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Vibration and Operation Technical Consideration Before Field Balance of Gas Turbine Utilities

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Abstract: one of the most challenging time in operation of big industrial plant or utilities is the time that alert lamp of bently Nevada connection in main board substation turn on and show the alert condition all of the maintenance groups usually make a lot of discussion. with operation and together rather this alert signal is real or fake this will be more challenging when condition monitoring vibration data shows 1X in fast Fourier transform (FFT) and vibration phase trends show 90 degree shift between two non-contact probe directions in recent days and CM group suspicious about unbalance rotor in this paper firs I try to introduce recent patent and innovation in balancing technologies and tools it can help the readers that not too much involve to preventive maintenance directly, to better understanding the balancing process on the other hand the readers who involve the vibration concept also can be more familiar to new data collectors related to balancing process and their new capabilities and options beside this I will introduce some recent more challenging case history in field balance of gas turbines(2012-2013).these processes will help us to evaluate the evidences that can help us to better understanding of machine condition in alert time and cause make better decision to let the machine to continue running or operate the balancing or any other maintenance action in further applications.

Key words: Gas turbine · Field balance · Turbine compressors · Balancing machine · Balancing tools · Balancing data collectors · Utility · Digital signal processor · APT Software · Condition monitoring · Non-contact probe

INTRODUCTION

The condition monitoring system of most critical equipment is one of the major important topic in preventive maintenance, Bentley Nevada systems widely develop in recent years and the option and capabilities of data collector improve so much also up to date almost every year the unbalance recommendation by condition monitoring group usually accrue when the alert condition appear in bently Nevada board in operation main board substation with three main vibration behavior of the rotor first two direction of non-contact probe vibration (X and Y) both considerably high in recent days secondly the main peak in fast Fourier transform (FFT) is 1X and the other peaks are not too much or considerable finally vibration phase trends show 90 degree shift between two non-contact probes directions in recent days [1]. Rotating machinery is commonly used in mechanical systems, including industrial turbo-machinery, machining tools, and aircraft gas turbine engines. Vibration caused by mass imbalance is a common problem in rotating machinery. Imbalance occurs if the principal axis of inertia of the rotor is not coincident with its geometric axis.

Higher speeds cause much greater centrifugal imbalance forces, and the current trend of rotating equipment toward higher power density clearly leads to higher operational speeds. Therefore, vibration control is essential in improving machining surface finish; achieving longer bearing, spindle, and tool life in high-speed machining; and reducing the number of unscheduled shutdowns [2].

The small or medium size rotor usually send to balance shop more easily because they are more easy to carry them to balance shop on the other hand the big or long rotors just will send to balance shop in critical operation condition. that is why main plant usually have central balance shop inside factory in the balance shop

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we have the wide type of balancing machines first classified by hard bearing and soft bearings type balancing machine the second consideration is due to flexible and rigid rotors the rotor of most critical equipment usually flexible and more challenging for balance the other consideration in length of the rotor the main balance shops and balance shops related to the main workshop of big plants usually equipped with wide and sufficient types of balancing machine also there are different type of balancing machine related to overhang or middle hang rotor the most critical equipment usually middle hang [3].

Beside this the rotor RPM is one of the most important consideration in balancing process the RPM of balancing process is directly related to amount of rotor RPM and usually much fewer and introduce in machine technical document.high speed rotor balance is usually one of the most challenging balancing process in balance world and need special balancing machine and equipped balance shops [4]. high speed balance is one of the newer balance techniques that developed by modern balancing machines. There are numerous advantages to high-speed balancing of generator and turbine rotors. These include, Smooth operation through the entire speed range up to over speed, The ability to access optimal weight planes, which are not normally accessible during operation in the machine, Verification of the mechanical integrity of the rotor and any assembled components, up to over speed and Electrical testing of generator rotors through their entire speed range can identify the existence of any speed related electrical faults. Also, long and slender rotors may not be able to be balanced with the planes available in the field due to the reduced influence of these areas on the unbalance in the rotor. In general, rotors that have had a change in their mechanical condition are best suited for a high speed balance [5] also the sensor of the balancing machine have two main groups first that work with the principal of vibration measurement and the second category is whom base on force measurement the main difference is balancing process the second type is less time consuming and usually need only a few try and error procedure but these kind of balancing machine develop just for rigid rotor and not applied with most critical equipment [6]. The grade of a balance is a number that will calculate with the balancing engineer due to the technical documents of the rotor like material, geometry and weight the grade of the balance will help the balance engineer to choose the most suitable balancing machine for the balance process [7]. Figure 7 will help to better understanding of some types of industrial rotors also the

Fig. 1: Type 7790-A Two-plane Balancing Consultant Type 7790 page.

flexible rotor usually balance in two or more panel for better balance quality.Beside this there are a number of valuable information about other stage of balancing procedure in machine technical documents. The field balance process is also apply with different software and data collector with different options, quality, accuracy and capabilities [8] in this section I am trying to introduce recent patent and innovation in balancing data collector capabilities and options. this process also will help better understanding of the balance procedure and options.

One of the recent patent in new balancing data collector and soft wares is Balancing - Type 7790-A. Two-plane Balancing Consultant Type 7790-A is an intuitive and effective tool for in-site (field) single-plane and two-plane balancing of rotating machinery in Two-plane Balancing method The experimental frequency spectrum usually obtain for both baseline and unbalanced condition under different unbalanced forces. And The experimental results of balanced and unbalanced rotors are compared at two different rotor locations [9]. Multiplane Balancing Consultant Type 7790-B adds three and four-plane balancing. A task-oriented user interface guides you quickly and safely through the necessary steps for setting up, measuring, validating and reporting. Fast trim balancing using stored rotor data is also supported [10]. The balance quality can be determined according to established balance quality grades (ISO1940.1) or according to maximum machine vibrations. The balancing procedure can be FFT-based or based on order tracking for the most accurate results.

The most important features divided in several categories like, Task-oriented user interface that guides you through all the stages of a balancing measurement, Balancing based on phase-assigned spectra, FFT-based balancing method for standard balancing on machines with stable speed, Order tracking-based balancing method for complex balancing on machines with unstable speed (requires Order Analysis Type 7702), Balance quality according to established grades (ISO 1940.1) or maximum machine vibrations, Alarms for excessive vibration levels and speed, 3D rotor geometry illustrations for easy overview of measuring planes and correction planes, 2D graphical views of correction planes with weight positions and of measuring planes with transducer positions,RPM meter with analog and digital read-outs, service speed range and maximum allowable speed, Display of triggered tacho signal for optimal settings of tacho detection parameters, Display of vibration time signals and spectra, Vector polar plots of fundamental frequency/1st order, Indication of initial, trial, final and optimization run results in vector polar plots, Tables of measurement results and applied masses, Weight splitting for use of standard masses and/or predefined mass positions, Support of predefined, distinct masses for simplified input, Fast direct print of reports in predefined layout, Reporting using Microsoft and Word in predefined layout or formatted according to ISO 20806, Vibration as displacement, velocity or acceleration and Support of both SI and Imperial units.these kind of modern data collector have a vide application in new technological industries specially in field balance of gas turbines. and also in other type Dynamic, in-site balancing of rotating machinery,Trim balancing using stored rotor data (influence coefficients) from previous balancing measurements and alsoPart of complete solutions for rotating machinery analysis and machine diagnostics including, Measurement transducers and accessories and Conditioning, measurement and analysis using the PULSE multi-analyzer system.Unbalance is a result of uneven distribution of a rotor's mass and causes vibration to be transmitted to the bearings and other parts of the machine during operation. Imperfect mass distribution can be due to material faults, design errors, manufacturing and assembly errors, and especially faults occurring during operation of the machine. By reducing these vibrations, better performance and more cost-effective operation can be achieved and deterioration of the machine and ultimately fatigue failure can be avoided. This requires the rotor to be balanced by adding and/or removing mass at certain positions in a controlled manner.Two-plane Balancing Consultant Type 7790A supports single-plane and two-plane balancing with determination of balance quality according to ISO 1940–1. The balancing process is performed as in site balancing (field balancing) where the rotor is balanced in its own bearings and supporting structure, rather than in a balancing machine. Trim balancing, using stored rotor data (influence coefficients) from previous balancing sessions is also supported, ensuring fast correction of small residual unbalances in cases where balancing has to be repeated. The Balancing Consultant has an intuitive, task-oriented, graphical user interface leading you quickly through the necessary tasks for setup, measurement and reporting.Balancing can be based on either frequency spectra (FFT) or order spectra (order tracking). Traditional FFT-based balancing is sufficient in many measurement situations. However, in cases with unstable machinery speed and/or high frequency resolution requirements, order tracking should be used to eliminate frequency smearing and provide more accurate results.Balancing using order tracking requires Order Analysis Type 7702. As Balancing and Order Analysis address the same kind of machinery, the hardware accessories for the two configurations are also the same.

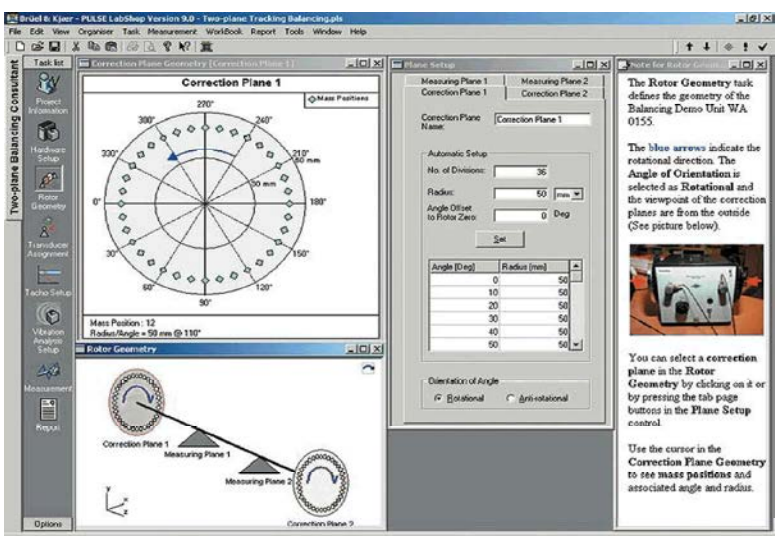

Fig. 2: The rotor's geometry and the available mass positions on the correction planes are easily defined using 2D and 3D geometries. Various one and two plane rotor types are supported.

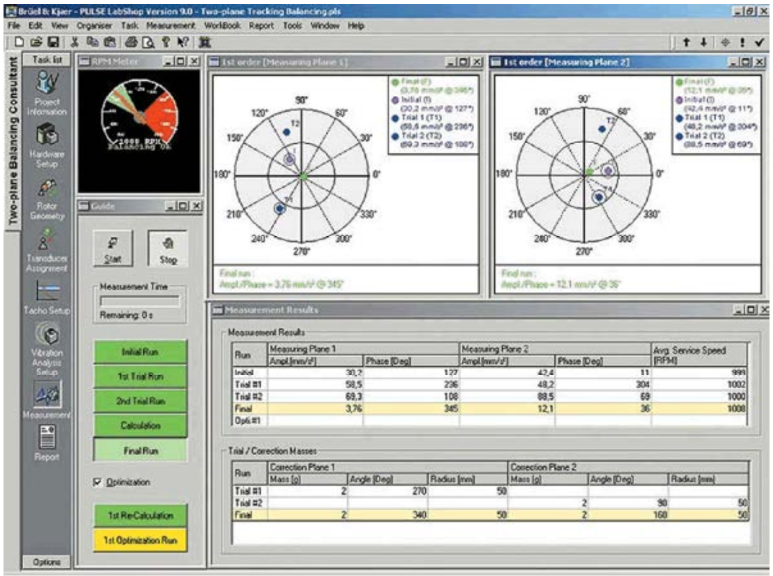

Fig. 3: The measurement is controlled using a Guide with controlled status indication. An RPM meter checks the speed and vector plots.

Fig. 4: BM Console (VMI)

Fig. 5: Measuring unit with transducer/sensor interface and digital signal processor.

The most important advantages of this balancing machine is its accuracy and its wide technical options that can help the balancing engineers in complex balancing activities with more technical flexibility. BM Console also is another data collector related to balancing activities recently introduce to preventive maintenance world by VMI company. The BM Console is a complete instrument for balancing rotating equipment on a balancing machine. A wide range of features are available to cover all the requirements of precision balancing, including comparison to established tolerances and printing a certificate to document the balancing result. The touch activated, LCD screen allows quick data entry and menu selection. Screen prompts and online help files assist the operator in obtaining fast and accurate results. Polar or large digital displays are available to provide the operator with a graphic representation of the balance vectors. The BM Console can be used for replacing older instruments to improve the performance of older machines.The BM Console electronics, based on a Pentium processor and a APT326 Balancing Interface, provides a wide range of balancing speeds, high measurement accuracy and signal filtering. The BM Console has four parts, 15" LCD Display with Touch Screen, Single Board computer running Windows XP and APT300 software, APT326 Balancing Interface Board and **a** mounting plate to be used to place a Speed Controller for any asynchronous AC electrical motor with power from 1.1 kW to 15kW.the most important advantages of this data collector related to balancing activities is that this equipment is easy to use and is user friendly but it is not suitable for field balancing activities because it is a kind of stationary balancing machine and not portable for site activities.

APT 326 is also one of new modern data collectors related to the balancing process manufactured by VMI used for both field balance and balance shop applications the software options is user friendly and easy to use rather than other types of equipment. Functions indicate as, Balancing with two transducers simultaneously, RS232 communication with PC software, Suitable as instrument update of older balancing machines, Large speed range. Balancing can be made between 30 to 192 000 rpm depending on transducer choice, CD with a complete balancing program and The program has several built in languages.

APT 326 have several options like Acceleration, velocity and displacement transducers, Transducer cables and Encoder for angle positioning of balancing weights.

The APT Software related to APT 326 balancing tool have special option and characteristic that make this tool easier to use comparative to previous tools or balancing data collectors. firstly The program can be controlled either by a mouse, the function buttons F1- F10 or with the use of the touch screen. Most of the measurements and calculations are made in the measuring unit so the demand on the PC-computer is limited. The software can run on almost any PC. Secondly The program both starts and finishes the measurements with trial and balancing weights automatically. A measurement starts automatically when the selected balancing RPM has been obtained and finishes automatically when the measurements are stable. A built in relay can automatically stop the machine when the measurements are saved. Beside this The program can store the balancing under different file names in a balancing library. The sensitivity to an unbalance is also stored as the Response Matrix that can be used next time the same or a similar rotor has to be balanced. The software then calculates the balancing weights directly without the need for trial weights and trial runs. Specially made shafts must sometimes be used when only a part of a rotor is balanced, for example only a fan wheel. The unbalance in these shafts can be stored in the Tool library. When the fan wheel is balanced the unbalance in the "tool" shaft is then automatically reduced from the measured vibrations. Finally The unit for vibration can instantly be change between mm/s or µm and the unit for unbalance can be change between grams or gram as well as the change between static and coupled and normal left and right unbalance.

APT Software have also some special characteristic first software have Flexible inputs. The program can be controlled either by a mouse, the function buttons F1- F10 or with the use of the touch screen. Most of the measurements and calculations are made in the measuring unit so the demand on the PC-computer is limited. The software can run on almost any PC. Beside this software can Starts and saves automatically. The program both starts and finishes the measurements with trial and balancing weights automatically. A measurement starts automatically when the selected balancing RPM has been obtained and finishes automatically when the measurements are stable. A built in relay can automatically stop the machine when the measurements are saved. Furthermore The program can store the balancing under different file names in a balancing library. The sensitivity to an unbalance is also stored as the Response Matrix that can be used next time the same or a similar rotor has to be balanced. The software then calculates the balancing weights directly without the need for trial weights and trial runs. Specially made shafts must sometimes be used when only a part of a rotor is balanced, for example only a fan wheel. The unbalance in these shafts can be stored in the Tool library. When the fan wheel is balanced the unbalance in the"tool" shaft is then automatically reduced from the measured vibrations. Finally The unit for vibration can instantly be change between mm/s or µm and the unit for unbalance can be change between grams or gram as well as the change between static and coupled and normal left and right unbalance.

The most important comfortable features of this tool related to previous options is Weight distribution to fixed positions The program can distribute the balancing weight to fixed positions e.g. to bolts in a coupling or to blades in a fan. this feature can reduce the volume of try and error process in balancing activities. another features is Weight summations, If a rotor has several old balancing weights the program can calculate one weight as a replacement for all the other weights.

The people that directly involve in balancing activities know how much in can help to the balancing process time and reduce the trouble because the rotors that have recommend for balancing by CM (condition monitoring) groups usually are bad actor in this area and previously several balancing process and several balancing weights are added to the rotor that some time need to eliminating by some machining process all in all

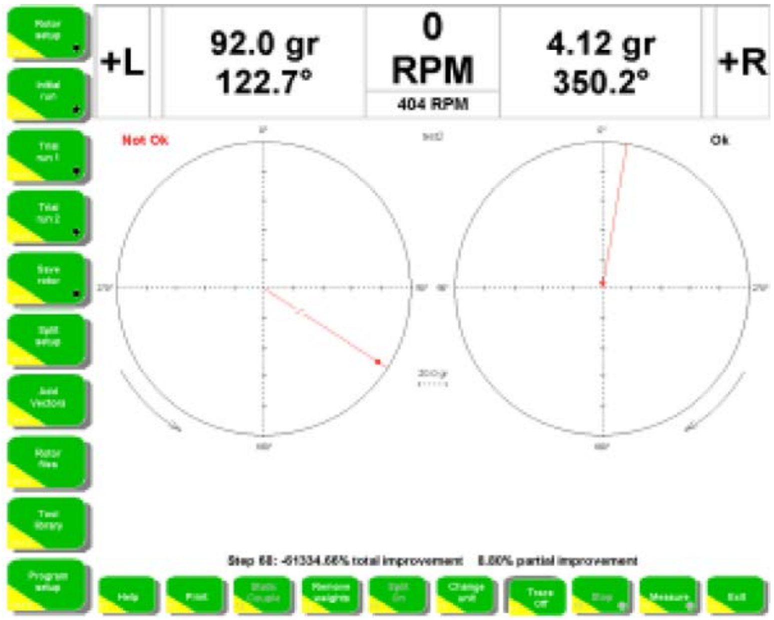

Fig. 6: Typical APT Software page

this option that developed in recent years helping to reduce the balancing process time considerably and more comfortable. Remember always it is important to input the dimension of rotors accurately during the balancing process it can cause better balancing quality the typical rotors that may balance by field balance or balancing in balance shop are shown in typical APT Software page shown in Figure 6. [11, 12].

Experimental Detail: In this paper I decide to explain 4 separate case history about vibration and operation behavior of gas turbine SIEMENS162MW- 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 8.

V94.2 Gas Turbine Combustion chamber features also represent in Figure 9.

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

Rotor and Typical blades of gas turbine SIEMENS162MW- V94.2 shown in Figure 11.and blades design features plot shown in Figure 12.

Also Employing Wet Compression System Available in Market Since 2003.

Now we have better understanding about machinery features and options of gas turbine SIEMENS162MW- V94.2and we can go through vibration concepts and our balancing case histories more effectively [13] the coupling unbalance is one of the most challenging concepts in preventive maintenance the alignment have usually complex procedure for most critical equipment the phase analysis between two side of coupling could help us to have better understanding about balance condition of the coupling nowadays different methods develop for evaluating and modeling the coupling motion all base on vibration modal analysis [14] also the shaft crack is one of the common fault in gas turbine and other most critical equipment that is hard to diagnosis the crack could be longitudinal or radial and usually in microscopic dimensions the bode diagram could help us in fault diagnosis monitoring of coast down and run up characteristics when passing through resonance (rotor critical speed) is the optimal way for fault diagnosis the cracked rotors usually sent to metal spray work shop for treatment activities [15] the lubrication system of most critical equipment is also one of the most challenging concept in this matter the centrifugal pumps usually feed the related lubricants to journals. Evaluation of Antiwear Property recently developed too much and the lubrication condition of machine improve considerably and this cause improving in machinery performance oil analysis also is another powerful tools used in preventive maintenance [16] the resolution of graphs in condition monitoring systems and also the filtering system of such data and diagrams is one of the other challenging concepts in preventive maintenance of gas turbines. these kind of

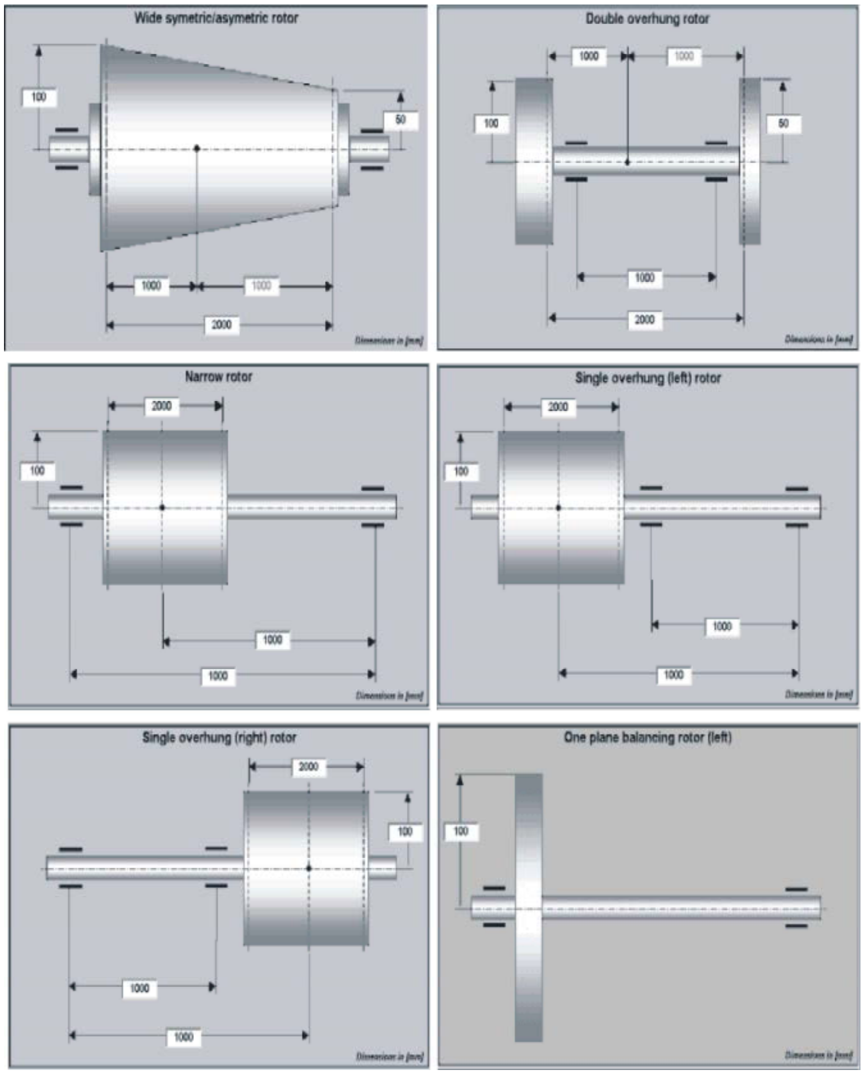

Fig. 7: Typical APT Software pages (rotor dimensions).

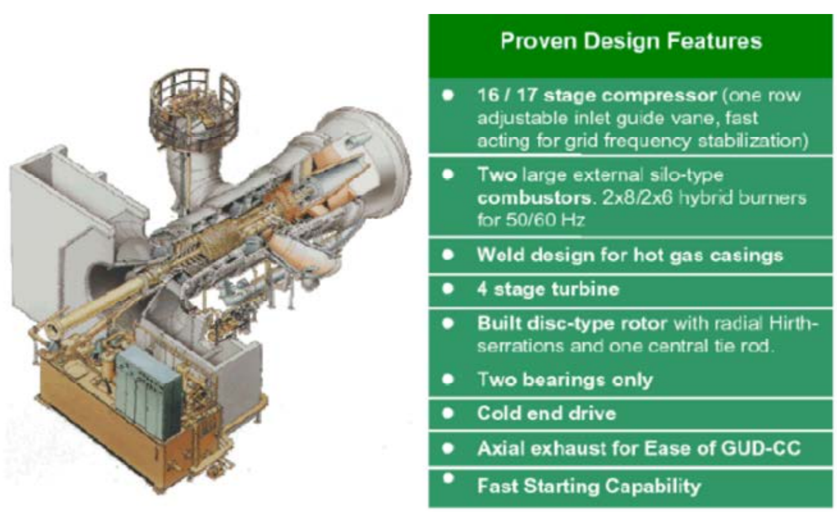

Fig. 8: SIEMENS V94.2 Gas Turbine Features

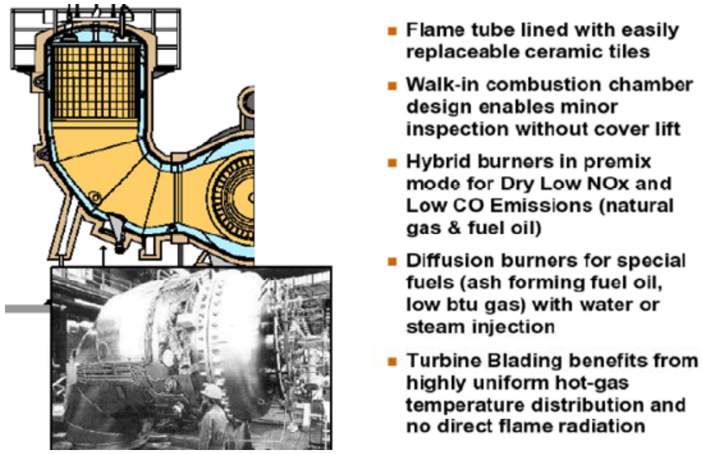

Fig. 9: V94.2 Gas Turbine Combustion chamber features

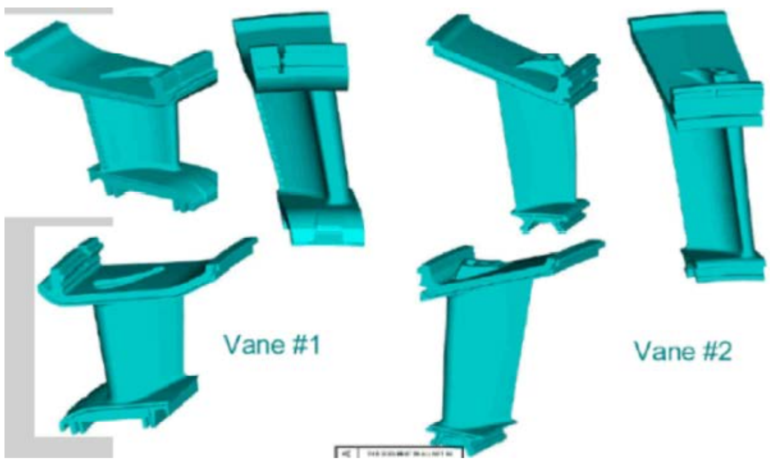

Fig. 10: Some SI3D Blading Samples

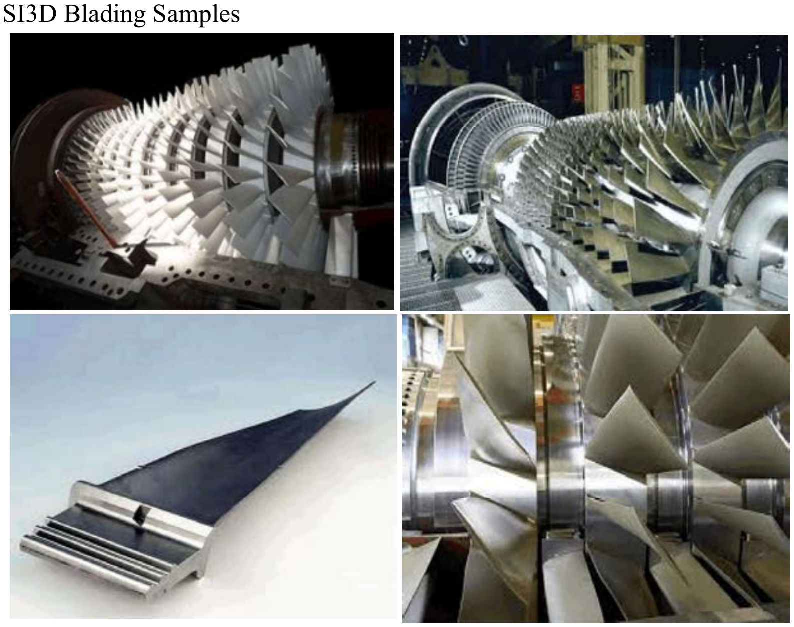

Fig. 11: Typical blades of gas turbine SIEMENS162MW- V94.2

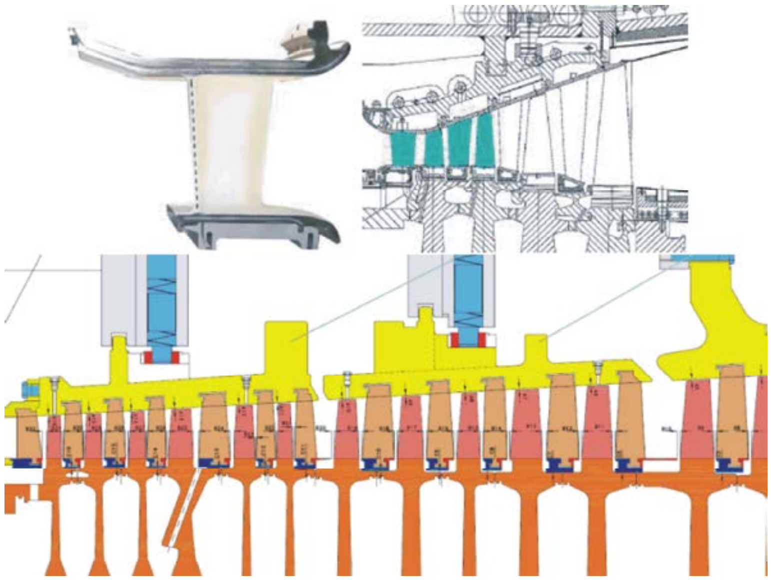

Fig. 12: Blades design features plot

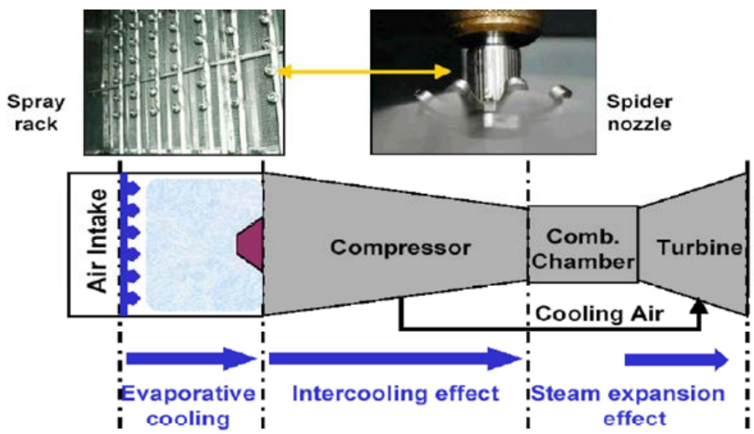

Fig. 13: Wet compression process

abilities improve too much in recent condition monitoring systems the Signal Decomposition Techniques and ability develop too much in recent years [17]. Wireless Sensor Network is one of the new patent and innovation in condition monitoring systems the most important advantages of these kind of facilities is that these kind of systems reduce the installation errors as well as possible bside this different maintenance groups can have continues and easy accesses to machine information that previously was not possible [18] new maintenance strategy and modeling systems developed in recent years reliability centered maintenance is a maintenance technology recently develop and could reduce the maintenance cost considerably. this method base on stochastically information in all maintenance parts combine with new vibration analysis techniques and new process planning soft wares [19] detective of the micro vibrations is one of the important capabilities in gas turbine monitoring systems recently develop too much these capabilities help us to have better understanding in diagnosis of some critical faults like bent shaft, shaft crack, rotor rub, wear, oil instability and so on.in these kind of techniques 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 [20] the vibration structure is also one the most important concept in vibration analysis of most critical equipment specially gas turbines the phase analysis is one of the most effective methods in this way. by triggering the TWF signals with base rotor vibration we can better understanding about different base vibration of machine in different points and positions such data will help us a lot to recommend optimal maintenance actions [21] axial vibrations consider as important factor in vibration analysis two parallel none contact probe measuring the axial vibration of rotor end in turbine and compressor these kind of probes should be equal to each other by 0.01 volt accuracy otherwise it may represented abnormal motion of the shaft. also misalignment and coupling motion could easily evaluated by these kind of techniques [22] the control loops of the gas turbine SIEMENS162MW- V94.2 consist of different parts like temperature control, speed control, compressor out pressure grad control, limit load control for both speed and temperature and also fuel system. the accurate and close monitoring of each items will help us to improve the quality of our vibration analysis. [23] the energy balance is one of the most important items in gas turbine utilities. several modeling techniques developed recently. Energy balance for each components and for the whole gas turbine system was considered in these kind of techniques. the first and second thermodynamic laws help us during these processes. compressor and turbine inlet and outlet pressure and temperatures are important factors in these kind of activities. process parameter balance will help us to improve mechanical and vibration machine behavior during operation.it means that is important for us to monitor the process condition and try to keep all process condition like inlet and out let pressure and temperature in the range of technical document of gas turbine as well as possible [24].

RESULT AND DISCUSSION

In this part I will explain four case history all about SIEMENS V94.2 Gas Turbine utility in different vibration alert condition in the main board operation recently developed. the first two was real alert signal and balancing operation face quite challenging process and finally was successful and cause changing the condition of machine as well as possible and gas turbine could continue operation after balancing the third case history was about the condition that the alert signal in the main board was unreal and the system could continue operation. the last case history show that sometime the recommended balance weights are out of technical document ranges and it is not possible to reduce high overall vibration by adding balancing weights. Finally i hope the readers have better understanding of the vibration behavior of gas turbine in bently Nevada alert condition.

Table 1: Relative Vibration μm before balancing

	Before Balancing				
Relative Vibration μm	980 RPM	CE	OCE	COMP	TUR
	Start Up	17.4	16.5	67.8	77.9

Table 2. Absolute Vibration mm/s before balancing

	Before Balancing		
Absolute Vibration mm/s	980 RPM	COMP	TUR
	Start Up	5.9	17.3

Table 3: Absolute turbine and compressor vibration after balancing

Fars utility (Unit 5)		COM.(abs)	TUR.(abs)
1000 RPM	Start up	2.3	8.4
	Shut down	2	8
1400 RPM	Start up	1.7	4
	Shut down	2	6.3
3000 RPM (116 MW)	2.5	6.4	

Table 4: Relative Vibration μm before balancing

	Before Balancing				
Relative Vibration μm	1800 RPM	CE	OCE	COMP	TUR
	Start up	64	152	71.4	35.3
	Shut down	51	159.3	72.3	51.4

case history number 1 :Fars utility-unit 5

duration:

From Tuesday, July 3, 2012 to Thursday, July 5, 2012

Due to the condition monitoring reports archive the vibration was over 17 mm/s in the startup time in 980 RPM this vibration is over dander limitation set up 14.7 mm/s therefore the gas turbine tripped. and it cause that we could not measuring any vibration data in operation RPM or in base load condition therefor balancing operation is more complicated and faced serious challenging because it should be in operation condition the vibration of the gas turbine in the shut down or trip moment was as following :

We analyzed the condition monitoring data in trip moment and realized that the main vibration peak was 1X two direction amplitude overall both considerably high and the phase data shows 90 degree shift between two main direction in that moment all these evidence lead us

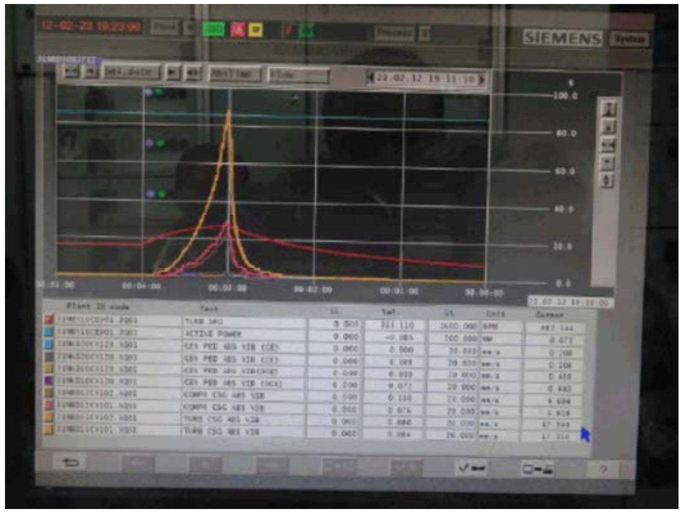

Fig. 14: Trip vibration condition

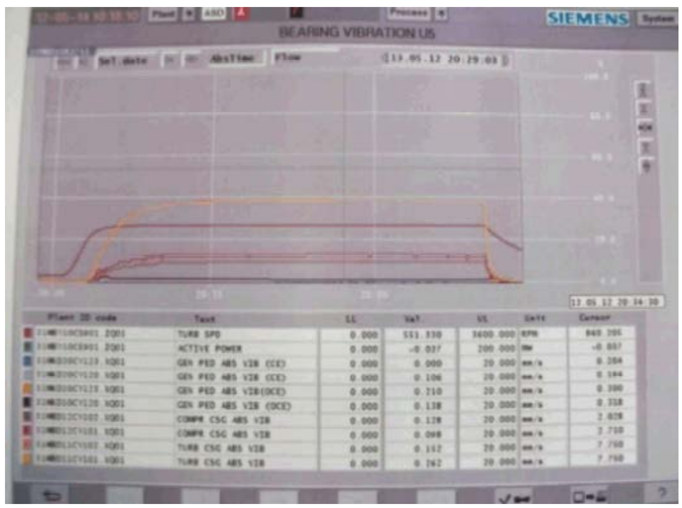

Fig. 15: Vibration condition in first balancing stage

Fig. 16: Vibration condition in 3000 RPM

Fig. 17: Vibration condition in 3000 RPM after synchronize the unit by process

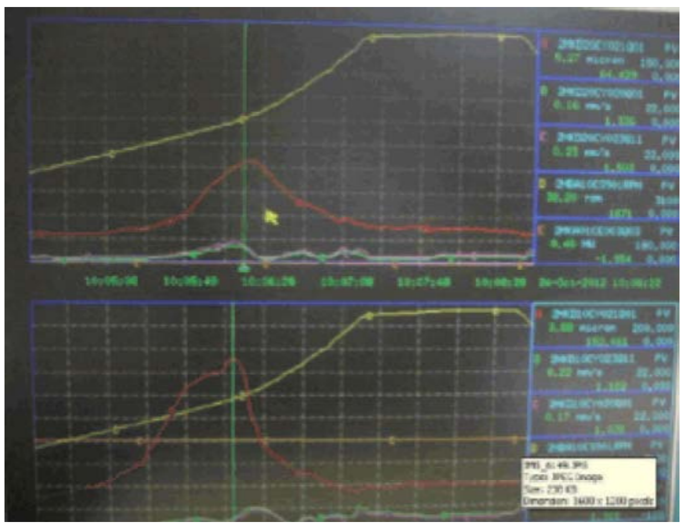

Fig. 18: Startup vibration of generator journal Before balancing process

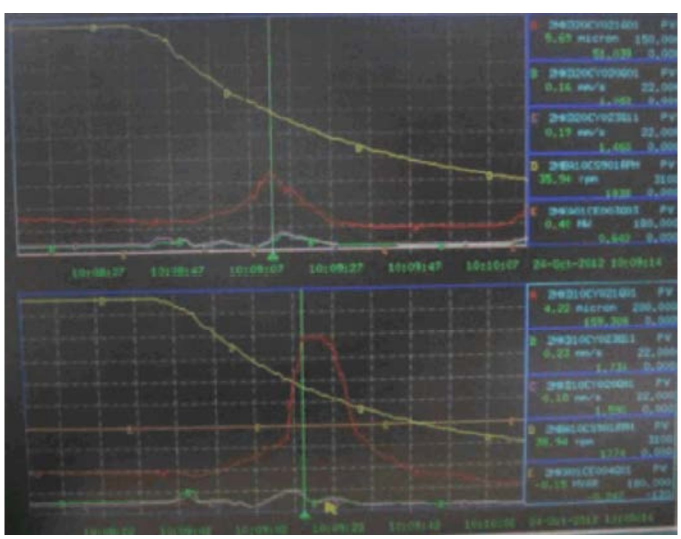

Fig. 19: Shut down vibration of generator journal Before balancing process

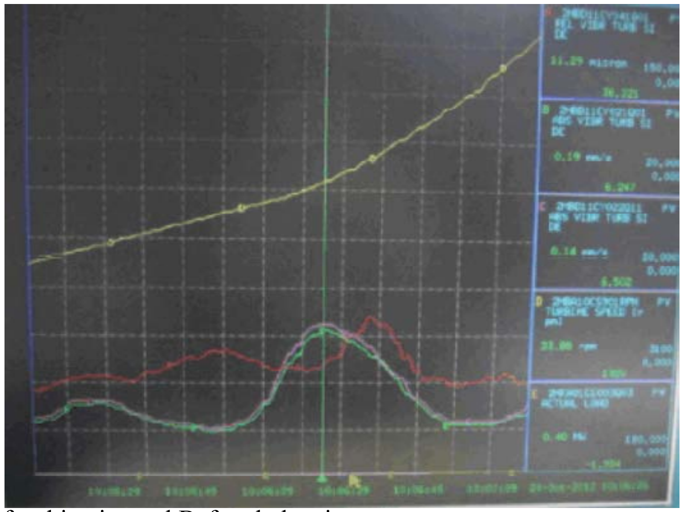

Fig. 20: Startup vibration of turbine journal Before balancing process

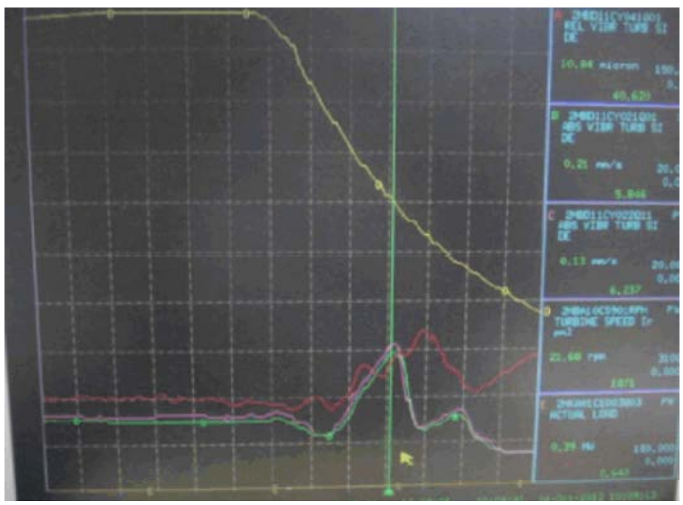

Fig. 21: Shut down vibration of turbine journal Before balancing process

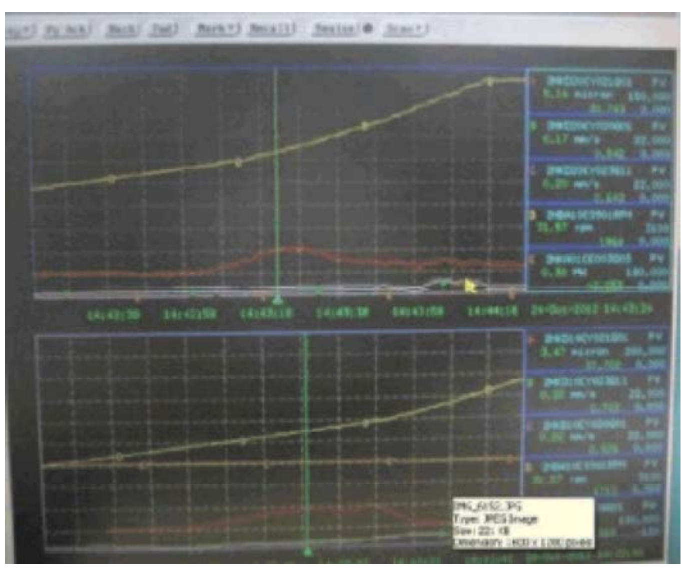

Fig. 22: Startup vibration of generator journal after balancing process

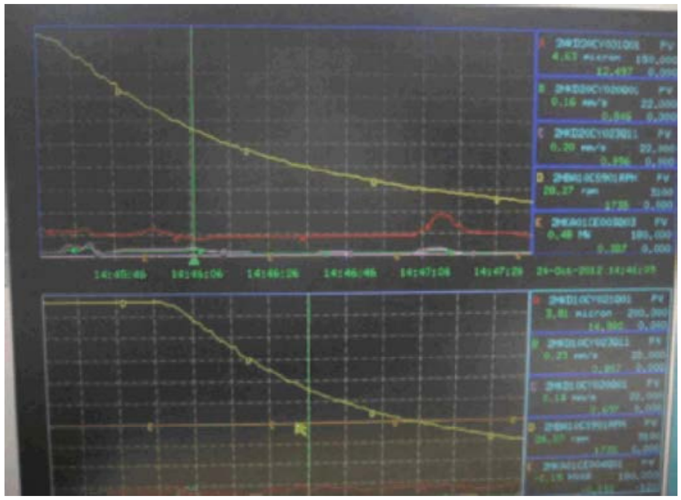

Fig. 23: Shut down vibration of generator journal after balancing process

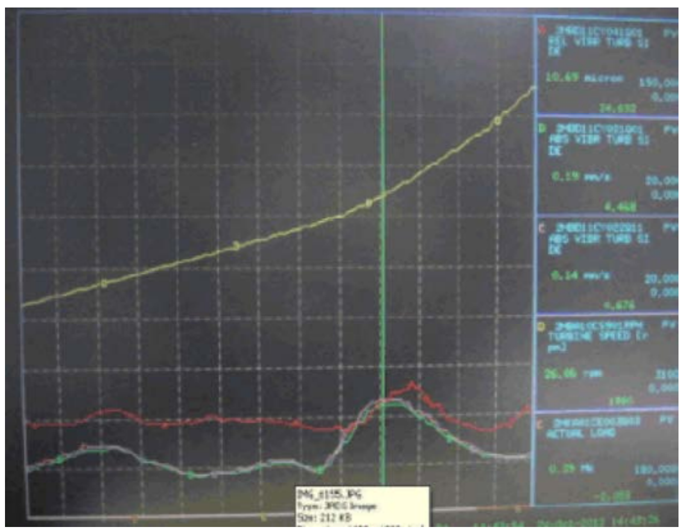

Fig. 24: Startup vibration of turbine journal after balancing process

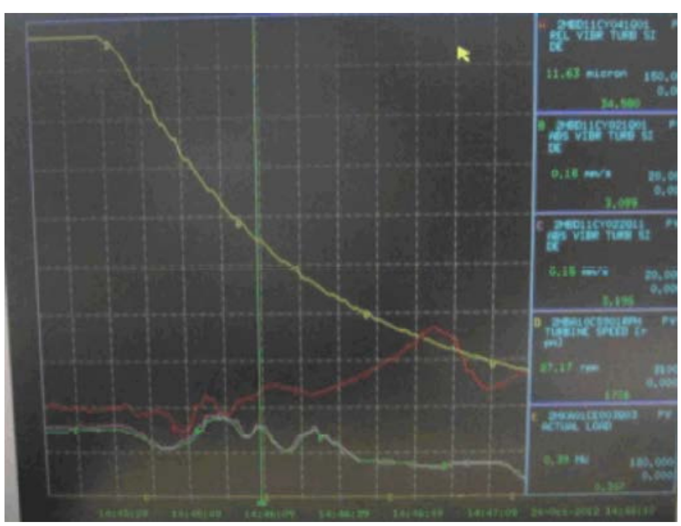

Fig. 25: Shut down vibration of turbine journal after balancing process

Table 5: Absolute Vibration mm/s before balancing

Absolute Vibration mm/s	Before Balancing		
	1800 RPM	COMP	TUR
	Start up	6.1	6.2
	Shut down	6.1	5.8

Table 6: Relative Vibration μm after balancing

Relative Vibration μm	After Balancing				
	1800 RPM	CE	OCE	COMP	TUR
	Start up	30.7	37.2	30.7	24.6
	Shut down	12	14	37.7	34.5

Table 7: Absolute Vibration mm/s after balancing

Absolute Vibration mm/s	After Balancing		
	1800 RPM	COMP	TUR
	Start up	2.9	3.5
	Shut down	2.7	3.1

to unbalance problem we decided to operate balancing program in two steps because gas turbine was on trip condition and we could not operate the machine in process RPM.in first step we planning to operate the balancing process in 3000 RPM between the period of Saturday, May 12, 2012 and Tuesday, May 15, 2012 in this stage we installed 19 balancing weights in Compressor Disk Stage ten 165° and 27 balancing weight in turbine Stage four 165° but unfortunately process have some considerations and they could not running the gas turbine in the operation condition then we had to waiting for the suitable condition to operate the next stage of balancing program.

In the next stage process operate the gas turbine in 3000 RPM and balancing operation continue between the period of Tuesday, July 3, 2012 and Friday, July 6, 2012, finally we decided to install 15 balancing weight in Compressor Disk Stage ten 150 ° and 23 balancing weight in turbine stage four 155°.

Absolute turbine and compressor vibration after balancing shown in following table :

In conclusion after synchronize the unit by process in Monday, July 23, 2012 and analysis the vibration trends in the base load we can operate the gas turbine in process condition with close monitoring.

case history number 2 :Kerman utility-unit 2

duration:

from Wednesday, October 24, 2012 to Thursday, October 25, 2012

The process of Kerman utility unit 2 reported that the relative vibration of OCE journal pass over 159 micrometer peak to peak after the turbine passing 1800 RPM(first critical speed) in shut down process after analyzing the vibration data we decided to operate the single panel balancing process on middle shaft at Wednesday, October 24, 2012.

After adding trial weights finally we achieve to 19 balancing weight 40 grams 155° the relative vibration of

OCE journal reduce too much when turbine passing 1800 RPM [25] the vibration data before and after balancing shown in below tables.

The vibration trends before and after balancing operation as following.

Due to the vibration overall amount after balancing processand vibration limits in technical document of this gas turbine the vibration condition of this machine is in good condition therefore this unit can continue operation without any problem.

case history number 3 : Shahrod utility-unit 2

duration

from Tuesday, May 1, 2012 to Friday, May 4, 2012

Due to the process report about high relative vibration in different point of gas turbine specially in OCE journal approximately 134 micrometer peak to peak after overhaul the session between different maintenance group in Tuesday, May 1, 2012 take placed. these vibrations caused the gas turbine shut downed the trends of process parameter was in the range of technical documents of both turbine and compressor also the machinery bearing clearances was in the range of the document therefor the session result was make a vibration committee by both condition monitoring (CM), electrical special tools and balancing group together to make decision about the signals accuracy first of all CM records show that the frequency shift random but the overall amplitude is relatively in same situation all over the startup and shut down process these kind of behavior reject the hypothesis of probe looseness and also the 1X vibration was not always dominate in different RPM beside this the phase have not 90 degree shift between two main direction therefore the unbalance hypothesis also rejected therefore they may have some problem in adjusting probe installation or any related electrical or electronic considerations. the electrical special tools group then planning the installation check in Wednesday,

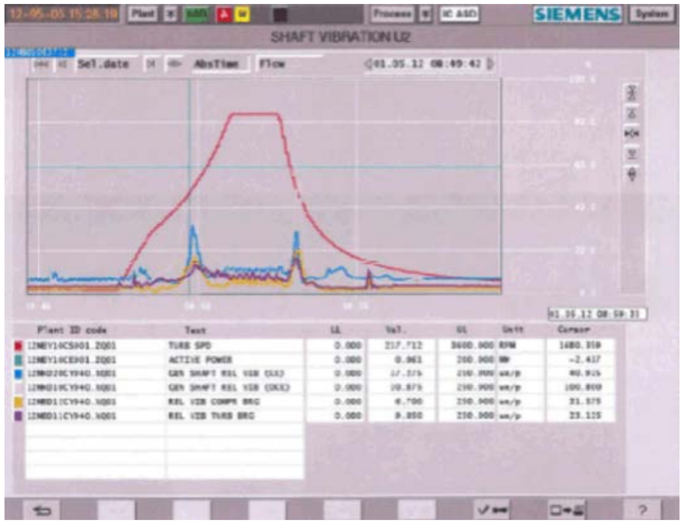

Fig. 26: Relative vibration trend startup turbine side before change the cables

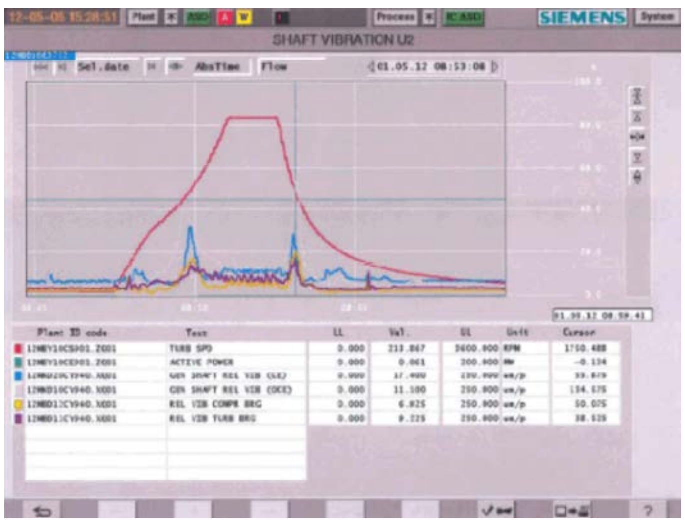

Fig. 27: Relative vibration trend shut down turbine side before change the cables

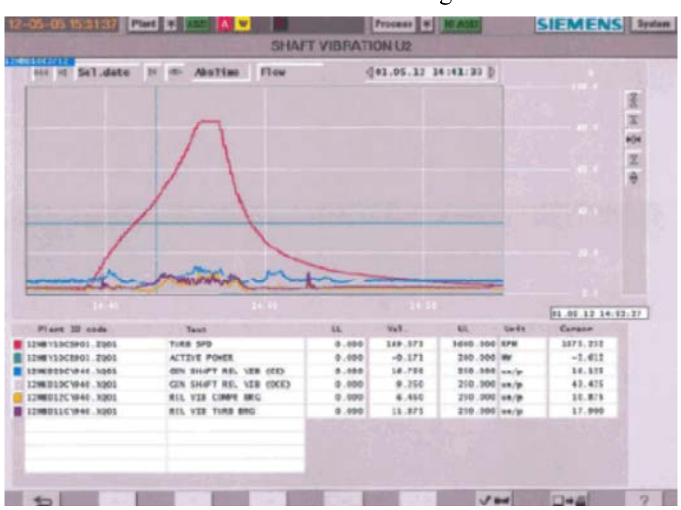

Fig. 28: Relative vibration trend startup turbine side after change the cables

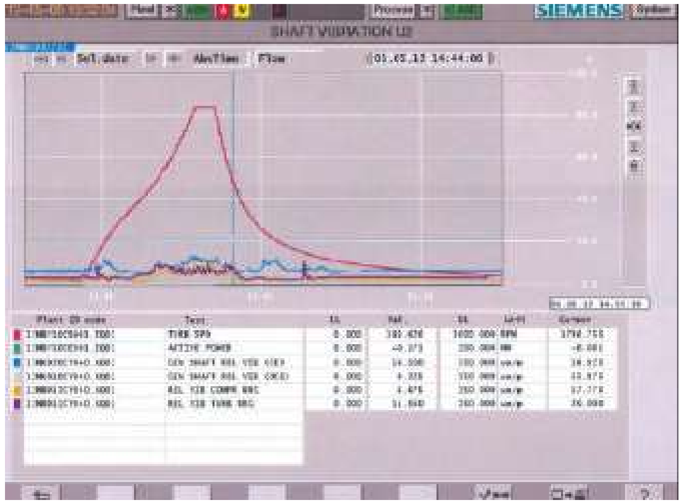

Fig. 29: Relative vibration trend shut down turbine side after change the cables

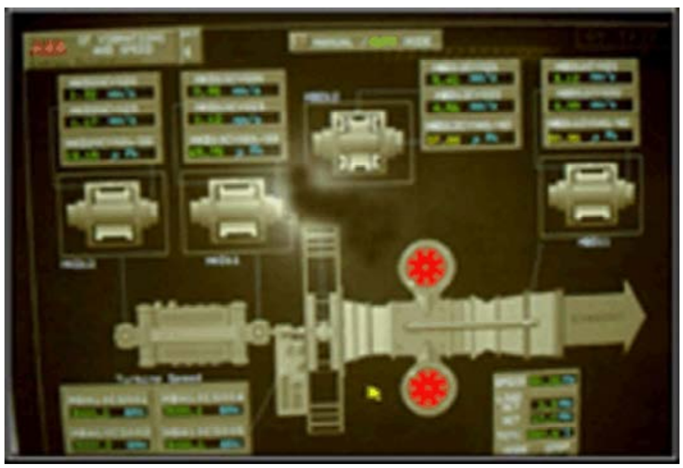

Fig. 30: Vibration condition SIEMENS V94.2 Gas Turbine utility 3000 RPM without any load

May 2, 2012 they first check the distance between probes and the shaft by digital volt meter all the records was correct by 0.01 volt accuracy then they check the angle that was 45 ° by 0.1 accuracy all was acceptable and in the range of technical document of gas turbine but there was a ridiculous mistake that the transfer cable must be 1 meter the installation guy install 1.5 meter cable that was the recommendedcable of gas turbine unit 6 by mistake and the electrical resistance of these length of cable caused unreal signal and unreal signal cause unreal shut down or trip the electrical special tools reinstall the probes with new cables and the gas turbine restart for operation the vibration trends in startup and shut down before and after change the cables is as following.

Dou to the vibration overall amount after change the cables the vibration of this gas turbine is in good condition after overhaul and this gas turbine can continue operation and the trip vibrations was unreal or fake.

case history number 4 :Kerman utility-unit 4

duration:

from Wednesday, February 27, 2013 to Wednesday, March 6, 2013.

from Monday, March 11, 2013 to Sunday, March 17, 2013.

from Thursday, April 18, 2013 to Thursday, April 25, 2013.

Due to vibration trip unit four of Kerman utility on Monday, February 25, 2013 after overhaul in 940 RPM the field balancing team sent from Tehran to Kerman the following operation accrue on unit four in first period (8 days). vibration analysis from this gas turbine

Table 8: Turbine and Compressor vibrations

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
3	66	15	158

Table 9: Turbine and Compressor vibrations after first stage balancing process

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
2.7	32	15	162

Table 10: Turbine and Compressor vibrations after second stage balancing process

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
7.54	130	10.35	103

Table 11: Turbine and Compressor vibrations after third stage balancing process

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
5.4	97	8.12	80

Table 12: Initial Turbine and Compressor vibrations

Compressor	Turbine		
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
5	100	8	85

Table 13: Turbine and Compressor vibrations Full speed-no load

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
4	73	6.2	76

Table 14: Turbine and Compressor vibrations Load= 40 MW

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
4.58	105	6.28	85

Table 15: Turbine and Compressor vibrations Base load

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
4.5	121	7.12	92

Table 16: Turbine and Compressor vibrations Base load after one hour

Compressor		Turbine	
Abs (mm/s)	Rel (µm)	Abs (mm/s)	Rel (µm)
4.7	138	9.25	106

represented unbalance it means vibration FFT was mainly in 1X, two main direction vibrations are both high and have 90 degree shift in phase trend these evidences represented high amount of unbalance the balancing operation was not successful and recommended high amount of balancing weights that was not possible according to the gas turbine technical document. we decided to checking the middle shaft run out in several point that everything was on machinery document ranges then we recommended LTE to operation the operation asked to field balance the rotor as well as possible then the balancing operation continued in previous RPM the vibration table was like below:

This time by adding the balancing weights like bellow the gas turbine continue operation up to 1867 RPM and then trip. five balancing weight added in 133° in Front Hollow Shaft and 14 balancing weight added in 125 ° in Compressor Disk Stage ten finally 9 balancing weight added in 120° in Rear Hollow Shaft.the new vibration amount as following:

In the next stage after adding the balancing weights like below we could continue up to 3000 RPM. 9 balancing weight added in 35° in Front Hollow Shaft, 8 balancing weight added in 88° in Front Hollow Shaft,21 balancing weight in 45° in Compressor Disk Stage ten and 10 balancing weight added in 205 ° in Rear Hollow Shaft the amount of new vibration recorded as following:

Finally by adding three weighting balance in Rear Hollow Shaft, 177° we achieved following vibration behavior in no load condition.

In these condition operation increasing the load up to 40 MW and the overall vibration increase up to 1 mm/s.

The exhaust liner was engage and the machinery maintenance action take place In the next stage the alignment check operate by machinery group between compressor and generator due to the condition monitoring vibration analysis. In the next stage We decided to continue the balancing operation to reduce the amount of vibration on Thursday, April 18, 2013. the initial vibration amounts as following:

The balancing process continue by adding the weights, six weighting balance 240 gram added in intermediate Shaft 70 °,one weighting balance 180 gram in Front Hollow Shaft 5°,one weighting balance 115 gram in Front Hollow Shaft 60°, one weighing balance 180 gram in Compressor Disk Stage ten 75°, three weighting balance 540 gram in Compressor Disk Stage ten 154°, three weighting balance 475 gram in Compressor Disk Stage ten 0° four balancing weight 720 gram in Rear Hollow Shaft

Fig. 31: Full speed-no load

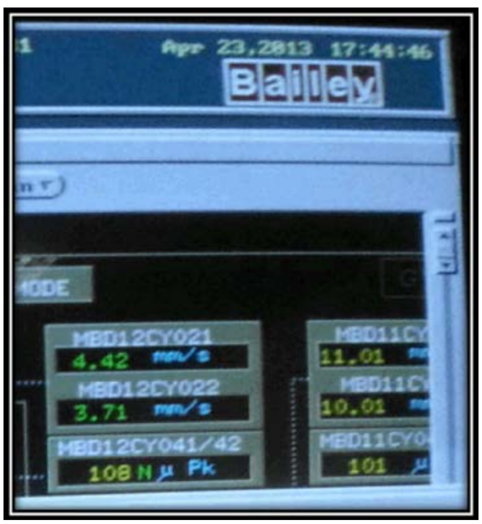

Fig. 32: Base load

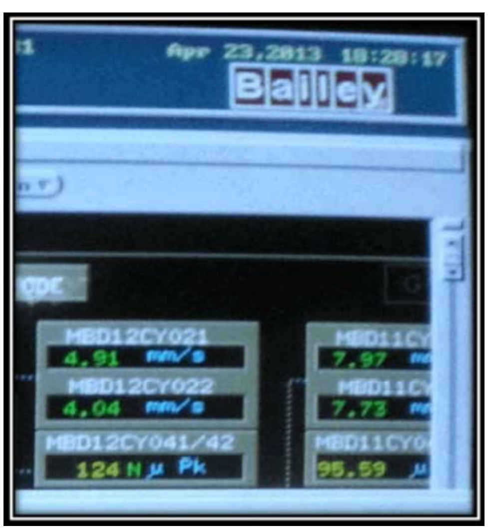

Fig. 33: After 45 minuteat Base load

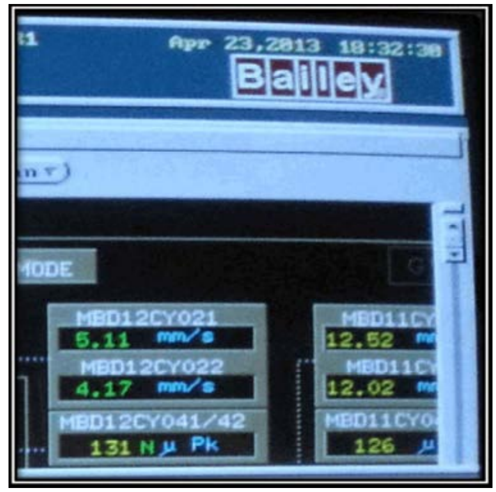

Fig. 34: After 49 minute at Base load

240° and two weighting balance 295 gram in Rear Hollow Shaft 180°.the relative and absolute vibration change by loading the process condition as following:

After two hours the vibration over all turbine side pass over 11.5 mm/s and gas turbine tripped and cause turbine shut down.the next stage in weight balancing process cause to reduce both journal bearings of turbine and compressor relative vibration but unfortunately the absolute vibration of turbine side increased too much finally we had to remove all the weights (25 weighting balance 1000 gram in intermediate Shaft 77°, three weighting balance 540 gram in Front Hollow Shaft 355°, two weighting balance 360 gram Front Hollow Shaft 60° and seven weighting balance 1260 gram in Rear Hollow Shaft 274°). in the next stage by removing all above balancing weight and restart the turbine the vibration behavior of gas turbine as following:

As it is clear from the above vibration data vibration in 3000 rpm and base load increasing gradually related to no load condition this increasing is in both absolute and relative vibration also in both compressor and turbine side absolute vibration decreasing suddenly in turbine side after 40 minute that turbine operate at base load to 3 mm/s but about 4 minute later it has a sharp raise up to 5 mm/s then it increasing gradually and finally cause turbine trip due to the high initial overall vibration of the gas turbine and also high amount of weights requested in balancing process and the document recommended limitation about balancing weights, this is the optimal condition of the balancing process and the next step will request out of rang weights therefore it is not possible to reduce high overall vibration by adding balancing weights or field balance.

Current & Future Developments: The vibration that can represented unbalance in most critical equipment like gas turbine utilities or steam turbine multistage compressors should have three main characteristic first both two main direction vibration should high then the phase trend in recent days should have 90 degree shift between two main direction beside this the FFT should have completely or more than 90 percent in 1X if any of these three condition was not satisfy you should not suspicious about unbalance the balancing process also sometimes face many challenges in field balance process or balancing operation in balance shop. the knowledge of the balance engineers about technical machinery and technical document of machine will help us to reduce the balancing process time furthermore the fluctuation of overall vibration may represented probe looseness or any process problem in gas turbine or turbine compressor.the CM engineer should have knowledge of process condition of machine specially inlet and out let pressure and temperature trend of both turbine and compressor and also the quality of steam in steam turbines that is why vibration analysts should have good cooperation with process and other maintenance groups and also have relative good technical knowledge of other maintenance parts or operation the random fluctuation in frequency of FFT may represented any probe maladjustment or incorrect probe installation or any possible mistake in related electrical or electronic areas cause unreal alert signal or unreal trip. In the gas turbines the absolute vibration will help us to distinguish these kind of unreal signals more easily by comparing absolute and relative vibration trends with each other all in all these kind of decisions should take with more consideration about all related aspect of the process like machinery, condition monitoring systems CM, balancing group history data, process trends, non-contact probe installation or any related maintenance group history data these groups should have good cooperation with each other to make the optimum decision in minimum time.

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