TURBINE TIPS
Pond And Lucier
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Turbine/Generator Vibrations: A Good or Bad Thing?

Subject: Measuring and Interpreting Vibration Data

Applies to: General Electric gas turbines. Example used herein is the MS5001 gas turbine/generator.

Overview:

Rotating machinery, like gas turbines and generators, are expected to vibrate during normal operation. It is unavoidable and perhaps even desirable to have rotating components vibrate within acceptable limits. However, a question that is frequently asked is: How much vibration is too much? Well, it depends. The fact that sometimes rotating machinery vibrates excessively is the machine's way of alerting you that ***something is wrong!*** That is a good thing.

General Electric, like most gas turbine manufacturers, sets vibration limits for its products. Factory-mounted vibration pickups (seismic, casing or bearing mounted devices) are typically used. The output signals (raw, unfiltered) are sent to panel-mounted devices with limits to ALARM and TRIP the plant if excessive. Typical limits are **__ inch per second (peak)** for **ALARM** and **1.0 inch per second (peak)** for **TRIP**. Other limits are sometimes chosen (usually lower settings), depending upon the circumstances and desires of the client.

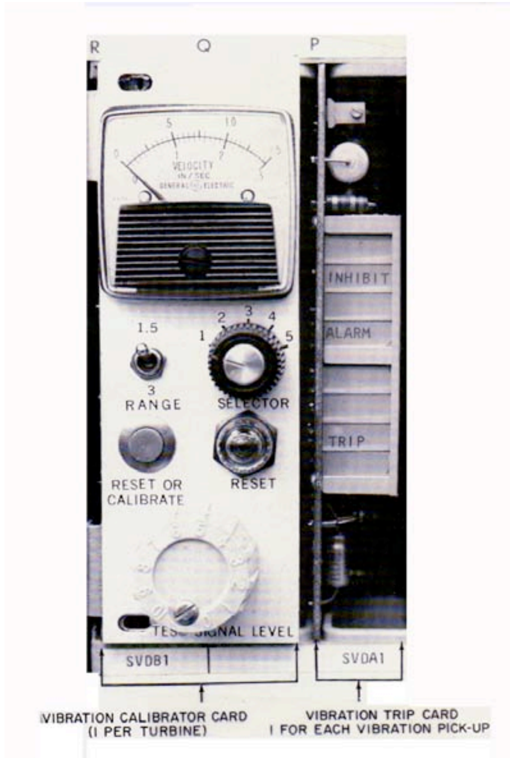

Fig. 1: Typical Panel-mounted Vibration Meter

Plant operators and field engineers often have trouble "interpreting" vibration data. That is, one might ask: "What does an inch per second mean?" The units of measurement in ***velocity*** (or the rate of change of displacement) are rather vague to most plant personnel. Since a turbine vibrating in the range of ***ONE INCH*** of displacement is unrealistic, why read the data in these units? A good question.

The rate of change of ***displacement*** is called ***velocity***. If a rotating shaft is vibrating at .005 thousandths of an inch (peak-to-peak) and the shaft is turning at 3,600 revolutions per minute (rpm), the ***velocity*** of the vibration component will be approximately 1.0 inches per second (peak). ***Note***: Displacement of .005 inches is sometimes called 5 mils.

Assume we are looking at a **GE MS5001**, single-shaft gas turbine driving a 2-pole AC generator through a speed reduction gear (a.k.a. load gear). The gas turbine will operate at approximately 5100 rpm and the generator at 3600 rpm when at 100% speed. Should a high vibration be experienced at the reduction gear, for instance, one might expect to have a frequency of either 5100 cycles per minute (cpm), if it were caused by the gas turbine or the high-speed pinion. On the other hand, if the low speed, bull gear or the generator rotor were vibrating, the primary frequency might be 3600 cpm. The ***first harmonic*** of vibration is sometimes called the ***1 per revolution***, abbreviated ***1/rev.*** Shaft mechanical **unbalance** often manifests itself at a frequency of ***1/rev***. In the case of the MS5001 gas turbine, when checking vibration levels at the reduction gear, you can expect to record two primary frequencies: 5100 cpm and 3600 cpm. ***Misalignment*** and bearing ***looseness*** often reveals itself at 2/rev. ***Oil whip*** is a phenomenon that often occurs at sub-harmonic frequencies like _ per rev.

> ***Note***: Some vibration analyzers have tuning filter systems that read vibrations in cycles per second (cps). Refer to the chart below.

Shaft Speed (rpm)	Frequency of first harmonic (cycles per minute, cpm)	Frequency of First Harmonic (cycles per second, cps)	Vibration Limit (inches per second, peak)	Vibration Limit (mils, p-p)
3600 rpm	3600 cpm	60 cps	1.0 ips	5.0 mils
5100 rpm	5100 cpm	85 cps	1.0 ips	3.0 mils

Both shafts have a trip limit of 1.0 ips. However, the vibration limit for the turbine operating at 5100 rpm is 3.0 mils, whereas the driven generator operating at 3600 rpm has a limit is 5.0 mils.

Filtered vibration signals of pure, sinusoidal wave shapes have four characteristic quantities:

- Displacement (mils)
- Velocity (inches per second)
- Acceleration (g = acceleration of gravity)
- Frequency (cpm)

A typical vibration detector mounted on a bearing housing or turbine casing is shown below. It is installed to read the vertical vibration on the stationary housing or casing. No horizontal motion can be detected. The output signal will be an AC voltage, which is proportional to the ***velocity*** of the vibration signal.

Fig. 2: Vertically mounted Velocity (seismic) Pickup

A vibration detector shown below is mounted in a "side saddle" position. Since it detects vibration along the axis of the detector, if there is some vertical or horizontal vibration it will detect it. Velocity pickups have small internal masses suspended by leaf springs at each end. The direction of vibration is in an axial direction.

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Fig. 3: Vibration Detector mounted "side saddle" on a Generator Bearing Pedestal

A useful vibration analyzer for work on gas turbines and generators is shown below. The brand name is an IRD Mechanalysis, Inc, model **IRD-320**. It comes with a velocity pickup, probe extension, cable and optional magnetic base. The latter allows for mounting the velocity pickup on a bearing housing or turbine casing, which is particularly useful in hazardous (hot) environments.

Fig. 4: IRD-320 Vibration Analyzer

A close-up of the hand-held **IRD-320** is shown below. It shows an amplitude meter on the upper left and frequency meter on the upper right. Selector switches are on the lower left and a tuning filter is on the lower right. This is a handy tool for determining the severity of a vibration signal (amplitude in mils or ips) and the frequency of the signal (cycles per minute, cpm). By tuning the filter, you can often identify the ***frequency*** of the vibration, which by harmonics, is often directly linked to the shaft causing the problem. There are many ranges for selection of the tuner and vibration amplitude. There is a selector switch on the rear for choosing displacement (mils) or velocity (ips).

Fig. 5: Close-up of IRD-320 control panel

Vibration analysis and balancing are best left to experts. However, determining the likely cause is something that power plant owners should be comfortable doing.

If you should be experiencing a vibration problem on a GE gas turbine or generator, please feel free to contact ***Pond And Lucier, LLC.*** We will dispatch a field engineer to your site with an **IRD-320** to confirm your problem. If further analysis or balancing is required, we may need to call in an expert from our affiliate company: ***TAB Services*** out of San Antonio, TX.