier module does'nt exceed above 0.5A.

## B. INVERTER

The rectified output is supplied to the inverter. It consists of 4 MOSFETs triggered by ATMEGA16 IC. The inverter converts the dc to ac of higher frequency, by varying the duty ratio of triggering pulses.A potentiometer is connected at the ATMEGA IC for this purpose.The frequency of the pulses can be varied from 30kHz-50kHz range.The main purpose of stepping up the frequency is to reduce the size of the transformer. Here the frequency is increased to 50kHz so the resultant output from the inverter is 120V/50kHz AC.
IRFP150N power MOSFETs are used in the inverter. It provides fast switching speed and more reliability.

## C. TRANSFORMER

Ferrite core transformer is used in PET since it is operating at a higher frequency. The advantage of ferrite core is its high resistance to high current and reduced eddy current losses for different range of frequencies. Reduction in transformer size is the main objective of developing PET. This is based on the concept that the size of the transformer is inversely proportional to its operating frequency.

According to the emf equation of the transformer,

$$E=4.44fNAB \tag{2}$$

For constant value of E,N,B by increasing f, area of core will decrease and therefore, the size of the transformer reduces.

Transformer is designed according to the required conditions.

Primary voltage, V1=120V
Secondary voltage, V2=15V
Primary current, I1=8.333A
Secondary current, I2 =66.666A
Magnetic flux density, Bm =0.4T
Frequency, Fs =50Hz
Window spacing factor (kw)-0.332

Selection of core,
Ac=Aw=Ap = (V2I2)/(2*kw*Bm*J*Fs) = 25097.89mm^4
Selected core = ETD 39/20/13

No. of turns (N1&N2)
V1=4BmAcN1Fs=N1=V1/(4BmAcFs)=12 turns
Primary &Secondary Inductance

Assume –N27 ungapped material
From the data sheet of ETD 39/20/13

L =N/S^2
Le =92.2mm
Ac =125mm^2
S = 0.0922/(1500*125*10^-6) = 0.5
LI=N1/s^2 = 12/(0.5^2) = 48L2 = N2/S^2 = 6

Using diff. formula
L1= Vin (min)*ton/ΔI1 = 0.132mH
L1/L2= (NI/N2)^1/2, L2=0.046mH
N2= V2/(4*Bm*Ac*Fs) =1.5

V1/V2=8
N1/N2=8

Derivation of primary and secondary wire gauge
$a1=I1/J=8.333/3=2.777mm^2$
$a2=I2/J=66.666/3=22.222mm^2$
$D1=2\sqrt{a1/\pi}=1.88mm \approx AWG=13$
$D2=2\sqrt{a2/\pi}=5.32mm \approx AWG=4$

The transformer output is 15V, 50 kHz AC.

### D. CYCLOCONVERTER

Cycloconverter has the capability to convert ac of a particular frequency to ac of another low frequency without an intermediate dc link. The circuit designed for cycloconverter consists of a rectifier and an inverter part. The rectifier used here is a full bridge rectifier and the inverter composed of MOSFETs triggered by another ATMEGA16 IC. The duty ratio of the gate pulses can be controlled by ATMEGA16, which in turn controls the frequency of output ac.
IRFP250N power MOSFETs with larger heat sinks are used in the inverter as the current in the transformer secondary is 8 times that in the primary.
The final output obtained is 15V, 400Hz AC which is required in aircrafts.

## IV. SIMULATION RESULTS

To check the feasibility of the proposed PET, here various simulation tests have been conducted at 25V/50Hz supply, and the results are obtained.

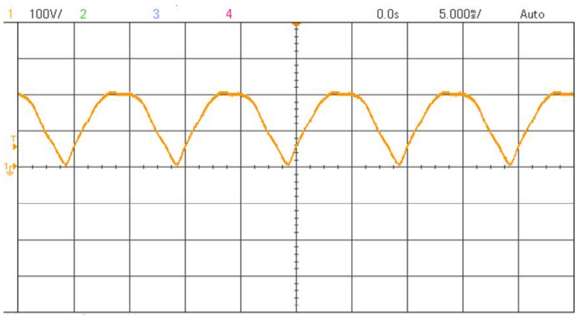


**Fig.3 Bridge rectifier output showing the rectified DC 0f 25V.**

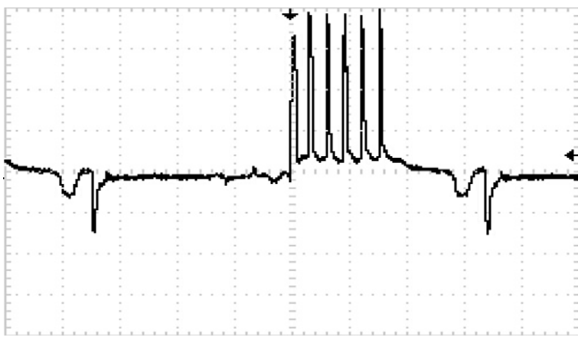

**Fig.4 Inverter output waveform showing AC of higher frequency (25V, 50kHz).**

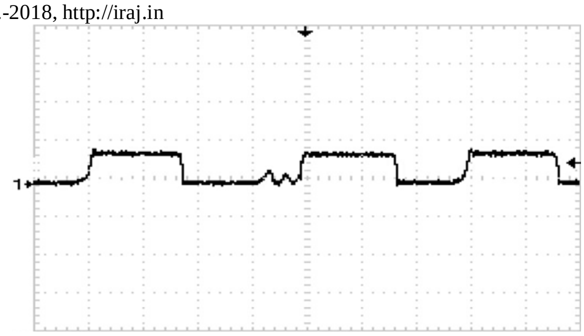

**Fig.5 Cycloconverter rectifier part output waveform showing DC voltage around 3V.**

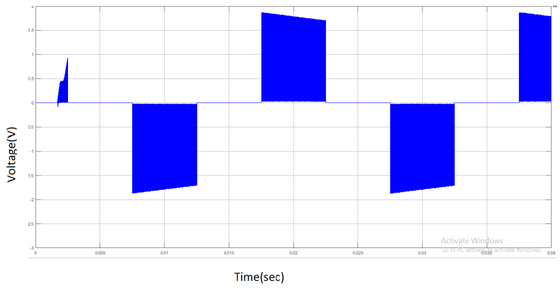


**Fig.6 Cycloconverter inverter part output waveform showing AC**

The cycloconverter output obtained is 3V, 50Hz AC when an input of 25V is given.

## CONCLUSION

Power electronic transformer can replace traditional low frequency transformers since it offers several benefits like reduction in weight and size.
A PET has been designed and can be implemented for inertial measurements of civil aircrafts, as reduction in size is ideal for aircrafts. The results obtained from the PET feeding from 25V/50Hz supply is observed and verified, which validate the feasibility of project in the aircraft systems.

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