Topic II-9: Life assessments, failure analysis and chemistry

REMEDIAL ACTION STEP OF SUBSYNCHRONOUS VIBRATION TRIP ON STEAM TURBINE: A CASE STUDY OF EGAT SOUTH BANGKOK POWER PLANT

Miss Parichart Suttiprasit, Electricity Generating Authority of Thailand (EGAT), Nonthaburi, Thailand
Tel. 66-2-436-7715, Fax. 66-2-436-7791, e-mail: parichart.su@egat.co.th

Mr. Chaiyant Tibdee, Electricity Generating Authority of Thailand (EGAT), Nonthaburi, Thailand
e-mail: chaiyan.t@egat.co.th

Mr. Narit Wongsa, Electricity Generating Authority of Thailand (EGAT), Nonthaburi, Thailand
e-mail: narit.w@egat.co.th

OVERVIEW

When Steam Turbine was not damaged at all, it kept on suddenly shutting down by trip vibration magnitude. It became the most serious issues on the top of the executive table. Immediate action was needed because we had to start up the unit as soon as possible. We initially had to choose the method from the shortest time taken and then the most efficient action. Due to the fact that Subsynchronous could be self-excited vibration which was always associated with the stimulated natural frequency of the rotor system, it could be the result of every single source of rotating behaviour. This paper presents the Subsynchronous trip event and remedial action step of 115 MW Steam Turbine at South Bangkok Combined Cycle Power Plant which was first synchronized in 1995 and had found the problem since March 15th, 2008. We trust that this Action Step can be applied for Subsynchronous vibration problem of all power plants.

INTRODUCTION

The 115 MW - single cylinder, single flow type - Steam Turbine of South Bangkok Combined Cycle Power Plant (SB-C10) manufactured by GE. There are 4 bearings which are comprised of bearing no. 1 and no. 2 supporting HP-LP Rotor as following figure and bearing no. 3 and no. 4 supporting generator rotor. The description of bearings manufactured by Kingsbury Inc. are shown in the table I.

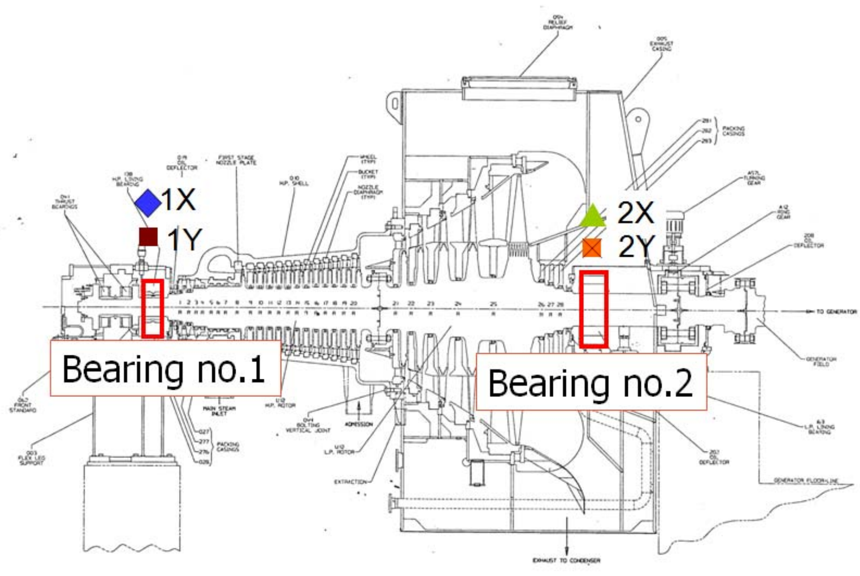
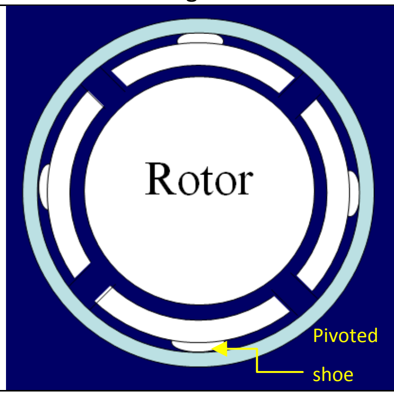


Figure 1 HP-LP Rotor with bearing no. 1 and no. 2 support

Table I Bearing Description

No.	Type	Diameter (Inches)	Figure
Bearing no. 1	DTP: Double Tilt Pad Bearing (Pivotted Shoe Journal Bearing, Button Type, Pin Located, 4Pads, 1Pad Down) from Kingsbury Inc.	12.018	
Bearing no. 2		16.024	

This combined cycle power plant is consisting of 2 Gas Turbine and 1 Steam Turbine units. The Steam Turbine unit was first synchronized in 1995 and had been executed with 5 minor inspection (MI) and 1 major overhaul (MO) outages. The Steam Turbine has been observed the symthom by condition monitoring which can be analyzed the trend simply and speedily. The significant condition monitoring data chosen are Overall Shaft Vibration, Admission Steam Turbine Inlet Pressure, LP Steam Turbine Inlet Temperature, LP Steam Extraction Temperature, Condenser High Vacuum Range Pressure, and Lube Oil Inlet Temperature. The Overall Shaft Vibration is recorded at bearing locations and the setpoint accepted by GE criteria of alarm and trip is 150 $\mu m_{p\text{-}p}$ and 225 $\mu m_{p\text{-}p}$ respectively.

On March 15th, 2008, the vibration trend presented as the following figure was recorded the trip event without alarm signal observed by operator. This was shown the MVARs (GEN VARS) decreased from +10 to -10 when it was brought a Gas Turbine unit down. Then Steam Turbine was tripped by the vibration 1X=230 $\mu m_{p\text{-}p}$ (2X=160 $\mu m_{p\text{-}p}$) within 20 minutes after. Moreover, the vibration at Bearing no.1 (VIB 1X, 1Y – BRG#1) was not consistency obviously. The Subsynchronous vibration could not be captured by Overall Vibration monitoring, so it was needed to measure the spectrum vibration.

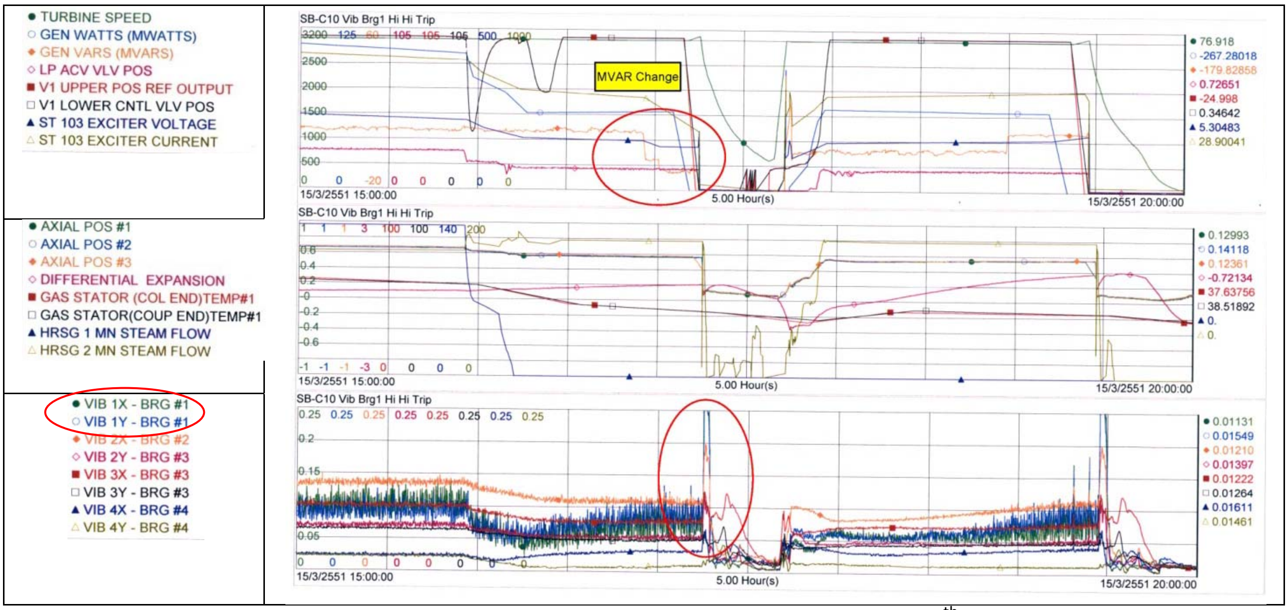


Figure 2 Vibration trend record of Trip event on March 15th, 2008

Methods

After the trip event with 230 μm_{p-p}, the vibration analyzing team had to record the Vibration Spectrum of minutes before trip again. During testing, it was found that the Steam Turbine suddenly had vibrated up to the overall magnitude of 1X=134 μm_{p-p} , 1Y = 139 μm_{p-p} at 60 MW (52% load) when MVAR changed and abnormal differential expansion appeared as shown in the figure 3. As shown in figure 4, the Subsynchronous of 8-12 Hz captured had value up to 10 μm_{p-p} and then at the moment of trip event its value increased immediately up to 75 μm_{p-p}. Practically the normal Subsynchronous had valued not over 4-5 μm_{p-p} when a Steam Turbine is running. Therefore, this problem was implied that the possible causes could be fluid induced instability, the result of Bearing wear, Bearing over clearance, abnormal of Bearing Alignment.

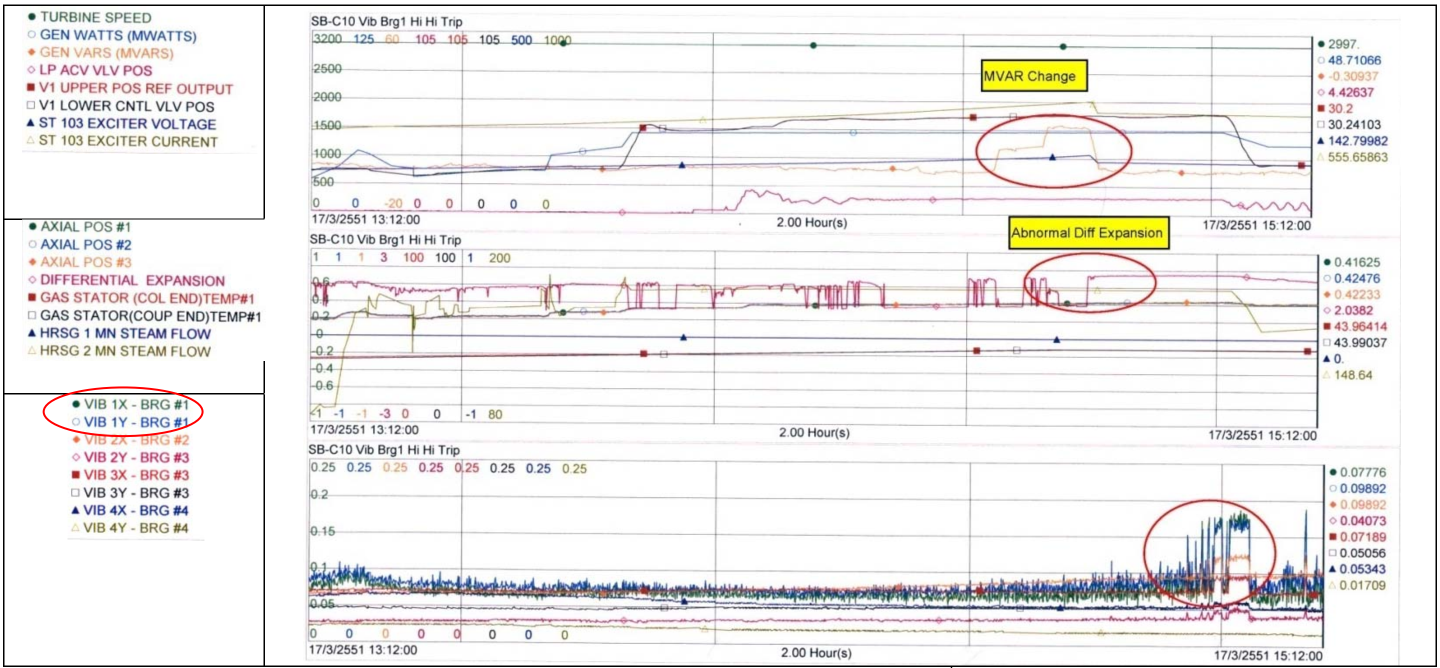


Figure 3 Vibration trend record of Trip event on March 17th, 2008

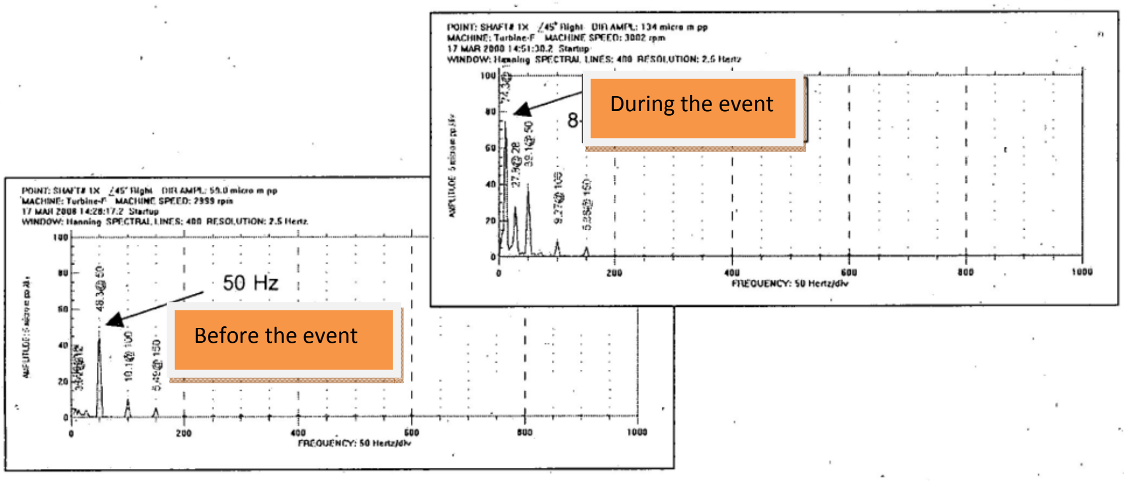


Figure 4 Subsynchronous vibration record of testing on March 17th, 2008

The history record told us that the vibration high problem was found since 2002. It is highly vibrated at Bearing no.1 during 60 MW (52% Load) while another Gas Turbine started up and Steam was admitted; however, It could not be found any severe damage on any bearings. Therefore, we kept on correcting the problem by low speed balancing, field balancing, and bearing replacement depended on which obvious evidences found during such outages. Furthermore, the root cause analysis diagram in the below figure was the main tool to check the possible causes during problem solving.

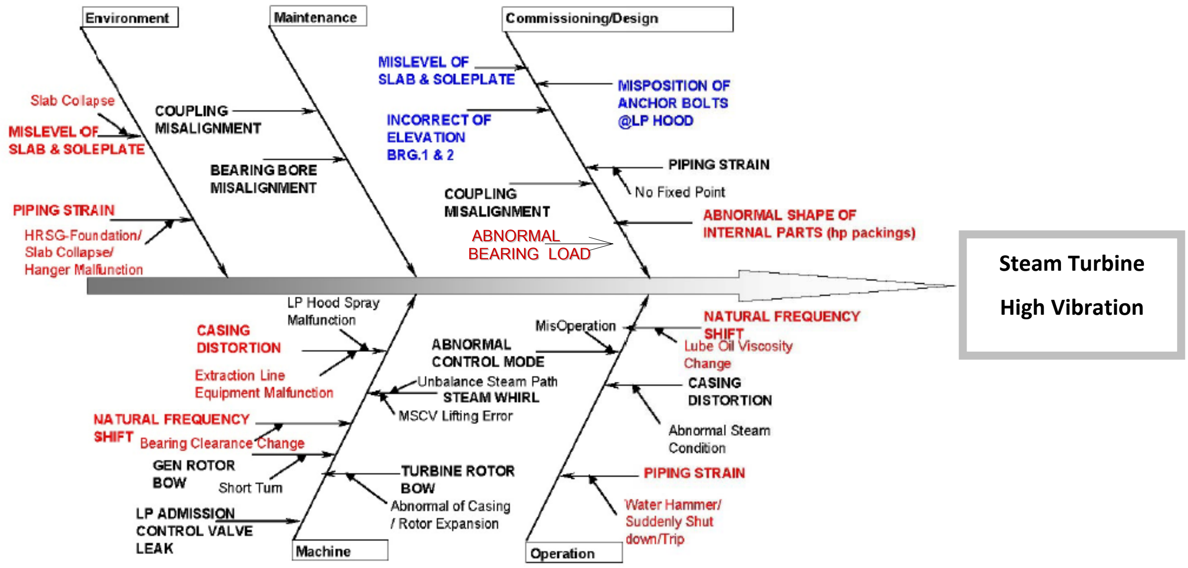


Figure 4 Root cause analysis diagram of Vibration high problem

In the initial countermeasure, there were 2 options, 6-day working on Compromised Balancing and 8-day for Bearing Inspection, in order to correct the problem. The 6-day working including Generator preparation on Compromised Balancing was selected. The Steam Turbine and Vibration team worked together to execute the three-run balancing and analyze the vibration vectors, but the vibration still high at 1x=200 μm_{p-p} , instability of which had resulted by Subsynchronous as usual.

Then we had the meeting again and come up with Bearing Inspection for 8 days. After the Bearing no. 1 disassembly, the wear of pivoted shoe was shown in the figure 5, so the Bearing had to be replaced. As the following steps, Re-alignment (Turbine-Generator Coupling) had to be finished, as well as rubbing reducing by increasing oil seal clearance.

Figure 5 The pivoted shoe of Bearing no. 1 Condition

When the unit was started up again on April 12nd, 2008, it was found the same signal that we had haven before. However, the Steam Turbine was able to supply higher load, longer as it could run. In the meanwhile, of 90 MW (78% Load) load and the Vibration at Bearing No.2 shown 130 μm_{p-p}, the Steam Turbine team tried to increase viscosity of inlet lube oil in order that the Bearing mechanism would be increased its stiffness. The temperature was adjusted from 49^{o}C to 46^{o}C, but the Vibration was still high. Then the temperature was brought back to the previous. It eventually tripped at Vibration 2X=300 μm_{p-p} (1X=220 μm_{p-p}) while MVAR was raised.

Following our experiences to resolve this difficulty, it could be summarized that Subsynchronous could be self-excited from every single source of rotating behaviour such as Load exciting, Load increasing, MVAR increasing, Steam Admission, Start-up mode switching, abnormal differential expansion, etc. The Steam path was likely to be seriously clogged, so it had no simple remedy for several days. If we continued the correction, we would need more input data from the OEM (Original Equipment Manufacturer) Engineering, accurate history record, besides our technical team experiences.

With GE recommendations, Bearing bores were adjusted and the rotor position was moved to proper position, but the result was that the Steam Turbine was heavily vibrated at 500-1,000 rpm. Consequently, the discussing meeting between the manufacturer, GE and user, EGAT had the additional issue about generator 2-pole short turn problem. GE technical advisor (TA) recommended that the first priority was improving the Steam Turbine condition to be ready to test run for the generator solving issue.

“**In the summary result of the meeting, it was shown that we could not reduce the vibration without Steam Turbine internal part correction anymore.”**

Hence that 45-day Major Overhaul was performed to rehabilitate the entire of the Steam Turbine rotor. In fact of any unforeseen evidences enhancing Subsynchronous vibration, all parts of rotor obstructed the Steam path, working fluid, had to be closely taken care by GE TA and EGAT team.

After upper half casing removal, the former activities performed were dividing flange level inspection, front casing weight unbalancing test (horn drop test), and Bearing level compared with design level. The inspection was found that the Left-side of dividing flange level was lower than the right side of 3 mm., 69% of front casing weight unbalancing, and Bearing no.1 level is lower than design of 2.7 mils. Not only was the evidence found, the water induction trace also appeared. On June 3rd, 2008, the front casing weight unbalancing was adjusted to be within 10% as shown in figure 6, causing Turbine casing Lifting. So the following step was Internal Alignment, all diaphragm stage centering, and the latter activities are rubbing decreasing, re-alignment, expanding the anchor-bolt holes, Bearing inspection and setting. In spite of foundation deformation found, the corrective action could not be done because of time constraints. It has continuously monitored to protect the problem in time.

Figure 6 Hydraulic lifting the Front casing in the process of Horn drop test

Figure 7 Water Induction Damage and Rubbing Repairing

Figure 8 Expanding the anchor-bolt holes of Base plate

Figure 9 Bearing Inspection and Setting

RESULTS

Executing most of remedial action steps, we started up the unit again on July 20^{th}, 2008. Notwithstanding Subsynchronous appearing of the 100 MW (87% load), the Turbine could bear on higher Subsynchronous magnitude of 80 μm_{p-p} compared with 10 μm_{p-p} of the previous trip event. In fact, the Steam Turbine condition was better, but it further needed fine tunning in the startup process by Compromised balancing to handle Turbine carefully. Because the Bearing no.1 is very sensitive, it can be stimulated natural frequency easily. Therefore suitable oil viscosity was adjusted by inlet Lubrication oil adjusting to help steadily rotatable bearings. The result was that the Subsynchronous magnitude reduced gradually. It was firstly decreased from $49^{o}C$ to 46.5 ^{o}C, then the Subsynchronous was reduced as shown in figure 10. Next the temperature was reduced to $45^{o}C$, and the Subsynchronous was reduced dramatically. Finally, the unit could be brought back to dispatching control center to Thailand national electric grid on August 1^{st}, 2008.

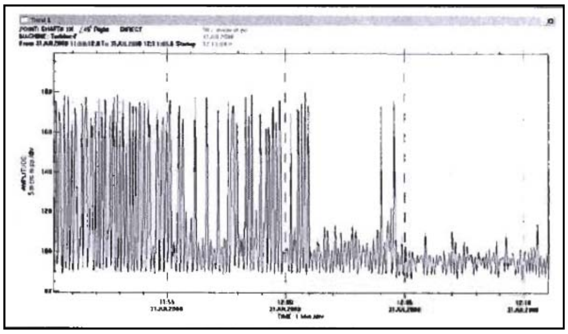


Figure 10 The Subsynchronous reducing from inlet Lube oil temperature Adjusting

During 2010 minor inspection outage, we had to analyse by the previous root cause analysis diagram along with the correcting activities in outage. The last possible cause which is abnormal bearing load was found by analysing the shaft position plot of all bearing positions. It was corrected by lifting the Bearing no. 3 support to distribute the load from Bearing no. 2 to other bearings and then the Subsynchronous was disappeared completely.

According to the experiences in Steam Turbine problem analysis and correction, mostly internal turbine part could be able to repair in our EGAT workshop, so our team must consider the most economical option with time and method trade-off depending on our workshop resources and team capabilities. Even though the checklist of the root cause analysis fishbone diagram for this complicated problem could be applied, in reality we countered the barriers during countermeasure in site. The most important factor must be considered is selecting the right method in the right time. For this reason, **the remedial action step of Subsynchronous vibration trip** could be summarized as followings.

For Bently Nevada vibration monitoring system, this steam turbine is observed the rotating condition by Overall vibration which had the 150 μm_{p-p} and 225 μm_{p-p} as alarm and Trip setpoints respectively.

If the Trip event is happened immediately after any manually or automatically processes occur, measure the spectrum vibration and observe whether Subsynchronous is shown. If it is appeared, then indicate the magnitude of Subsynchronous vibration.
The processes can be load reducing by shutting down one of Gas Turbine, load increasing by starting up one of the Gas Turbine and Steam admission, MVARs raising, load exciting, startup mode switching, etc.

In case, the magnitude of Subsynchronous is not over 10 μm_{p-p} to bear trip event. The Steam Turbine condition is most severe. The internal parts of Steam Turbine have to be inspected and corrected. Check the horn drop test and correct if needed, centering, rubbing Parts reducing, Bearings and pivoted shoes inspection, coupling alignment etc.

In case, the magnitude of Subsynchronous is about 80 μm_{p-p} to bear trip event. It is meant that Steam Turbine condition is abnormal. There are 3 options without upper half casing removal to choose.

1. Adjusting inlet lubrication oil for 1-2 day during running
   Caution: Bearing metal temperature at other location might be high because of viscosity change, so it is needed closely monitoring during adjustment.
2. Compromised balancing for 6 day: This is also depending on the position to insert required weights. If it is inserted at Turbine-Generator coupling, the balancing is only needed 2 day correction.
   Caution: This method will support the Turbine running at full load, but it might suddenly vibrated highly at 75% load. Hence the operator has to carefully carry the turbine passing through this condition smoothly.
3. Bearing inspection for 8 day
   Caution: The disadvantage of this method is that re-alignment during high turbine metal temperature is quite difficult.

Normally, if it does not have trip event, but the Subsynchronous signal sometimes appears during operation. The Steam Turbine Condition is quite normal. Keep monitoring the data: Bearing Metal Temperature, Lube Oil Inlet Temperature, Noise at last stage blade position, Back Pressure, Stator Cooling Temperature, MW and MVAR Change compared with Subsynchronous trend. Record Subsynchronous and compare with the previous and prepare to inspect and correct possible rubbing parts and Bearings inspection during scheduled Overhaul.

CONCLUSIONS

In Conclusion, the Subsynchronous vibration problem analysis needed to consider the entire area of rotating behaviour. The EGAT team also had to make decision under time limit and less effort restriction. Moreover, the most important before following the Action Step, the Steam Turbine condition and accurate maintenance record had to be considered. The obvious example is that the first action of Compromised Balancing and Lube oil temperature adjusting was not succeeded because of the serious damage from water induction. Therefore, it primarily needed to correct all possible rubbing internal parts.

ACKNOWLEDGMENT

As in the previous section, I have relied on comments and information from a number of engineers with whom I have worked and cooperated on a number of projects over the past years. Their comments and observations have been of considerable assistance in identifying areas where more detailed information is required and in bringing to my attention subjects that I may not have been, at that time, addressing in sufficient detail, or even at all. For these reasons, their assistance and advice has been invaluable.

As in this paper, my special thanks go to my colleagues Supaniti Songsawas, Manassavee Thuphom, and Cheewin Young-ngern for allowing me to interrupt his work. Their review and input from their experience have added considerably to any value other plant engineers may find in this paper. Their concept and the time taken to read and comment on the text and the way it has been arranged have been invaluable.

I would also like to acknowledge the input from the followings. Each has made information available to me or has been prepared to discuss certain aspects of units and our joint experiences. Santhiti Chanthauthai, head of Engineering Section in Steam Turbine Department, Supawat Kladthong, Kobchai Wasuthalainan, Apichat Paugsopatai, Sompong Pantmuk of Steam Turbine Department, Sahathep Joipradit of other departments in Mechanical Maintenance Division, Pramote Kajornpol of South Bangkok Power Plant, EGAT, Athikom Jumrutsri, GE Technical Advisor.

To make the text clearer, I have used several of figures and tables. Some of these were presented at the power plant site, conferences, and seminars I attended.

Special thanks go to my office staff in Steam Turbine Department, for their assistance, especially Wasuthep Sinmayo and Phipob Chomboonchoy. Their help in particular was invaluable.

REFERENCES

[1] General Electric Company, Electrical Generating Authority of Thailand: South Bangkok Combined Cycle Plant, South Bangkok, Thailand, *File No. 62.1001 Steam Turbine Generator 103, Maintenance and System Description, Turbine No.270T238*, Generator No.290T238, Schenectady, New York: GE, 1992

[2] Grissom, B(2002), *Fundamentals of Rotating Machinery Diagnostics*, Minden, Nevada

[3] H.P. Bloch, and M.P. Singh, *Steam Tubine Second Edition: Design, applications and re-rating*, the United States of America, 2009.

[4] Electricity Generating Authority of Thailand, *Root cause analysis report: Steam Turbine Vibration High Trip, SB-C10*, Thailand, 2008

[5] Electricity Generating Authority of Thailand, *Learning organization knowledge management report: Rubbing Correction of Subsynchronous Vibration Steam Turbine, SB-C10*, Thailand, 2008

[6] General Electric, *Steam Turbine Vibration Report: Forced Outage Vibration*, Thailand, 2008

Miss Parichart Suttiprasit obtained a Bachelor’s degree of Mechanical Engineering from Chulalongkorn University, Bangkok, Thailand in 1999. Since joining Electricity Generating Authority of Thailand (EGAT) as a mechanical engineer in steam turbine department, she had carried out several works regarding problem solving on steam turbine operation and maintenance including auxiliaries in EGAT power plants. Currently, she works as a planning engineer in business planning department of generation deputy.

Mr. Chaiyant Tibdee obtained a Bachelor’s degree of Mechanical Engineering from Songklanakarin University, Hatyai, Thailand. In 1999, he initially worked as mechanical engineer in boiler department; he had carried out several works regarding problem solving on boiler operation and maintenance. After joining the testing engineering department, he works as a mechanical testing engineer and he has been executed many vibration analysis testing projects in EGAT power plants.

Mr. Narit Wongsa obtained a high vocational certificate in mechanical area and has worked as steam turbine site manager in steam turbine department. Since joining EGAT in 1980, he has executed a lot of steam turbine outages in EGAT power plants as technical skill, foreman, and site manager. Regarding to his work experiences, he executed the issues on steam turbine and auxiliaries such as problem solving, function testing, site managing, etc. and he also supplied the details of this topic in his responsible areas.