CONNECTION TECHNOLOGY CENTER, INC.

LEVEL 2 – LESSON 3

MONITORING MACHINERY VIBRATION USING DYNAMIC AND PROCESS CONTROL SIGNALS

INTRODUCTION

Welcome to **Level 2, Lesson 3** of CTC's free online vibration analysis training. We're glad you have taken the time to view this self-paced lesson on monitoring machinery vibration using dynamic and process control signals. We hope you enjoy the training and will continue to build your vibration analysis knowledge as you progress through Level 2.

OBJECTIVES

After completing this training module you will understand:

- ❑ The difference between a **dynamic signal** and a **process control signal**
- ❑ The **strengths and limitations** of each type of signal
- ❑ 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** (**a 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**.

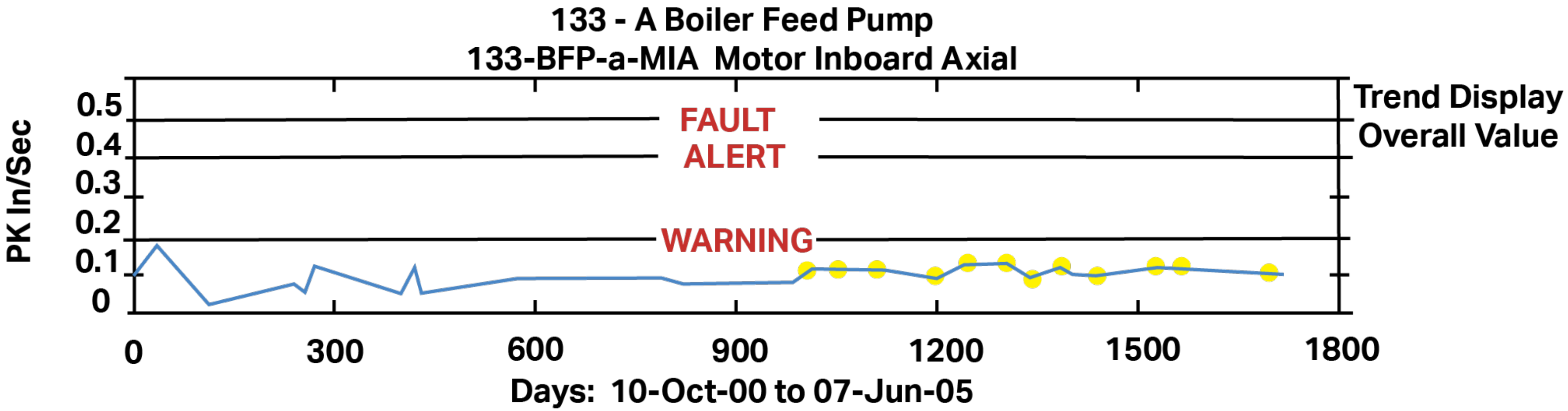
The first alarm, many times referred to as the "**yellow alarm**," would warn analysts or end users that vibration levels have increased and an in-depth analysis of machinery is in order. At higher vibration levels, typically a "**red alarm**" is triggered indicating that catastrophic failure is a serious near term threat. Sometimes red alarm levels can trigger either an automatic or manual shutdown of the machinery.

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

Overall Value, Peak Value, Crest Factor

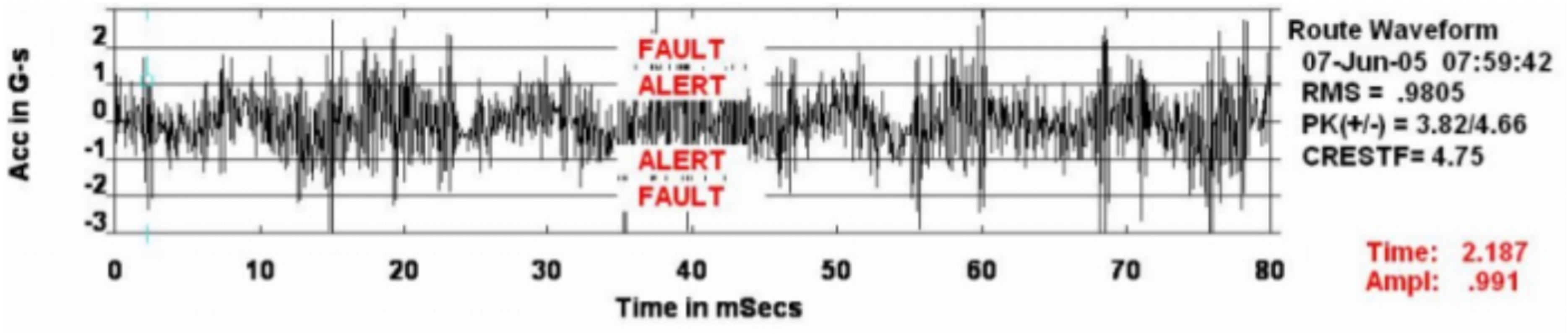


In this trend display, the **overall value** has been recorded over a period of 5 years. Warning, alert, and fault alarms were set, but never exceeded. You could have also trended the peak value or crest factor.

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

Peak, or Peak to Peak Values



In this time 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.

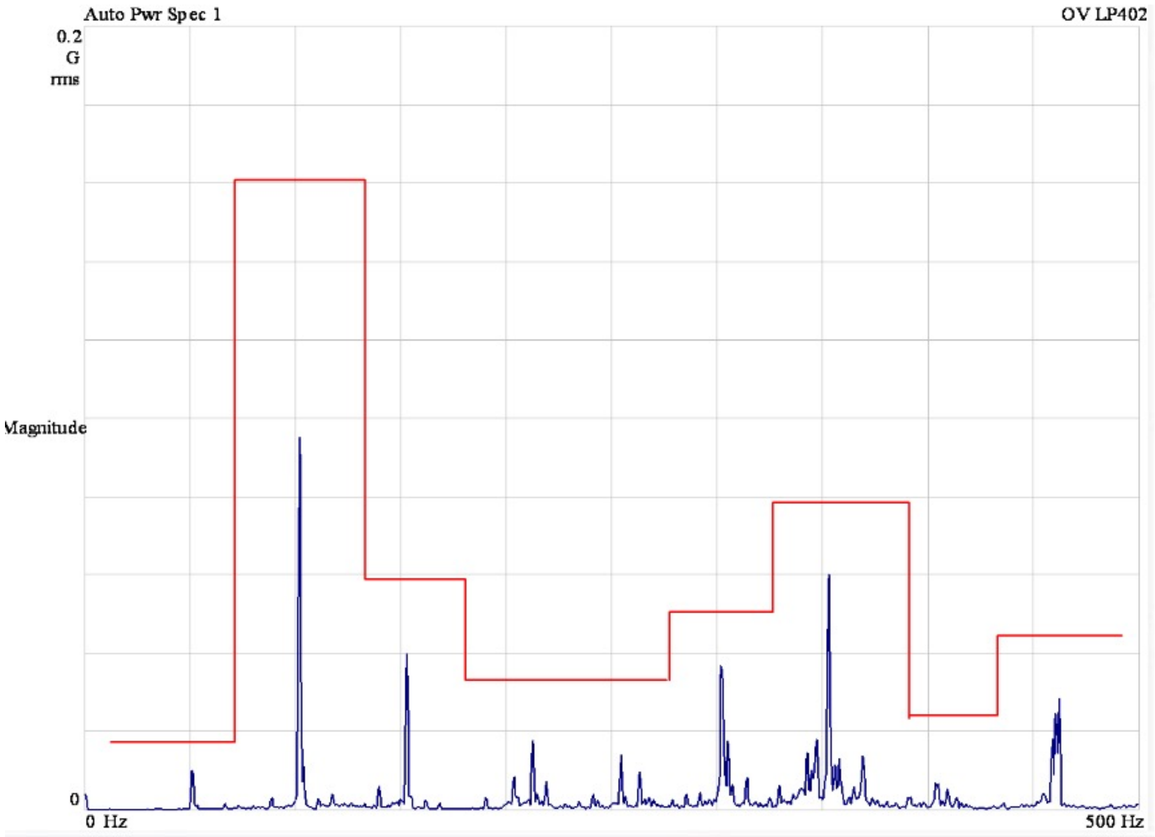
Again, a specific fault frequency which could indicate a bearing fault (for example) could be overshadowed by lower frequency, higher amplitude vibrations. This tends to be a good alarm method for catching lower frequency transients, and impacting.

VIBRATION MONITORING – FFT

Masking / Banding / Enveloping

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, these monitoring methods have required specialized vibration instrumentation.

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

TRADITIONAL CONCEPTS – ADDED VALUE OF PROCESS CONTROL

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

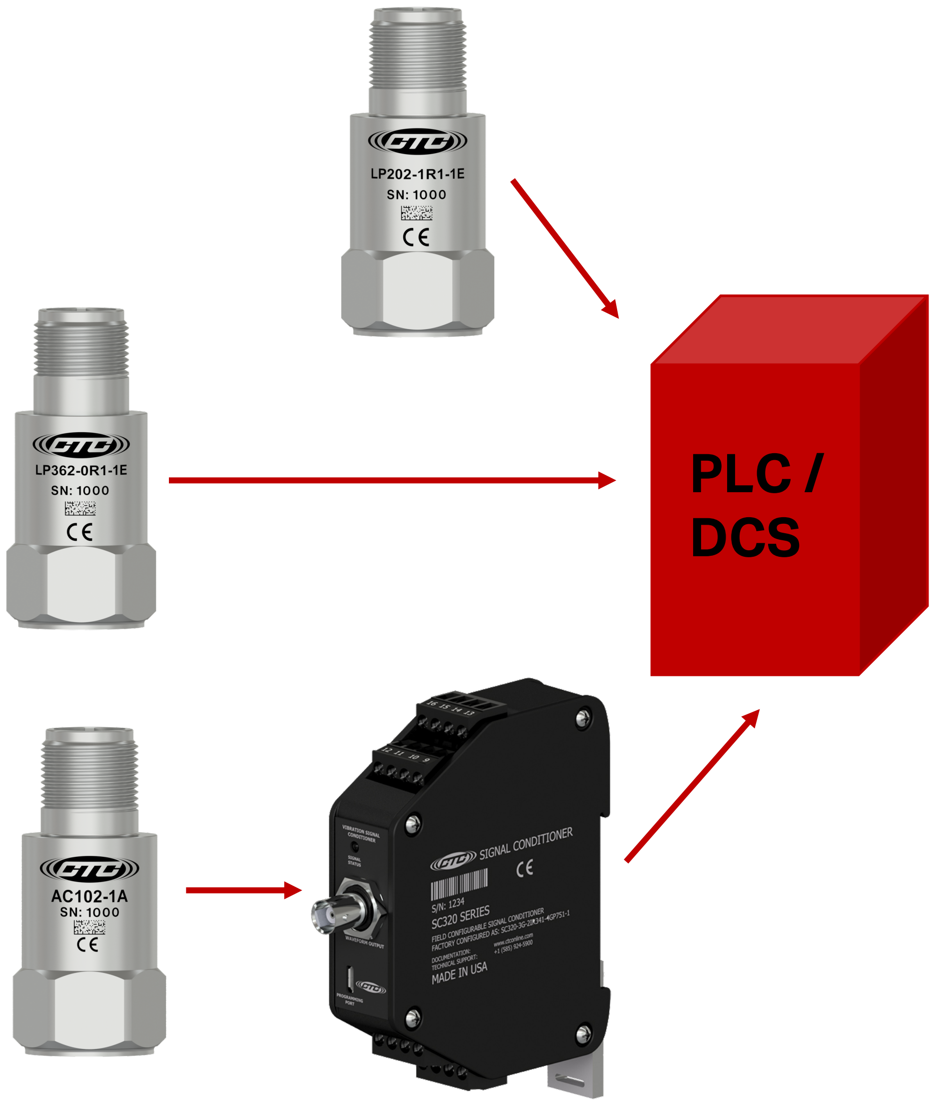
- ❑ **Critical applications**
- ❑ **Applications which can fail quickly**
- ❑ **Applications which can fail "dramatically"**
- ❑ **Applications which are remote, or where no operators can monitor the machinery**

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.

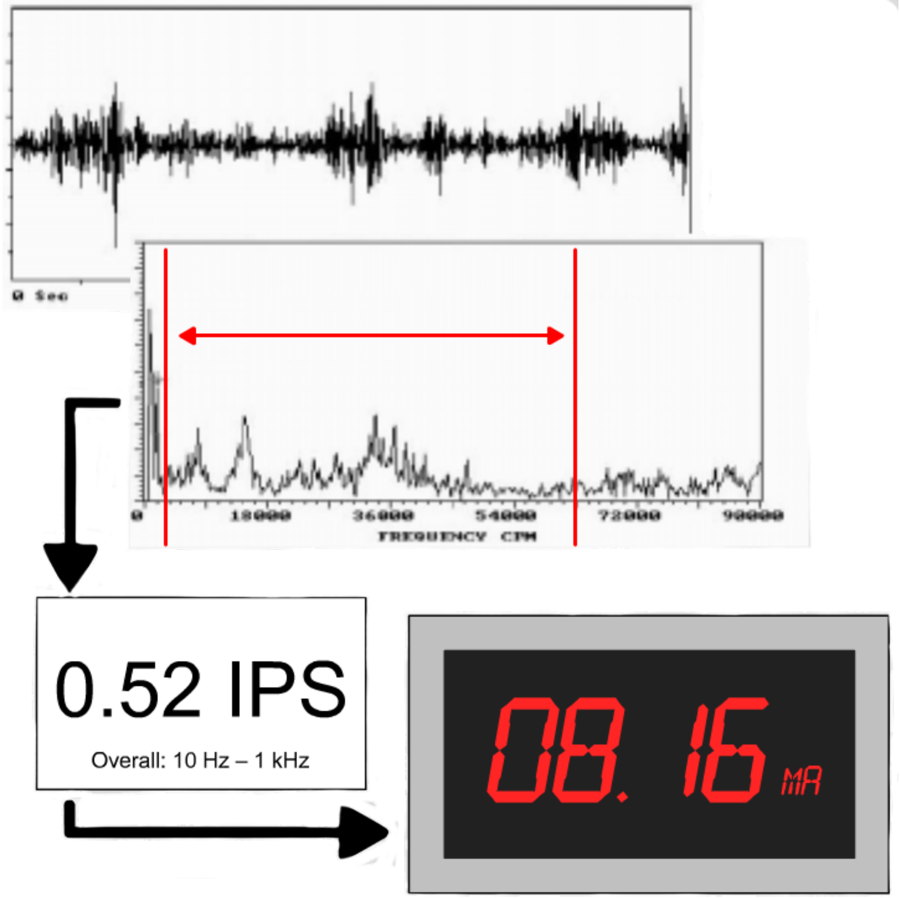
PROCESS CONTROL – FOR PLCs OR DCS SYSTEMS

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

- ❑ **4-20 mA loop power sensor**
- ❑ **Dual output loop power sensor** that provides 4-20 mA and temperature output
- ❑ **Transmitter** which converts or “conditions” a standard mV (dynamic) signal to a 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 **4-20 mA signal output is proportional to the overall amplitude generated within 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**.

See the Tech Resources section of our site at www.ctconline.com for a worksheet to assist with setting your scale measurement range. The chart below shows the scaled output for a 0 to 2 g or 0 to 2 IPS (50.8 mm/s) scale.

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	6	12	14	16	18	20
			NORMAL		**ALARM**			**SHUT DOWN**	

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 would be 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

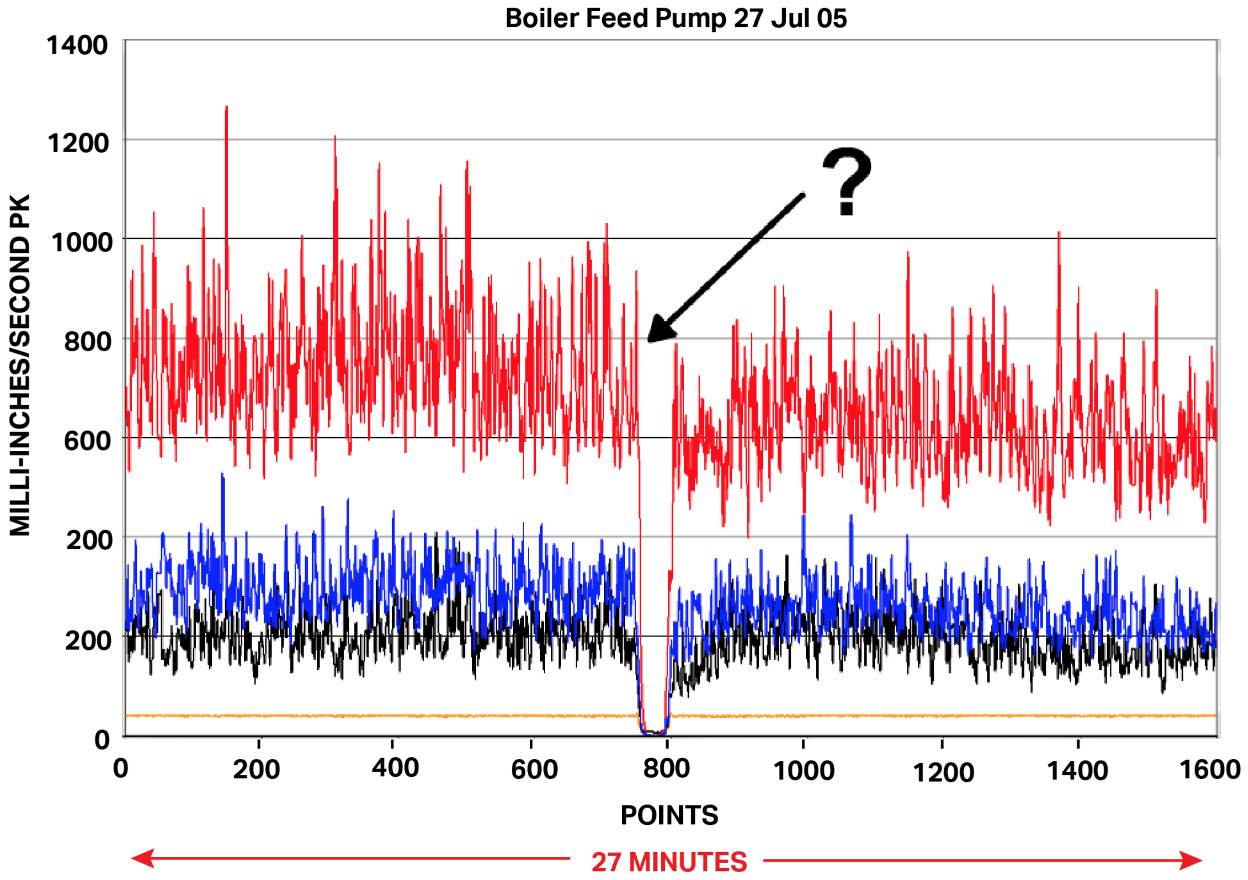
Loop power sensors are normally available in acceleration or velocity output. Acceleration output will give the higher frequencies more proportional value in the overall amplitude relative to a comparably specified velocity output sensor.

The acceleration or velocity units can be expressed as **Peak** or **RMS** values. Generally speaking, **Peak will provide more information 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 – 1000 Hz (600 – 60,000 CPM)
- ❑ 3 – 2500 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 is 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?**

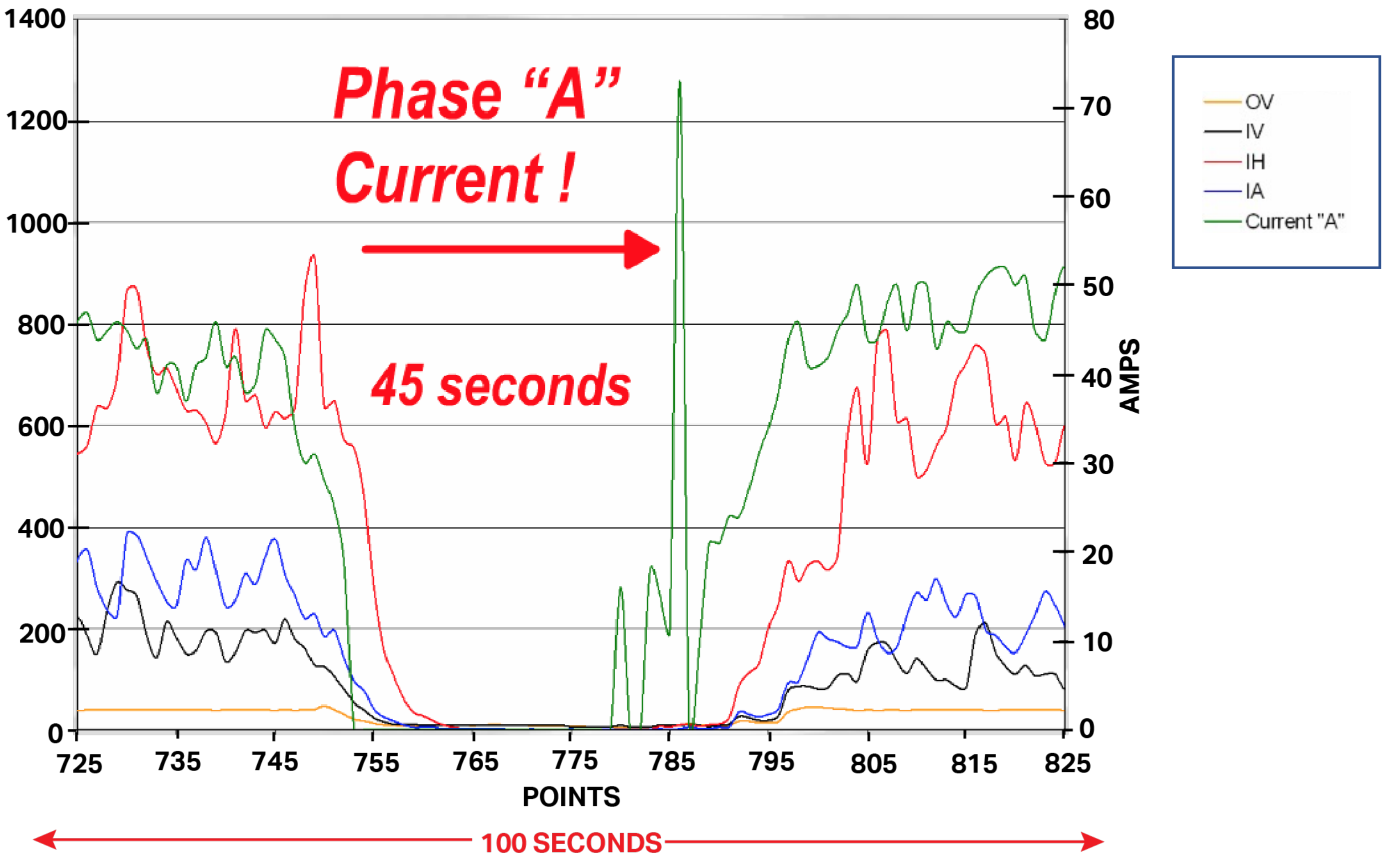
PROCESS CONTROL – VIBRATION DATA WITH MOTOR CURRENT

Let's re-display 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 **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 solution 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 the safety of technicians and analysts
- ❑ **Better use of analysts' time** since the analyst can spend less time trending perfectly healthy equipment and more time analyzing data
- ❑ **Team approach to protection and monitoring** brings additional resources to protecting machinery and plant health

BLENDED APPROACH – DYNAMIC SENSOR AND TRANSMITTER

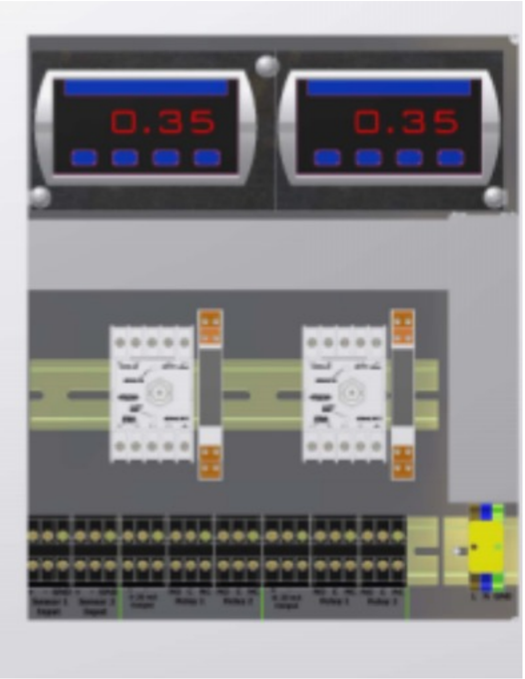
The **dynamic signal** from a permanently mounted vibration sensor can also be converted to a process control signal by a vibration transmitter (or signal conditioner).

The **transmitter** receives a mV signal form 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. This ability for analysts to choose from a menu of high pass and low pass filters provides the opportunity to target alarms more accurately around a fault, rather than relying on less specific overall values.

BLENDED APPROACH – DYNAMIC SENSOR 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:

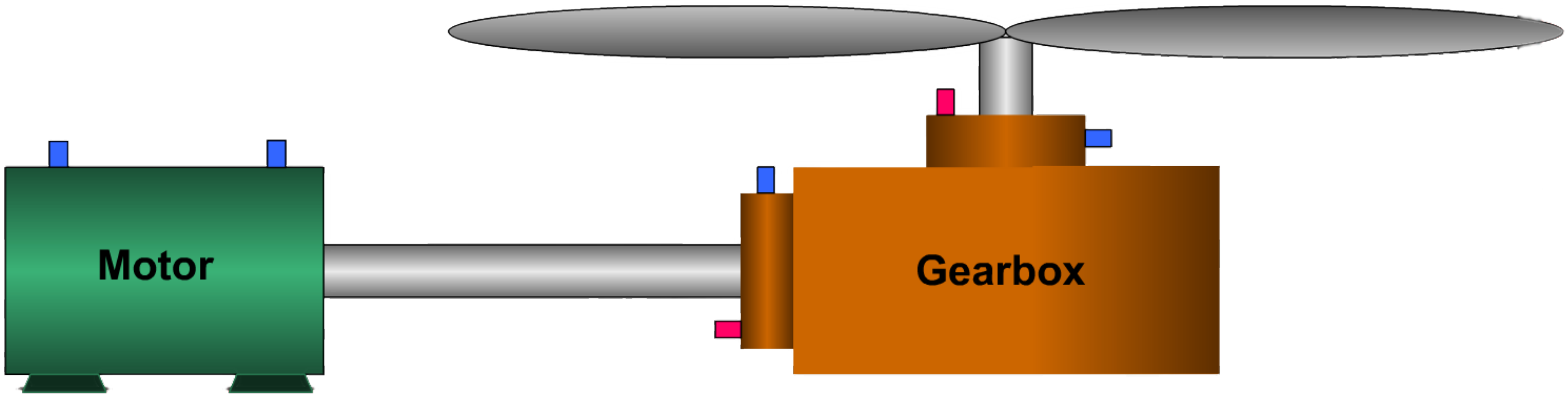
- **Relays** - make it possible to shut down machinery in the event that vibration levels exceed a user-defined level
- **Digital displays** of vibration levels in the scaled or actual value
- Visual or auditory **alarm options** such as lights or sirens
- **Retransmission** of a process control signal 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:

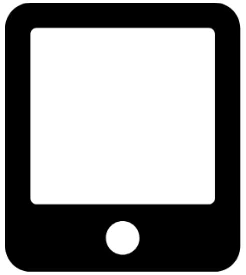
- **Dual output sensors** (**red**) – on the input and output shafts of the gearbox
- **mV/g sensors** (**blue**) on all bearings

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

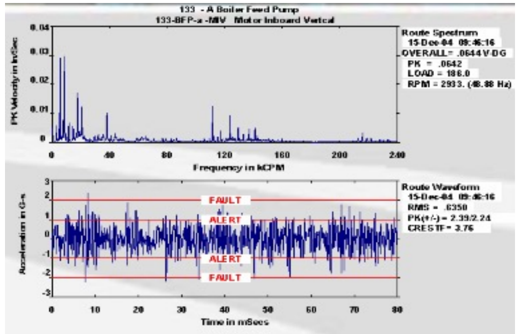


PROCESS CONTROL – INTEGRATION

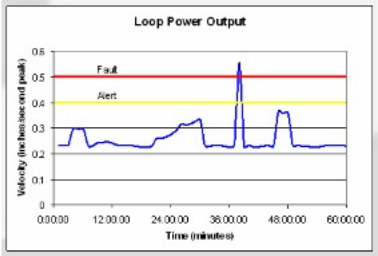
DUAL OUTPUT LOOP POWER SENSORS
- OR -
SENSORS AND TRANSMITTERS



DYNAMIC VIBRATION



PROCESS CONTROL



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

SUMMARY

Thank you for taking the time to review this training lesson. We hope that you learned something that will help you to collect more accurate and quicker data, to allow you to make better "calls."

For more technical information, additional white papers, and training materials, we invite you to visit our website at **www.ctconline.com**.

SUMMARY

CTC offers a full range of vibration analysis hardware and process and protection instruments for industrial use. Our customers choose us time and time again based on:

- ❑ **Superior durability**
- ❑ **Accuracy and performance**
- ❑ **Quick service (shipping most orders in 3 days)**
- ❑ **Knowledgeable support staff**
- ❑ **Industry's only UNCONDITIONAL LIFETIME WARRANTY on all CTC Line products**

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