Reduction in Vibration Level on Turbine - A Case Study

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ABSTRACT

Turbo Generation (TG) vibrations are due to various reasons, some of which are Fluctuation in Bleed and Extraction, Grid Fluctuation, High frequency / variation in frequency and Load throw on turbine, HP steam of dissimilar pressure and temperature, Deposition of Impurities, Dependency on Lube oil temperature and pressure. Some of these were eliminated by wet cleaning, sand blasting and proper load distribution with microprocessor based Grid supervision relay. After wet cleaning the problem of tripping of TG due to high vibration at load was faced whenever bleed was taken in line. A case study taken up with Bently Nevada, is also included in this paper.

INTRODUCTION

In Pulp and Paper industry requirement of steam in paper machine varies with GSM, Paper break, speed of machine and steam condensate system. In Pulp mill the demand of steam varies with number of digester in loading, steaming, cooking and blowing. In the system, we supply the steam to pulp and paper mill through Bleed and extraction of turbine. As the bleed and extraction of turbine are designed for certain values when there is fluctuation in demand of steam, turbine experience the vibration which ultimately leads to the triping of the system.

Water chemistry plays a vital role in the turbine. Deposition of impurities on the turbine blades ultimately results in vibrations and stresses so the silica in superheated inlet steam comes into picture. This inlet steam depends on the type of condensate recovered from the process and the DM water quality. By sand blasting we can remove the deposited impurities from turbine but this process takes lot of time(4-6days) which incurs heavy losses. Alternate method to remove at least the soluble impurities is Wet cleaning. Time requirement for this is 36 hrs maximum.

For getting the maximum output from Turbo Generator (TG) it is advisable to run the generator in parallel with the Grid but synchronization with grid has its own constraint. With increase in Grid frequency, turbine speed also increases. When the load on Grid reduces, frequency increases and vice versa. At the time of fluctuation in grid frequency vibration level of the turbine increases. Similarly when there is fault at grid side Turbo generator also feed the fault, which in turn increases the vibration level of TG.

We have two high pressure boilers (63 kg/cm^{2}g pressure) with the capacity of 50 T/hr (Fluidized bed, husk fired water tube boiler with option for mixture of 20% alternate fuel, with overbed feeding) and 20.7 T/hr (165 T Dry solid/day, Black liquor Fired Water tube) at 465 +- 5^{0}C and 455 +- 5^{0}C respectively. The steam of these two Boilers is fed to the common header (HP). HP header provides the steam input to the 9.4 MW (Bleed, extraction and condensing type) turbine. We also have two number identical low pressure (17.5 kg/cm^{2}g pressure) Boilers having capacity of 12 T/hr. The turbine is governed by a 505 E Woodward make Governor, synchronized with the 66 KV PSEB grid and has all the necessary protection system.

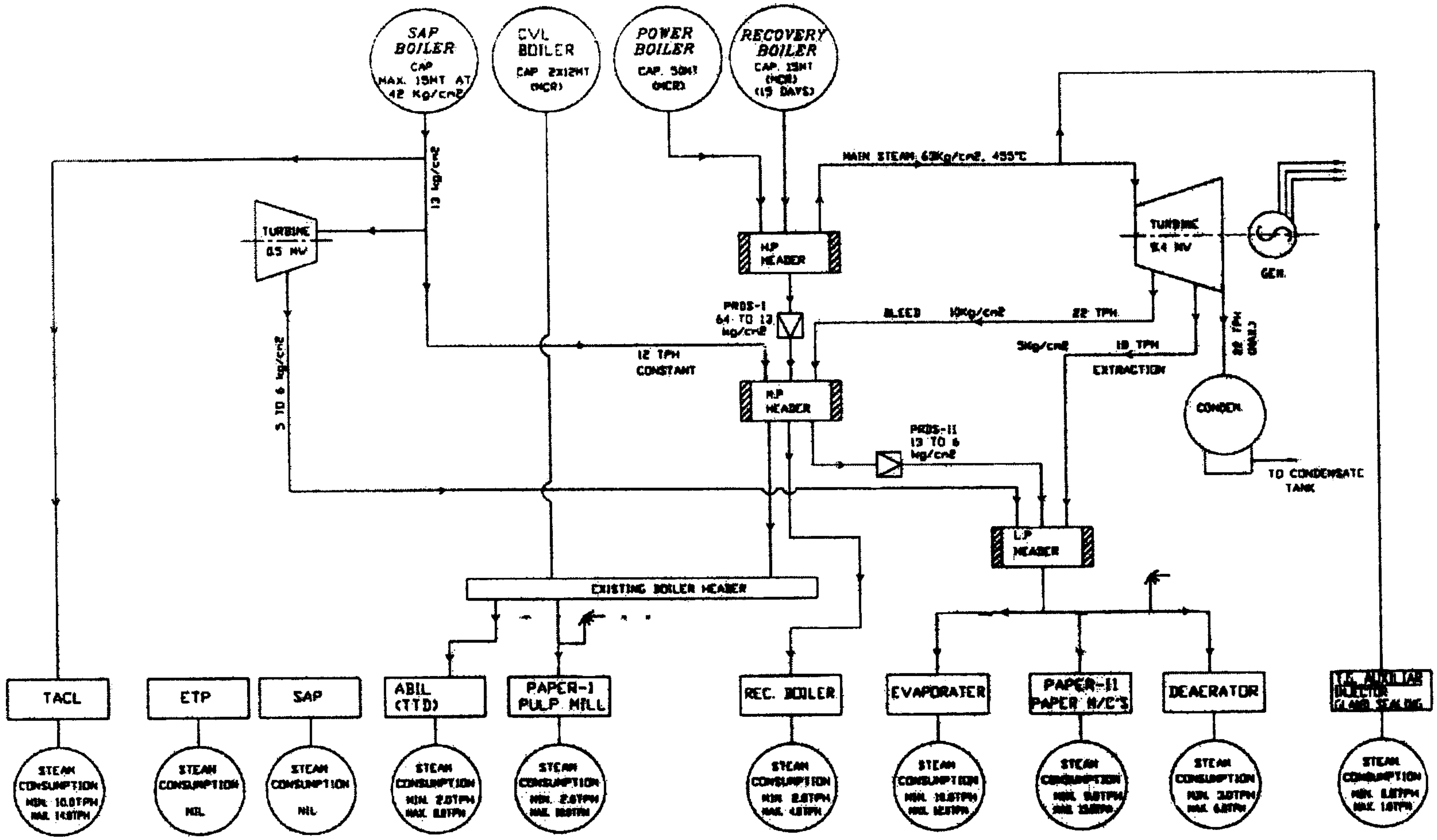
Steam flow distribution and Power Distribution schemes are attached in Fig. 1 and Fig. 2.

Turbine has monitoring and tripping system of Bently Nevada, which senses the thrust vibration and shaft vibration (Front and rear bearing vibration at 45^0 left and 45^0 right).

EXPERIMENTAL

Fluctuation in Bleed

Demand of the Bleed (MP) varies from 8-19 tonne/ Hr, as per process requirement. In addition to this due to high demand of extraction (LP) steam, some



POWER CONSUMPTION

TACL	1.5 MW
ETP	0.4 MW
SAP	0.7 MW
ABIL (TTD)	3.0 MW
PAPER-1 PULP MILL	1.0 MW
REC. BOILER & EVAPORATER	0.8 MW
PAPER-II PAPER M/C'S	2.9 MW
T-G & BLR. AUXILIAR.	1.3 MW
TOTAL	11.6 MW

POWER BALANCE

POWER DEMAND - 11.6 MW
OUR GENERATION (TG) - 9.4 MW
POWER FROM PSEB - 2.2 MW

STEAM CONSUMPTION

(1) H. P STEAM MIN - 6.0 TPH
MAX - 22 TPH

(2) L P STEAM MIN - 22 TPH
MAX - 33 TPH

Fig. 1 Existing steam balance with CVL boiler

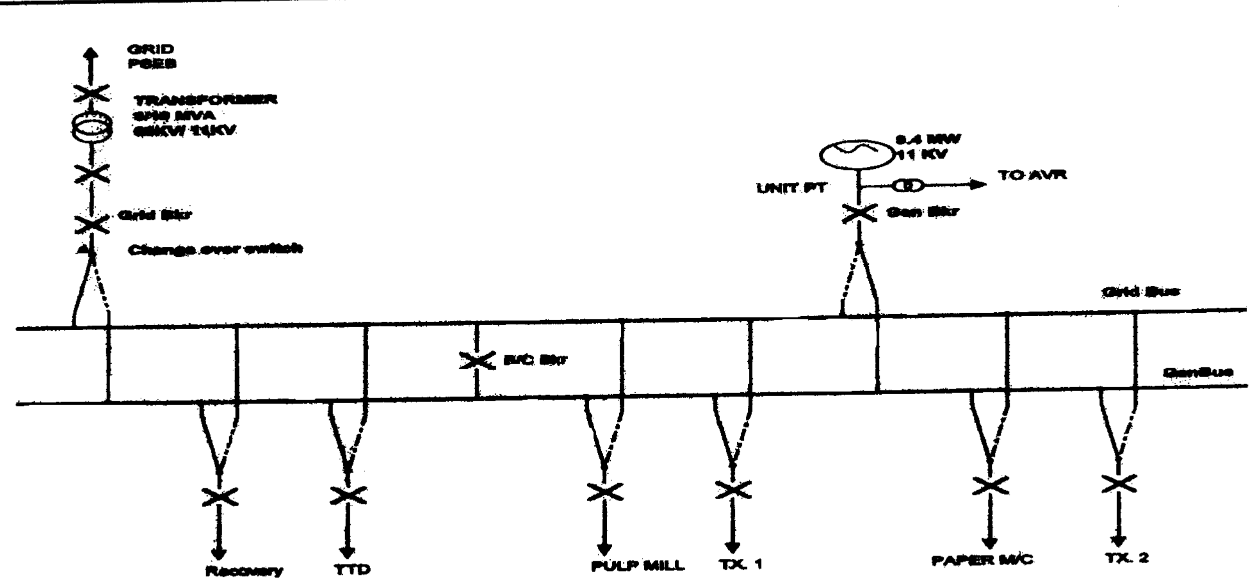


Fig. 2 Power Evacuation Scheme

Bleed (MP) steam is converted to LP through PRDS II. This results in Bleed (MP) steam flow fluctuation from 17 T/h to 25T/h against the designed flow of 22 T/h. Due to this vibration on the turbine increases. To the extent the virbation is controlled by taking PRDS I in line so that flow of bleed remains same.

Fluctuation in Extraction

Demand of the Extraction (LP) varies by 10Tons/h approx. whenever paper breaks. The Design value of Extraction is 18 tonne/hr. So when the demand of Extraction (LP) reduces, the bleed (MP) flow also decreases as the PRDS2 (MP to to LP) has to be closed whenever Extraction flow reduces.

Grid Fluctuation

High frequency/variation in frequency

TG runs in parallel with grid in constant load (KW) mode. It is controlled through 505E woodward Governor in cascade mode, in which 5% speed droop is set for secondary stabilization. It is observed under normal running condition the droop varies from 2.5 to 3.5% but when the Frequency of the Grid increases the droop also increases as for the same KW set point, actual KW reduces. As soon as the frequency reduces to normal value, load on the turbine increases rapidly and turbine trips from shaft vibration Hi-Hi.

Overload on turbine

When Grid trips with overloading on the turbine, TG trips due to Vib Hi-Hi. To isolate the Generator from the Grid whenever there is a fault, two numbers grid supervision relay (Voltage supervision relay with dV/dt element, Frequency supervision relay with df/dt element.) are interlocked. At the time of fault at grid these relays trip the Bus coupler which isolate the Generator from Grid. The plant load is 11.00 MW, in which 8.8 MW shared by Generator and rest of the load is shared by Grid. Whenever there is disturbance at Grid, bus coupler trips because of Grid supervision Relays. It is observed that load on the Generator exceeds to 9.00 MW and Turbo generator trips because of Vibration Hi-Hi.

As we have parallel Bus switchgears at 11KV, we shifted some of the load in grid Bus from the Generator Bus. Now whenever Bus coupler trips, load on the turbo generator does not exceed above 9.00 MW.

It is also observed when there is grid failure, load on the turbine increases because Grid supervision relays do not operate on "No Power" condition and Grid load shifted to Generator and Generator Tripped. To capture this type of Fault a power relay is commissioned at the position "a" which supervises the load flow from Grid to Turbo Generator. When the load on the Grid reduces to 120 KW or below. the relay trips the bus coupler and system isolates from the Grid.

HP steam of dissimilar pressure and temperature

As per the steam flow diagram (Fig. 1) system works with three distinct steam pressures and temperatures named HP, MP and LP respectively in which HP Header is having steam from Recovery Boiler (14

Tonne, 445 +- 10°C, 64 Kg/cm²) and power boiler (50 Tonne, 460+-5°C, 64 Kg/cm²). As these two streams of different enthalpy mix and enter into turbine it creates the phenomenon of steam churning, which increases the shaft vibration.

Deposition of Impurities

The investigation of deposition on a larger number of turbine has shown that some definite depositions collect in the particular pressure areas. Thus for example, in the part with highest pressures we encounter copper oxides and aluminium silicates. In the higher pressure areas of the intermediate pressure stage we find salts and silicates, while towards the end of the intermediate pressure stage and in the low pressure stage we meet silicic acid, mainly with Fe. As per requirement in superheated steam in turbine, silicic acid content in continuous operation should be below 0.02 mg SiO_2/Kg and total iron content less than 0.02 mgFe/Kg. A maximum allowable copper content in steam is 0.003 mg/Kg. This leads to non uniform depositions on blade and due to modified pressure ratio through blades addtional bending forces and stresses generate. These stresses and vibrations cause corrosion especially in wet steam range.

The depositions soluble in water are removed by a wet steam rinsing. Water insoluble depositions shall be removed by mechanical cleaning such as sand blasting and chemical cleaning. In all cases it is recommended to carry out wet cleaning as a first step.

The rinsing procedure is carried out when the turbine is in cold, at speed approximately 20% of the nominal (but far enough from the critical speed). In the main stop valve installed ahead of emergency stop valve the line is throttled to the value ensuring the emergency stop valve and control valves to remain wide open. By injecting feed water, steam wetness is increased gradually to the value of X=0.95 and upto 0.85. Water should only be admitted to the turbine in the form of fine vapour and not in the form of droplets. The observation at the time of experiment is shown in Table 1.

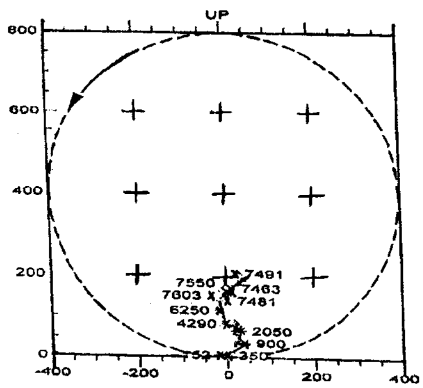
Dependency with lube oil temperature and pressure

It has been observed that vibration level of the TG depends upon the lube oil pressure and temperature. By increasing the lube oil pressure in bearing with constant speed, stability of operation increases marginally with increase of temperature, in 60% of the cases vibration level reduces but in remaining 40% cases, lowering of the temperature has been proven to be effective. We reduced the temperature to 47°C of the lube oil and observed that fluctuation in Vibration increased and then temperature was increased up to 52°C and it was observed that fluctuation in Vibration decreased.

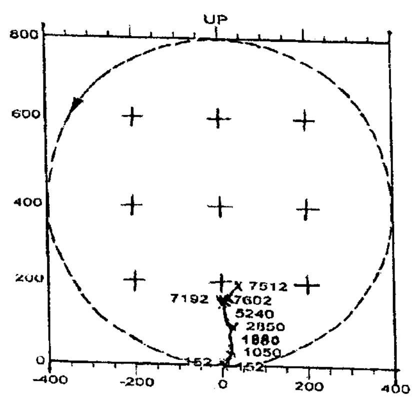
Table 1

Main Steam Pressure Temperateure Speed	40 Kg/sq cm 240 +_ 3°C 1500 rpm								
Time	pH	SiO_2 ppm	Conductivity micro siemens	Total Hardness ppm	Chloride ppm	Caustic Alkalinity ppm	Phosphate ppm		
1:30 PM	9.98	49	370	2	50	14	34.26		
2:00 PM	8.82	2.9	18	Nil	4	Nil	1.87		
2:15 PM	9.63	12.8	70	Nil	12	10	traces		
2:30 PM	8.86	3.45	25	Nil	2	Nil	traces		
2:45 PM	8.1	0.75	12	Nil	Nil	Nil	traces		
3:15 PM	7.7	0.3	10	Nil	Nil	Nil	traces		
3:45 PM	7.5	0.21	9	Nil	Nil	Nil	traces		
4:15 PM	7.6	0.59	14	Nil	Nil	Nil	traces		
5:00 PM	7.67	0.16	8	Nil	Nil	Nil	traces		
6:30 PM	7.87	0.77	21	Nil	Nil	Nil	traces	Cu,	Fe
8:00 PM	8.1	0.1	19	Nil	Nil	Nil	traces	ppm	ppm
11:30 PM	8.4	0.5	//	Nil	Nil	Nil	traces	Nil	0.02

Shaft average centerline plot
Company: Varinder Agro
Machine Train : ABB Steam Turbine
Plot No.
Plant: Power plant
Job Reference: MMS/2001
Point: Turbine V Governor 45°C Left Ref. 10.4 Volts 0.122
Point: Turbine H Governor 45°C Left Ref. 10.0 Volts -0.071
Machine: Turbine (-17.1, 4.65) 152
From 27 FEB 2001 22:00:24 to 27FEB 2001 23:03:49 Startup
(not orbit or polar plot)



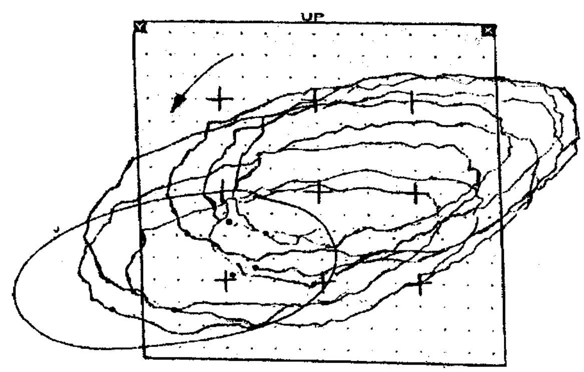
50 micro m/div
Point: Turbine V Coup 45°C Left Ref. 10.1 Volts 0.041
Point: Turbine H Coup 45°C Right Ref. 10.1 Volts 0.029
Machine: Turbine
From 27 FEB 2001 22:00:24 to 27FEB 2001 23:03:49 Startup
(not orbit or polar plot)



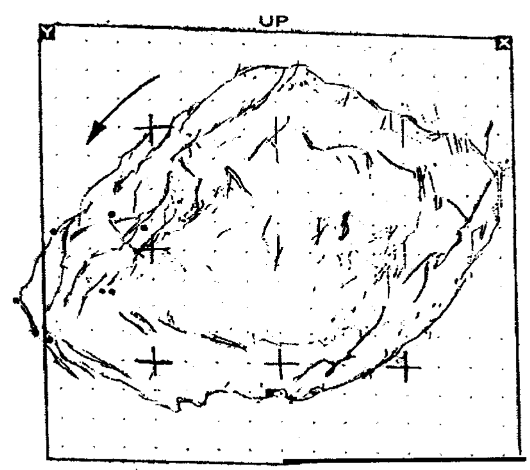
50 micro m/div
COMMENTS
Session started with Database: 27 Feb 01-22:00:24. Transeint Database with temporary Keyphasor probe.
Machine synchronised at 22:24:47 at 1 MW load, Extraction taken in line at 22:39:40 at 4.5 MW load Bleed taken in line at 22:49:35 at 6.9 MW load

Fig. 3

Orbit Plot
Company: Varinder Agro
Machine Train : ABB Steam Turbine
Plot No.
Plant: Power plant
Job Reference: MMS/2001
Y: Turbine V Govornor 45°C Left DIR AMPL: 62.9 micro m pp
X: Turbine H Govornor 45°C Left DIR AMPL: 102 micro m pp
Point: Turbine H Governor 45°C Left Ref. 10.0 Volts -0.071
Machine: Turbine
27 FEB 2001 23:03:34 Startup DIRECT



50 micro m/div ROTATION: X TO Y (CCW) 7601 rpm
Y: Turbine V Coup 45°C Left DIR AMPL: 50.7 micro m pp
X: Turbine H Coup 45°C Right DIR AMPL: 77.3 micro m pp
Machine: Turbine
From 27 FEB 2001 23:03:34 Startup DIRECT



50 micro m/div ROTATION: X TO Y (CCW) 7601 rpm
COMMENTS
Session started with Database: 27 Feb 22:00:24. Transeint Database with temporary Keyphasor probe.
Machine synchronised at 22:24:47 at 1 MW load, Extraction taken in line at 22:24:47 at 1 MW load Extraction taken in line at 22:39:40 MW load, Bleed taken in line at 22:49:35 MW load

Fig. 4

A case study by Bently Navada

The machine was giving fluctuating high vibration on turbine bearings while running on higher loads, especially more than 6MW of load when extraction and bleed steam are in line, Further increase in load/ bleed flow was causing more fluctuation in the turbine vibrations which finally resulted in to tripping of the critical machinery.

CASCADE PLOT

Company : Varinder Agro

Machine Train : ABB Steam Turbine

Plot No.

Plant: Power plant

Job Reference : MMS/2001

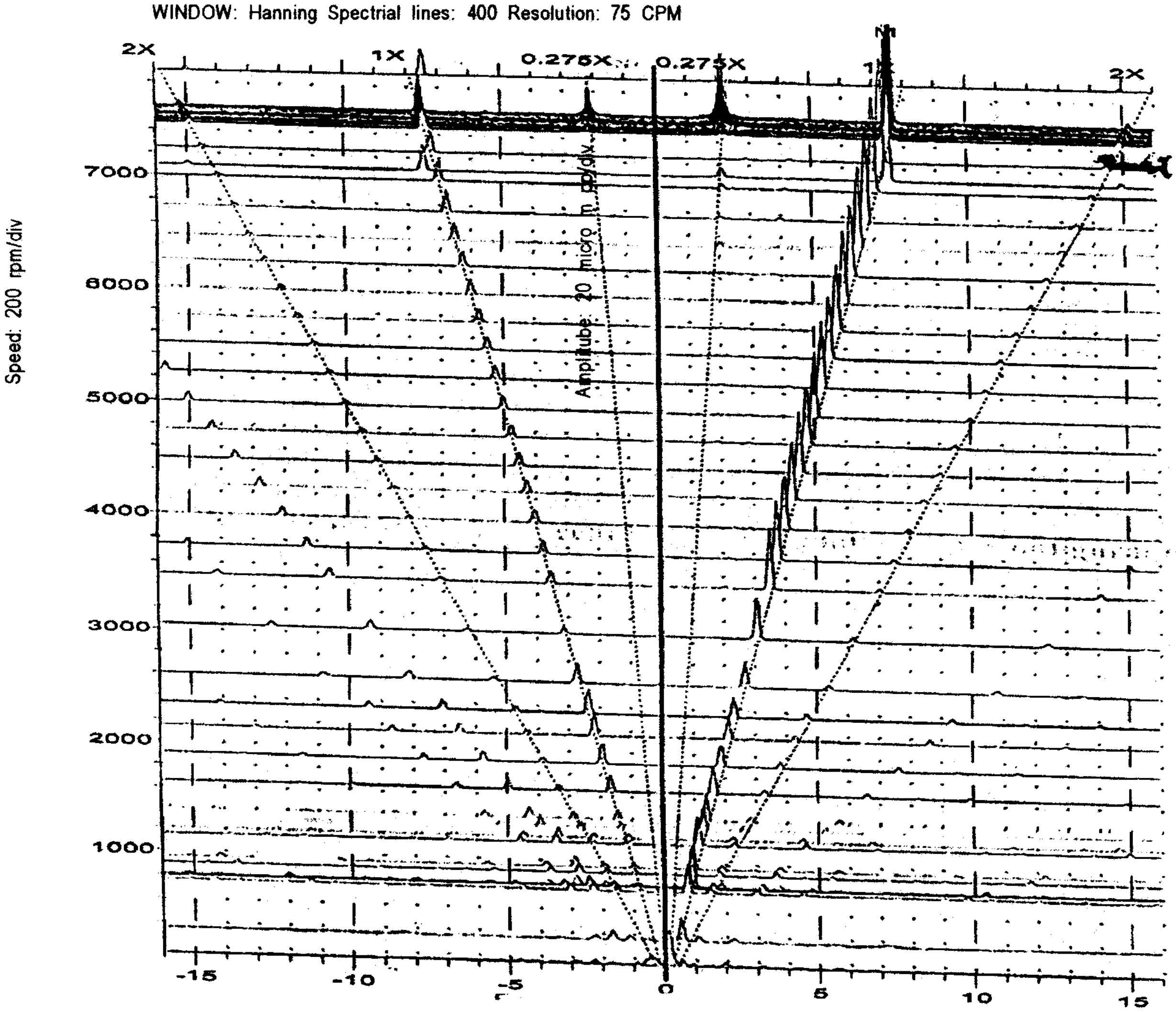
Point : Turbine V Coup 45°C Left

Point : Turbine H Governor 45°C

Machine : Turbine

From 27 FEB 2001 22:00:24 to 27FEB 2001 23:03:48 150 rpm

WINDOW: Hanning Spectrial lines: 400 Resolution: 75 CPM



REV VIB COMPONENTS FWD VIB COMPONENTS

Session started with Database: 27 Feb 01:22:24. Transeint Database with temporary Keyphasor probe.

Machine synchronised at 22:24:47 at 1 MW load, Extraction taken in line at 22:39:40 at 4.5 MW load, Bleed taken in line at 22:49:35 MW load

Fig. 5

The objective of this study was to identify the root cause of the fluctuating high vibration level at turbine DE and NDE side bearings.

The normal running machine for transient and partial load running condition, gives mainly 1x vibrations with direct values less than 60 micro meter pp with

1x value component less than 56 micrometer pp. The 1x component is having rising tendency with speed mainly for turbine front bearing, which is quite obvious synchronous rotor response on account of acceptable degree of residual unbalance. During loading of machine, mainly more than 6MW load when extraction and bleed steam are in line, the direct values of vibration represents fluctuating tendency on account of fluctating presence of 0.278x frequency component. This component appears getting dominated once bleed flow increases. At the time of higher loads, the orbit pattern indicates frequent dynamic positioning of the rotor shaft, which gives a primary hint for the presence of fluid (steam whip condition) induced instability possibly on account of steam flow across the turbine rotor. The centerline plot, Orbit plot and full spectrum diagram are attached at the end of this shown in Fig-3, 4 and 5.

RESULTS AND DISCUSSION

Occurrence of sub synchronous component only at higher load in conjunction with normal lift of the rotor in bearing clearance boundary eliminates possibility of bearings being the source of instability. Frequency of the self excited vibrations is approaching to observed first balance resonance speed of the turbine rotor, which indicates coincidance of the mechanical resonance with fluidic resonance, termed as steam whip in this condition, thus establishing desirable conditions for on setting of steam whip instability. Possible location of such kind of instability may be gland seal area, interstage labyrinth seal area (such as balance drum labyrinth seal area) in the high pressure side of the turbine.

Synchronous response motion (d) = unbalanced force/(spring stiffness + Damping stiffness + Mass stiffness). Here in this case the response is dependent on residual unbalance force.

Fluctuation in Extraction and Bleed flow leads to high vibration in the turbine. By putting TTD on the Grid Bus the overloading on the turbine, whenever there is grid failure, is eliminated and so is the turbine triping due to vibration Hi-Hi. Due to Silica deposition the nozzle box pressure was 44Kg/sq cm and the HP actuator value opening at 7.5 MW was more than 90%. After wet cleaning the nozzle box pressure came down to 33Kg/sqcm and HP actuator valve opening to 78% at 8.9 MW load. This means load had also been increased from 7.5MW to 8.9MW. For the same load i.e. 7.5MW nozzle box pressure is 28 Kg/sqcm and HP actuator valve opening is 65%.

The new problem arose after wet cleaning for which study was done and it was found that due to self excited vibrations the turbine rotor is under instability condition due to which turbine was tripping above 6 MW load whenever bleed was taken in line. It was also brought into notice that this might be because of uneven silica removal from the turbine blades and the nozzle box. Slowly and gradually we started increasing the load on the turbine and we reached up to 8.9 MW. The vibration levels were still more than 70 micrometer pp in turbine shaft front and rear bearing. The Lube oil temp and pressure was adjusted and the fluctuation in vibrations were controlled. Sand Blasting was done after seven months and the results were positive, the vibration levels came down to less than 45 micrometer pp at 8.9 MW and the load on the turbine could be increased upto 9.4 MW (designed load) and turbine was run on that load for some time.

CONCLUSION

If any one of the parameters in the turbine deflects from nominal ranges, it leads to instability of the turbine rotor shaft, which ultimately leads to vibrations in the shaft and protection relay operates. These vibrations may be due to more cleraness between the shaft and the bearing, Lube oil film thickness, Pressure and temperature of lube oil, Steam churning due to two different pressure and temperature steam mixing, self excited vibrations as known by intermittent sub synchronous frequency component of the order of 0.278-0.28x and the location may be gland seal area, inter stage labyrinth seal area in the high pressure zone, overloading of the turbine due to grid side failure. Even if live steam temperature and pressure fluctuates, then there is increase in vibration level. Wet cleaning and there after sand blasting is a good method for removal of impurities which leads to increase in the loading on turbine with reduction in vibration levels. It is very important to keep dryness fraction of the steam between 0.85-0.95 for wet cleaning.

REFERENCES

1. Muszynska, A., Whirl and Whip-Rotor bearing stability problems. Journal of sound and vibration, 110 1986.
2. Bently, D.E., Dynamic instability of seals and Bearings. ERPI Pump Sympo, 2-4 June 1982, Cherry Hill, New Jersey, USA.
3. Cleaning of turbine interior, Operational & Maintenance Manual - ABB.