Acoustic and Vibration Analysis of Motor Generator System using FFT Analyser

S. Rama Krishna [#1], Pagoti Ram Vikas [*2]

[#1]*Associate Professor Department of mechanical engineering, G V P College of Engineering, Visakhapatnam-53048, India*

[2]*Department of mechanical engineering, G V P College of Engineering, Visakhapatnam-530048, India*

Abstract — *Opening up machines for inspection is expensive, and owners need to consider all relevant information in making the decision. The forces and resultant vibration caused by inadequately balanced rotors destroy bearings and seals, damage foundations, transmit noise and increase maintenance costs can be detected and monitored using condition monitoring by Vibration analysis. The present problem is to carry out vibration and acoustic analysis of motor generator system using FFT analyze to identify problem. From vibration and noise analysis, the signals are recorded in computer memory. Each recorded signals are analyzed to predict the vibration and noise characteristics of the machine. From the data onboard, the condition of the machine either it is normal condition or if any problem it can be identified from the data. Static structural analysis, Modal analysis, Harmonic analysis is performed for the motor generator system using ANSYS and these results are validated by the experimental results. From the results it is concluded that the vibration levels are well below the acceptable limit 3 mm/sec but noise observed is more than the acceptable limit 80 dB for the machine so suggested that designed acoustical enclosure to the reduce noise levels.*

Keywords — *Motor generator system, FFT analyser, vibrations, noise, modal analysis, harmonic analysis*

I. INTRODUCTION (SIZE 10 & BOLD)

A motor generator (M-G) set refers to a composite device consisting of a motor and a generator mechanically coupled through the common shaft. Practically a motor generator set is a system where a motor and a generator are connected or rather placed in a single circuit [1]. It is a device used to convert electrical power from one form to another. That is mainly it converts electrical power to any other type of power. a typical motor generator set, the power is given externally to a motor and as a result the shaft of the motor rotates the rotor of the generator. That means, motor receives electrical energy input from the supply line. Its shaft rotates and since the generator shaft is mechanically coupled with it, the generator also receives its mechanical input through shaft. Thus generator also creates electrical output power or in other words generator converts the mechanical energy into electrical energy [2]. Thus while the power at the input as well as output side is electrical in nature, the power flowing between the machines is in the form of mechanical torque. This provides isolation of the electrical system as well as some buffering of power between the two electrical systems.

The use of an FFT (Fast Fourier Transform) analyzer as a teaching tool is reviewed. Lab experiments are described that provide a good foundation for future career applications in vibration dynamics and mechanical systems [3]. Time streams are always available for viewing and recording. It is a very useful tool to observe whether the input signals are in the valid range. The recorded sine wave can be used for further post-processing [4]. Resonant vibrations may lead to fatigue failures. Flexural vibrations of the exposed surfaces of a machine radiate audible noise, and in fact represents one of the primary source of noise. Excessive vibration and noise characterize all rotating, reciprocating and flow machinery [5]. The control of noise from vibrating bodies at the source involves control of vibration. Sound is a longitudinal wave in air, and wave is a travelling disturbance. A wave is characterized by two state variables, namely, pressure and particle velocity [6].

II. EXPERIMENTAL ANALYSIS BY USING FFT ANALYZER

The Motor generator system (test bed) consists of four electrical machines an alternator (A.C generator), two D.C machines, an induction machine. D.C machine and induction machine are coupled; the other D.C machine and the alternator are coupled in the test bed. All four machines are mounted on the common shaft has transmitting a power of 15KW at a speed of 1500 rpm from the motor to generator. Motor generator system is mounted on the concrete foundation. It is having the eight anti vibration mounts to reduce the vibrations from machine to concrete machine foundation. A variable resistive load is connected to the D.C generator, which is varied to five different values of load currents. Table I shows the input values for experimentation using FFT analyser for measurement of noise and forced vibrations.

Table I Input values for Experimentation

S.No	Load (%)	Voltage (Volts)	Current (Ampere)	Power (KW)	Speed (Rpm)
1	0	222	0	0	1500
2	20	214	1.15	246.1	1500
3	40	209	2.24	468.16	1500
4	60	205	3.39	674.45	1500
5	80	201	4.32	862.32	1500
6	100	198	5.30	1049.4	1500

A. Noise Measurements

Noise measurements are carried using FFT analyser (CoCo 80 system) and condenser microphone. Noise is measured by pacing the condenser microphone is placed at 1m above the motor generator system. Fig 1 shows the photograph of noise measurement taking at D C motor using FFT analyser (CoCo 80 system) and condenser microphone. ½ inch microphone is connected to channel 1 of FFT analyser. The microphone capable of measure the noise from 0 dB to 160 dB in the frequency range of 0 Hz to 20,000 Hz. The sensitivity of microphone is 10.6 mv/Pa. Noise spectrum is obtained in the frequency range of 0 Hz to 100 Hz. For all noise measurements the reference pressure is 1µPa. These measurement data is exported to Engineering Data Management software for to obtain the noise spectrum. Fig. 2 shows the noise spectrum at above the D C motor generator system. Overall sound pressure level is observed at the one meter distance above the motor is 80.13 dB at the full load of 1049.4 KW for speed of 1500 rpm. It is quite high as per the standards it must be below the 75 dB.

Fig. 1 Noise measurement taking at of D C motor by using FFT analyzer and Condenser micro phone

Fig. 2 Noise Spectrum at the top of the Motor Generator System

B. Forced Vibration Measurements

Forced vibrations of motor generator system is measured on top of the bearing of DC motor, on the frame and on the amount are measured using CoCo FFT four channel analyser (Model 6348)and piezo electric sensor (Model 9300) to characterize the vibrations levels. CoCo is a hardware platform that can run in either DSA (Dynamic Signal Analyser) or VDC (Vibration Data Collector) mode. Sensitivity of accelerometer (sensor) is 106 mV/g and sensing material is ceramic. The sensor is connected to channel 1 of FFT analyser and place at the above the bearing near the D C motor. The frequency range is set to 0 to 2200 Hz because operating speed is only 25Hz. All measurements are recorded in analyser after 32 averages in the frequency range of 0 to 2200 Hz with the resolution of 2 Hz (1100 lines are used in entire frequency range). Signal are recorded in the time domain then it is converted to frequency domain by using hanning window. Then this measurement data is exported to Engineering Data Management (EDM) software for post processing. The acceleration (m/sec^2) date is converted to velocity (mm/sec) data by using inbuilt tools available in the (EDM) software. Frequency spectrum is plotted by considering the velocity (mm/sec) in Y-axis and frequency (Hz) in the X-axis. All the vibrations levels are presented for full load of 1049.4 KW for speed of 1500 rpm. Fig. 3 shows the photograph of vibration measurement at the DC motor using FFT analyser and piezo electric sensor.

Fig. 3 Vibrtion measurement at the D. C motor using FFT analyser and piezo electric sensor

Fig. 4 shows the vibration measurement at the DC motor using FFT analyser and piezo electric sensor. From the figure it is observed that maximum peak velocity is 2.9 mm/sec at 470 Hz. It is hormonic of rotational speed. Fig. 4 and Fig 5 shows the vibration measurement at the top of frame and on the mount using FFT analyser and piezo electric sensor. Fig. 4 clearely shows that maximum peak velocity is 1.3 mm/sec at 28 Hz it is due to close to rotational frequency 25 Hz. From the Fig. 5 it is observed that maximum peak velocity 1.1 mm/sec at 10 Hz is close to sub harmonic of rotational speed of 25 Hz. All vibration levels at all ositions are below the accptble limit of velocity 3 mm/sec for industrial machine rinning below 2000 rpm as per IS 1941 code. So from the results the it is concluded that there is no vibration problem in the motor generator system.

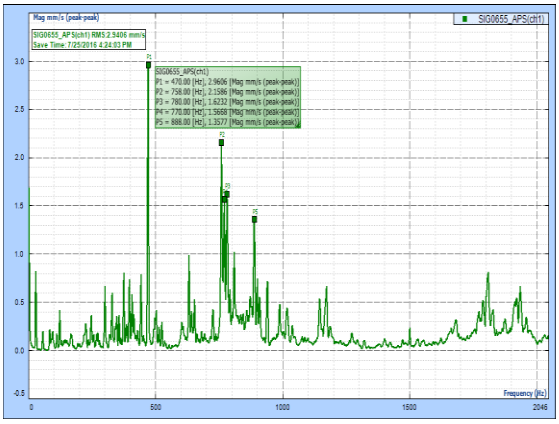

Fig. 4 Frequency spectrum at top of the DC Motor

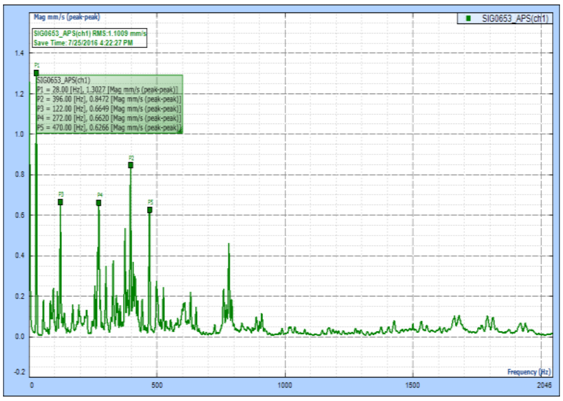

Fig. 5 Frequency spectrum at top of the frame

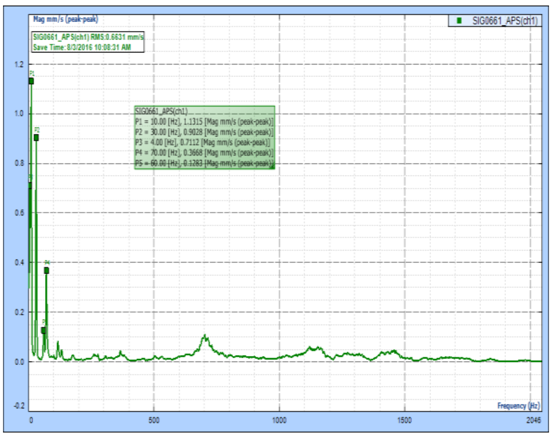

Fig. 6 Frequency spectrum on the mount

C. Natural Frequency Test

Natural frequencies of the motor generator system is obtained using impact hammer method. Fig. 7 shows the photograph of instruments, hardware and software used for Natural Frequency Test (NFT) on motor generator system. The sensitivity of the impact hammer is used for present test is 10.6 mV/g and maximum force can be applied 500 lb impact hammer is attached to the channel 1 of FFT analyser and accelerometer is attached to channel 2 of FFT analyser. The sensitivity of the accelerometer is 106 mV/g. The frequency range is selected for present measurements is 0 Hz to 400 Hz. Impact force is applied on the motor generator system and vibration levels are measured using accelerometer and FFT analyzer. Total four impacts are considered to average recorded data in the frequency range of 0 Hz to 400 Hz. Coherence spectrum is used identify the natural frequencies in the spectrum. Coherence spectrum shows the ratio of output energy from accelerometer to input energy from impact hammer. All peaks in the spectrum near to coherence values are near to 0.9 are considered as natural frequencies. Fig. 8 shows the frequency spectrum obtained from the NFT test. Fig. 8 clearly shows that first peak is at 51.87 Hz. It is far away the rotational frequency 25 Hz.

Fig. 7 Photograph of instruments, hardware and software used for Natural Frequency Test (NFT) on motor generator system

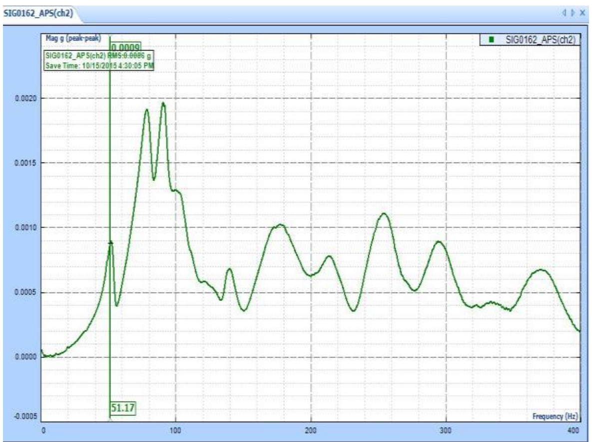

Fig. 8 Frequency spectrum at top of the DC Motor

III.MODAL ANALYSIS OF MOTOR GENERATOR SYSTEM

History speaks of many accidents which occurred and whose cause could not be ascertained. Later it was revealed that there is a phenomenon of vibration called resonance which can occur in any engineering structure which has mass and elasticity. Different techniques, experimental and theoretical have been developed to analyze problems related to vibration. But in the present era computational techniques are quite common and are very reliable as far as the vibration analysis is concerned.

The goal of modal analysis in structural mechanics is to determine the natural mode shapes and frequencies of an object or structure during free vibration. In many engineering applications, the natural frequencies of vibration are of interest. This is probably the most common type of dynamic analysis and is referred to as an 'eigenvalue analyses. In addition to the frequencies, the mode shapes of vibration which arise at the natural frequencies are also of interest. These are the undamped free vibration response of the structure caused by an initial disturbance from the static equilibrium position. The total number of eigen values or natural frequencies is equal to the total number of degrees of freedom in the model. Each eigenvalue or frequency has a corresponding eigenvector or mode shape. The mode shapes are also of interest to the engineer. These are normalised to the maximum displacement of the structure. The input conditions which initiate the vibration control the amplitudes of vibration in any problem. The natural frequencies and mode shapes are important parameters in the design of structural components for dynamic loading conditions. Natural frequencies and mode shapes are a starting point for a harmonic analysis. Modal analysis is carried on the motor generator system to identify the critical modes and mode shapes. For this purpose motor generator system is modelled using CATIA V5 R20 and these results exported in to ANSYS Workbench 15.

A. Modelling of Motor Generator System

The individual parts (A.C generator, two D.C machines, and an induction machine) of motor generator system are modelled using part modelling and mounted on the common shaft, arranged in respective positions. For the design of motor generator system left end of the bearings are positioned at a distance of 500 mm and again second bearing are positioned at a distance of 1050 mm and third bearing is positioned at a distance of 1800 mm and last bearing is positioned at a distance of 2200 mm. All the individual parts are modelled by keeping same mass and overall dimensions of the physical parts of motor generator system by simplifying complex geometry which are no significant contribution in the modal analysis to reduce the computational effort of computing system. Fig. 9 shows the solid modal of the motor generator system.

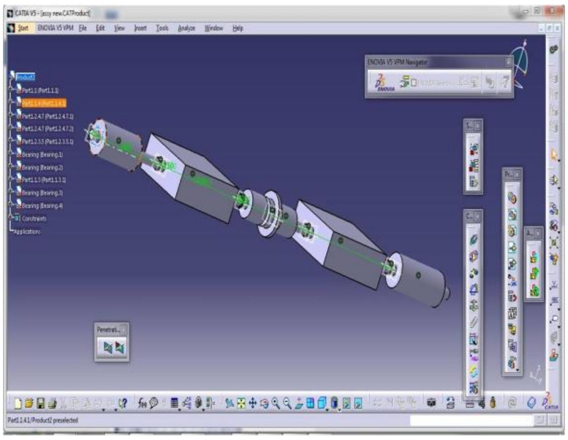

Fig. 9 Solid modal of the motor generator system

B. Analysis of Motor Generator System

The assembly of motor generator system is modelled in CATIA V5 R20 and it is exported into ANSYS Workbench 15 in IGES format. Properties of the materials are applied to the geometry. SOLID187 element is used for the meshing and convergence is reached for the mesh size of 22 mm. After convergence the final solid model of motor generator system has 28431 nodes, 5643 elements. Left end of motor generator system is fixed, and displacement is constrained in all the three directions. Fig. 9 and Fig.10 shows the meshed model and boundary conditions of motor generator system respectively. The first mode natural frequencies for the system is obtained as 44.5 Hz. Fig. 11 shows the first mode of motor generator system. From the Fig. 11 it is observed that maximum total deformation obtained is 7.3157 mm. Table II shows frequencies at different modes of motor generator system.

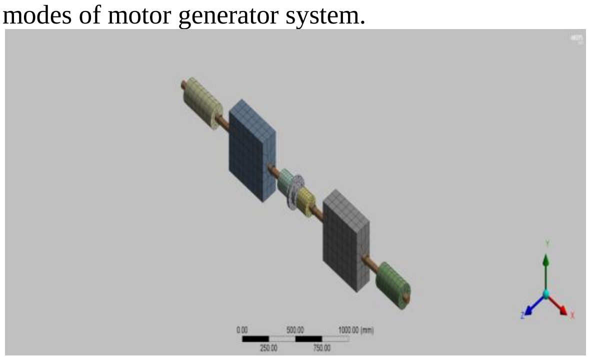

Fig. 9 Meshed Model of Motor Generator System

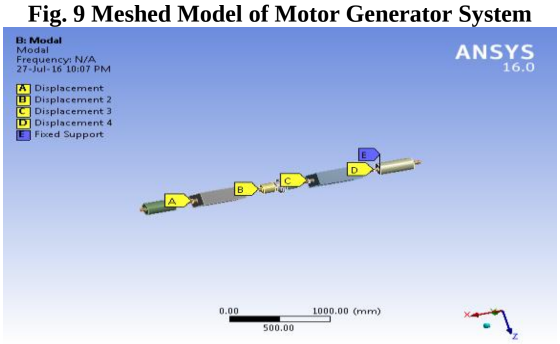

Fig. 10 Boundary Conditions of Motor Generator System

Table II Frequencies at different modes of motor generator system

S.No	Mode	Frequency (Hz)
1	1	44.5
2	2	95.0
3	3	107.5
4	4	106.2
5	5	175.6
6	6	183.3
7	7	188.2
8	8	207.9
9	9	440.8
10	10	452.4

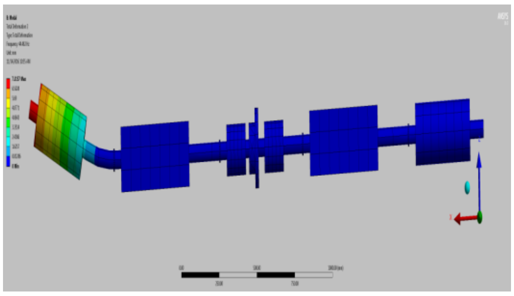

Fig. 11 First mode of Motor Generator System

Table III shows the comparison of frequency obtained from the FFT analyser and Numerical analysis using ANSYS. From the results observed that the first natural frequency is at 44.5 Hz from ANSYS and 51.87 Hz from FFT analyser. From the results it is observed that error between the FFT analyser results and ANSYS results is around 14.24 %. It shows that good agreement between the FFT analyser and ANSYS Results

Table III. Comparison of natural frequency

S.No	Frequency (Hz) from FFT Analyser	Frequency (Hz) from Numerical Analysis	%Error
1	51.87	44.5	14.24

IV. Conclusions

Noise levels are measured using condenser phone and FFT analyzer. It is quite higher than the acceptable limit. FFT analyzer and accelerometer is used to analyze the vibrations levels of motor generator system. From the analysis, it is observed that all the vibrations levels are within the limit. NFT (Natural Frequency Test) test is carried on the motor generator system to obtain natural frequency or critical speeds of the system. From the analysis, it is observed that all natural frequencies are far away from the operating speed. Modal analysis is carried out in motor generator system using ANSYS Workbench. To validate the numerical methodology it is compared with results obtained from NFT test and it is found that there is a good agreement between the numerical and experimental results.

All vibration levels are well below the acceptable limit of 3 mm/sec but noise observed is more than the acceptable limit for the machine. So it is suggested that design acoustical enclosure around the motor generator system to the reduce noise levels and to provide safe operating conditions for students working on the test bed.

References

[1] Ling Xiang, ShixiYang, ChunbiaoGan, *Torsional vibration measurements on rotating shaft system using laser Doppler vibrometer*, Optics and Lasers in Engineering 2012, vol 50, pp- 1596–1601.

[2] Du Dongmei, Zhang Zhi He Qing, *A System of calculation and Analysis of Torsional vibration for Turbine-Generator shaft*, Proceedings of POWER2007 ASME Power, San Antonio, Texas, 2007, vol-12, pp-323-327.

[3] Peishuh Wang, Patricia Davies John M. Starkey, and Richard L. Routson, *A Torsional Vibration Measurement System*, 1992, vol. 41, pp. 16-21.

[4] N.A. Halliwell, C.J.D. Pickering and P.G, Eastwood, *The Laser Torsional Vibrometer*: A New Instrument, Journal of Sound & Vibration, 1984, vol- 93, pp.588-592.

[5] Gatzwiller K, B&K, Rylander A. Solvinga, Critical propulsion problem at volvopenta using two torsional vibration meters type 2523, http://www.bksv.com/doc/bo0425.pdfS.

[6] Xue-LaiLiu, Wen-Bin Shangguan, Xingjian Jing, Waizuddin Ahmed, Vibration isolation analysis of clutches based on trouble shooting of vehicle accelerating noise"Department of Mechanical Engineering, The HongKong Polytechnic University, P RChina, 2016, vol- 382, pp.84-92.