Middle-East Journal of Scientific Research 18 (4): 546-556, 2013
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2013.18.4.11722

Different Aspects of Gas Turbine Siemens 162MW-V94.2 Vibration Analysis

Omid Ali Zargar

Department of Mechanical Engineering - Jawaharlal Nehru Technological University Hyderabad, Kukatpally, Hyderabad-500085 andra Pradesh, India

Abstract: Analysis of most critical equipment was one of the most challenging activities in preventive maintenance.utilities considering as heart of the process in big industrial plants like petrochemical zones.Vibration analysis methods and condition monitoring systems of these kind of equipment develop too much in recent years on the other hand there are too much operation condition consideration in these kind of equipment.in this paper I tried to introduce some most effective vibration analysis concepts of gas turbine vibration analysis. After that I will explain a gas turbine vibration case history, SIEMENS 162MW- V94.2for this purpose I had to fist introduce these kind of turbine technical specification.at the end I hope that readers could have better understanding about most critical equipment condition monitoring systems and vibration analysis.

Key words: Gas turbine · Turbine compressors · Vibration data collectors · Utility · Condition monitoring · Non-contact probe · Relative Vibration · Absolute Vibration · Time wave form (TWF) · Fast Fourier transform (FFT).

INTRODUCTION

There are two set of probes in gas turbine first none contact probes who measuring the shaftRelative Vibration by micrometer peak to peak. The condition monitoring of these kind of probes are usually bently Nevada system and also there are some contact probes measuring Absolute Vibration mm/s RMS.both systems equipped with alert and danger board inprocess main board sub stations and will trip the gas turbine in danger condition. The advantage of this method is that if there are some mistake in any installation of any probe system the parallel condition monitoring system can reduce the risk as well as possible the reliability of these kind of system in turbine rough condition is improve too much by this method. One of the gas turbine monitoring system is SKF DYMAC and Vibro-Meter's new generation of sensors and monitoring systems that represented below.

The CM condition monitoring group data collectors like easy viber or vibro 60 can easily connected with these kind of board facilities by adjusting the data collector software like spectra pro or XMS options. The CM group can achieve valuable vibration data and trends as well as the time wave form (TWF) or fast Fourier transform (FFT)

Fig. 1: None contact probe connection main board in sub station.

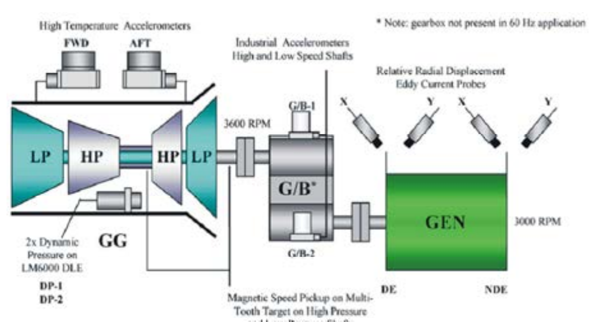

Fig. 2: Typical relative vibration monitoring system of gas turbines

Corresponding Author: Omid Ali Zargar, Department of Mechanical Engineering - Jawaharlal Nehru Technological University Hyderabad, Kukatpally, Hyderabad-500085 andra Pradesh, India.

Fig. 3: Typical Eddy Current Probe System (CMSS 68)

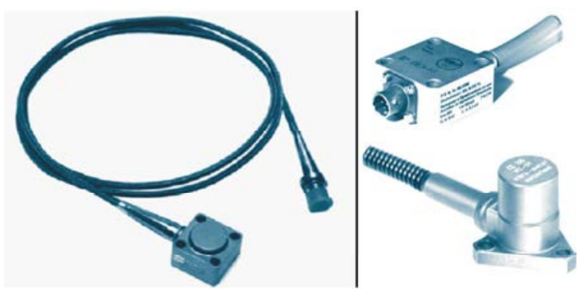

Fig. 4: CA303 and CE136 Accelerometer.

and phase values that will support the process of gas turbine vibration analysis. The regular and close monitoring will help the CM group for better further decisions in this process. A typical relative vibration monitoring system of gas turbines shown in figure 2. These kid of systems equipped with none contacted Eddy Current Probe System shown in figure 3.

The vibration monitoring system of gas turbines usually equipped with some contact probe piezoelectric (Accelerometer measuring) Absolute Vibration mm/s RMS. These kind of facilities will help us when some fake trip accrue in the system by any mistake in different special electronic installation systems. Typical gas turbine condition monitoring contact probe shown in figure 4. The system usually equipped with vibration indicator that can represented the absolute or relative vibration data or trends on process monitoring system. The advantages of these kind of information is that continues monitor the vibration condition automatically [1].

Misalignment and unbalance is the most cause of machine vibration. An unbalanced rotor always cause more vibration and generates excessive force in the bearing area and reduces the life of the machine. Understanding and practicing the fundamentals of rotating shaft parameters is the first step in reducing unnecessary vibration, reducing maintenance costs and increasing machine uptime. Both these faults can diagnosis by vibration analysis in different ways by above systems

Each fault have unique characteristics in FFT, TWF or phase behavior of machine. These process could predicted unexpected shut down in industrial plants [2]. The shaft crack is also one of the most challenging concept in fault diagnosis in most critical equipment. The shaft crack characteristics is unique and identified in different way in different aspect of vibration signals in both absolute and relative vibration data. A parametric study has been conducted to discussed the effect of the crack location and material gradient on both the natural frequencies and the corresponding mode shapes [3]. The lubrication and journal bearing wear is one of the other critical aspect in gas turbine preventive maintenance. The oil sample location and techniques also discussed in different aspect in mechanical engineering maintenance groups. Nowadays new lubricant introduce to mechanical engineering world every week. An environmental friendly palm-grease has already been formulated from modified RBDPO (Refined Bleach Deodorized Palm Oil) as base oil and lithium soap as thickener. Such palm-grease is dedicated for general application and or equipment working in different industries. Tribology performance, especially the anti-wear property of lubricants discussed in different methods in recent years [4].

The signal processing methods developed too much in recent years. One of the alternative statistical analysis method, known as I-kaz Multi Level. This method was originally developed base on I-kazTM but with higher order of signal decomposition.This new I-kaz Multi Level method was proven to be very sensitive and detects very well in amplitude andfrequency changes of a measured signal. Nowadays we can achieve TWF and FFT with more resolutions [5] a robust real time surveillance and secure system, for critical oil pipeline infrastructures, with combination of conventional network and wireless sensor network along with microwave network represented recently.This system shows a significant improvement with eleven times more efficient to conventional system by reducing leakage and loss reportingtime to control center. This system will be more efficient to detect any threats in real time and can report to central control room without any further delay. [6] different maintenance strategies such as corrective maintenance, time based preventive maintenance, condition-based maintenance and predictive maintenance for different equipment

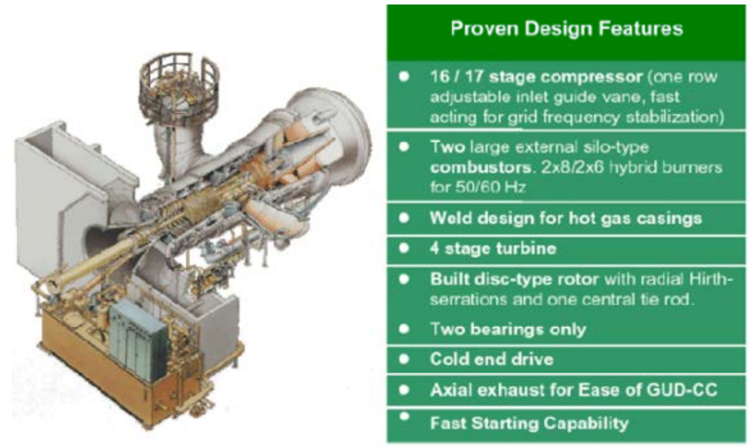

Fig. 5: SIEMENS V94.2 Gas Turbine Features

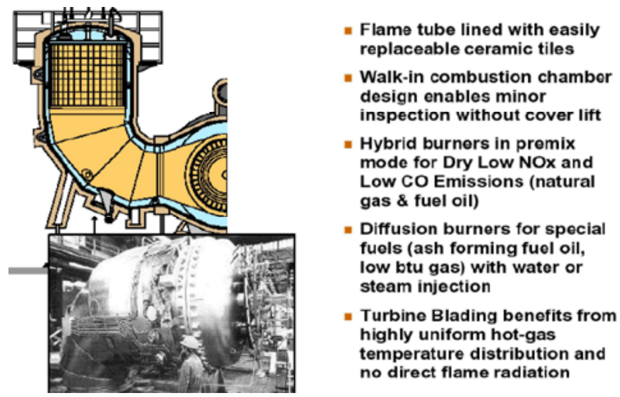

Fig. 6: V94.2 Gas Turbine Combustion chamber features

Fig. 7: Some SI3D Blading Samples

developed in recent years. A new fuzzy multi criteria model is introduced and it is used for the optimization decision making of the complex system maintenance strategy. Maintenance strategies has been modeled with consideration of several fuzzy parametersIn any equipment, its different parts with respect to introduced criteria may need different maintenance policies. Thus it is important for different parts of equipment with respect to their Sensitivity suitable maintenance policies can be selected [7].

Experimental Details: In this paper I decide to explain a case history about vibration and operation behavior of gas turbine SIEMENS 162MW- V94.2. for this purpose firstly I had to talking about these kind of turbine technical specification. V94.2 Gas Turbine Features represent in figure 5.

V94.2 Gas Turbine Combustion chamber features also represent in figure 6.

The blading system is SI3D as the following photo description for vane #1 and vane #2.

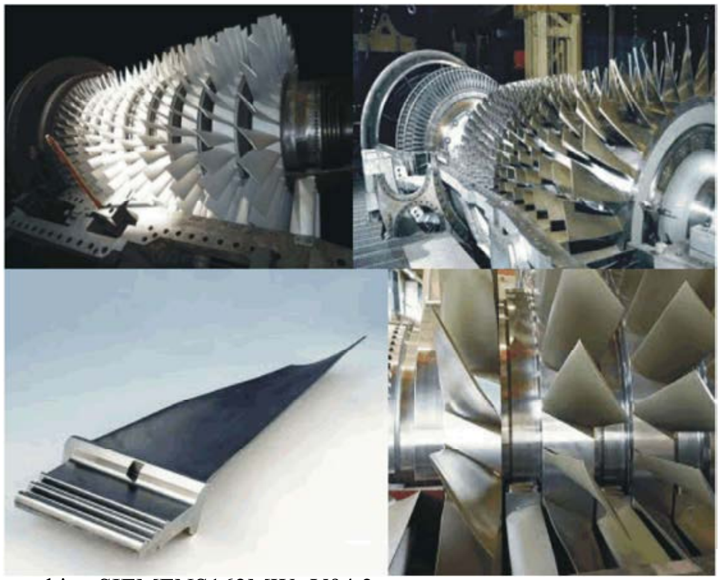

Fig. 8: Typical blades of gas turbine SIEMENS162MW- V94.2

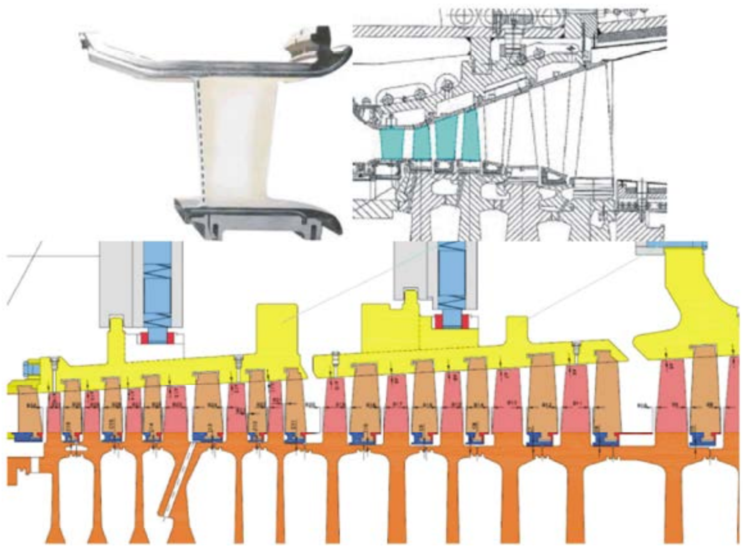

Fig. 9: Blades design features plot

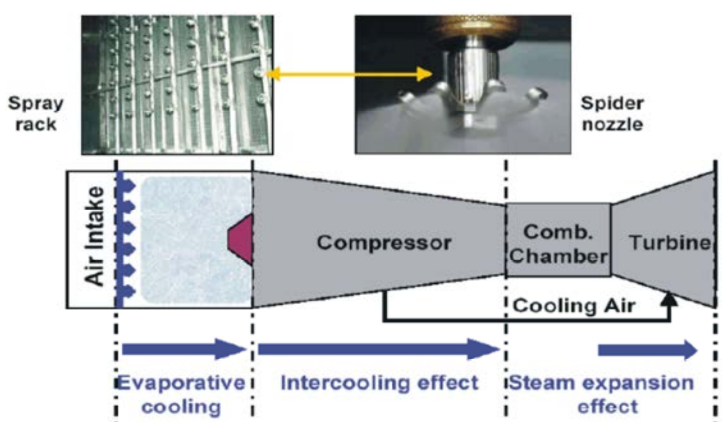

Fig. 10: Wet compression process

Rotor and Typical blades of gas turbine SIEMENS162MW- V94.2 shown in figure 8.and blades design features plot shown in figure 9.

Also Employing Wet Compression System Available in Market Since 2003.

Now we have better understanding about machinery features and options ofgas turbine SIEMENS162MW- V94.2 and we can go through vibration concepts and our case history more effectively [8].

RESULT AND DISCUSSION

In this part I will explain a case history about SIEMENS V94.2 Gas Turbine utility in specific trip vibration condition in the main board operation recently developed.At the end readers should have better understanding about Different aspects of Gas turbine vibration analysis.

Case History:

Duration: Tuesday, April 24, 2012 to Friday, May 4, 2012.

After facing some problems in gas turbine Fars utility start up the gas turbine trip in 1000 RPM because of high vibration amounts. The vibration groups taking part a session for analyzing the balancing condition of rotor and gas turbine foundation conditions.both the balancing and foundation maintenance data was in good conditions then vibration groups decided to close monitoring the gas turbine. Further investigations in maintenance actions show that middle shaft of gas turbine was falling during machinery maintenance actions and installed after maintenance in machinery workshop. There was a strong hypothesis that this may the main root of all vibration problems in this machine. The vibration analysis in this case will discuss this hypothesis and other possibilities and also will help all readers who directly involve to vibration mater in further gas turbine vibration analysis. And help others to have better understanding about vibration analysis of most critical equipment.

First the group checked the absolute and relative conditioners to adjust the related options with technical documents. Then the analyzer group readjust all the adaptation numbers in turning gear condition with technical document considerations. Then all the relative vibrations in turbine, compressor and generator monitored in 600 RPM in the next stage. The operation condition was not agree to continue increasing RPM then in the next day fist start up the gas turbine up to 600 RPM then process decided to reduce the RPM up to 450 and after one hour they increasing the RPM little by little up to 990 RPM that gas turbine trip because of high amount of absolute vibrations. As we checked all the trend of vibration monitoring data it was clear that the gas turbine do not have any problem up to 750 RPM. And also there was an acceptable adaptation between all monitoring systems in process board and CM vibration trends in both absolute and relative monitoring systems. But unfortunately after 750 RPM the related vibration was increasing little by little. And after that the absolute vibration increased dramatically after 940 RPM but relative vibrations decrease slightly simultaneously. This increasing in absolute vibration in turbine side was 17.5 mm/s RMS that caused vibration trip in 990 RPM. The absolute and relative vibrations decrease slightly in the same manner in trip period of time.alsoAll journals temperature monitoring was normal and in range during this process.the decreasing relative vibration with increasing in absolute vibration never seen in other gas turbines by the vibration groups and seem to be a new phenomenon or vibration behavior.

Because of low frequency condition the absolute sensor cannot help in vibration analysis but there are some valuable information in relative sensor data that called slow roll in CM texts. And will help us in shaft center line analysis.

Fig. 11: Absolute and relative vibration trends from process main board control system monitor.

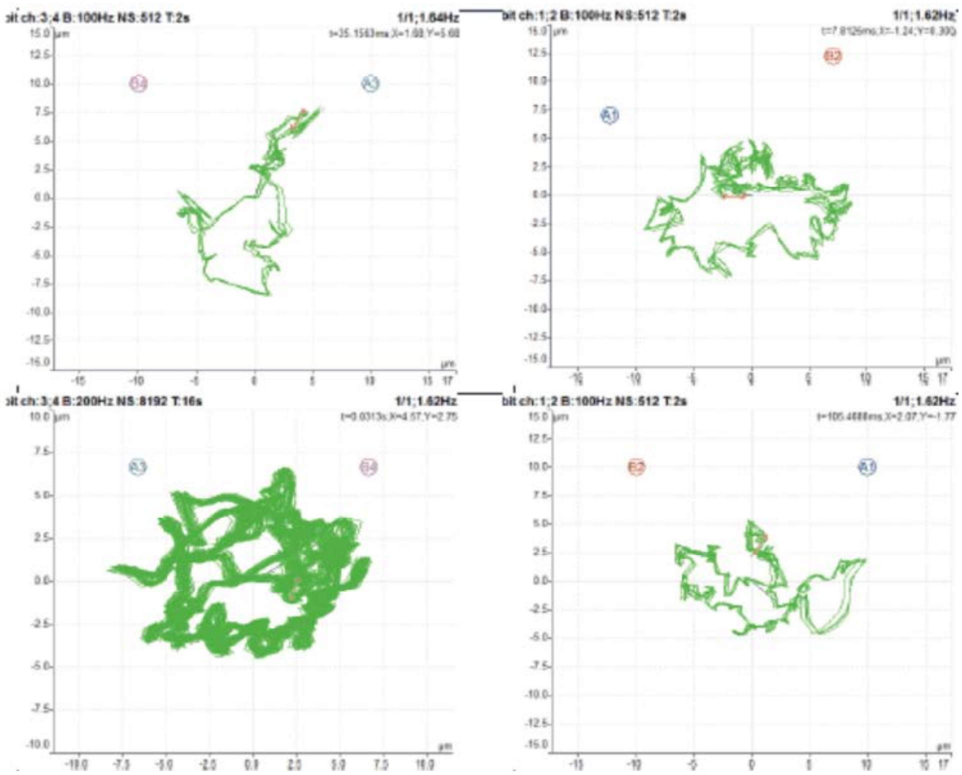

Fig. 12: Turbine and compressor orbit OCE and CE in turning gear condition

Y	X
-40	-75
-45	115

Fig. 13: Shaft position by 9 volt initial installation.

We focus to vibration information that measured in 750 RPM. Also the FFT in 600 RPM shown in figure 14.

750 RPM approximately is beginning of first critical speed ofgas turbine SIEMENS162MW- V94.2and the vibration data in this condition can help too much for vibration analysis of this gas turbine.

By using the phase value trends in different position of gas turbine the modal analysis shown in figure 17.

Monitoring system in operation main board showed that The relative vibration decreasing suddenly when absolute vibration cause trip in gas turbine.CM vibration graphs also indicate parallel information.

The reason of this phenomena could be discover by drawing bode diagram for relative vibration sensors information in both turbine and compressor sides.

As shown in bode diagrams amplitude overall vibration decreasing in one sensor and increasing in other sensor simultaneously. The increasing is related to a vibration mode turbine side 940 RPM in a sensor direction 30° but after increasing RPM this vibration mode disappeared and replace by another vibration mode in another sensor and direction 90°that cause high amount of vibration in turbine side. This phenomena could see in Nyquist diagrams of gas turbine and called Split Resonance. Andmay cause Backward whirl between 940 to 980 RPM in both turbine and compressor journals [9].

At the end three dimensional FFT diagram of both turbine and compressor relative vibration in startup and trip conditionscould help us to develop some hypothesis in gas turbine fault diagnosis.

In this part we are comparing some of the rotor faults in most critical equipment with the vibration evidences in our gas turbine. Small amount of these kind of faults usually exist in normal behavior of industrial rotors but high amount of these faults may cause trip in all kin of most critical equipment.The piezoelectric layers are used as sensors and actuators. Micro-vibrations, generally defined as low amplitude vibrations at frequencies up to 1 kHz, are now of critical importance in a number of areas like preventive maintenance An adaptive inverse dynamics control was used to suppress the vibration of a simply supported panel with equipment these kind of techniques also can use in condition monitoring of most critical equipment [10].

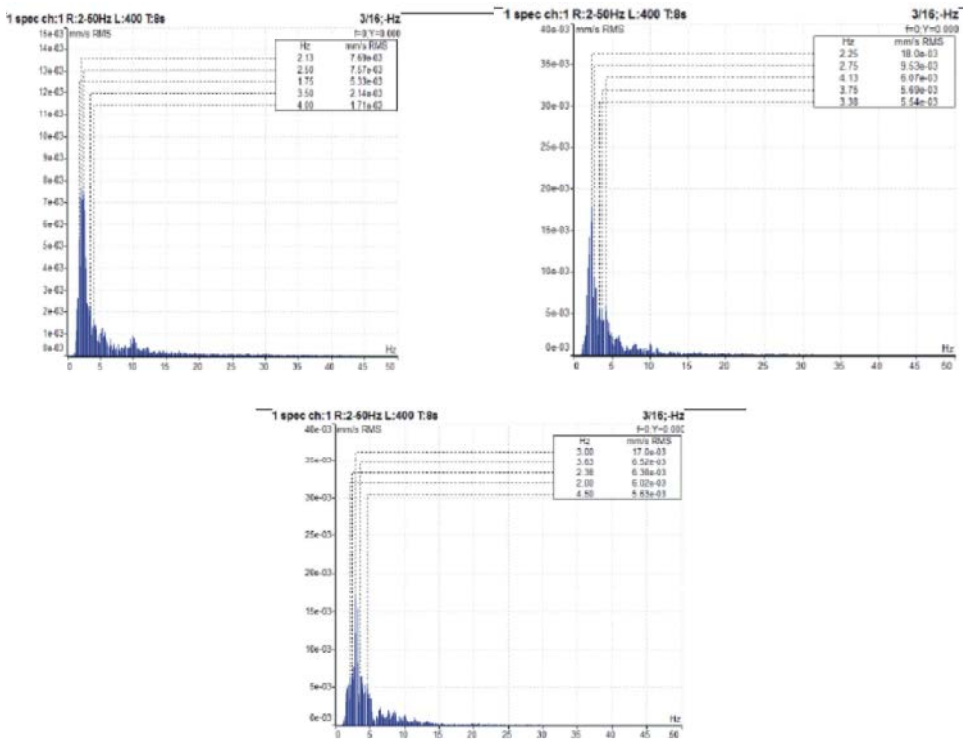

Fig. 14: FFT absolute vibrations turbine side in 600 RPM (horizontal, vertical and axial)

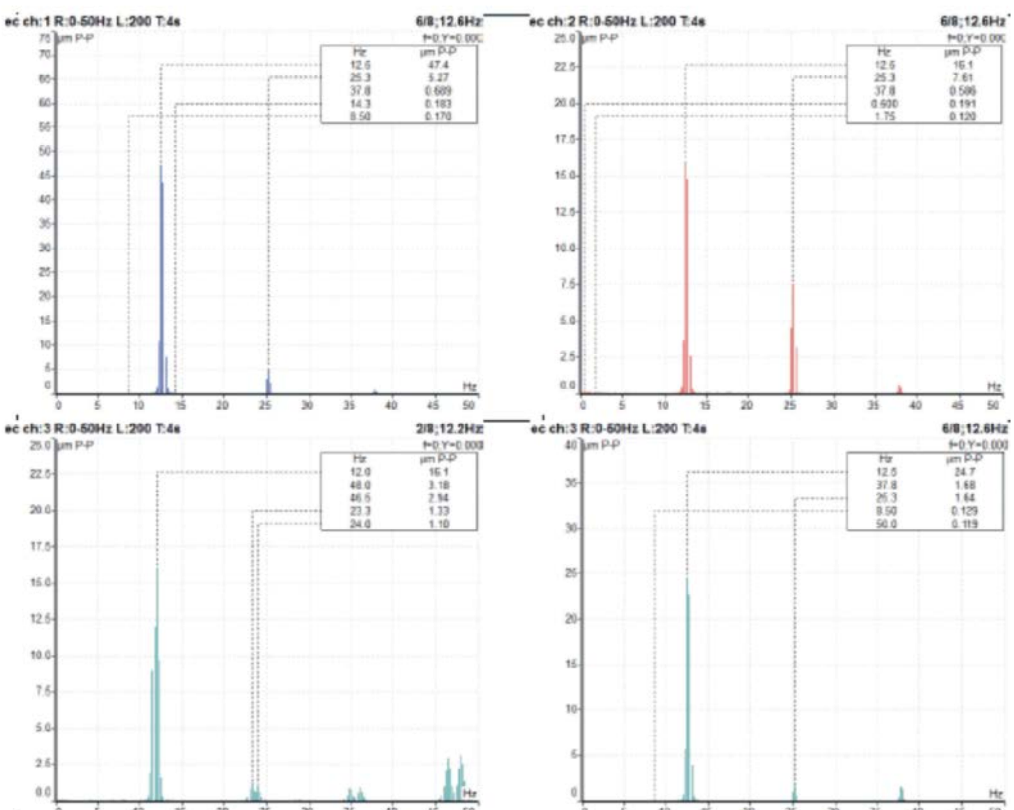

Fig. 15: Relative vibrations FFT turbine 1, turbine 2,compressor and OCE in 750 RPM.

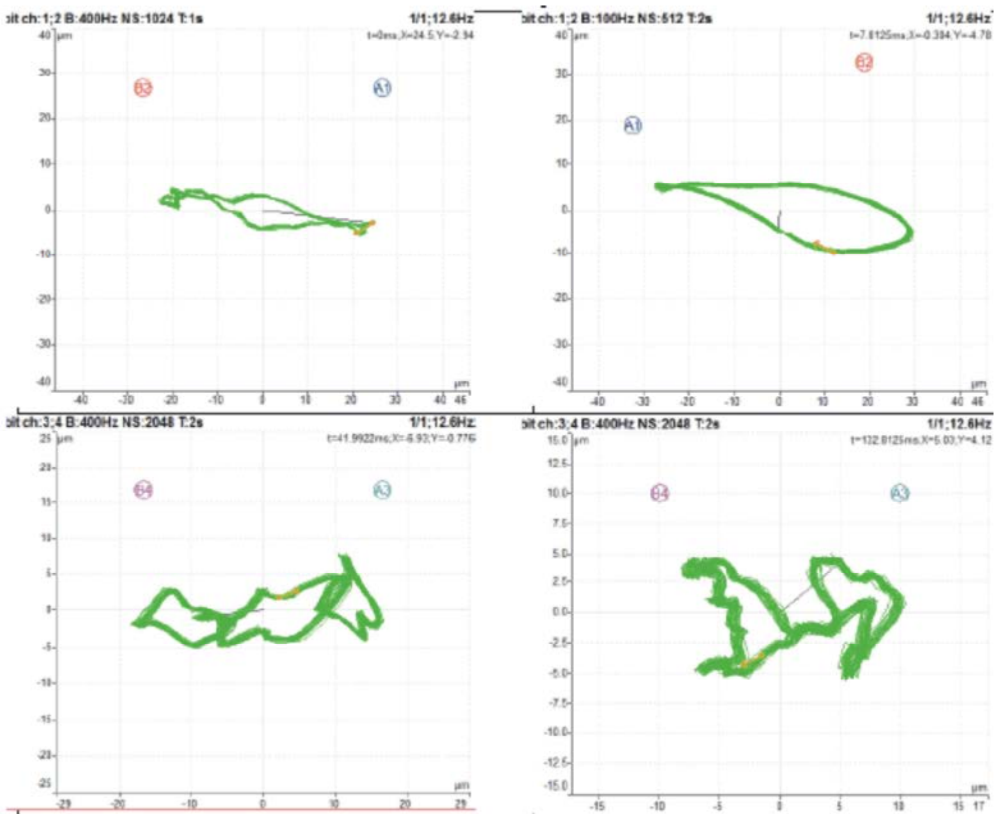

Fig. 16: Orbits turbine, compressor, OCE and CE in 750 RPM.

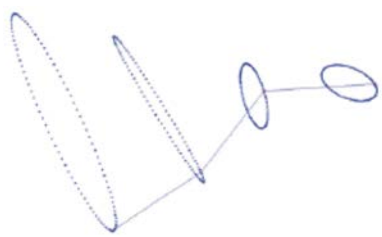

Fig. 17: Vibration modal analysis 1X (left is related to turbine side)

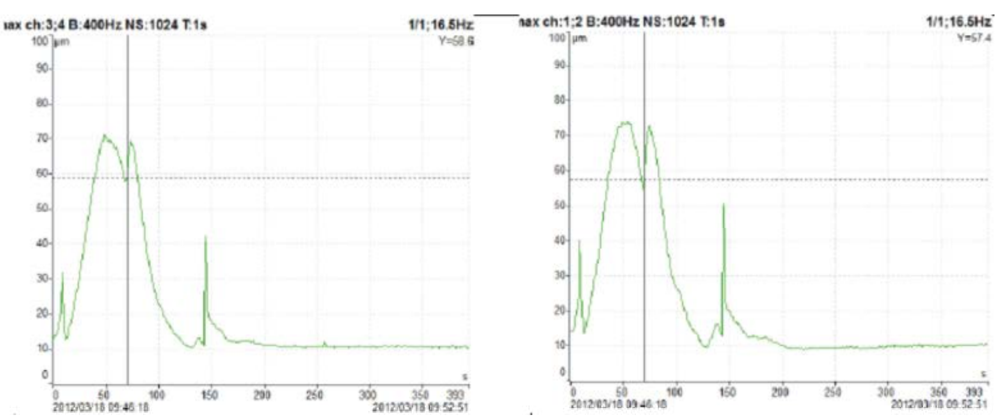

Fig. 18: Turbine and compressor start up and shut down condition (cursor indicate trip position)

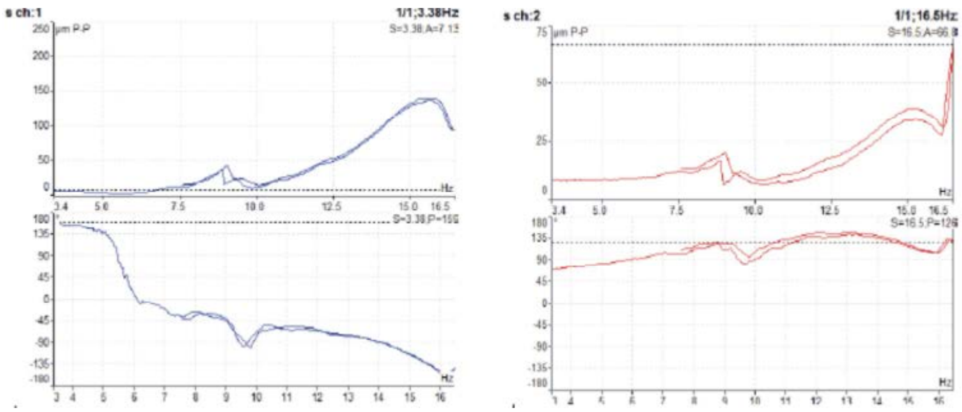

Fig. 19: Bode diagram for relative vibration sensors information in turbine side.

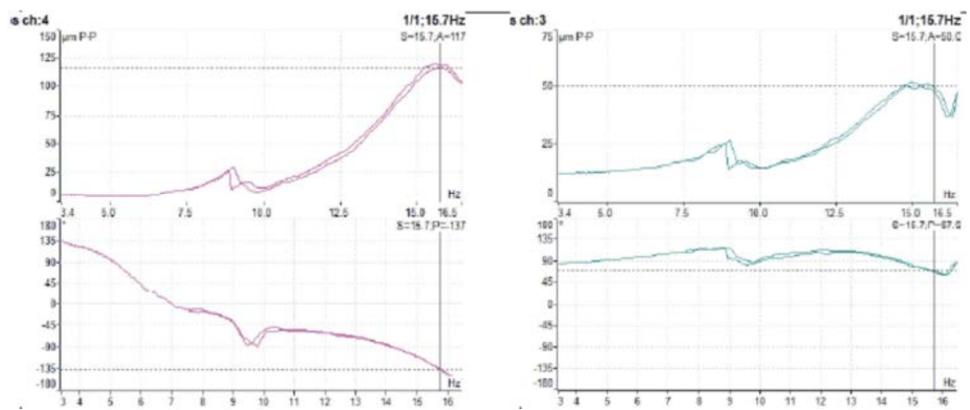

Fig. 20: Bode diagram for relative vibration sensors information in compressor side.

Also stochastic identification technique is proposed to estimate both the parameters and order of multi-input multi-output vibrating structural systems.in complex machinery systems like gas turbine hundreds of parts may originate hundreds of frequency vibration is such a complex condition time modeling systems like vibration modal analysis can help to fault diagnosis and sometime cause some partial modification to improve the performance and vibration behavior of machine [11]. Sub harmonic vibrations exist specially in higher RPM of gas turbine but trip was in low RPM and wear could not be a main problem in this machine. Angular misalignment base on axial vibration but there is no high axial vibration in this machine. And also phase analysis have no evidence of any misalignment in this machine. There was no 0.48 X in this gas turbine FFT then Oil whip/whirl could not be the problem. Recent investigation show that lateral natural frequencies increases by applying tension axial loading and decreasesby applying compression axial loading at the ends of the rotating shaft. In vibration behavior of this gas turbine there are no evidence of natural frequencies and also the axial vibrations was not too high [12]. Also there was no shaft crack evidences like 2X in half critical speed shown in 3 dimensional FFT.there was no rotary looseness evidence in TWF of gas turbine also the phase analysis in foundation show that there is no looseness in the gas turbine foundation.turbine limit load control is one of the most important parts in any gas turbine system. And have direct effects in vibration behavior of machine. There are a number of methods recently developed for these kind of behavior and characteristics in gas turbines [13]. Three condition should be exist simultaneously to represent unbalance fist all relative vibration in different direction should be high considerably.the main direction none contact vibration should have 90° shift phase. And the main frequency should be 1X in FFT. All these evidences was exist in this gas turbine. The vibration analysis group recommended rotor unbalance after field balance of the rotor. Turbine startup.both absolute and relative vibrations was in range and there was no trip any more. The vibration analysis could predict the gas turbine fault successfully.

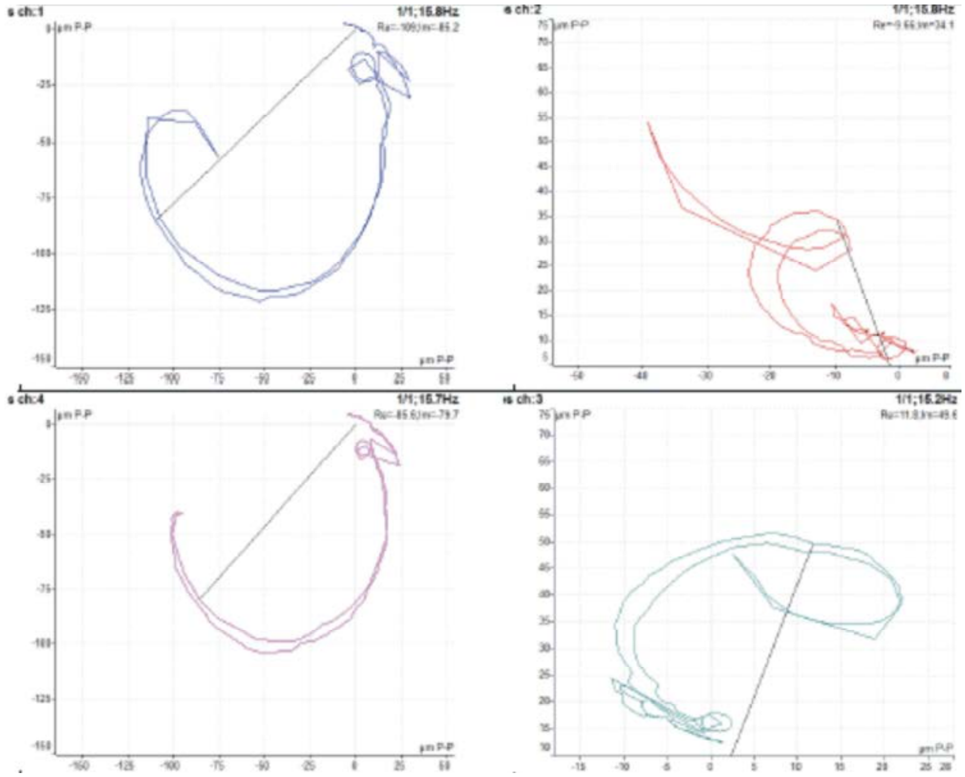

Fig. 21: Relative vibration sensor Nyquist diagram of both turbine and compressor.

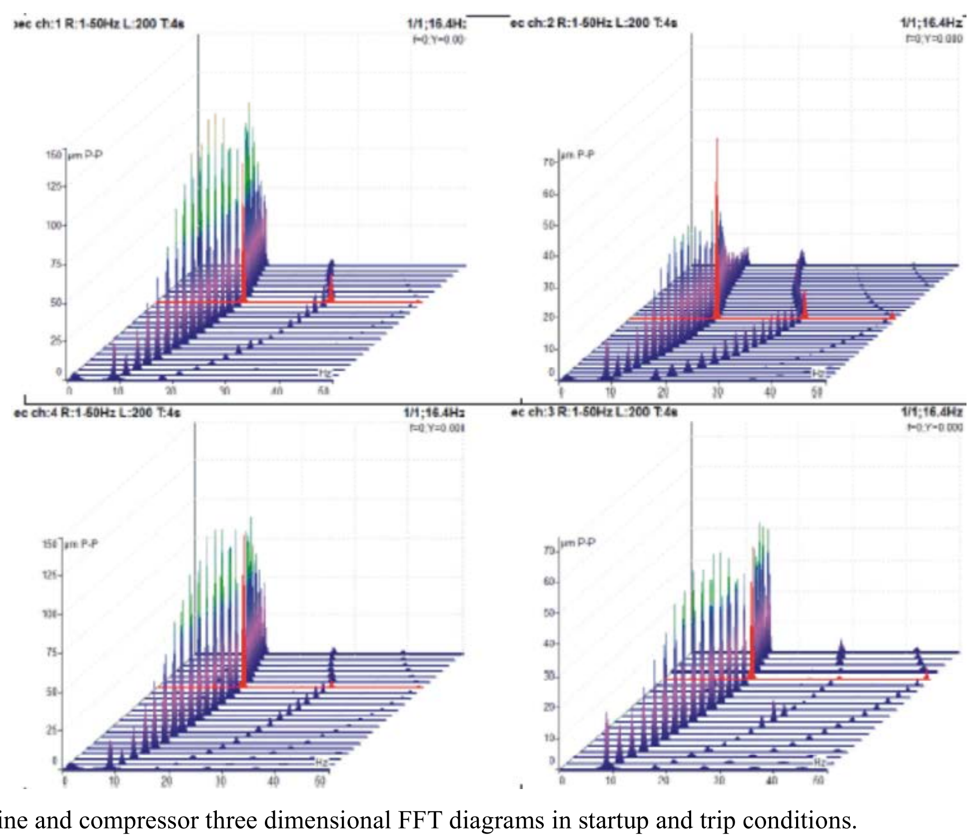

Fig. 22: Turbine and compressor three dimensional FFT diagrams in startup and trip conditions.

CONCLUSION

In vibration analysis of most critical equipment like gas turbine utilities vibration analysis group first should study the process parameter trends like inlet and outlet temperature and pressure. And make sure that all parameter is in the range of technical document of gas turbine. Also they should have good information about changing in load and RPM every day. Sometime this kind of process activities cause serious mechanical and machinery problems in most critical equipment. After that the condition monitoring group should have provide good trends of different vibration data and graphs like absolute and relative over all vibrations, FFT.TWF as well as phase characteristics in different point of machine. Also vibration analysts should have a good understanding about machinery characteristics of gas turbine. By comparing the vibration trend and data and all machinery and process evidence with different main machine fault characteristics like wear, misalignment, Oil whip/whirl, shaft crack, looseness and unbalance the vibration analysis could recommend optimal maintenance action on gas turbine or any other most critical equipment.

ACKNOWLEDGEMENTS

It is with great pleasure and deep sense of gratitude, that I acknowledge the successful completion of this paper. My profound thanks and deep sense of gratitude to my dear sister Elahe Ali zargarand my dear friend KambizKian for their guidance and encouragement which were instrumental in the successful completion of this paper.

REFERENCES

1. James, C., 2003. Protection and Condition Monitoring of the LM6000 Gas Turbine. SKF Reliability Systems, 4141 Ruffin Road, San Diego, California 92123 USA, Web: www.skfreliability.com.
2. Hariharan, V. and P.S.S. Srinivasan, 2010. Vibrational Analysis of Flexible Coupling by Considering Unbalance. World Applied Sciences Journal, 8: 1022-1023.
3. Eftekhari, M., M. Javadi and R.E. Farsani, 2011. Free vibration analysis of cracked functionally graded material beam.World Applied Sciences Journal, 12: 1223-1225.
4. Sukirno, R. Fajar, S. Bismo and M. Nasikin, 2009. Biogrease Based on Palm Oil and Lithium Soap Thickener:Evaluation of Antiwear Property. World Applied Sciences Journal, 6: 401-407.
5. Karim, Z., M.Z. Nuawi, J.A. Ghani, S. Abdullah and M.J. Ghazali, 2011. Optimization of Integrated Kurtosis-Based Algorithm for Z-Filter (I-KazTM) Coefficient Using Multi Level Signal Decomposition Technique. World Applied Sciences Journal, 14: 1546-1548.
6. Alsaade, F., N. Zaman, A. Abdullah and M. ZafarDawood, 2012. Enhancing Surveillance and Security of Oil Pipelines Transportation Using Wireless Sensor Network. Middle-East Journal of Scientific Research, 11: 1029-1030.
7. Akhshabi, M., 2011. A New Fuzzy Multi Criteria Model for Maintenance Policy. Middle-East Journal of Scientific Research, 10: 33-38.
8. Siemens website, Siemens Gas Turbines, Technical Papers, 2012. http://www.energy.siemens.com.
9. I learn vibration training website, 2013. http://www.mobiusinstitute.com/.
10. Azadi, M., E. Azadi and M. Roopaei, 2011. Adaptive Inverse Dynamics Control for Vibration Suppression of Flexible Panel with Piezoelectric Layers. World Applied Sciences Journal, 12: 2343-2351.
11. Abu-El-Yazied, T.G., S.Y. Abu-El-Haggag and F.S. Al-Fares, 2009. Identification of Vibrating Structures with Application to a Steel Tower.World Applied Sciences Journal, 6: 1673-1674.
12. Hosseini, H., D.D. Ganji, M. Abaspour and H.D. Kaliji, 2011. Effect of Axial Force on Natural Frequency of Lateral Vibration of Flexible Rotating Shafts. World Applied Sciences Journal, 15: 858-859.
13. Afkhami, H., A. Argha, M. Ropaee and M.A. Noori, 2011. Surveying the control loops of the governor of the V94.2 gas turbine.World Applied Sciences Journal, 15: 1438-1440.