1. Introduction

Availability of electrical power round the clock and throughout the year is most essential for industrial and economic growth of any country. In the present era of fierce competition and financial constraints, the reliability and availability of operating power plants, are becoming a challenging issue. The thermal power plants produce larger part (i.e. almost 70%) of the electricity of world’s requirement compare to other power plant. India is one of the largest producers of electricity in world and majority of the plants are coal based [1].

Rankine cycle is the basic principle of the thermal power plant [2]. In a power plant, the combustion of fuel is used to get steam from water. The generator (coupled with turbine) produces the electricity. Continuous electricity generation from a power plant depends on the availability of its components. To enhance the availability, various maintenance culture and strategies are adopted [3, 4 & 5]. These are;

- Breakdown Maintenance
- Routine Maintenance
- Precautionary Maintenance
- Condition Based Maintenance (CBM) or Condition Monitoring

In spite of high initial cost, the CBM is implemented to reduce the downtime and raise the reliability and safety of the plant. CBM watches and monitors the performance parameters of the equipment very regularly which enable to know whether any problems exists or likely to appear. There are different condition monitoring techniques, such as: Vibration Analysis [6], Noise Analysis [7], Temperature Monitoring [8], Motor Current Signature Analysis (MCSA) [9] and Wear Debris Analysis [10].
2. Methodology and Experimentation

The present work is based on a super thermal power station of Vedanta Limited, Jharsuguda, India. It has nine units and total power of 1215 MW. The plant has adopted the world class technology.

The basic components of power plant (i.e. boiler, generator and turbine) are singular and auxiliary devices like ID fans (Induced draft fans), FD fans (Forced draft fans), coal mills, Boiler feed pumps, condensate extraction pumps, cooling water pumps, ash handling units, coal handling plants etc. have inbuilt standbys. The maintenance practice at CPP of Vedanta Limited, Jharsuguda, shows that the failure rate of power components (Turbine, Induced Draft fan, Forced Draft fan etc.) is many times higher than other. In this paper, the condition monitoring of an Induced Draft fan (ID fan) by vibration analysis has been described.

3. Condition Monitoring of Induced Draft Fan (ID Fan)

An ID fan is in between dust collector and chimney. It takes the hot flue gases from furnace via a dust collector (dust separation system, Electrostatic Precipitator i.e ESP or fume extraction system) and will deliver to chimney. It produces the negative pressure in the furnace to remove the flue gases from furnace via electrostatic precipitators and to push the flue gases to chimney. The figure of ID fan is in Figure 1.

3.1 Detail Specification

Power: 1700KW, Speed: 991 RPM, Motor’s NDE (Non-Drive End)/Outboard Bearing: NU240 ECM, Motor’s DE (Drive End)/Inboard Bearing: 23044 CC/C3W33. Fan DE & NDE (Both Inboard & Outboard) Bearings: 22232EASMC3, Vibration velocity (RMS) limit (as per OEM); Normal: below 1.5 mm/s, Little abnormal: 1.5-4.0 mm/s, Sub critical: 4.0-6.5 mm/s, Critical: above 6.5 mm/s. Peakvue limit; Normal: less than 1.

Figure 1: Schematic Diagram of a typical ID Fan

3.2 Diagnostic Symptoms:

The ID Fan is monitored through the vibration analysis. The information are recorded and analysed by using accelerometer and AMS Suite Software. A case study was observed during July 2019 – August 2019 and has been considered here. Usually, vibration readings are taken weekly. If there is some abnormality observed, then the frequency of measurement is increased. During taking readings, accelerometer is mounted on both the inboard and outboard bearings of the motor and fan. Because of unusual sound was observed on 5th August, the analysis was started to diagnose the defect. Vibration amplitude (at all bearing) in different directions; horizontal (H), vertical (V) and axial (A) were measured and analysed. The RMS values and peakvue values are presented in Table 1 and Table 2 respectively. Similarly, the vibration spectra are presented in Figure2 to Figure4.
Table 1: RMS value of vibration (in mm/s) in various days

| Location          | Direction | 25th July | 1st Aug | 5th Aug | 6th Aug | 11th Aug | 12th Aug | 14th Aug |
|-------------------|-----------|-----------|---------|---------|---------|----------|----------|----------|
| Motor Outboard    | H         | 1.318     | 1.519   | 0.194   | 0.424   | 0.684    | 0.949    |          |
|                   | V         | 0.580     | 0.470   | 0.741   | 0.846   | 0.362    | 0.316    |          |
|                   | A         | 0.522     | 0.396   | 1.167   | 0.953   | 0.350    | 0.350    |          |
| Motor Inboard     | H         | 1.055     | 1.228   | 1.064   | 1.284   | 0.587    | 0.953    |          |
|                   | V         | 0.322     | 0.482   | 0.859   | 1.216   | 0.387    | 0.347    |          |
|                   | A         | 0.798     | 0.443   | 1.314   | 1.214   | 0.332    | 0.411    |          |
| Fan Inboard       | H         | 1.269     | 1.283   | 2.577   | 2.804   | 0.643    | 1.054    |          |
|                   | V         | 0.476     | 0.311   | 1.627   | 1.656   | 0.331    | 0.310    |          |
|                   | A         | 0.602     | 0.630   | 1.725   | 2.726   | 0.392    | 0.469    |          |
| Fan Outboard      | H         | 1.439     | 1.168   | 1.087   | 1.173   | 0.625    | 0.839    |          |
|                   | V         | 0.387     | 0.242   | 0.545   | 0.605   | 0.265    | 0.372    |          |
|                   | A         | 0.611     | 0.324   | 0.636   | 0.885   | 0.493    | 0.443    |          |

Figure 2: Vibration spectrum of ID Fan-Inboard (Horizontal).

Figure 3: Vibration spectrum of ID Fan-Inboard (Vertical)
Figure 4: Vibration spectrum of ID Fan-Inboard (Axial).

Table 2: Peakvue value at Fan Inboard bearing in various days

| Position      | Direction | 25th July | 1st Aug | 5th Aug | 06th Aug | 11th Aug | 12th Aug | 14th Aug |
|---------------|-----------|-----------|---------|---------|----------|----------|----------|----------|
| Fan Inboard   | H         | 0.297     | 0.398   | 1.264   | 1.14     | Bearing  | 0.295    | 0.291    |
|               | V         | 0.476     | 0.311   | 1.727   | 1.541    | Replaced | 0.331    | 0.317    |
|               | A         | 0.602     | 0.630   | 1.825   | 2.594    |          | 0.392    | 0.384    |

3.3 Observations and Analysis

- The Table-1 shows that there is sudden increase of vibration amplitude (on 5th August) on the Fan DE bearing, which indicates that there is some problem in rotating element of ID fan.
- Also, the increase in Peakvue values (in table 2) signify the same thing.
- From the vibration spectrum (Fig. 2), the peak at 8623.9 cycles per minute (cpm) (which is a non-synchronous frequency) with its’ harmonics indicate the abnormalities in the Fan DE bearing.
- The same frequency match with the Ball pass frequency outer race (BPFO). So it indicates that there is problem in outer race of the bearing.
- The peak at 34486 cpm and its sidebands (i.e. 4BPFO±1xRPM) indicates/ensures the outer race problem in the bearing.

As per the recommendation, the Fan-Inboard bearing was opened and it was found that there was erosion in outer race of the bearing. That is shown in Figure5 to Figure7. After replacing the bearing (on 12th August), the Fan was put back to operation. After that, vibration spectra (are shown in Figure 8 to Figure 10) shows that there is no significant peak at non synchronous frequency (i.e. at 8623.9 cpm) and the vibration amplitude (rms) is very normal.
Figure 5: Bearing housing
Figure 6: Bearing inner race
Figure 7: Eroded outer race

Figure 8: Vibration spectrum of ID Fan-Inboard (Horizontal) (after bearing replacement)

Figure 9: Vibration spectrum of ID Fan-Inboard (Vertical) (after bearing replacement)
Figure 10: Vibration spectrum of ID Fan-Inboard (Axial) (after bearing replacement)

4. Summary

Vibration analysis is a very strong and sensitive technique for condition monitoring of plant machineries. It can detect the defect or any irregularity in the rotating element of the machine like; ID fan in power plant etc. Also, it can detect the defects when the machine is under operation and no need to stop it for inspection. Condition monitoring decreases the down time and improves the reliability of the plant. Also, it eliminates the sudden breakdown of the system. Equipped with proper condition monitoring technique and strategy, a power plant ensures the safe and reliable operations.

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