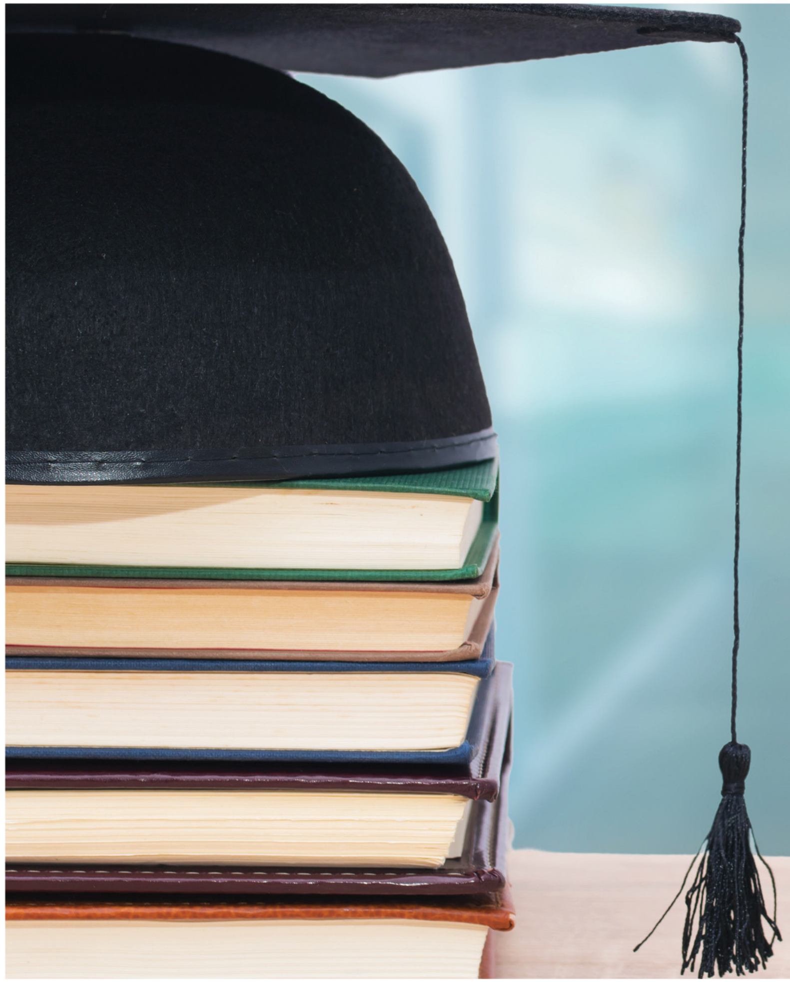
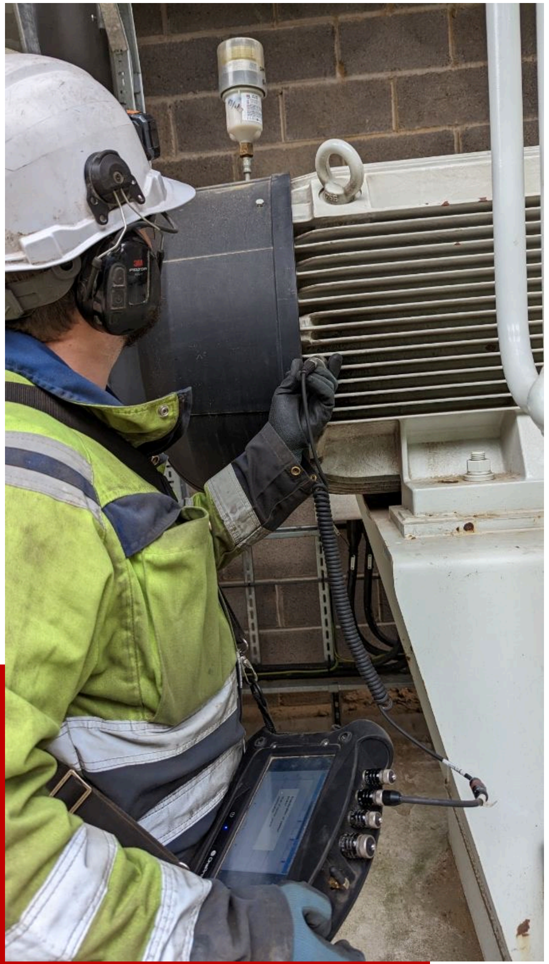


CTC UNIVERSITY

LEVEL 2, LESSON 3

MONITORING MACHINERY VIBRATION USING DYNAMIC AND PROCESS CONTROL SIGNALS

Introduction



Welcome to **Level 2, Lesson 3 – Monitoring Machinery Vibration Using Dynamic And Process Control Signals**, part of CTC's free online vibration analysis training series.

We hope you enjoyed and benefitted from the previous course and will continue to build your vibration analysis knowledge as you progress through Level 2.

Training Objectives

This training will focus on the following concepts:

Dynamic Signal

Process Signal

Upon completion of this lesson, you will:

1. *Understand the difference between a dynamic signal and a process signal*
2. *Understand the strengths and limitations of each type of signal*
3. *Understand how to use dynamic signal and process control signal together in some instances to offer an optimal level of protection for critical machinery*

Traditional Vibration Monitoring

Traditionally, industry has been monitoring machinery vibration with various specialized vibration analyzers. The most widely used systems are designed to trend the vibration levels of various critical capital equipment.

Typically, a vibration sensor sends a dynamic signal (an mV output of the time waveform) to the analyzer. The analyzer can then convert the time waveform into an FFT which displays the amplitudes of the individual frequencies which make up the complex time waveform.

A trained analyst can study the FFT and time waveform trends to determine what types of problems a piece of machinery might be experiencing and further identify the root cause of such problems.

Vibration analysis systems typically take the form of online monitoring systems which continually poll a series of measurement points; **or portable data collectors** which can be used for periodic measurements. Either type of equipment can be very effective for analysts to trend vibration levels, set alarms and monitor a wide range of faults on a wide range of applications.

Vibration Monitoring – Traditional Methods For Vibration Alarms

Several methods have been used to establish vibration alarms. At their most basic, **all methods attempt to establish a baseline at which a piece of machinery operates in a normal or healthy state**.

Analysts will typically set two alarm levels (although some utilize more) at some level of increased vibration over this normal state. The alarms are designed to alert an analyst or end user to a potential problem with the machinery.

A yellow alarm *is the first alarm that warns analysts or end users that vibration levels have increased and in-depth analysis of the machine is in order.*

A red alarm *is triggered at higher vibration levels, indicating catastrophic failure is a serious near-term threat. Sometimes red alarm levels can trigger an automatic or manual machine shutdown.*

Vibration Monitoring – Typical Alarm Methods

Some examples of typical alarm methods are:

Trending

Overall or peak values, or the crest factor

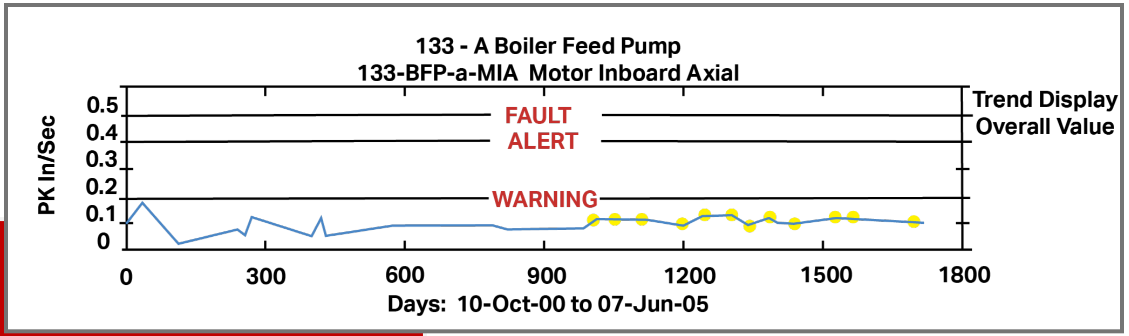
Time Waveform Values

Peak, or peak to peak

FFT Monitoring

Masking, banding, or enveloping

Vibration Monitoring – Trending



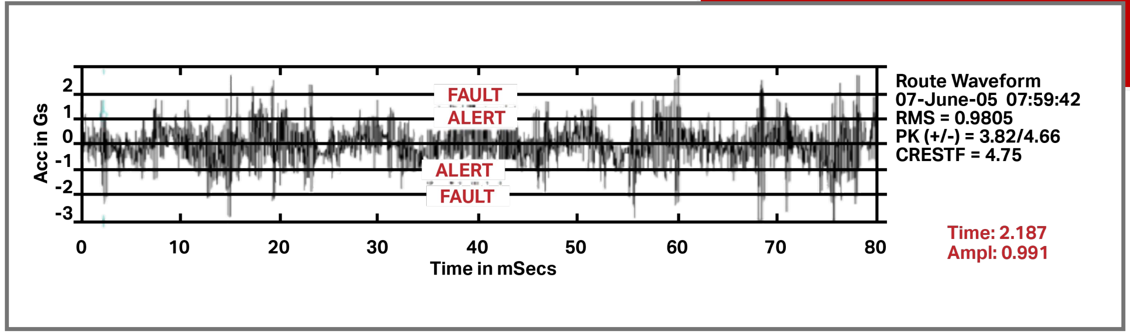
- In this trend display, the overall value has been recorded over a period of 5 years.
- Warning, alert, and fault alarms were set but never exceeded.
- The peak value or crest factor could also have been trended.
- Trending alarms based on overall, peak, or crest factor are very useful for alarming for a general vibration level.
- It is important to keep in mind that **an individual fault frequency could be overshadowed by the increase or decrease in amplitudes of other fault frequencies; or it could be ignored or disproportionately weighted** relative to other frequencies contributing to the trend value.

Vibration Monitoring – Time Waveform

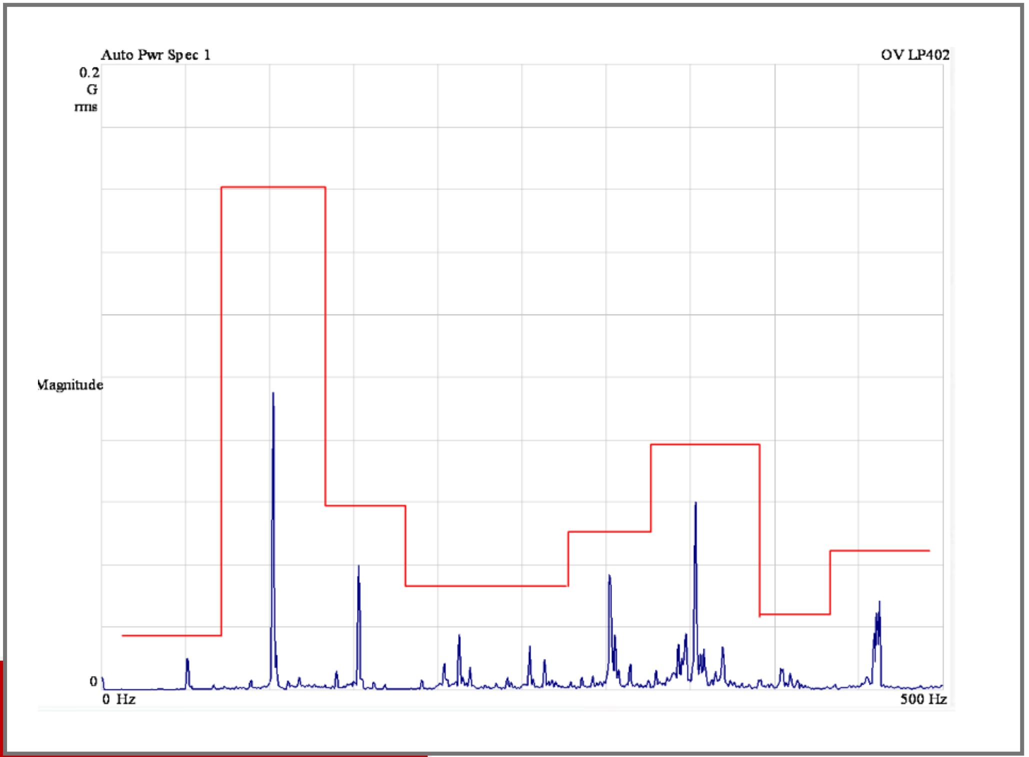
In this waveform, the Peak, or Peak to Peak values of the time waveform can be alarmed.

This is a much more instantaneous type of alarm, and the impacts in the time waveform are exceeding the alert and fault limits.

Again, a specific fault frequency which could indicate a bearing fault (for example) could be overshadowed by lower frequency, higher amplitude vibrations. This tends to be a **good alarm method for catching lower frequency transients and impacting**.



Vibration Monitoring – FFT



In this FFT, a process of Masking, Banding, or Enveloping specific frequency regions is being used.

This method **works very well when you want to have different alarm levels at different frequency ranges** so that you can monitor for specific faults.

Traditional Vibration Monitoring

Historically, online monitoring and portable data collection have required specialized vibration instrumentation.

However, in today's environment of Process Control, 4-20 mA current loops can be used with PLCs or DCS systems to generate vibration alarms, primarily using systems which many industrial plants already have on site.

Online Monitoring

Portable Data Collection

Traditional Concepts - Added Value Of Process Control

A process control signal (such as 4-20 mA) can assist traditional vibration analysis in protecting:

- **Critical applications**
- **Applications which can fail quickly**
- **Applications that can fail dramatically**
- **Applications which are remote, or where no operators can monitor the machinery**

The PLC or DCS can constantly monitor for catastrophic failure and alarm analysts for potential problems.

This allows analysts to spend more time on analysis and less time putting out fires, or worrying about a catastrophic failure due to operator error or environmental issues between route measurements.

Process Control –
For PLCs Or DCS Systems

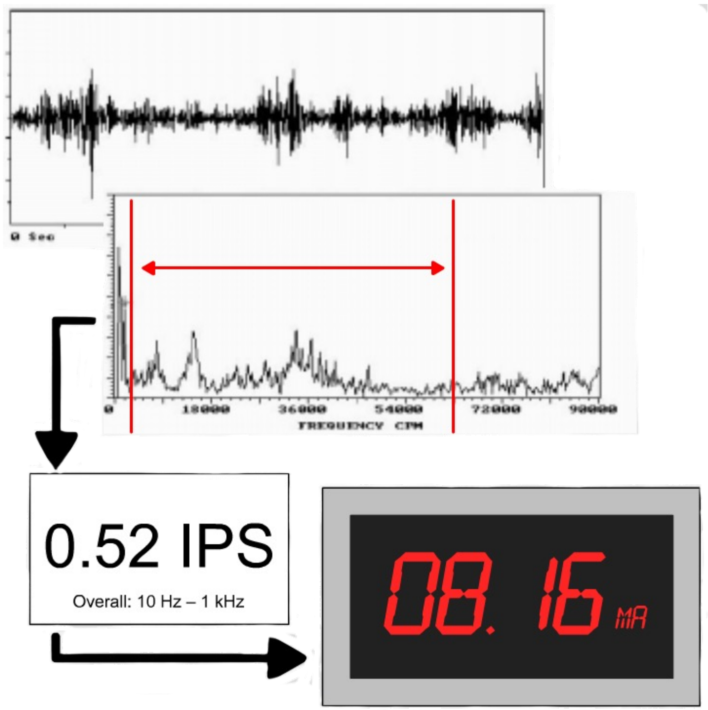
The 4-20 mA signal can be provided to the PLC or DCS by any of the following methods:

4-20 mA Loop Power Sensors

Dual Output 4-20 mA Loop Power Sensors that provide 4-20 mA and temperature output

Transmitters which convert or conditions a standard mV (dynamic) signal to an mA signal

Traditional Concepts – How Does It Work?



The loop power (4-20 mA) sensor or transmitter generates a current signal which is scaled to the maximum load (the highest vibration level the user would plan to alarm for) and is represented by a 20 mA output.

An output of 4 mA represents no load (no vibration).

It is important to understand that the **overall 4-20 A signal output is proportional to the overall amplitude generated with a defined frequency band**.

Therefore, the signal does not include data from frequencies outside the frequency band and includes all vibration (critical faults and non-critical) within that band.

Process Control – Process Scaling

- Scaling is an important factor to consider when specifying a loop power sensor.
- The scale (or measurement range) you choose should position the vibration levels at normal or healthy conditions at roughly 8 to 10 mA of output.
- This will allow you to establish alarm limits (for example) at 12 to 16 mA and shutdown limits at 18 to 20 mA.
- It is important that you remember that the **overall amplitude will be based on the frequency band you have selected for your sensor or transmitter**.

Process Control – Process Scaling

Gs or IPS (Input)	0.00	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
mm/s (Input)	0.00	6.4	12.7	19.1	25.4	31.7	38.1	44.4	50.8
mA Output	4	6	8	10	12	14	16	18	20
			Normal		Alarm			Shutdown	

This chart shows the scaled output for a 0 to 2 G or 0 to 2 IPS (50.8 mm/s) scale

Process Control – Process Scaling

In some cases, **a broader than normal scale may be desired** when a significant increase in vibration above normal can be tolerated before alarm and shutdown is required.

For example, your application might operate normally at 0.75 IPS and varying loads might make higher overall levels a normal occurrence that would not merit an alarm. Instead, alarms and shutdown might not be desired until 4.5 IPS.

Normal
= 0.75 IPS
= 6.40 mA

Shutdown
= 4.50 IPS
= 18.40 mA

IPS (Input)	0.00	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00
mA Output	4	6	8	10	12	14	16	18	20
		Normal					Alarm	Shutdown	

Process Control – Loop Power Sensor: 4-20 mA

Loop power sensors are normally available in **acceleration or velocity output**.

Acceleration output will give the higher frequencies more proportional value in the overall amplitude relative to a comparably specified sensor.

The acceleration or velocity units can be expressed as **Peak or RMS values**.

Generally, Peak will provide more info about transient variations, while RMS (which essentially averages the peaks) will give less attention to transients.

The **frequency ranges** for loop power sensors are generally available in two fixed bands, such as:

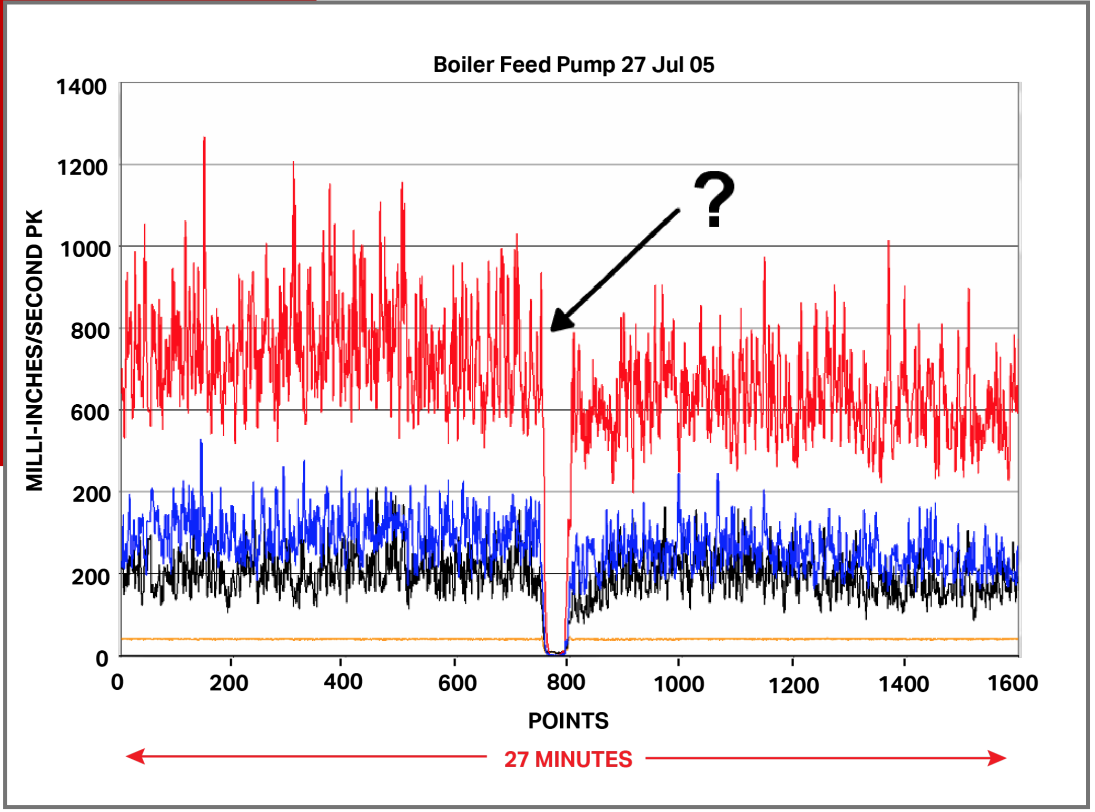
10-1,000 Hz (600-60,000 CPM)

3-2,500 Hz (180-150,000 CPM)

Loop power sensors are great for **trending and alarming the overall vibration**.

Just remember, that since there is no dynamic output from this sensor, there is also no time waveform or FFT, and therefor is not intended for diagnosing what the alarm might be caused by.

Process Control – Vibration Data



This chart shows a 27-minute trend of process vibration data from a 600 HP Boiler Feed Pump.

Initially, it looks as if the power failed on all four of the vibration sensors, creating the zero output in the center of the display.

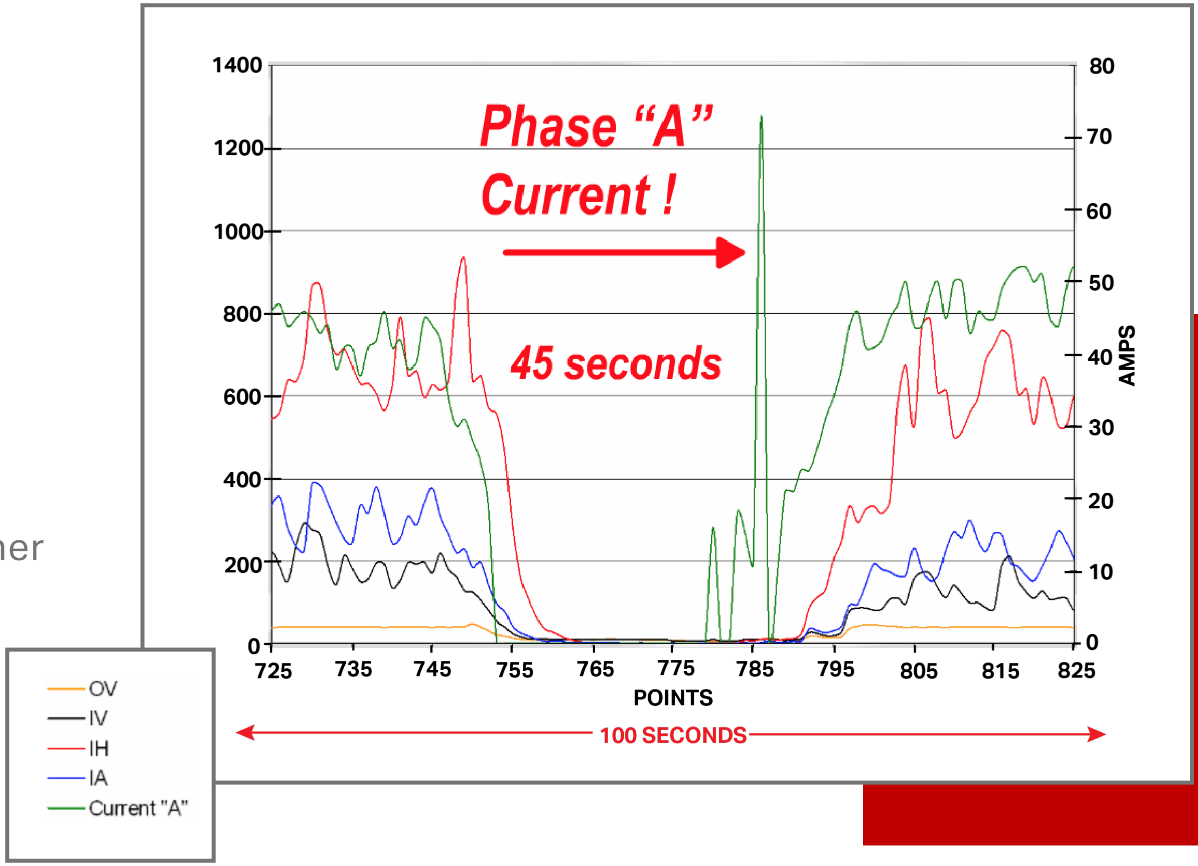
How can this be analyzed?

What do you think we should start looking for as a cause for the loss of data?

Could this be a powering issue with our PLC or sensors?

Process Control – Vibration Data With Motor Current

- Let's redisplay the data in a 100 second interval and add the motor current to the display.
- The motor current also went to zero.
- With the addition of other process control data, we can see that the motor, not the sensors, was accidently shut off for 45 seconds, and then turned back on.
- This could be a topic for coaching the end-user, rather than searching for power issues on the vibration sensors.
- **This is a good example of how process control data can help to paint a fuller picture.**



Blended Approach – Best Of Both Worlds

Dynamic vibration sensors paired with signal conditioners (vibration transmitters) provide a 4-20 mA output and a dynamic signal output. By utilizing both signals, companies have a solutions that gives the best of both worlds:

Continuous monitoring through the PLC or DCS system

Alarming for catastrophic failure through the PLC or DCS system

Diagnostic analysis and trending for specific fault frequencies via a dynamic signal analyzer

Convenient access to all data via permanently mounted sensors which speeds route collection and increases safety

Better use of analysts' time since they can spend less time trending perfectly healthy equipment and more time analyzing data

Team approach to protection and monitoring brings more resources to protecting machinery and plant health

Blended Approach – Dynamic Sensors And Transmitter

- The **dynamic signal** from a permanently mounted vibration sensor **can also be converted to a process control signal** by a vibration transmitter (or signal conditioner).
- The transmitter receives an mV signal from the sensor, then filters and scales the signal to a 4-20 mA output.
- The 4-20 mA signal can then be passed to a PLC or DCS where it can be monitored with other process control data.
- Transmitter systems also allow access to the dynamic signal so that analysts can trend specific fault frequencies or diagnose the cause of alarms.
- Most units offer a buffered output via a BNC on the face of the transmitter, as well as a pass-through via screw terminals so analysts can run the signal to a traditional switchbox.
- The larger size of the transmitter allows manufacturers to offer greater flexibility for filter options than standard loop power sensors.
- The ability for analysts to choose from a menu of high pass and low pass filters provides the opportunity to target alarms more accurately, rather than using less specific overall values.

Blended Approach – Dynamic Sensors And Transmitter

Standard sensors and vibration transmitters can also be configured with a local monitoring system to offer several options which are valuable in a variety of applications, making them an extremely versatile tool for vibration analysts and process control engineers.

These systems can include:

Relays
make it possible to shut down machinery in the event vibration levels exceed a user-defined level

Digital displays
of vibration levels in the scaled or actual value

Alarm options
visual or auditory, such as lights or sirens

Retransmission
of a process control signal to a PLC or DCS

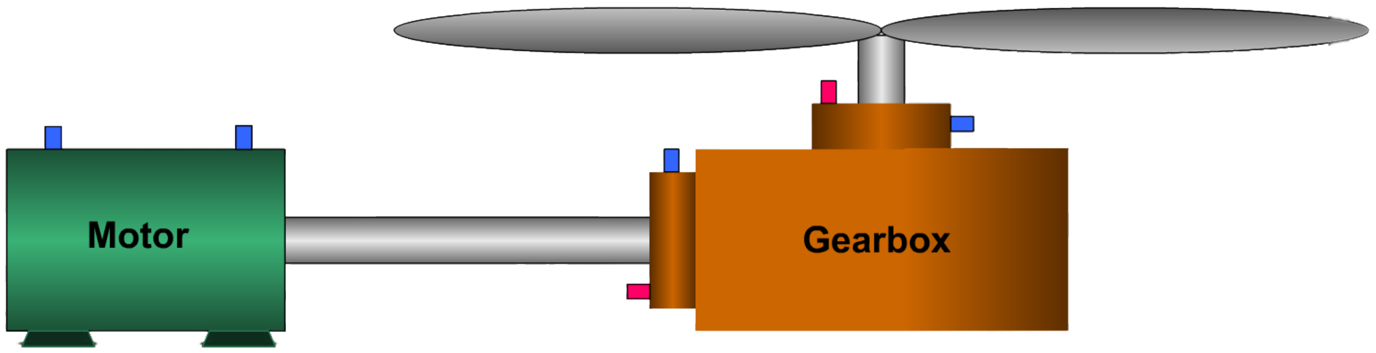
Blended Approach – Cooling Tower Application

A good example of protecting equipment or processes using diagnostic and process control signals is a cooling tower application where the gearbox has been the primary source of problems.

Dual output sensors (shown in red) are on the input and output shafts of the gearbox.

mV/g sensors (shown blue) on all the bearings.

This allows analysts to trend for bearing faults and alarm for imbalance or gear noise.



Process Control – Integration

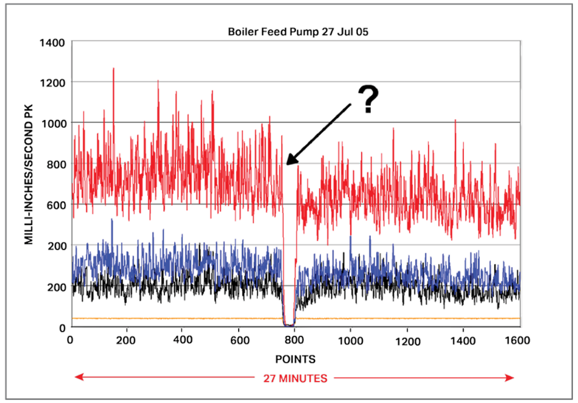
Remember, integrating dynamic vibration with process control can make a very successful program for monitoring your machines.

Dual Output Loop Power Sensors

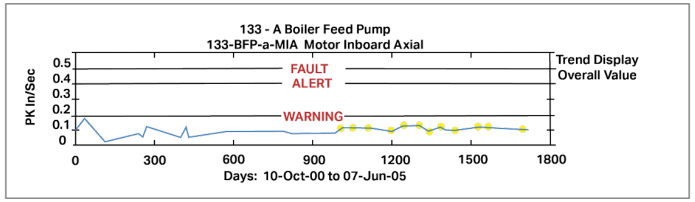
OR

Sensors and Transmitters

Dynamic Vibration



Process Control



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