Performance Evaluation and Analysis of Engine Mounted High Speed Alternator

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***Abstract:* In this paper, performance evaluation and analysis of high speed engine mounted alternator is discussed. In aero-space, power generating unit consists of high speed alternator driven by variable speed gas turbine engine and digital engine controller unit to statically convert the alternator output to user power. A high speed also allows direct coupling of the alternator to a gas turbine for power generation in aircraft. Either permanent magnet or homo-polar kind of alternators are being used in this kind of applications. Due to its compactness, robust construction, and high efficiency characteristics, high speed alternators are becoming more popular in defence sector. An evaluation and analysis of high frequency test data of alternator is necessary to improve its efficiency. A dedicated test set up to monitor and capture the important parameters of engine mounted alternator is developed for further analysis purpose. Test set up details, Instrumentation, data acquisition and monitoring unit are presented in details.**

Keywords- Current transducer; Data acquisition; Gas Turbine; High Speed Alternator; Load bank; Probes; Power supply

I. INTRODUCTION

Performance monitoring of engine mounted special alternator which runs on high speed same as engine speed is a challenging work. Many factors influencing the behaviour of alternator like its surrounding temperature, loading pattern, field current regulation and engine high speed etc. In-situ characterisation and monitoring of high frequency alternator is necessary because it powers the main engine controller unit. Engine can lose its controllability if it starts malfunctioning. This specially designed high speed alternator (2KVA, 2×3φ, 3.5 kHz) is suitable for variable speed from zero to max rpm of engine speed. Evaluation of engine mounted high frequency alternator depends on engine dynamics and its response at high speed. Engine speed stability can only enable the initialisation of alternator testing. Due to the availability of high speed data monitoring system, it is possible to capture the behaviour of alternator at various speed of engine on engine test bed itself. Exclusive high frequency instruments with proper isolation are suitable for this type of monitoring. This paper describes the test set up, instrumentation details, data acquisition and monitoring system and analysis of acquired data.

II. TEST SET UP

To acquire high frequency data, test setup is developed in such a way to suit engine environment as well as to provide all raw data simultaneously. High sampling rate data acquisition system is deployed to capture transient value in real time. Since this high speed alternator is powering engine controller and its redundant system, it has inherent features of twin three phase power output with well-regulated magnetic field. Due to unavailability of neutral, differential voltage probes are connected between lines to monitor alternator output voltages. High frequency current transducer are also mounted for load current measurement.

A. Test Set-up Details

Alternator integrated engine is mounted on engine test bed for its evaluation in engine room. All the measuring instruments are placed in control room to avoid noisy environment arises during engine run at high speed. Special care and proper isolation are maintained for cable harnessing from engine room to control room to minimise the interaction between alternator power cables and instrumentation cables.

Power cables (2×3φ) from engine room are terminated to moulded case circuit board (MCCB) in control room and from there one three phase cables are connected to AC load banks and another three phase are connected to separate AC load bank. High frequency differential voltage probes with suitable attenuation ratio are also connected parallel to data acquisition and monitoring system through proper isolation. DC regulated power supply is also connected to alternator to provide sufficient DC current to excitation winding to get working magnetic field. DC input commands are controlled and monitored by data acquisition system.

Test set up schematic of instrumentation, measurements and data acquisition systems to monitor critical parameters of high speed alternator is shown in fig.1& 2 below. This set-up is used for no load (open circuit characteristics) and also for load test of alternator.

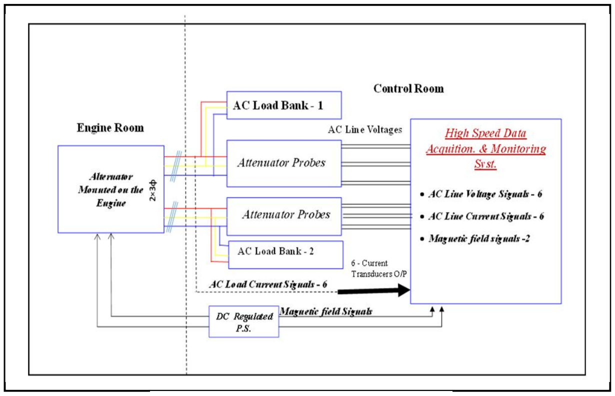

Fig. 1. Schematic of Test set-up

Fig. 2. Actual view of Test set up (control room)

III. Instruments And Measurements

A. Voltage Measurement

Differential voltage probes with suitable attenuation ratio are used for voltage measurement purpose because alternator neutral is not accessible. Six phase output voltages (2×3φ) of the alternator are continuously monitored and same signals are taken to the high speed acquisition system for data logging and processing.

B. Load Current Measurement

High frequency six phase AC currents are measured by current transducers with nominal output of 4 volts at full range. The performance of these transducers are checked before use. All six transducers are located in proper place so that all six output cables can be accessible and also parallel to the high speed data acquisition system.

C. Field Current Measurements

A DC regulated power supply (600W, 0-32V, 20 Amp) is used to feed variable excitation current to achieve desired alternator output terminal voltage. DC excitation currents are measured using current transducers (attenuation of 1000:1), with nominal output of 25mA at full range. Resistor 220 Ω is connected at the output of CT's to get voltage signal (compatible for measurement) corresponds to actual current signal. DC excitation voltages are measured in PXI system across 25kΩ resistor connected in series with 5kΩ to get voltage within limit and then multiply with attenuation factor of 6 in PXI system to show actual excitation voltage fed to the alternator. The performance of this transducer is checked before use. Transducer is located in such a way that DC output cables can be accessible and also parallel to the high speed data acquisition system.

D. Loading Arrangement

All six phases of alternator is loaded with the help of two separate three phase AC load bank (Voltage: 30V/phase, Current- 30A/phase). Loading/unloading is done in step manner to see the alternator response and also to maintain the engine dynamics.

E. High Speed Data Acquisition System

A high speed data acquisition system with a bandwidth of 10 kHz is designed using a PCI eXtensions for Instrumentation (PXI) based embedded controller and data acquisition cards. All steady state parameters are measured and given to the data acquisition card, which measures voltage, current and frequency. All the process and instrumentation parameters are integrated to this system. This data acquisition system (DAS) unit is integrated to PXI system using General Purpose Interface Bus (GPIB) control technique.

All time domain signals namely six AC line voltages, AC line currents, DC excitation current and voltage are measured using two high speed simultaneously sampling cards. These sampling cards receives the raw data from high speed instruments and after processing provides data to Lab VIEW. Full alternator load test architecture is defined in Lab VIEW in such a way that critical parameters like transients in voltage/current with respect to loading/unloading, field current variation, output power and waveforms etc. can be seen in real time and can also store data simultaneously for future analysis.

F. Moulded Case Circuit Breakers (MCCB)

Moulded case circuit breakers (MCCB) are connected at the (2× 3∅) output terminal of alternator to avoid high circulating current during alternator loading and also to protect the entire instrumentations.

IV. Tests Performed

Alternator performance is measured by its open circuit characteristics (OCC) and rating tests. These tests are conducted when engine speed and vibration are well within limit.

A. Open Circuit Characteristics(OCC)

OCC is conducted when engine reached at certain speed (like 85% or 90% of rated engine speed) and also engine vibration level is within limit. Alternator excitation voltage is first set to max. value (28VDC) and excitation current is changed slowly from zero to max. 1 amp in small steps to get rated alternator terminal voltage (27VAC). Simultaneously corresponding line voltages, ripples in output voltage and Total Harmonic Distortion (THD) is measured. Line voltage with respect to excitation current for various engine speed is noted and plotted. Plot for different speeds should follows the same trends.

B. Rating Test (Load Test)

At fixed speed of engine (like 85% or 90% of rated engine speed), excitation voltage and current is fixed to produce rated alternator terminal voltage (27VAC). Loading is started in steps to max. 2KVA. When load increased terminal voltage drops, excitation current is increased accordingly to maintain the constant terminal voltage.

V. Test Results

A. No Load Test

Once engine gets stable at certain speed like 85% or 90% of full speed, no load (open circuit) test is conducted. Alternator output terminal voltages (line-line) are measured by changing the magnetic field (excitation) current. Plot at engine speed of 85% and 90% are shown in fig.3 below. This plot shows that Open circuit characteristic (OCC) are maintaining the same trend at different speeds of engine.

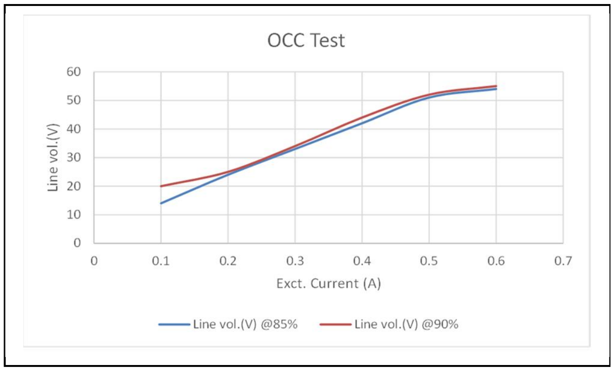

Fig. 3. OCC Plot

B. Load Test

After confirmation of instrumentation functionality, all alternator's output terminals are connected to the load bank. Loading are done in step manner to extract total power of 2.0KVA from alternator @ 85% and 90 % of engine speed at fixed field current. Voltage drops are observed when alternator loads increased. Gradual increase of loading was not performed because terminal voltage should not go beyond limit (14V-19V) rms. To maintain this, magnetic field current is increased so that terminal voltage reached to 19Vrms. This is required to avoid insulation break in stator winding due to temperature rise. Plot is shown in fig.4 below:

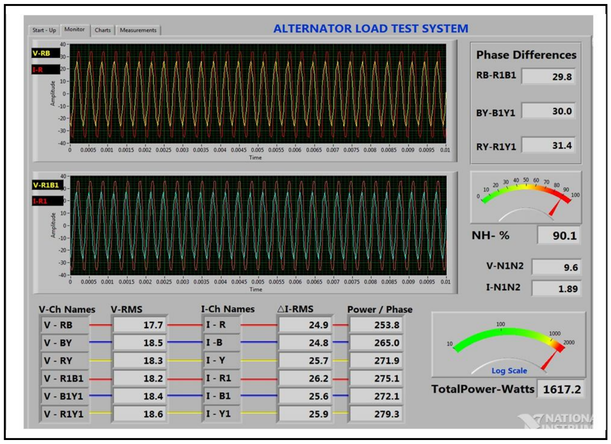

Fig. 4 Loading Plot

VI. Data Analysis

Alternator line voltages are measured and stored in high speed sampling rate PXI system with respect to variable load at different speed of engine like 85 % and 90%. Alternator loading, waveform plotting and all critical data measurement and analysis is done on high speed data acquisition system.

A. At 85% of engine speed

Alternator is loaded up to 1.45 KW. Data shown on PXI system below (fig.5):

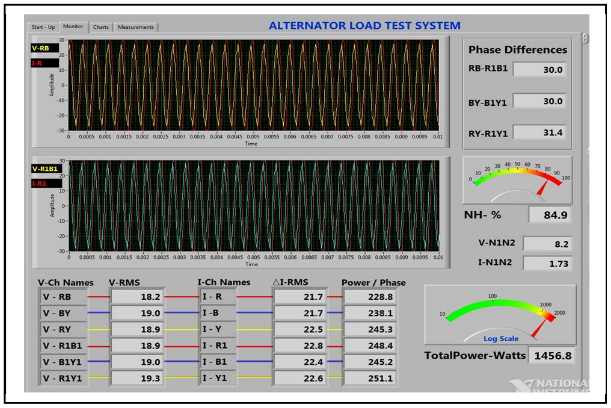

Fig. 5 Loading Plot @ 85% of engine speed

B. At 90% of engine speed

Alternator is loaded again up to 1.6 KW to see its waveform deviations and voltage drop against loading. Data shown on PXI system below (fig.6):

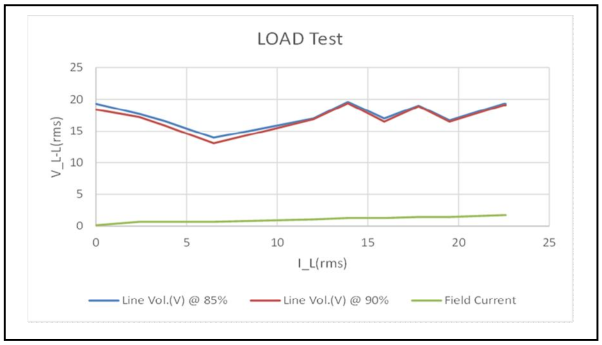

Fig. 6 Loading Plot @ 90% of engine speed

VII. CONCLUSION

High speed alternator is delivering 2.0KVA, AC power @ 85% and 90% of engine speed. The alternator, all high frequency measuring instruments and high speed data acquisition system performed well. Hence performance evaluation and analysis of engine mounted high speed alternator is successfully meets all the objectives.

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