Detecting Proximity Probe Cabling Errors Using Dynamic Calibration

IMI SENSORS
A PCB PIEZOTRONICS DIV.

www.pcb.com

Table of Contents

Proximity Probe System

Proximity probes are used to protect some of the world's most important rotating equipment, such as gas and steam turbines. The equipment is very valuable – in some cases generating more than one million dollars in US funds in revenue per day. Many times, proximity probes and non-contact displacement sensors (Eddy current probes) are used to protect these rotating shafts. The probes are installed 90° from each other. The tips of the proximity probes measure the motion of the shaft and the orbit plot of the shaft to determine if the shaft is out of balance or misaligned. Sometimes loading causes a vibration issue with the shaft. When those situations arise, unexpected outages occur that can cost companies millions of dollars.

Proximity probes are most commonly checked through the API 670 method of static calibration. This entails checking the output of the probe against a 4140 steel target at various gaps, essentially, 10, 20, 30, 40, 50 mils and so on and plotting that information. In the case we are evaluating here, we are going to demonstrate how to detect proximity probe cabling errors using dynamic calibration. Dynamic calibration often involves a wobble-plate design or in this case, a Model 699A06 or 699A07 Portable Vibration Calibrator which, essentially, take a 4140 steel target and place it on top of a precision quartz reference accelerometer to simulate actual turbine vibration.

Proximity probes protect important rotating equipment.

Proximity Probe System

Let's first look at the typical proximity probe system. The typical system contains a probe driver, which is similar to a signal conditioner for the proximity probe. This is also known as a probe driver. It contains the proximity probe itself, also known as an Eddy current probe, and an extension cable. The proximity probe is nothing more than a coil of wire. It has no moving parts. It does have a cap on the end that essentially protects it from impacting the shaft. Other than that, it's just a coil of wire inside a housing. Its impedance changes with fluctuations in the magnetic field. The turbine shaft or the target, is a ferrous material and the proximity probe is measuring the distance from the tip of the probe to the shaft using the magnetic field.

Proximity Probe

- "Eddy Current Probe"
- Coil of Wire
- No Moving Parts
- Impedance Changes Based Upon Magnetic Field

Includes

- Probe Driver
- Proximity Probe
- Extension Cable

Probe Driver Signal Conditioner

The probe driver could be considered a signal conditioner. Its job is to essentially convert the probe impedance into a linear voltage signal. The probe impedance is not necessarily linear. In fact, it is never linear but the probe driver takes the probe impedance and converts it to a linear signal from the probe range of 10 mils to 90 mils. If you are 10 mils from the target, the probe will read somewhere around -1 VDC or if you're 90 mils from the target, it's close to -17 VDC. The output of the probe is 200 mV/mil and is very linear over its 10 to 90 mil range.

The probe driver though, because it is converting probe impedance to voltage, is essentially tuned to a specific cable length. The standard lengths are one meter, five meters and nine meters. In the picture on page 4, the probe driver is set for a five meter cable. If a technician were to input a different cable length to the probe driver the output of the system would not be linear and a shift in dynamic sensitivity would occur. The probe driver, also has connections for power (V_T), common (COM) and output (OUT).

The probe driver converts probe impedance into a linear voltage signal.

Initial Set-Up

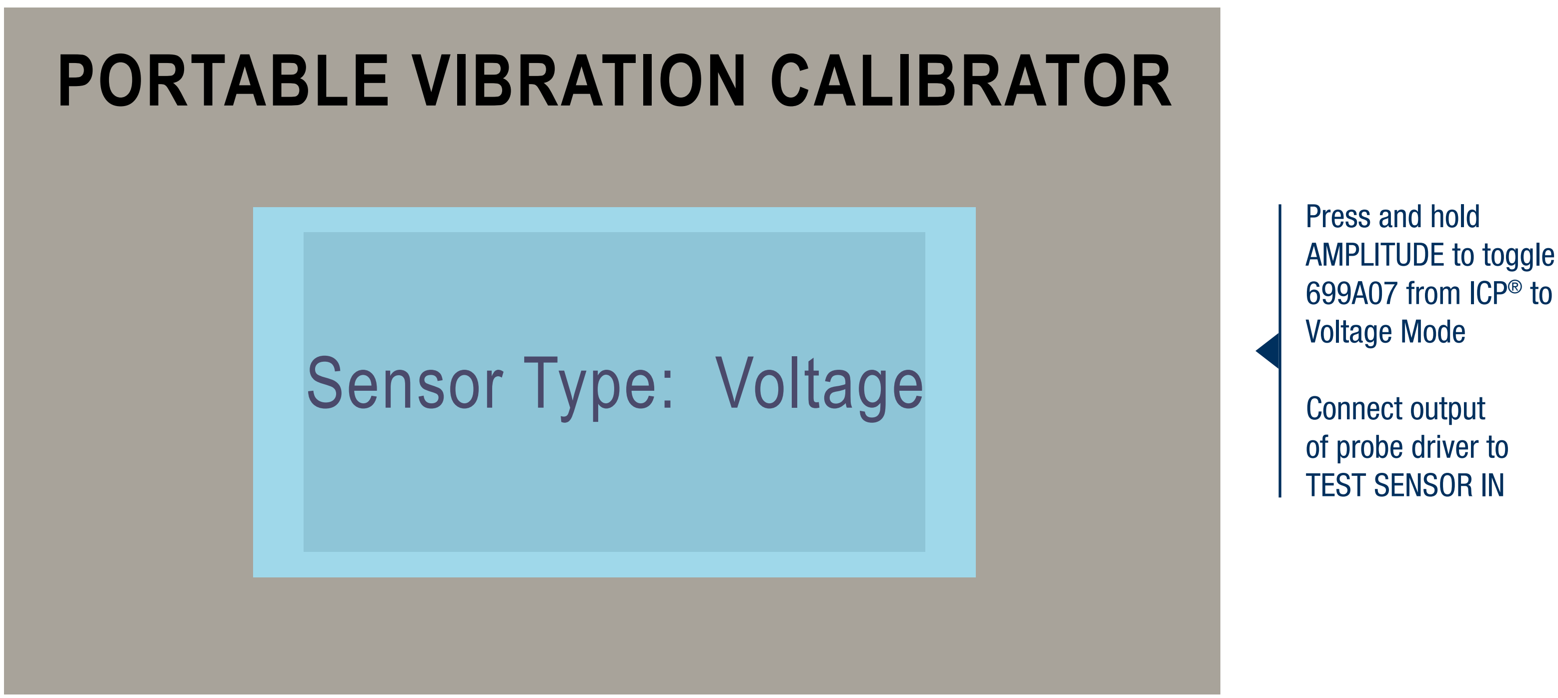
Before testing, the initial gap needs to be set up for the proximity probe.The proximity probe is linear from 10 mils to 90 mils or in millimeters, about 0.25 mm to 2.5 mm. The probe tip needs to be 50 mils from the turbine shaft or the target.

If the appropriate cable is connected, the initial gap is not terribly important in terms of accuracy. Setting the gap at 50 mils is helpful in this example as it is the exact center of the dynamic range of the probe (between 10 mils to 90 mils). Essentially, the turbine shaft or the target can move 40 mils in either direction and the proximity probe can still measure accurately. If the initial gap is set at 60 mils, nothing harmful would happen. An incorrect output would be avoided as long as the right cable lengths were installed. You would just have a different range. If the probe begins 60 mils from the turbine shaft before it is started, then the shaft can travel 30 mils from the probe and up to 50 mils closer to the probe and displacement will still be measured accurately. Radial probes have alert and alarm settings below 10 mils in almost every application. It's not practical to assume that a radial probe will measure +/– 40 mils peak-to-peak in a real application. Turbine shafts are so well balanced that even 8 mils or 4 or 5 mils of vibration is going to trigger the alert or alarm setting on that particular turbine shaft. Having the initial gap correct is important – but, from a practical stand point, as long the correct cable is installed, being anywhere from 40 to 60 mils from the turbine shaft is perfectly acceptable. Setting the gap at 40 mils in this example gave a voltmeter reading of -8 VDC. This wouldn't have an effect on the dynamic output, but in the example to the left, the proximity probe has been set to the initial gap of 40 mils and the DC output at 50 mils is -9 VDC as per the datasheet for the proximity probe.

- Center of Dynamic Range is 50 mils (1.27 mm)
- DC Output = -9.00 V

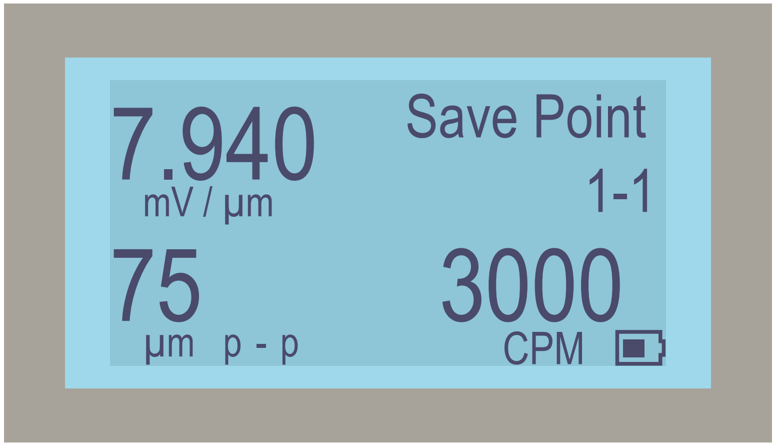
Measuring Dynamic Output

To measure the dynamic output of the proximity probe, the portable vibration calibrator needs to be in voltage mode. To do this with IMI Sensor's Model 699A07, press down on the Amplitude button to toggle from ICP® to Voltage Mode. Often, ICP® accelerometers are permanently installed on bearing housings or used in route-based applications with a magnet on the end of the sensor. Portable calibrators from IMI Sensors can create calibration certificates for these types of installations. When the calibrator is in ICP® mode, it will power those sensors. In this example, the proximity probe is being powered with the probe driver. The AC voltage output is being measured as the dynamic signal from that probe driver. To change the calibrator to be in Voltage Mode, the Amplitude button is held down. Then the output of the probe driver is connected to the test sensor input BNC.

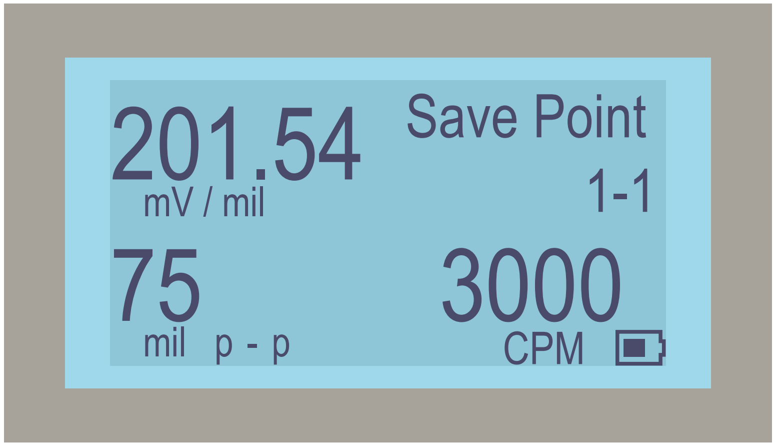


Correct Dynamic Output

Below is the correct dynamic output. If the correct cable is attached (a four meter extension cable and a one meter integral cable on the probe) the results will read as 200 mV/mil or 7.90 mV/µm. The images on the right show 3 mils peak-to-peak and 3000 CPM. Vibration is simulated at 3000 CPM or 60 Hz. The reading created a result close to the desired dynamic output of 201 mV/mil. Tolerance is 5%, meaning that anything from 190 to 210 mV/mil is within tolerance for a simulation at 3 mils peak-to-peak. In metric, the simulation is at 75 µm peak-to-peak and again at 3000 CPM results in an output of 7.94 mV/µm. This is very close to the desired output of 7.90.

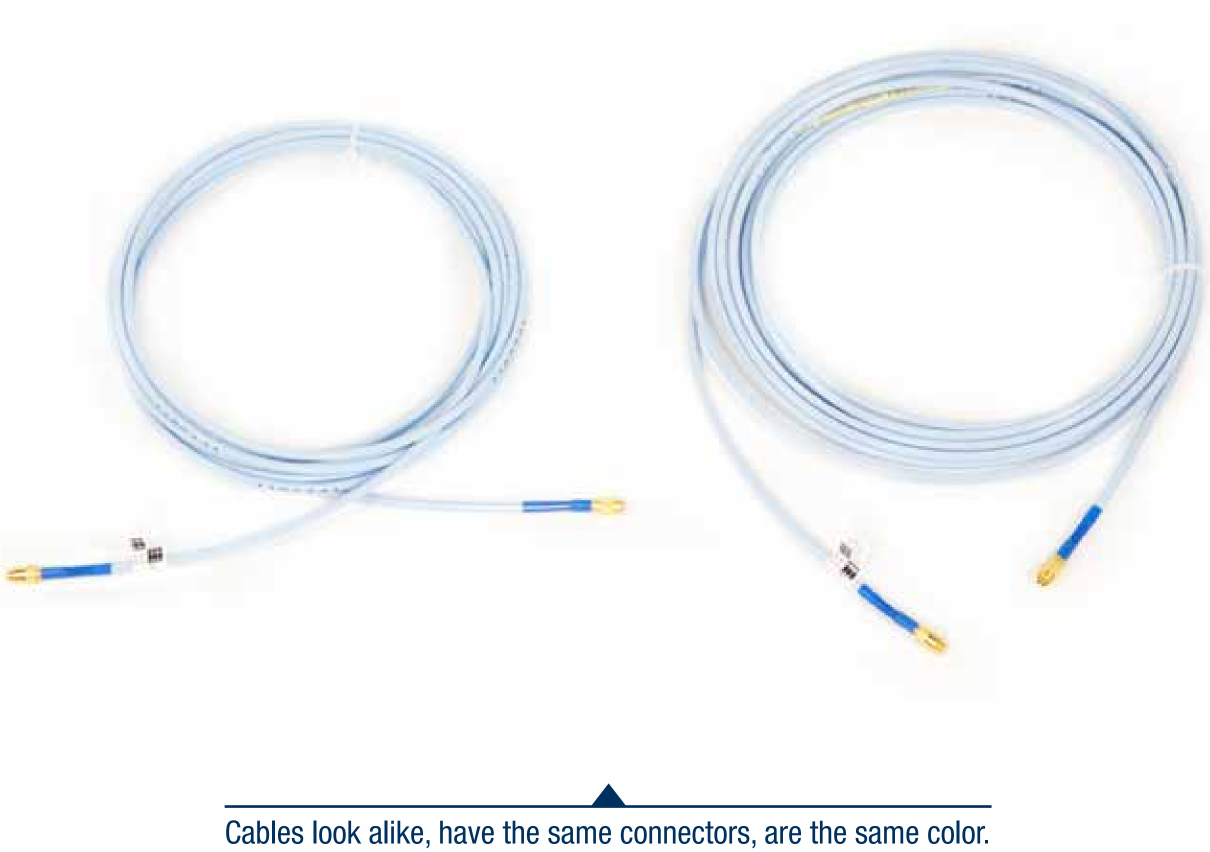


Desired Dynamic Output
- ~200 mV/mil
- ~7.90 mV/µm



Desired Dynamic Output
- 5 m system
- Prox Probe = 1 m cable
- Extension cable = 4 m cable

Introducing Error



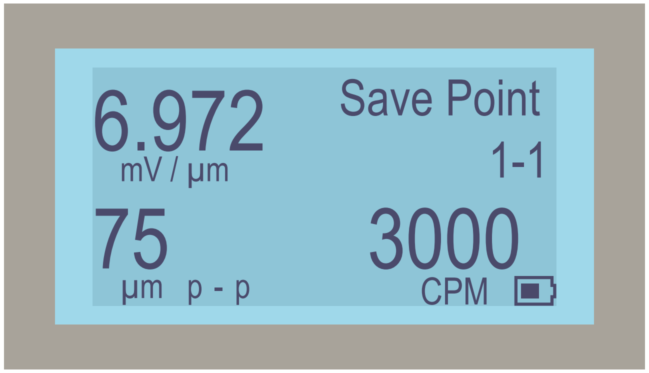
Cables look alike, have the same connectors, are the same color.
What if a 4.5 meter extension cable is used in our demo?

What happens if we introduce cable error? These cables look very similar. The cables are the same color, they have the same connector and they share an almost identical part number.
If the digits after the first dash are 040, the cable is 4 m. If they are 045, the cable is 4.5 m.
It would be best to use a 4.5 m cable when working with a 5 m system and a proximity probe with 0.5 m of integral cable. In this example, an error is introduced, essentially extending the probe driver an extra 0.5 meter.

What happens if we introduce cable error?

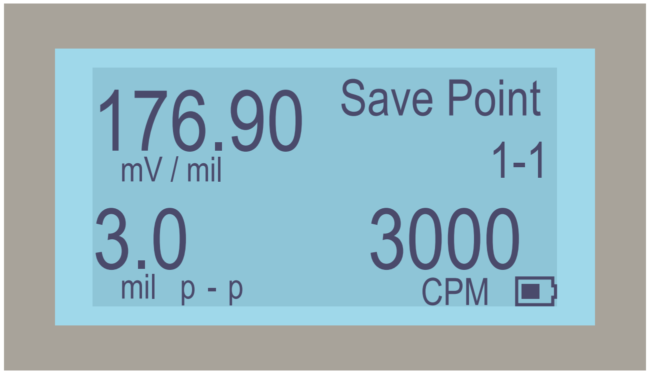
Incorrect Dynamic Output

The data here shows use of an incorrect cable. The readout shows measurements for a probe driver expected to be using 5 meters of cable. In reality, the proximity probe has 1 meter of integral cable and the extension cable is now 4.5 meters long. The probe driver is being sent an extra 0.5 meter of cable, which is causing an 11.5% drop in dynamic output. 200 mV/mil are anticipated, and in actuality, the number reported is approximately 177 mV/mil at 3 mils peak-to-peak, 3000 CPM (in metric, 6.97 mV/µm at 75 microns peak-to-peak at 3000 CPM). By making this mistake in cabling, the vibration protection system is expecting an output of 200 mV/mil with the alert and alarm levels set based on this scale. If the vibration protection system is receiving 177 mV/mil, then the alert and alarms are actually tripping 11.5% too late or 11.5% low. More vibration will need to be generated to trip the alarms.



Desired Dynamic Output

- ~200 mV/mil
- ~7.90 mV/µm
- % error = 11.5%



- 5 m system
- Prox Probe = 1 m Cable
- Extension Cable = **4.5 m Cable**

Adjusting Gap Voltage

Incorrect cable length causes gap voltage to decrease

Technician adjusts position of proximity probe to correct for this error

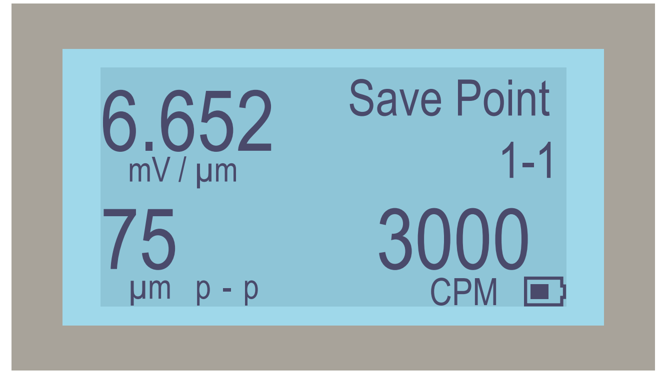
The problem continues with incorrect cable length when technicians mistake that error for incorrect probe position. This is very easy to do. In many installations, the position of the tip of the proximity probe cannot be seen during installation on the turbine shaft. Obviously, in the calibration example, it is very easy but to the naked eye it's very difficult to discern: "What's 50 mils? Does that look right? Does that look like 50 mils? Is it really 40 mils?" Whether its 1 mil or 10 mils, it's difficult to see the difference.

Many times when the probe is installed and an incorrect cable is used, the gap voltage is going to read incorrectly. In the example to the left, the top reading is 7.69 volts DC. In the practical application, it would read the same on the front panel of the data acquisition system and the technician would say, "Oh, my proximity probe is not installed in the correct place. Let me adjust the position of the tip relative to the shaft so that I can get exactly 50 mils initial gap before I turn on this turbine. I want to see -9 VDC." Unfortunately, the probe may be installed in the correct position and the incorrect voltage reading is due to a cabling error.

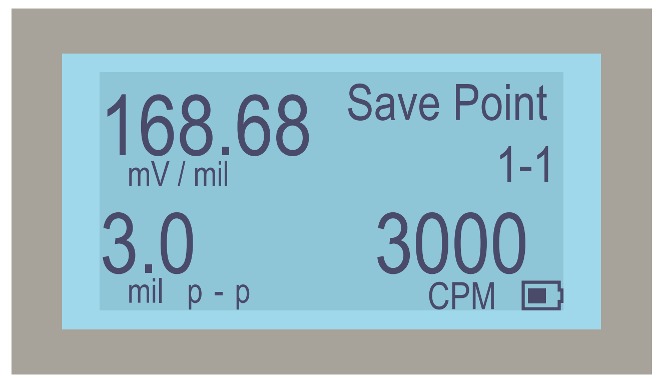
Compounding Dynamic Error

In this example, if the position of the proximity probe is adjusted, the gap voltage can be manipulated to read correctly. In actuality, it will increase the dynamic output error in the system. When the 5.5 m of cable were connected to the 5 m probe driver an error of 11.5% was encountered. The error has been compounded by mistakenly adjusting the position of the probe and having the incorrect initial gap, to become a 16% error.

The objective is to look for 200 mV/mil and instead the recording is 169 mV/mil. In addition, the dynamic output is 7.90 mV/µm and the actual dynamic output is 6.65. So, once again, if a vibration alarm were set at 3 or 5 mils peak-to-peak and the vibration protection system was based on 200 mV/mil, the alarm will trip later than desired because only 169 mV/mil are being sent from the proximity probe.



Desired Dynamic Output
- ~200 mV/mil
- ~7.90 mV/µm
- % Error = 16%



- 5 m system
- Prox Probe = 1 m Cable
- Extension Cable = **4.5 m Cable**
- **Gap Voltage Corrected**

Summary

Probe extension cable lengths are one of the biggest reasons for proximity probe errors in the power generation and petrochemical markets. It can be easy to confuse them, making a mistake. Technicians can compound a mistake by adjusting the proximity probe position to try to make the initial gap voltage look correct. Using the dynamic calibration method, before a gas or steam turbine is turned on, is a great way to find out if the proximity probes are operating correctly–resulting in correctly functional alert and alarm levels.

In fact, proximity probes don't actually have to be connected to the calibrator like in the examples demonstrated. The probe can be left connected to data acquisition and the displacement turned to the alert and alarm level to see if the thresholds have tripped and if an alarm is being sent to your phone. This allows occurance of an alarm to be confirmed.

It's important to note that through the static proximity probe calibration method, this type of error in cable length can be identified. A typical static test produces linear DCV output from 10 mils to 90 mils. Performing this test with an incorrect cable will result in non-linear calibration curve.

The dynamic test method is the only way to test the entire measurement chain: probe, cable, probe driver and monitoring system. Dynamic testing simulates actual machine vibration conditions at running speed. The dynamic mode creates a way to check the alert and alarm levels and a method to confirm the cable and proximity probe output.

With a portable calibrator from IMI Sensors, you can create calibration certificates for both frequency response and for proximity probes (linearities in particular), so you can have a calibration record to save in the quality department.

With a portable calibrator you can create calibration certificates for both frequency response and for proximity probes.