Proceedings of the International Joint Journal Conference on Engineering and Technology (IJJCET 2011)

Mobile Integrated Power Supply System for Military Applications Incorporating Dual Frequency Alternator

VV Parlikar, Sc 'G', PM Kurulkar,Sc'F, KP Rathod, Sc 'D', Poonam Kumari,Sc'C'

Research & Development Establishment (Engrs.), Dighi, Pune, DRDO, India

Email: VVparikar@sify.com,pradeepkurulkar&gmail.com,roymaheshkumar@gmail.com,ese_rd@yahoo.co.in pk_rde@yahoo.co.in

***Abstract* - This paper presents a Dual frequency alternator, which generates power output at 50Hz and 400Hz. In weapon system applications 50Hz and 400Hz power is required to meet the requirement of different loads which operate at different frequencies simultaneously. To cater power supply to these loads either separate generators are required to be used or 50Hz and 400Hz power is obtained by solid-state conversion using power converters. These separate power sources increases the logistics, space requirement, maintenance, repairs and overhauls. To overcome these difficulties special kind of machine called Dual Frequency Alternator has been designed to give power outputs of 50Hz and 400Hz frequencies simultaneously with a single prime mover (Engine). In this paper design, development and performance evaluation of the Dual frequency output alternator along with integrated system is discussed. Experimental results are also presented that demonstrate the high performance of Dual frequency output Alternator technology for future Power generation system.**

***Index Terms*--Integrated Power Supply, Dual Frequency Alternator, EMI Filter, Dual Rotor Shaft, Excitation Rectifier, Weapon system application, Prime Mover**

I. INTRODUCTION

In weapon system applications electrical power at 50Hz and 400Hz is required simultaneously to meet the critical mission. This type of power is generated either by two separate generators each working at different frequency or one frequency power is generated or other is derived from it by suitable conversion scheme [1]. Though latter reduces the requirement of extra power generators but it increases the cost and space requirements due to use of power electronic converters and power conditioners besides the increase of cost, capacity, space requirement and size of the generator. Also use of power converters produces harmonics and EMI/EMC problems. The use of two alternator sets for each Frequency power supply increases logistics and stores by double amount. It requires two prime movers, two containers, two transporting vehicles and double space along with increase in maintenance and repair cost, fuel intake and man power. A dual frequency alternator is designed which caters power requirement of loads operating at 50Hz and 400Hz simultaneously. A permanent magnet synchronous alternator [2] can also help to reduce the size of the alternator but its cost is very high and control of excitation current is not possible. So, Concept of Synchronous generator [3] is used to design the stator and rotor of the dual frequency alternator [4]. This alternator is designed using standard equations mentioned in the references [4, 5] and [6].

In this paper, dual frequency alternator is described in brief. Design calculations are discussed to calculate quantitative characteristics of the alternator. This alternator is designed to give outputs of three-phase, 50Hz, 415V (line to line) and three-phase, 400 Hz and 200V (line to line). Electrical calculations are carried out using standard electrical machine design equations while mechanical dynamic analysis is carried out using ANSYS software. Experimental results after design and development of this alternator on 50Hz and 400 Hz loads are also discussed.

II. DESCRIPTION OF DUAL FREQUENCY ALTERNATOR

Dual Frequency Alternator is a brushless, self-exciting, rotating field type synchronous machine rotating at a synchronous speed of 1500 rpm. It consists of two armature windings, two field windings, two exciter systems and two rotating rectifier assemblies one each for 50 Hz and 400 Hz alternator all housed under one frame. The field windings of main machines, armature windings of exciter machines and rectifier assemblies are mounted on a common shaft as shown in configuration diagram of Fig.1.

The main constructional parts of alternator are stator, rotor and exciter. The stator core is assembled in the frame of the machine. The stator cores are having sufficient number of slots for placing armature windings in them. Rotors are rotating part of the machine having field poles. The field windings are wound on poles to which DC excitations are supplied. The alternator is self excited being fed from an exciter machine housed in the alternator frame. Field winding of the exciter is housed in the stator and armature winding is mounted on the rotor.

AC output voltages of both the frequencies are rectified by a rotating rectifier assembly mounted on the rotor shaft. DC output of the rectifier is fed to the field winding of the respective machine.

In Fig.1, Configuration figure of the dual frequency output alternator is shown. The photographs of the rotors of this alternator for 50Hz and 400Hz power output are shown in Fig.2. Large rotor is designed for power output of 400Hz and small rotor is designed for power output of 50Hz. The complete alternator is shown in Fig.3.

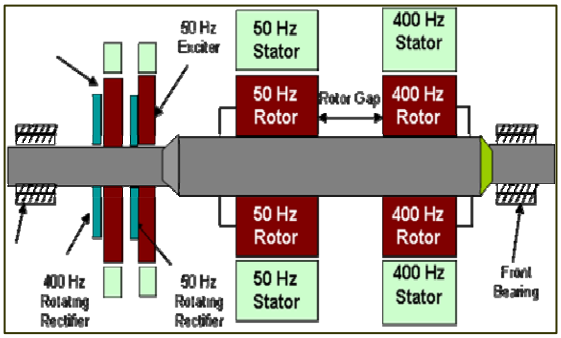

Fig.1 Configuration figure of the Dual frequency Alternator

Fig.2 Rotor of Dual frequency

Fig.3 Integrated view of Dual Frequency Alternator with Prime mover

Apart from these Integrated Mobile power supply system consists of the Prime mover (Diesel engine) , Skid and fuel tank Dual frequency alternator with AVRs , Control panel (400 Hz & 50 Hz output) , Base platform & Acoustic canopy following sub-assemblies mounted on a light weight frame (base platform on vehicle chassis) with suitable anti-vibration mountings:

III. DESIGN METHODOLOGY

Design calculations are carried out taking some assumptions as and when required. Design calculations are carried out considering load requirement of weapon system. This alternator generates power output for different load combinations of 50 Hz & 400 Hz. The alternator is designed to operate at + 55^0 C with an altitude of 3000 meters. The maximum site rating of a generator is obtained from the relation given below.

Site KVA = (Nominal KVA) x (Derating factor)

As this alternator takes input power from a diesel engine running at 1500rpm, the number of poles required for generating 50Hz and 400Hz power supply are calculated using formula [4] $P= 120f/N_S$. The number of poles for 50Hz is 4 and for 400Hz is 32. All electrical parameters pertaining to Rotor and stator circuits are designed using Electrical Machine standard design equations given in reference [5]. The power output of the alternator at each frequency is given by $S = 1.11\ K_w\ \Pi^2 .B.ac.\ D^2.L.ns \times 10^{-3}$ kVA Rotor to rotor gap is calculated suitably so that there is no coupling effect between the magnetic fields generated by rotor windings and stator windings at different frequencies. $2/3^{rd}$ pole pitch have been used to reduce the third and it multiple harmonics. Air gap between each rotor and stator is selected such that losses are minimum. Stator frame material and shape is designed so that each assembly has minimum magnetic and static interference with each other. All the preliminary machine design calculations were carried for both 50 Hz & 400 Hz system and finally Modeling & simulation was carried out using RMxpert & Maxwell software.

Appropriate rating of EMI power filters are also fitted for both 50 Hz & 400 Hz system to cater the EMI /EMC requirement as per Mil std 461D. The schematic of filter is given in fig. 4.

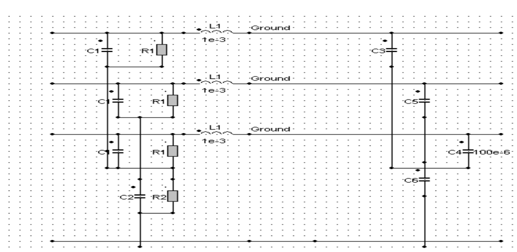

Fig .4 Circuit of EMI Filter

The rotor shaft is designed for 1500 rpm with proper distribution of weight and load at different location of the shaft for maximum power output.

IV. PERFORMANCE EVALUATION AND RESULTS

This special alternator is designed and developed for total 80-kVA power output. The performance evaluation of the alternator was conducted for its rated capacity. For same the alternator was subjected to different loading conditions (unity, 0.8 PF at inductive) with various combinations. Tests for Voltage Stability, regulation, TVD/TVR& response time, Frequency regulation etc were conducted on this alternator for conforming the specified parameters. The quality output voltage waveform of both the frequencies is shown in Fig. 5. In this figure, single phase voltage of 50 Hz output is shown by graph A and single-phase voltage of 400 Hz is shown by graph B. It can be seen from these waveforms that the output voltages are pure sinusoidal and are sufficient to cater load requirements at these frequencies. Power from this alternator can be taken in various combinations as per load requirement. This proves that this integrated alternator can give output power either to cater load requirement of both the frequencies simultaneously or anyone load of these frequencies. Power from this alternator can be taken in various combinations as per load requirement. After the rigorous testing of this dual frequency alternator, the unit was integrated with prime mover (diesel Engine), Control panel & other subsystems to make it as a dedicated power supply system. Finally this integrated system was put into the acoustic container. After Integration the performance evaluation of the integrated system was carried out for different loading conditions. After confirming the specified parameters, the system was tested with all loads of Weapon system

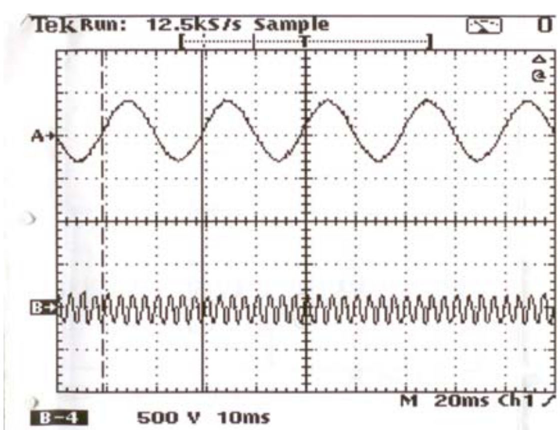

Fig .5 Graph A is 50 Hz and Graph B is 400 Hz voltage wave form

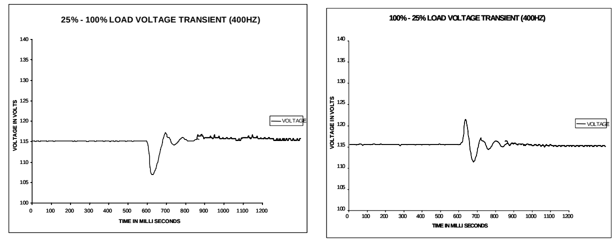

Fig .6 TVD / TVR Test on Dual frequency Alternator

V. CONCLUSION

This alternator is very useful for field operations requiring power supplies of 50 Hz and 400Hz to fulfill a desired operation. Design and development of this unified alternator was a challenging job taken in hand by R&DE (E) scientists. This development is successfully completed and is being explored for its applications in various fields of military uses such as weapon systems etc. Severe and extreme tests have been carried out on this generating set to verify the performance for the weapon application to demonstrate its worthiness. Looking into all the above aspects “Dual frequency & voltage output alternator” will be very useful for the applications where dual output is required and can be used for future mobile power generation systems.

The various performance parameters obtained after successful design and development of Dual Frequency Alternator are given in the table below [1]:

Voltage Regulation	± 1%
Frequency Regulation	± 1%
Total Harmonic Distortion	Within 5%
TVD / TVR	Within 10%
Response / recovery Time	Within 300 ms
Efficiency	85 %

Table: 1 Performance Parameters

ACKNOWLEDGEMENT

The authors wish to thank Dr S. Guruprasad, Director, R&DE (Engrs.), Pune-411015, for his encouragement and valuable guidance to publish this paper without which it could not have been possible. Thanks to the entire design team for their valuable suggestions and support.

Notations used:

D = Diameter of stator bore, m

L = Stator core length, m

P = No. of poles

ns = Synchronous Speed, r.p.s.

S = electrical rating of machine, KVA

Kw = winding factor

B = Specific magnetic loading

ϕ = Flux in air gap

E_{ph} = voltage per phase

I_{ph} = current per phase

ac = Specific Electric loading, amp conductors /m

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