Mechanical Engineer

INTRODUCTION

Time duration	December 28, 2017 to Jan 2, 2018
Location	Saudi Arabia
Organization	General Electric (www.gepower.com)
Project	High Vibration on Air Cooled GE 7A6 Generator
Position	Senior Manager (Site Manager)

[CE 2.1]

I joined GE in a Services Leadership Program which was designed to train experienced new hires about GE's design, operation and financial processes on fast track basis. I had the opportunity to learn and get hands-on experience of maintenance and troubleshooting of several Industrial Gas Turbine ranging from 50MW to 180MW. After completing my one year on job training, I was assigned as Lead Contract Performance Manager to a multi-million dollar long-term maintenance contract with one of prestigious customer i.e. ENGIE. After my hiring I was responsible for preparing computerized maintenance plans, budgeting, coordinating to resolve all technical and contractual issues, executing planned & unplanned outages of assigned power plants. I was also responsible for availability and reliability guarantees of the plants.

BACKGROUND

[CE 2.2]

My assigned Power Plant is having 9 x GE Frame 7FA.03 & 2 x 7EA Gas Turbines with the total capacity of 1800 MW. GT2 installed in an oil refinery of Saudi Arabia. The machine train consists of a GE 7E turbine driving a generator running at a design speed of 3600 RPM. Proximity probes are permanently installed at all fluid film bearings of the train to monitor radial vibration levels. Two proximity probes are installed axially on turbine outboard to monitor rotor axial position. The unit underwent a major inspection (MI) where generator rotor was rewound. Comparison of the vibration data before and after MI outage revealed an increase in vibration amplitudes in most of the locations (specifically on the generator). As vibration was on increasing trend so customer was worried. Customer requested me to perform vibration analysis & evaluation of gas turbine along with generator train balancing.

The unit underwent a major inspection (MI) where generator rotor was rewound. Comparison of the vibration data before and after MI outage revealed an increase in vibration amplitudes in most of the locations (specifically on the generator) but they are still well below the alert limit. I decided to start the analyses by ADRE data collection. Onsite data collection was done because seismic vibration data was not available in System 1 Turbine mid-span probe 39VS-21 gap voltage was outside OK limits since May 2017. Data collection from Mark VI was conducted on 31/12/17 and 01/01/18 to capture steady-state, shutdown and cold start-up events.

Machine Component	Turbine	Generator
Manufacturer	GE (S/N: 298490)	NA
Model	7FE	NA
Power	80 MW	
Operation Speed	3600 RPM	
Rotation (driver to driven)	CCW	
Bearing Type	Fluid-Film Bearings	
Pertinent Information		
All seismic velocity probes are installed vertically Probe type: Metrix (150 mV/IPS)		

[CE 2.3]

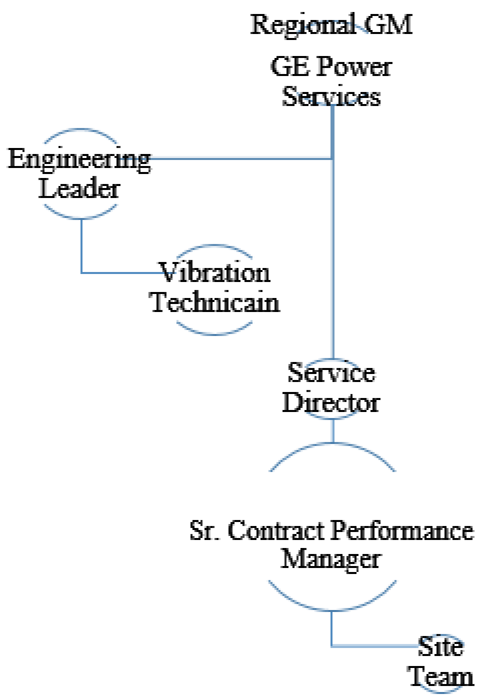
Main objective of this project was to reduce the vibration values below 15 mm/sec by insitu balancing of generator rotor. This includes 4 phases:

- Data collection
- Analyses of data
- Calculation of balance weight/location
- Installation of balance weights
- Trial run to see affect and repeat above

As this was hit & trail method so we anticipated that multiple attempts will be made to solve the issue. In this case it took 7 trials to reach up to required vibration levels.

[CE 2.4]

The project Hierarchy is given below. I was responsible to carry out analyses and coordinate meetings with all involved parties. I met field service team who performed last outage on this machine. I came to know that stator rewind was carried also out on generator so I also carried out review meetings with workshop team as well.



PERSONAL ENGINEERING ACTIVITY

[CE 2.5]

My Roles & Responsibilities

I worked as Site Manager on this project. Some of tasks I performed were:

- I discussed in detail with customer to understand their Critical to Quality (CTQs) about this job.
- I clarified the scope, duration and challenges of the project to customer. In this case I explained them that they must shut down & start the machine multiple times since it was hit and trial method.
- I explained the support required from customer during the project execution like logistics, site accesses, work permits, lighting etc.
- I arranged meetings within my company (GE) with multiple linked stakeholders to explain the required resources, customer CTQs and expertise. In this case arrangement of ADRE equipment, qualified technician and craft were required.
- I coordinated with the parts team and provided them the part number of possible balance weigh which will be used.
- While unit was running, I mobilized the technician and asked him to hook up ADRE so that I can capture steady state and shutdown data to perform baseline assessment. On 28/12/17, vibration data was captured for steady-state and shutdown events. On 01/01/18 data was captured for

cold startup and steady-state events to identify machine thermal behavior and compare slow roll vectors in hot and cold states.

- With the baseline data I examined different plots like 1X-filtered slow roll orbits, direct orbits, polar plots and average shaft centerline plots. With this examination I ruled out the other unbalance reasons like misalignment, thermal effects or bowed/bent, seal / bearing wear or looseness.
- Then I asked the customer to shut down the machine. After cool-down and making access to the rotor I marked /identified timing mark (key phasor in this case).
- Finally, I made drawing which showed rotor blades, probes placement and angles. This served as starting point of calculating trial weight amount and angle which I performed afterwards.

[CE 2.6]

PROBLEMS FACED & THEIR RECTIFICATIONS

Problem definition:

During balance correction, data gathered while trial runs I used two different ADRE units.The X-Y readings indicated swapped probes which meant that ADRE units were hooked up in wrong orientation.

Effect of problem:

Resulted in incorrect assessment and 1 day of delay

Root Cause of Problem:

The proper labeling cable was not made for ADRE data cables. Technician didn’t install correctly.

Final Solution:

I performed 3 actions to resolve this issue:

1. Contacted the GE vibration team and arranged a configuration drawing of ADRE & BN 3500 circuit.
2. I asked the technician to perform loop check.
3. I made firm Document about configuration of Probe orientation for all GT units and Labeled in PLC Panel where the BN-3500 was installed.

Problem definition:

While installing balance weights I found cracked balance weight stake marks.

Effect of problem:

These cracks have the potential to propagate due to continuous cyclic loading at high temperature. Crack propagation increases the risk of material liberation during operation which can lead to hardware damage downstream in the flow path.

Root Cause of Problem:

Crack initiation in stake marks were due to tensile overload during the staking process residual stresses & stress concentrations.

Final Solution:

All cracked stake marks were removed by the following steps.

ENGINEERING DESIGN

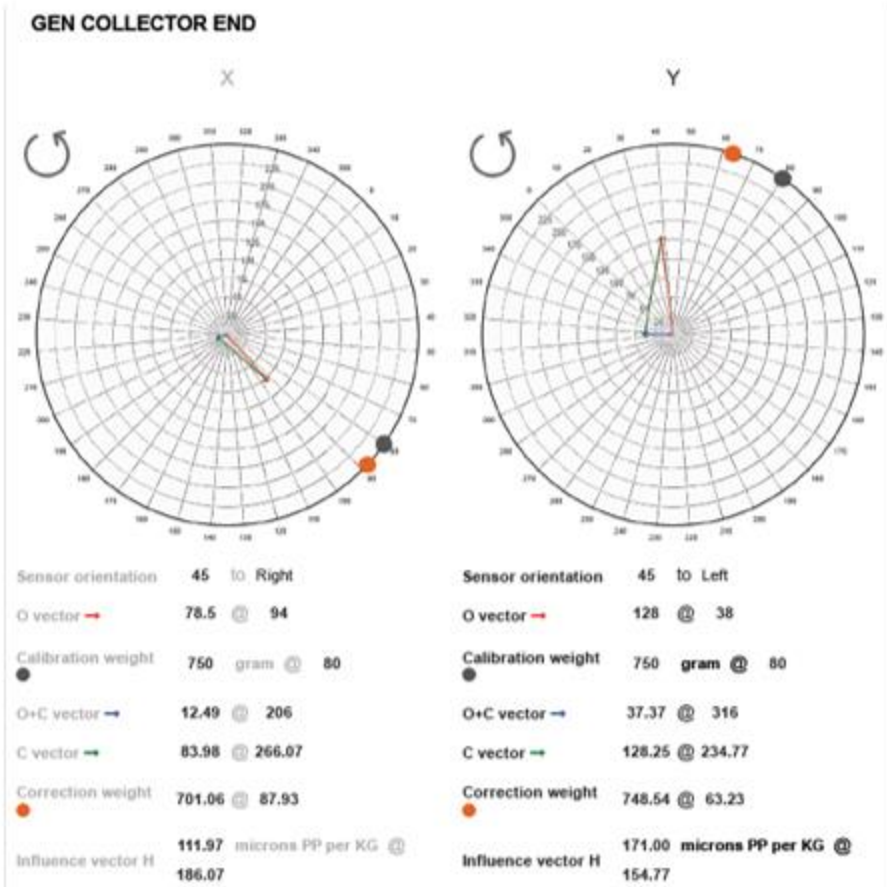
I analyzed slow roll data at hot and cold conditions and found that there were insignificant differences. However, turbine and generator rotors both had high direct runout values. Slow roll 1X-filtered values were negligible when compared to direct ones which were mainly caused by rotor scratches and surface roughness. The scratches readings were superimposed onto rotor vibrations at the entire speed range of the machine. I decided to polish the rotor journal to remove this run out. For this surface polishing there was no tool available. I designed a small lathe machine and a fixture. I brought portable lathe machine and attached it with circular fixture. I made a travel track of the machine. In this way I could polish the rotor journal area without rotating the rotor. This helped me in getting actual unbalance weight. Rotor journal area polishing was done to meet API standard 670.

[CE 2.8]

ENGINEERING CALCULATIONS

I performed the calculation to get trial weight. I used the formulae: Cf = m r ω2 Here: Cf is centrifugal force in LBf (which basically is the output we want to achieve using balance weight) m = Mass of the rotor = Weight (G)/Gravity(G) = Lb/386.4 in/sec2 r = Weight add radius in inches ω = Rotor speed in radians 1st I calculated trial weight to generate a force equal to 10% of the rotor weight. Secondly I added weight at a 8” radius Later I calculated the speed of the rotor in radians With all above values I could get mass of the rotor. Now, m = W/G, W = m * G In similar way I calculated the weight in every attempt and keep repeating the same till I got required vibration levels. Please refer to below Appendix-2 for detail off each attempt, graphical representation and conclusion.

GTG#2 Generator Balancing							
Initial Run							
	91X	92Y	BB10	BB11	101X	102Y	BB12
Direct	55.39 microns pp	74.50 microns pp	18.41 mm/s pk	18.12 mm/s pk	78.49 microns pp	132.24 microns pp	19.18 mm/s pk
1X	39.41 microns pp	50.20 microns pp	18.07 mm/s pk	17.71 mm/s pk	66.38 microns pp	127.13 microns pp	18.33 mm/s pk
Phase in Degrees	268	203	290	287	94	38	287
Calibration weight of 450 grams installed at 220 degrees on collector end balance plane							
Direct	65.53 microns pp	90.38 microns pp	22.18 mm/s pk	22.86 mm/s pk	95.10 microns pp	136.32 microns pp	24.95 mm/s pk
1X	49.41 microns pp	75.61 microns pp	21.67 mm/s pk	22.52mm/s pk	79.47 microns pp	131.62 microns pp	23.53 mm/s pk
Phase in Degrees	259	186	277	280	79	25	269
Correction weight of 1050 grams installed at 110 degrees on collector end balance plane							
Direct	37.24 microns pp	69.91 microns pp	11.85 mm/s pk	12.33 mm/s pk	32.22 microns pp	75.45 microns pp	8.02 mm/s pk
1X	28.95 microns pp	65.33 microns pp	11.12 mm/s pk	11.66 mm/s pk	14.25 microns pp	65.55 microns pp	7.18 mm/s pk
Phase in Degrees	178	79	221	226	19	341	194
After relocation of the weights of 1050grams at 85 degrees on collector end and data was taken after 12 hours of base load							
Direct	44.26 microns pp	62.5 microns pp	9.97 mm/s pk	10.25 mm/s pk	24.67 microns pp	47.42 microns pp	4.85 mm/s pk
1X	27.7 microns pp	56.3 microns p	9.38 mm/s pk	9.65 mm/s pk	12.49 microns pp	37.37 microns pp	4.17 mm/s pk
Phase in Degrees	150	58	162	164	206	316	124
After relocation of the weights to 750 grams at 80 degrees on collector end and data was takenat FSNL							
Direct	29.03 microns pp	41 microns pp	85 mm/s pk	8.8 mm/s pk	29.27 microns pp	60.2 microns pp	1.94 mm/s pk
1X	19.03 microns pp	32.48 microns pp	7.76 mm/s pk	7.98 mm/s pk	10.75 microns pp	47.67 microns pp	1.18 mm/s pk
Phase in Degrees	170	66	180	182	101	346	198
After relocation of the weights to 750 grams at 80 degrees on collector end and data was taken at baseload							
Direct	32.12 microns pp	47.9 microns pp	8.05 mm/s pk	8.28 mm/s pk	23.73 microns pp	55.9 microns pp	1.85 mm/s pk
1X	17.66 microns pp	36.32 microns pp	7.35 mm/s pk	7.63mm/s pk	9.79 microns pp	40.91 microns pp	1.15 mm/s pk
Phase in Degrees	165	60	181	184	139	340	132
After relocation of the weights to 750 grams at 80 degrees on collector end and data was taken after 1 hour of baseload							
Direct	36.69 microns pp	54.8 microns pp	8.68 mm/s pk	8.74 mm/s pk	24.76 microns pp	53.1 microns pp	3.10 mm/s pk
1X	18.30 microns pp	39.8 microns pp	7.89 mm/s pk	8.18 mm/s pk	11.05 microns pp	36.58 microns pp	2.42 mm/s pk
Phase in Degrees	153	52	164	167	163	327	103
After relocation of the weights to 750 grams at 80 degrees on collector end and data was taken after 15 hours at baseload							
Direct	42.40 microns pp	59.5 microns pp	8.91 mm/s pk	9.16 mm/s pk	21.98 microns pp	51.3 microns pp	3.74 mm/s pk
1X	22.35 microns pp	42.13 microns pp	8.26 mm/s pk	8.53 mm/s pk	9.13 microns pp	39.99 microns pp	3 mm/s pk
Phase in Degrees	150	47	165	167	166	323	105
After relocation of the weights to 600 grams at 65-70 degrees on collector end and data was taken after 24 hours at baseload							
Direct	40 micron	60 microon	7.98 mm/sec	8.14 mm/sec	30 micron	50 micron	2.23 mm/sec



[CE 2.9]

SUMMARY

I recommended and executed following actions after my analyses:

Sieving of Coarse Aggregate

This job significantly increased my understanding on onsite balancing of such hugely unbalanced rotor. Usually it takes 3-4 attempts but this job was completed in eight balance shots/attempts. Main reason was that generator rotor was completely overhauled/rewind however since it was done implying same copper so as per workshop SOP, shop balancing was not required. I suggested the shop team to change the work instruction and perform balancing in the workshop for such jobs as this can be done quite easily and quickly in the shop.