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Vibration Monitoring Experiment for Annual Rotor Balance and Shaft Alignment of Turbo Generators for Healthy Operating Conditions

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ABSTRACT

Strength consideration of concrete with ages has influence sourcing for suitable materials, which can be added to concrete in small quantities without leaving adverse effect on the properties of fresh and hardened concrete. This project examines the possibility of using limestone as an additive, replacing fine aggregate in small quantity in concrete production. The experiment includes sieve analysis which gives a well graded fine aggregate, slump test, compression test, and water absorption rate. The slump result gives a less workable concrete on the addition of limestone in concrete while the water absorption rate of concrete increases on the addition of limestone in concrete mix. The strength attained after 7 and 28 curing days shows that, limestone can be added to concrete in 5% to 10% replacement of sharp sand, in which there is tendency to achieve higher strength with age.

Keywords: *Eccentricity, Proximity probes, Shaft speed, Transducers, Vibration amplitude*

1. INTRODUCTION

The purpose of vibration monitoring is to establish objectively and scientifically the running condition of machinery. This has been widely used in Canada and United States but generally under-utilize in developing countries. Companies that use vibration monitoring have many advantages such as less downtime, less spare parts inventory, better management time allocation, less overhaul-overkill, longer production runs and better quality [16,17].

Off-set in the eccentricity of turbine shaft during operation causes erratic noise that necessitates vibration monitoring analysis of shaft centre line to prevent overheating of the rotor to stator contact. Vibration monitoring improves the health status and performance of turbo generators, reduces the risk of disastrous machine damage, lessen unscheduled outages via early failure warning alerts thereby improve production throughput of power generation and allow a modern condition-based maintenance approach. Investments in on-line monitoring offer a marked reduction in the cost of operating and maintaining the overall process facility [6].

Vibration monitoring has been employed effectively to detect mechanical defects in rotating machinery. Most experiments have been performed in the detection mode and diagnosis mode to determine the operating and mechanical condition of machinery. Practical machinery vibration analysis has been used predict maintenance technique that identifies improper maintenance or repair practices; high temperatures, speeds or loads for improved equipment repairs and reliability[2]. Vibration measurement is rather rigorous non-destructive method to monitor machine conditions during start-ups, shutdowns and normal operations. Vibration analysis system usually consists of four basic parts: the signal pick up(s) or a transducer; signal analyzer; analysis software; and a computer for data analysis and storage

Experiments have mostly been carried out with transducers velocity pickups, accelerometers and eddy current or proximity probes for vibration analysis[16]. Handheld vibration meters and analyzers, portable data collectors/analyzers and permanent online data acquisition has been used to measure vibration. Most vibration data captured using transducers are converted into electrical signal processed with collectors /analyzers and transformed to electrical signals of its components. Two types raw signals (time wave form and face reference) are emitted from machines.

Machinery vibration monitoring and analysis are fundamental to predictive maintenance and continuous plant improvement. Since all operating machines vibrate, it is possible to gain information about a machine's condition by monitoring vibration levels. The overall level of vibration indicates the general condition of the machine. Increase in vibration is always accompaniedd by deterioration in running conditions. The principle of monitoring the health of plant machinery involves the determination of the cause of vibration such as unbalance, misalignment, or bearing defects [6].

Today portable data collectors and online monitoring systems are used to gather data from hundreds or thousands of points to allow computer analysis of equipment health. Ideally, this information could be integrated via a computerized maintenance management system or an enterprise asset management system with other asset health data for an overall picture of total plant and operations equipment condition. With expanded use of the Internet and access to wireless technology, remote monitoring of machinery and data transmission is getting easier and quicker. All segments of an organization, including operations and management, can share information and access data [16].

A financial analysis is imperative, noted Nelson Watson of Watson Engineering, Inc. He added, "Take the time and effort to perform an economic justification for the new investments. The investment must be cost effective and meet company return on investment requirements (ROI)". A good monitoring system has the potential to save organization considerable money as well as optimize equipment operation. He urged managers to identify all costs associated with all maintenance functions, especially repairs and/or breakdowns; the items required to maintain an

inventory to replace broken or failed equipment; and the effect of mechanical/electrical failure on production rates or increased scrap rates to determine the cost and product cost margins. This is a lot of paper work, but it is extremely necessary to justify the added expense of new equipment or consulting services[16].
Vibration analyzers are now available offering over 100,000 lines of resolution allowing better detection of machinery faults. These tools have built-in features to help the user decipher different machinery problems within the field machinery fault frequencies, bearing frequencies, and alarm levels. Software programs are now more users friendly and assist in the analysis of data," offered Greg Lee of Ludeca Inc. [4]
In 1992, CIGRE presented Benchmark model for the analysis of torsion oscillations in the turbo generator shaft set. A rather tedious mathematical model was used to compute torsion oscillations of turbine shaft represented by several concentrated rotating masses [8,9,11,13]. The level of accuracy required is ± 0.1 mm outside the stern tube bearing and ± 0.05 mm within the stern tube bearing. This level of accuracy has not been achieved.

2. MATERIALS AND METHOD

The equipment and materials used for vibration monitoring experiment consists of:

i. A hydro turbine condition monitoring test rig was attached with Data Flow PCM 360 System, DAQ Card 6220 on unit 411G3 turbo generator at the Shiroro Hydro power station as shown in Plate.1.
ii. Transducers TM0110/120/60; Proximity probes TMO 180 (X, Y) for shaft radial vibration and shaft axial position phase reference were installed.
iii. Monitors PT2060/10/20/31/35/40/43/53/91/96/98/90;
iv. Velocity sensor TMO 79 (which operates on principle of magnetism to give out electrical signals relative to the speed of vibration).
v. Accelerometer Sensor TMO 793 coupled with Air Gap Sensor for partial discharge forms the experimental setup/ procedure to monitor the vibration of turbo generators.
vi. Controlled frequency Transmitter Monitor- DTM10/DTM120/DTM96/99 excited the blade vibration to measure the shaft twisting and blade bending respectively.
vii. Light detector (photodiode/phototransistor); Red light emitting diode (LED) ; 2 x 1.5V batteries in battery holder (to power LED); Optical fiber connectors (SMA 905 multimode type connectors); and Fast-curing adhesive..
viii. Special service tool box containing set of Allen keys, hammers, spanners and screw-drives.
ix. Safety gadgets – overall, safety boot, hand gloves and nose fume protector gloves.

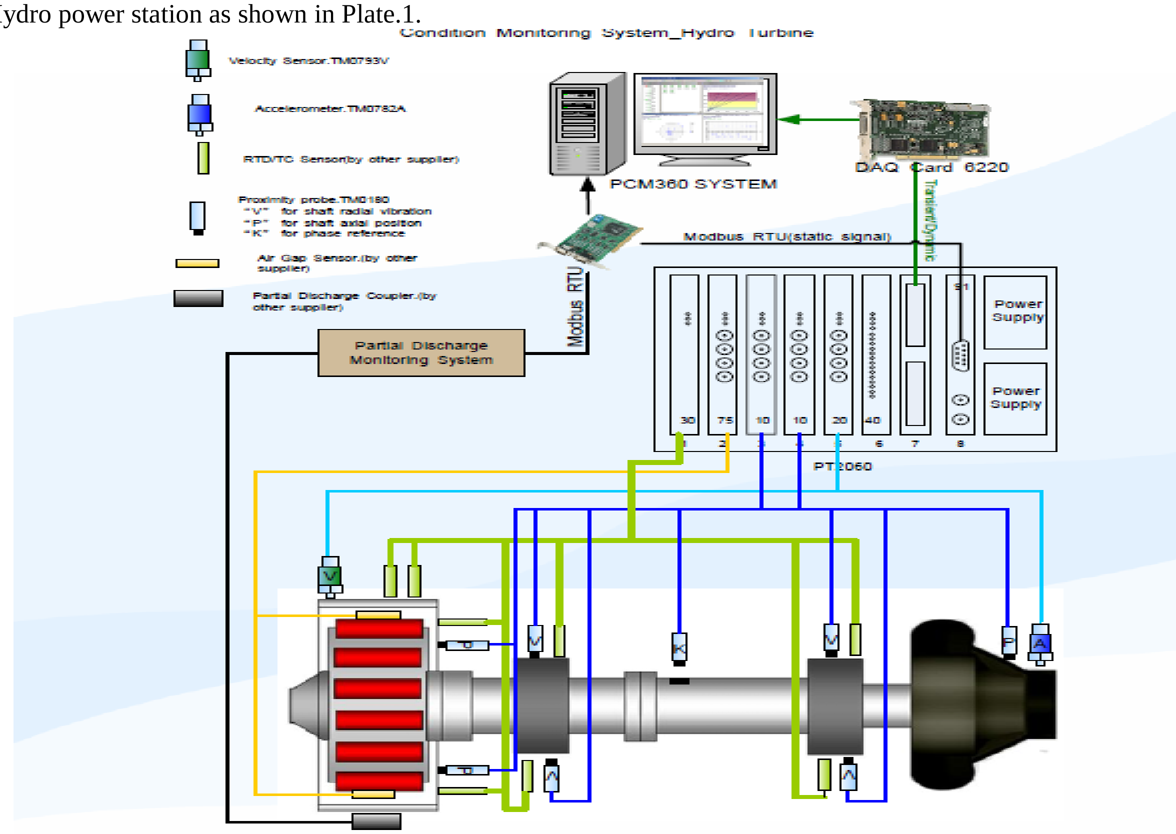

Figure 1: Procedures/ Experimental Setup for Condition Monitoring

II. Vibration Measurement Method

i. ***Shaft X, Y Vibration (Radial Vibration):*** Proximity probe TM0105 (5mm) and TM0180 (8mm) were mounted inside the machine by probe clamp to measuree rradial vibration. TM0393X was used to adjust the penetration depth ±13mm (0.512") for shaft dynamic motion at normal pressure or high pressure.
ii. ***Thrust Position (Axial Position):*** Proximity probes TM0110 (11mm) and TM0180 (8mm) were used to measure the movement of shaft in the axial direction with respect to a fixed reference (thrust bearing support

structure or casing member to which the displacement probe is mounted).

iii. ***Seismic Vibration (Casing Vibration):*** The absolute vibration of machine case or structure was measured with accelerometers sensor TMO 793 and velocity sensor TMO 793 and indicated by PK or PK-PK or RMS installed horizontally or vertically.

iv. ***Rotation Speed:*** Velocity Sensor TMO 793 that operates on the principle of electromagnetism was used to measure rotor speed during normal machine operating conditions as well as during start-up and shut down. The signal output caused by the excitation of inductive coil of a magnetic speed sensor measures the level and speed of shaft rotation.

v. ***Over Speed:*** Proximity probes TM0110 (11mm) and TM0180 (8mm) were used to form over speed protection system mandatory for critical machines due to high speed of rotation the turbine shaft.

vi. ***Reverse Rotation:*** Proximity probes TM0105 (5mm) and TM0180 (8mm) were mounted on the gear or shaft with a notch to monitor the Reverse Rotation. Reverse flow causes stoppage of water supply that absolutely results in bearing overheating and total machine shutdown.

vii. ***Zero Speed:*** Velocity Sensor TMO 793 was used to monitor Zero Speed in order to trip the machine operation when it rotates too slowly than it should be.

viii. ***Phase Reference:*** Proximity probe, magnetic pickup and optical pickup were used for measuring phase rreference. Transducers TM0 602 produced a voltage pulse for each turn of the shaft. This signal measures shaft relative speed and serves as a reference for measuring vibration phase lag angle.

ix. ***Differential Expansion:*** Differential expansion was measured with proximity probe transducer mounted to the machine casing when machine start-up and shutdown as the machine has a big thermal expansion during that period.

x. ***Case Expansion:*** LVDT (Linear Variable Differential Transformer) was used to measure changes in casing axial position which are the result of thermal expansion and contraction of the casing during start-up and shutdown.

xi. ***Eccentricity:*** The deviation of the rotor physical centre and the theoretical centre was measured with PT2060/10 proximity module. The eccentricity measured valves were used to set shaft alignment for a good combination of slow rolling and heating effect of the rotor to stator contact.

xii. ***Valve Position:*** Air Gap Sensor was used to measure the position of the process inlet valves on a machine and expressed as a percentage of the valve opening; zero percent is fully closed, 100 percent is fully open.

xiii. ***Temperature:*** Controlled frequency transmitter (DTM 96/99) was used to acquire process signal for ttemperature measurement which was recorded to form an important parameter for monitoring the health status of the turbo generator.

xiv. ***Flow Rate, Pressure and other process variables:*** Data Flow-PCM360 system was employed to obtain control feedback and process signals transmitted to condition monitoring system to determine the health status of the turbo generator.

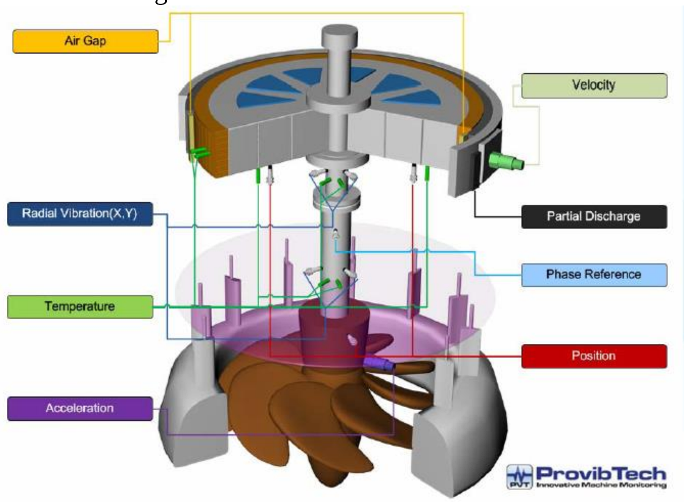

Figure 2 Vibration Measurement Points for Hydro Turbine

3. RESULTS AND DISCUSSION

The result of vibration experiment conducted is presented in table 1.

Table **1** Vibration Amplitude (in Frequency Domain)

Motor Drive and Non Drive End Bearing (Vertical)	**50 Hz**	**100Hz**	**195Hz**
Acceleration[mm/s^2]	2.6	0.5	0.7
Velocity [mm/s]	7	0.7	0.6
Displacement[nm]	24.4	1.7	1.0
Pump Outboard Bearing Next to The Coupling (Horizontal)	**50 Hz**	**100Hz**	**195Hz**
Acceleration[mm/s^2]	0.1	1.18	0.9
Velocity [mm/s]	0.5	1.75	0.8
Displacement[nm]	1.3	2.7	0.65
Pump Outboard Bearing Away from The Coupling (Axial)	**50 Hz**	**100Hz**	**195Hz**
Acceleration[mm/s^2]	2.5	0.75	1.85
Velocity [mm/s]	7.5	1.2	1.65
Displacement[nm]	2.5.5	0.35	0.15

The natural frequencies of the turbine shaft rotation speed with blade vibrations were registered in vertical, horizontal and axial planes with three measuring points at positions 1 - motor drive and non-drive end bearing, 2- pump outboard bearing next to the coupling, and 3 -pump outboard bearing away from the coupling as shown in table 1. The blade bending vibration displacement at 50Hz appeared dominant 24.4nm and 25.5 nm for vertical position - 1 and axial position- 3 but as low as 1.3nm for horizontal position -2. The amplitudes at 100Hz for horizontal position was high 2.7 nm and drops to as low as 0.65 nm implying in the shaft torsional vibration signals for all blade vibration frequencies undulates from 50Hz and 195Hz. For frequencies higher than 60 Hz, less of the torsional vibration to the blade vibration was observed for acceleration and velocity measurement at all positions

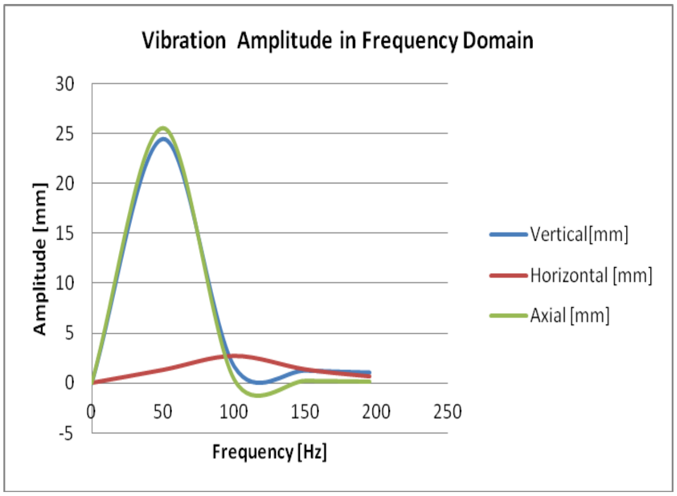

Figure 1 Vibration Graphical Spectrums

The mode of shapes was determined from the measured amplitudes and the phase response spectra were plotted graphically. The comparative vibration spectra planes reveal isotropic behaviour of shaft line as shown in figure 1. From the results that are presented table 1 more heat was generated at the turbo generator upper guide bearing. This is the worst vibration regime where displacement was 25.5 nm at 50 Hz. The heat generated at the bearing was less at the horizontal position where the vibration displacement level was considerably low as 1.3 nm at 50 Hz implying lower heat generation at the bearing.

4. CONCLUSION

Vibration analysis carried out was used to prevent shaft mis-alignment and unbalanced conditions that cause bearing defect. Off-set in the eccentricity of turbine shaft in Unit 411 G…3 during operation as result of slacked bolts causes erratic noise. Thrust and seismic casing vibration show loose and damage parts required to be replaced. Alignment of shaft centre line prevents heating of the rotor to stator contact. Valve position setting ensures control feedback and process signals transmission for monitoring health status of the turbo generator. Vibration monitoring improves the safety and performance of turbo generators, reduces the risk of disastrous machine damage, lessen unscheduled outages via early failure warning alerts thereby improve production throughput of power generation and allow a modern condition-based maintenance approach. Investments in on-line monitoring offer a marked reduction in the cost of operating and maintaining the overall process facility. Good custom system presents advantages such as less down time, less spare part inventary, better time allocation, less overhaul, longer production runs with better quality. Electromagnetic disturbances recorded in 3-pole short circuit were presented for comparison with the vibration acceleration, velocity and displacement. *Alert, Alarm and Trip* vibration levels fitted in turbo generator online-condition monitoring system can be used to enhance the machinery health.

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