Brüel & Kjær Vibro
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Instructions

VC-8000 for Hydro and Low Speed Machines

Including Machine-State Alarming

Operation and Maintenance

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Instructions - **VC-8000 for Hydro and Low Speed Machines**
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1 Overview

This application note is an addendum to the VC-8000 Operation & Maintenance Manual (S1079330), and the SETPOINT Condition Monitoring System Operation Manual (S1176125). Please refer to these manuals for basic operating instructions.

This application note provides information specific for hydro turbine generators, other low speed machines, and machines using Machine-State alarming. This includes the following channel types:

Channel Type	Application
Air Gap	Air gap measurements on the generator.
Hydro Radial Vibration	Machines up to 720 rpm using proximity probes.
Hydro Velocity	Machines up to 720 rpm using velocity sensors.
Low F Acceleration	Fans or other low speed machinery.
Low F Velocity	Fans or other low speed machinery
(any)	Machine-State alarming

1.1 Vertical Machines

Please consider the following when configuring channels on vertical machines.

1.1.1 Sensor Orientation & Direction of Rotation

Sensor Orientation and Direction of Rotation are measured as follows: The observer is looking from the top of the generator down towards the turbine. The reference location (0 degrees) is decided at the customer site (typically 0 degrees = upstream).

2 Hydro Radial Vibration

The Hydro Radial Vibration channel is optimized for low speed (< 720 RPM) and provides a selection of tracking filters and bandpass filters.

Table 2-1) Hydro Radial Vibration

Measurement	Description
Direct	Overall dynamic amplitude bandpass filtered measurement. High Pass = 0.3 Hz minimum (14 pole) Low Pass = 200 Hz maximum (12 pole)
Gap	Gap voltage for diagnostics.
1X Amplitude, 1X Phase	Amplitude and phase measurements. This measurement defaults to 1X, but can be changed if desired (i.e. 0.5 X).
2X Amplitude, 2X Phase	Amplitude and phase measurements. This measurement defaults to 2X, but can be changed if desired (i.e. 0.5 X).
Bandpass 1 Bandpass 2	Peak-Peak bandpass filtered measurements that can be added (if desired). See MPS Manual S1079330. Search for "Adding Measurements". High Pass = 0.3 Hz min (14 pole) Low Pass = 200 Hz max (12 pole)

2.1 Configure Hydro Radial Vibration

There are no special configuration settings for the Hydro Radial Vibration channel. Please see the main VC-8000 Operation & Maintenance Manual (S1079330) for general information on channel configuration.

2.1.1 Rack Layout

Hydro Radial Vibration channels (XY pairs) must be in the same UMM using Ch 1 & 2 (or Ch 3 & 4).

Hydro Radial Vibration channels (XY pairs) must have the same CMS Navigation path. This "groups" the two channels together and allows the software to show Orbit plots etc.

2.2 Verify Hydro Radial Vibration

Set up the test equipment as shown. Set the power supply to the transducer Gap voltage.

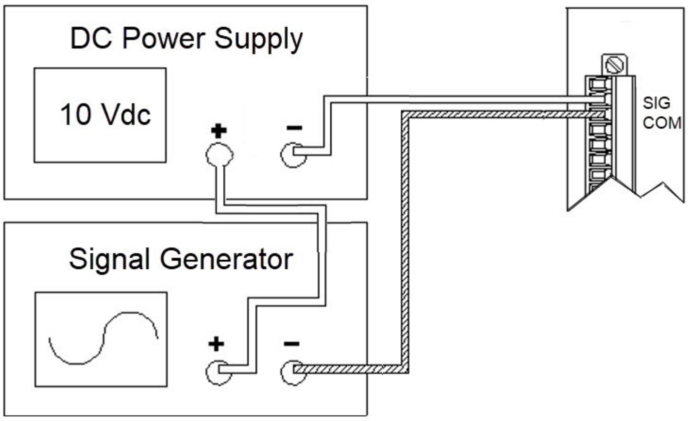


Figure 2-1) Test Setup for Hydro Radial Vibration

Set the function generator to a frequency inside your band-pass filtered region (i.e. 10 Hz) so the filter does not attenuate the signal. Set the amplitude as follows (units are shown in mils):

Equation 2.1) Input (Vrms)

$$Input\ (Vrms) = Vibration\ (mils) * \frac{Scale\ Factor\ \left(\frac{mV}{mil}\right)}{1000\ \left(\frac{mV}{V}\right)} * \frac{1}{2\sqrt{2}}$$

Where:

- Input (Vrms) = Simulation voltage from function generator
- Vibration (mils, or µm) = Direct vibration reading that is desired (i.e. 5 mils pp, 125 µm pp)
- Scale Factor (mV/mil or µm) = Configured transducer scale factor (i.e. 200 mV/mil, 7.87 mV/µm)
- 1000 = conversion factor from mV to V
- $\frac{1}{2\sqrt{2}}$ = conversion factor from Vpp to Vrms

Example 1: To simulate a 75 µm pp signal with a 7.87 mV/µm transducer.

$$0.208\ Vrms = 75\ \mu m\ pp * \frac{7.87\frac{mV}{\mu m}}{1000} * \frac{1}{2\sqrt{2}}$$

3 Hydro Velocity

The Hydro Velocity channel is specifically designed for Hydro machines. It provides a good selection of tracking filters (1X, 2X) and bandpass filters to be used depending on the installed location of the sensor.

The Hydro Velocity channel also has a very steep High Pass filter (14 pole). This allows the channel to return a strong signal at the lowest frequencies and still eliminate noise from the channel.

Table 3-1) Hydro Velocity Measurements

Measurement	Description
Direct	Overall dynamic amplitude measurement. High Pass = 0.7 Hz minimum (14 pole) Low Pass = 200 Hz maximum (12 pole)
Bias	Bias voltage for diagnostics.
1X Amplitude 1X Phase	Amplitude and phase measurements. This measurement defaults to 1X, but can be changed if desired (i.e. 0.5 X).
2X Amplitude 2X Phase	Amplitude and phase measurements. This measurement defaults to 2X, but can be changed if desired (i.e. 0.5 X).
Bandpass 1	Peak-Peak bandpass filtered measurement (can be added) High Pass = 0.7 Hz minimum (14 pole) Low Pass = 200 Hz maximum (12 pole)
Low F Bandpass 2	Peak-Peak bandpass filtered measurement (can be added) High Pass = 0.2 Hz minimum (14 pole) Low Pass = 25 Hz maximum (12 pole)

The Hydro Velocity channel has excellent filter options for a low speed machine. The Low Pass and High Pass corner filters are configurable in the VC-8000 Setup Software (Measurements tab, All view). The filters are specific to the Direct, and Bandpass measurements. The Asynchronous and Synchronous waveforms are not bandpass filtered.

3.1 Configure Hydro Velocity

There are no special configuration settings for the Hydro Velocity channel. Please see the main VC-8000 Operation & Maintenance Manual (S1079330) for general information on channel configuration.

3.1.1 Rack Layout

To view casing orbit plots in SETPOINT CMS software, the Hydro Velocity channels must be in Ch 1 & 2, or Ch 3 & 4 and the two channels must be paired. Otherwise, the Hydro Velocity channel can be in any location.

3.2 Verify Hydro Velocity

3.2.1 Test Setup

Simulate the Hydro Velocity channel depending on the sensor selected.

3.2.1.1 Constant Current Velocity Sensor

Use a 3.3 kΩ resistor to set the bias voltage (+10 Vdc). The 940 µF (or larger) capacitor is used to force the current through the resistor. A large test capacitor is needed because of the low frequency characteristics of the input signal.

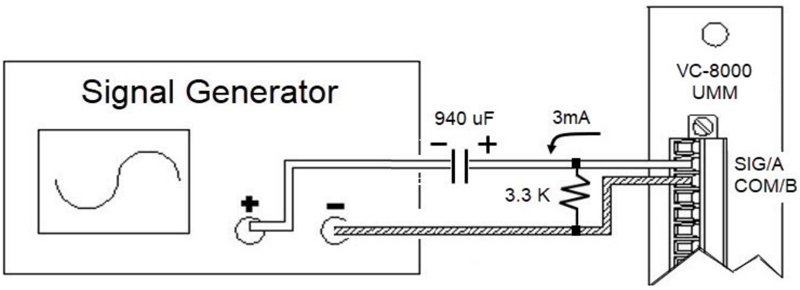


Figure 3-1) Constant Current Sensor

3.2.1.2 Velocity (Moving Coil) Sensor

Simulate a velocity (moving coil) sensor as shown here.

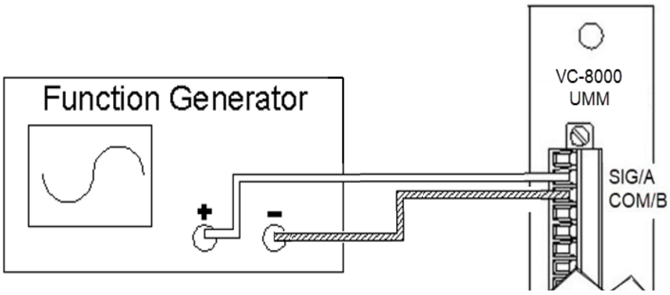


Figure 3-2) Velocity (Moving Coil) sensor

3.2.2 Simulate Signals (Standard - in/s)

Use a test frequency compatible with the Hydro Velocity Channel (i.e. 25 Hz). Use the following equations to calculate the velocity input value:

Equation 3.1) (in/s pk)

$$Input\ (Vrms) = \frac{1}{\sqrt{2}} * Vibration\ \left(\frac{in}{s} pk\right) * \frac{Scale\ Factor\ \left(\frac{in}{s}\right)}{1000\ \left(\frac{mV}{V}\right)}$$

Equation 3.2) (in/s rms)

$$Input\ (Vrms) = Vibration\ \left(\frac{in}{s} rms\right) * \frac{Scale\ Factor\ \left(\frac{in}{s}\right)}{1000\ \left(\frac{mV}{V}\right)}$$

Where:

- Input = Simulation voltage from function generator (Vrms)
- Vibration = Desired vibration reading (i.e. 0.5 in/s pk, 10 mm/s pk, etc.)
- Scale Factor = Configured transducer scale factor (i.e. 20 mV/mm/s, 508 mV/in/s)
- 1000 = conversion factor from mV to V
- 1/√2 = conversion factor from pk to rms

Example 1: To simulate a 0.5 in/s pk signal with a 508 mV/in/s transducer.

$$0.180\ Vrms = \frac{1}{\sqrt{2}} * 0.5\ \frac{in}{s} pk * \frac{508\ \frac{mV}{in/s}}{1000}$$

Example 2: To simulate a 0.5 in/s rms signal with a 508 mV/in/s transducer.

$$0.254\ Vrms = 0.5 \frac{in}{s} RMS * \frac{508 \frac{mV}{in/s}}{1000}$$

TIP

A multimeter may have trouble measuring the test signal at low frequencies.
Temporarily increase the signal frequency (i.e. 60 Hz) to verify the amplitude.

3.2.3 Simulate Signals (Standard - mm/s)

Use a test frequency compatible with the Hydro Velocity Channel (i.e. 25 Hz). Use the following equations to calculate the velocity input value:

Equation 3.3) (mm/s pk)

$$Input\ (Vrms) = \frac{1}{\sqrt{2}} * Vibration\ \left(\frac{mm}{s} pk\right) * \frac{Scale\ Factor\ \left(\frac{mm}{s}\right)}{1000\ \left(\frac{mV}{V}\right)}$$

Equation 3.4) (mm/s rms)

$$Input\ (Vrms) = Vibration\ \left(\frac{mm}{s} rms\right) * \frac{Scale\ Factor\ \left(\frac{mm}{s}\right)}{1000\ \left(\frac{mV}{V}\right)}$$

Where:

- Input = Simulation voltage from function generator (Vrms)
- Vibration = Desired vibration reading (i.e. 10 mm/s pk, etc.)
- Scale Factor = Configured transducer scale factor (i.e. 20 mV/mm/s)
- 1000 = conversion factor from mV to V
- 1/√2 = conversion factor from pk to RMS

Example 2: To simulate a 10 mm/s pk signal with a 20 mV/mm/s transducer.

$$0.141\ Vrms = \frac{1}{\sqrt{2}} * 10\ \frac{mm}{s} pk * \frac{20\ \frac{mV}{mm/s}}{1000}$$

Example 1: To simulate a 10 mm/s rms signal with a 20 mV/mm/s transducer.

$$0.200\ Vrms = 10 \frac{mm}{s} RMS * \frac{20 \frac{mV}{mm/s}}{1000}$$

3.2.4 Simulate Signals (Integrated – mils pp)

Use a test frequency compatible with the Hydro Velocity Channel (i.e. 25 Hz). Use the following equations to calculate the velocity input value:

Equation 3.5) (mils pp)

$$Velocity\ in/s\ pk\ = \frac{mils\ pp * Frequency\ (Hz)}{318.3}$$

Where:

- Velocity = Velocity at the given displacement and frequency
- mils pp = desired displacement value
- Frequency = Input Frequency
- 318.3 = conversion factor

Example 1: To simulate a 10 mils pp integrated signal, where the signal frequency is 25 Hz and the scale factor is 508 mV/in/s, first use **Equation 3.5** and then input the result into **Equation 3.1**

$$0.79\ in/s\ pk = \frac{10\ mils\ pp * 25\ Hz}{318.3}$$

$$0.28\ Vrms = \frac{1}{\sqrt{2}} * 0.79\ in/s\ pk * \frac{508\frac{mV}{in/s}}{1000}$$

3.2.5 Simulate Signals (Integrated – µm pp)

Use a test frequency compatible with the Hydro Velocity Channel (i.e. 25 Hz). Use the following equations to calculate the velocity input value:

Equation 3.6) (µm pp)

$$Velocity\ mm/s\ pk\ = \frac{\mu m\ pp * Frequency\ (Hz)}{318.3}$$

Where:

- Velocity = Velocity at the given displacement and frequency
- µm pp = desired displacement value
- Frequency = Input Frequency
- 318.3 = conversion factor

Example 2: To simulate a 250 µm pp integrated signal, where the signal frequency is 25 Hz and the scale factor is 20 mV/mm/s, first use **Equation 3.6** and then input the result into **Equation 3.3**

$$19.64\ mm/s\ pk = \frac{250\ \mu m * 25\ Hz}{318.3}$$

$$0.28\ Vrms = \frac{1}{\sqrt{2}} * 19.64\ mm/s\ pk * \frac{20\frac{mV}{mm/s}}{1000}$$

4 Low F Velocity

The Low F Velocity was not designed for Hydro monitoring. It is a modification of the Standard Velocity channel with some improvements for lower frequency measurements.

The band-pass frequency of the channel is very wide. The integration of a signal (with low frequency and a wide band-pass) requires extra processor power; some measurements were removed to allow for this option.

Table 4-1) Low F Velocity Measurements

Measurement	Description
Direct	Overall dynamic amplitude measurement.
Bias	Bias voltage for diagnostics.
1X Amplitude 1X Phase	Amplitude and phase measurements. This measurement defaults to 1X, but can be changed if desired (i.e. 0.5 X).

Table 4-2) Low F Velocity Band-pass

Measurement	High Pass Min (LP[1])	Low Pass Max (HP[1])
Direct	0.2 Hz (1000 Hz) (4 pole)	5000 Hz (1 Hz) (4 pole)
Direct (Integrated)	0.7 Hz (3500 Hz) (4 pole)	5000 Hz (1 Hz) (4 pole)

1. The High Pass (HP) and Low Pass (LP) filters must be within 5000x. For example, if I select a High Pass filter of 0.2 Hz, my Low Pass filter must be less than 1000 Hz.

4.1 Configure Low F Velocity

There are no special configuration settings for the Hydro Velocity channel. Please see the main VC-8000 Operation & Maintenance Manual (S1079330) for general information on channel configuration.

4.1.1 Rack Layout

If the customer is viewing casing orbit plots in SETPOINT software, the Low F Velocity channels must be in Ch 1 & 2, or Ch 3 & 4. Also, the two channels must be paired.

If the sensor is not providing casing orbit plots in CMS, the channel can be in any location in the rack and is not required to be part of an XY pair.

4.2 Verify Low F Velocity

The instructions to verify a Low F Velocity channel are the same as for the Hydro Velocity channel. Please see Section 3.2.

5 Low F Acceleration

The Low F Acceleration channel can be used for Hydro monitoring, but it was not specifically designed for Hydro monitoring. It is a modification of the Standard Acceleration channel with some improvements for lower frequency signal components.

The band-pass frequency of the channel is very wide. The integration of a signal (with low frequency and a wide band-pass) requires extra processor power; some measurements were removed to allow for this option.

Table 5-1) Low F Acceleration Measurements

Measurement	Description
Direct	Overall dynamic amplitude measurement.
Bias	DC sensor bias voltage for diagnostics.
1X Amplitude 1X Phase	Amplitude and phase measurements. This measurement defaults to 1X, but can be changed if desired (i.e. 0.5 X).
Bandpass	Bandpass filtered measurement that can be added (if desired).

Table 5-2) Low F Acceleration Bandpass

Measurements	High Pass Min (LP[1])	(HP[1]) Low Pass Max
Direct	0.2 Hz (- 1000 Hz) (4 pole)	(1 Hz -) 5000 Hz (4 pole)
Direct (Integrated) pk	0.7 Hz (- 3500 Hz) (4 pole)	(1 Hz -) 5000 Hz (4 pole)
Direct (Integrated) rms	0.2 Hz (- 1000 Hz) (4 pole)	(1 Hz -) 5000 Hz (4 pole)
Bandpass 1	2.0 Hz (- 10,000 Hz) (4 pole)	(2.0 Hz -) 10,000 Hz (4 pole)
Band-pass 1 (Integrated) pk	10 Hz (- 10,000 Hz) (4 pole)	(10 Hz -) 10,000 Hz (4 pole)
Band-pass 1 (Integrated) rms	2.0 Hz (- 10,000 Hz) (4 pole)	(2.0 Hz -) 10,000 Hz (4 pole)

1. The High Pass (HP) and Low Pass (LP) filters must be within 5000x. For example, if I select a High Pass filter of 0.2 Hz, my Low Pass filter must be less than 1000 Hz.

TIP

The High Pass and Low Pass filter settings only affect the measurement specified (i.e. Direct, Bandpass). These settings do not affect 1X measurement, or the waveforms used to create the time-base and spectrum plots in SETPOINT CMS software.

The Low F Accel channel has a Direct measurement, and a Bandpass measurement. If the sensor is installed (for example) on the draft tube of the Hydro machine, you can set the Direct measurement with a bandpass of 0.5 to 25 Hz to measure flow turbulence, and then set the Bandpass measurement for 25 Hz to 5000 Hz to measure cavitation.

5.1 Configure Low F Acceleration

If you are using this channel for a Hydro machine, you a will probably need to modify a few of the default channel settings. These are explained below.

5.1.1 Setting the Low Pass Filter

To set the Low Pass filter correctly, you need to know what you are measuring. The default Low Pass filter is 200 Hz. That may seem low for an accelerometer, but for a Hydro machine that is equivalent to 12,000 RPM (very high). If you are using this for 1X and 2X vibration you will want to modify the Low Pass filter to 25 Hz or lower.

The following example highlights how the filter settings will affect this measurement.

The AS-477 Accelerometer has a scale factor of 500 mV/g with a low frequency range down to 30 CPM (0.5 Hz) (-3 dB). A machine running at 166 RPM (2.7 Hz) with 5.0 mm/sec RMS (0.20 in/sec RMS) of 1X vibration, is equivalent to 0.012 g's pk which is a signal of only 6 mV.

In comparison, higher frequency components with smaller signal amplitudes will be larger than the 1X signal component. For example, a 0.5 mm/sec amplitude vibration at 200 Hz = 0.09 g's pk = 45 mV. The vibration is 10 times smaller, but the signal component is 8 times larger.

This example, again, highlights why it is better to use a velocity sensor, over an accelerometer, if you are using it to primarily measure low frequencies.

5.1.2 Rack Layout

If the customer is viewing casing orbit plots (this is rare) in SETPOINT software, the channels must be in Ch 1 & 2, or Ch 3 & 4. The two channels must be paired.

If the customer is not using casing orbits in CMS software the channels can be in any location in the rack and they are not required to be in XY pairs.

5.2 Verify Low F Acceleration

5.2.1 Test Setup

Use a 3.3 kΩ resistor to set the bias voltage (+10 Vdc). The 940 µF (or larger) capacitor is used to force the current through the resistor. A large test capacitor is needed because of the (expected) low frequency characteristics of the input signal.

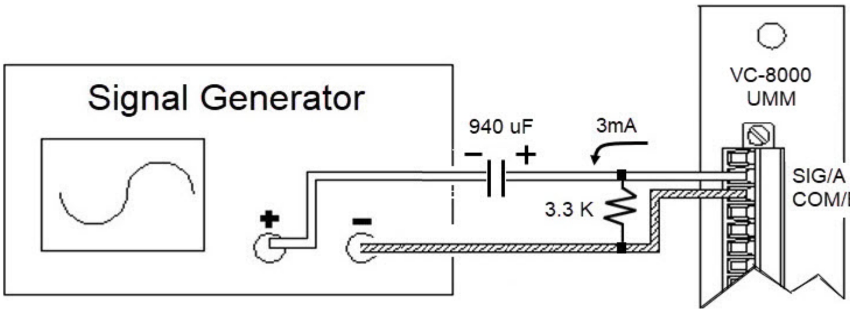


Figure 5-1) Constant Current Sensor

5.2.2 Simulate Signals (Standard)

Use a test frequency compatible with the configuration of the channel (i.e. 25 Hz). Set the function generator amplitude as follows:

Equation 5.1) (Units g pk)

$$Input\ (Vrms) = Vibration\ (g\ pk) * \frac{Scale\ Factor\ (mV/g)}{1000\ (mV/V) * \sqrt{2}}$$

Equation 5.2) (Units g rms)

$$Input\ (Vrms) = Vibration\ (g\ rms) * \frac{Scale\ Factor\ (mV/g)}{1000\ (mV/V)}$$

Where:

- Input = Simulation voltage from function generator (Vrms)
- Vibration = Desired vibration reading (i.e. 0.5 g pk)
- Scale Factor = Configured transducer scale factor (i.e. 100 mV/g, 500 mV/g)
- 1000 = conversion factor from mV to V
- √2 = conversion factor to Vrms

Example 1: To simulate a 0.5 g pk signal with a 100 mV/g transducer.

$$35.3\ mVrms = 0.5\ g\ pk * \frac{100\ mV/g}{1000 * \sqrt{2}}$$

TIP

A multimeter may have trouble measuring the test signal at low frequencies. Temporarily increase the frequency (i.e. 60 Hz) to verify the signal amplitude.

5.2.3 Simulate Signals (Integrated – in/s)

Use a test frequency compatible with the configuration of the channel (i.e. 25 Hz). Use the following equations to calculate the acceleration input value:

Equation 5.3) (in/s pk)

$$Acceleration\ (g\ pk) = \frac{Velocity\ (\frac{in}{s}\ pk) * Frequency\ (Hz)}{61.45}$$

Equation 5.4) (in/s rms)

$$Acceleration\ (g\ rms) = \frac{Velocity\ (\frac{in}{s}\ rms) * Frequency\ (Hz)}{61.45}$$

Where:

- Acceleration (g pk) = Acceleration value for input signal
- Velocity in/s pk (or mm/s pk) = desired velocity value
- Frequency = Input signal frequency
- 61.45 = conversion factor

Example 1: To simulate a 1.0 in/s pk integrated signal, where frequency is 25 Hz and the scale factor of the sensor is 100 mV/g, first use **Equation 5.3** , and then input the result into **Equation 5.1**.

To see 1.0 in/s pk (integrated) I need to input a signal equivalent to 0.41 g pk.	$0.41\ g\ pk = \frac{1.0\ in/s\ pk * 25\ Hz}{61.45}$
0.41 g pk is 28.7 mVrms (multimeter).	$28.7\ mVrms = 0.41\ g\ pk * \frac{100\ mV/g}{1000 * \sqrt{2}}$

Example 2: To simulate a 1.0 in/s rms integrated signal, where frequency is 25 Hz and the scale factor of the sensor is 100 mV/g, first use, **Equation 5.4** and then input the result into **Equation 5.2**.

To see 1.0 in/s rms (integrated) input a signal equivalent to 0.41 g rms.	$0.41\ g\ \text{rms} = \frac{1.0\ in/s\ \text{rms} * 25\ Hz}{61.45}$
0.41 g rms is 41 mVrms (multimeter).	$41\ mVrms = 0.41\ g\ \text{rms} * \frac{100\ mV/g}{1000}$

5.2.4 Simulate Signals (Integrated – mm/s)

Use a test frequency compatible with the configuration of the channel (i.e. 25 Hz). Use the following equations to calculate the acceleration input value:

Equation 5.5) (mm/s pk)

$$Acceleration\ (g\ pk)\ = \frac{Velocity\ (\frac{mm}{s}\ pk) * Frequency\ (Hz)}{1560}$$

Equation 5.6) (mm/s rms)

$$Acceleration\ (g\ rms)\ = \frac{Velocity\ (\frac{mm}{s}\ rms) * Frequency\ (Hz)}{1560}$$

Where:

- Acceleration (g pk) = Acceleration value for input signal
- Velocity in/s pk (or mm/s pk) = desired velocity value
- Frequency = Input signal frequency
- 1560 = conversion factor

Example1: To simulate a 25 mm/s pk integrated signal, where frequency is 25 Hz and the scale factor of the sensor is 100 mV/g, first use **Equation 5.5** and then input the result into **Equation 5.1**.

To see 25 mm/s pk (integrated) I need to input a signal equivalent to 0.40 g pk.	$0.40\ g\ pk = \frac{25\ mm/s\ pk * 25\ Hz}{1560}$
0.40 g pk is 28.3 mVrms (multimeter).	$28.3\ mVrms = 0.40\ g\ pk * \frac{100\ mV/g}{1000 * \sqrt{2}}$

Example 2: To simulate a 25 mm/s rms integrated signal, where frequency is 25 Hz and the scale factor of the sensor is 100 mV/g, first use, **Equation 5.6** and then input the result into **Equation 5.2**.

To see 25 mm/s rms (integrated) input a signal equivalent to 0.40 g rms.	$0.40\ g\ \mathrm{rms} = \frac{25\ mm/s\ \mathrm{rms} * 25\ Hz}{1560}$
0.40 g rms is 40 mVrms (multimeter).	$40.0\ mVrms = 0.40\ g\ \mathrm{rms} * \frac{100\ mV/g}{1000}$

6 Selecting a Seismic Sensor

There are several things to consider before selecting a sensor.

1. What is the speed of the machine?
2. What am I trying to measure?
3. What is the environment?
4. What are the specifications for the system (Sensor, VC-8000, CMS)
5. What is the cost of the sensor?

These topics are addressed in the following sections.

6.1 Machine Speed

All Hydro machines are low speed. But this makes sensor selection more difficult, rather than easier. At 300 RPM (or above) your 1X vibration will be at 5 Hz (or above) and there is a wider array of sensors available. Many of these sensors are general purpose and are not designed specifically for low frequency applications.
Below 300 RPM you will probably need a sensor specifically targeting low speed machines. For example, at 166 RPM your 1X vibration will be at 2.7 Hz. If you are interested in vibration related to flow turbulence (or vortex) you will want to see 0.4X (1.1 Hz).

6.2 Hydro Measurements

There can be a lot of regional differentiation in what is measured and how it is measured. The following guidelines may help when selecting a sensor.

<u>Draft Tube - Flow Turbulence (Vortex)</u>
Vortex typically causes a vibration around 0.4X to 0.5X of the running speed of the machine. Since this vibration is very slow an accelerometer will not provide enough signal amplitude to measure this. A velocity sensor should be used.

<u>Draft Tube - Cavitation (High Frequency)</u>
Use an accelerometer. Cavitation is typically around 5000 Hz.

<u>Stator Vibration</u>
The frequencies of interest for Stator Vibration will typically be 1X and an accelerometer could be used.

<u>Radial Bearing Housing (XY)</u>
The frequencies of interest for bearing housing vibration will typically be 0.4X and 1X. Also, when measuring vibration at the bearing housing it is common to integrate to displacement units; therefore, a velocity sensor should be used.

<u>Turbine Cover (Blade Pass)</u>
The frequencies of interest for Turbine Cover (Blade Pass) vibration will typically be 1X and greater, and an accelerometer could be used.

<u>Protection or Condition Monitoring</u>
If the measurement is purely for condition monitoring (and not to protect the machine) than it may be acceptable to choose an accelerometer to reduce cost if the customer understands the trade-offs involved.

6.3 Environment (Noise)

Accelerometers are becoming more common in many low speed applications because of their low cost. However, an accelerometer is not appropriate in the following situations:

Noisy Signal
If you anticipate a noisy signal or you have long cable runs (which often cause noisy signals), you should use a Velocity sensor. Most low frequency velocity sensors have a large scale-factor, and therefore a much better signal to noise ratio than the standard Accelerometer. Further, the acceleration signal will most likely be integrated. Integration of the low frequency signal will amplify noise and could make the signal completely unusable.

Signal Amplitudes
Low speed vibration generates very small G forces, and the accelerometer signal will be small. For example, A machine running at 166 RPM (2.77 Hz) with 5.0 mm/sec RMS (0.28 in/sec pk) of vibration is only 0.012 g's pk of acceleration. If the accelerometer has a scale factor of 100 mV/g the vibration signal will be only 1.2 mV pk. If the accelerometer has a scale factor of 500 mV/g the vibration signal will be 6.0 mV pk. These are very small signal amplitudes.
In contrast, the typical velocity probe for low speed machines has a scale factor of 20 mV/mm/s (508 mV/in/s), and will provide a signal of 100 mV in the same example described above.

Displacement Units (µm pp or mils pp)
In some applications the customer may want to view the low frequency vibration in displacement units (µm pp or mils pp). In this case a velocity sensor is clearly the correct choice.

6.4 System Specifications

Sensor selection impacts the channel types that can be used in VC-8000. This, in turn, impacts what can be viewed in SETPOINT CMS software. The following sections explore these relationships.

6.4.1 Channel Type Selection

If you select to use an Accelerometer on a low speed machine, you must use one of the acceleration channels. If you select a velocity sensor you must use one of the velocity channels. This will affect what measurement options are available to you. For example, Low F Accel and Low F Velocity channels do not provide a 2X, or nX measurement (see **Table 6-1**).

Of these five seismic channel types, only the Hydro Velocity channel was designed specifically for Hydro machines; It has the best options and the most flexibility when compared with the other channel types.

Table 6-1) Comparison of VC-8000 Seismic Channel Types

Measurement	Standard Accel	Low F Accel	Standard Velocity	Hydro Velocity	Low F Velocity
Direct	X	X	X	X	X
1X Amplitude	X	X	X	X	X
1X Phase	X	X	X	X	X
2X Amplitude	X	-	X	X	-
2X Phase	X	-	X	X	-
nX Amplitude	X	-	X	-	-
nX Phase	X	-	X	-	-
Band-pass 1	X	X	X	X	-
Band-pass 2	-	-	-	X	-
Max (X/Y)	X	-	X	-	-
Async Waveform	X	X	X	X	X
Sync Waveform	X	X	X	X	X

The Low F Accel, and the Low F Velocity channels can be used for some Hydro applications, but they were designed for higher speed machines, with an “interest” in low frequencies rather than for lower speed machines where nearly everything is low frequency.

6.4.1.1 Band-pass Filters

The Channel Type you select will affect the band-pass filter options that are available to you.
The Direct measurement of each channel is band-pass filtered (see **Table 6-2**). Protection systems use band-pass filters on the Direct measurement to improve the integrity of the signal that is (normally) used to trip the machine.

Other band-pass measurements can also be added – depending on the channel type. For example, the Hydro Velocity channel can add two additional band-pass measurements whereas the Low F Velocity channel cannot add any band-pass measurements (see **Table 6-1**).

The band-pass filter options are viewed and set from the Measurements tab, All view in the VC-8000 Setup Software. The filters are only applied to the measurement(s) indicated; waveforms are not bandpass filtered.

Table 6-2) Example band-pass filters (-3 dB)

Channel Type	Measurement	High Pass Min (LP)	(HP) Low Pass Max
Standard Acceleration	Direct	2.0 Hz (- 2,000 Hz) [1]	(25 Hz -) 25,000 Hz [2]
Low F Acceleration	Direct	0.2 Hz (- 1,000 Hz) [2]	(1 Hz -) 5,000 Hz [2]
Standard Velocity	Direct	2.0 Hz (- 2,000 Hz) [1]	(5 Hz -) 5,000 Hz [1]
Hydro Velocity	Direct	0.7 Hz (- 200 Hz)	(0.7 Hz -) 200 Hz
Low F Velocity	Direct	0.2 Hz (- 1,000 Hz) [2]	(1 Hz -) 5,000 Hz [2]

1. The High Pass (HP) and Low Pass (LP) filters must be within 1000x. For example, if I select a High Pass filter of 2.0 Hz, my Low Pass filter must be less than 2000 Hz.

2. The High Pass (HP) and Low Pass (LP) filters must be within 5000x. For example, if I select a High Pass filter of 0.2 Hz, my Low Pass filter must be less than 1000 Hz.

When you select a sensor for a low speed machine, you will need to be aware of the bandpass filter settings of the VC-8000. If the specification calls for the system to accept a signal down to 1.0 Hz (-3 dB), both the VC-8000 channel and the sensor must comply.
Both the Low F Acceleration channel, and the Low F Velocity channels have filter options that are acceptable for low speed machines. However, as discussed in Section 4, and Section 5 these channels have reduced functionality to provide a wide band-pass range.

6.4.1.2 Filter Steepness

The Channel Type you select determines the steepness of the filter. A steeper filter provides a stronger signal near the corner frequencies and it also does a better job of removing low frequency noise. The Hydro velocity channel has the steepest filters (14 pole);

Table 6-3) Comparison of filter steepness (poles)

Channel Type	High Pass	Low Pass
Standard Acceleration	-24 dB/octave (4 pole)	-24 dB/octave (4 pole)
Low F Accel	-24 dB/octave (4 pole)	-24 dB/octave (4 pole)
Standard Velocity	-24 dB/octave (4 pole)	-24 dB/octave (4 pole)
Hydro Velocity	-84 dB/octave (14 pole)	-72 dB/octave (12 pole)
Low F Velocity	-24 dB/octave (4 pole)	-24 dB/octave (4 pole)

6.4.2 Sensor Specifications

It is important to verify the specifications for sensors installed on low speed machines. **Table 6-4** lists a few examples. For low speed machines the most important specifications will be the frequency response (lower is better), and the scale factor (higher is better).

Be aware that some specifications will list the frequency response as -0.45 dB (5%). While others will list the frequency response at -3 dB (30%).

Table 6-4) Sensor Examples

	Sensor	Type	Scale Factor	Frequency Response (+/- 3dB)
Velocity	BN 9200	Coil	20 mV/mm/s (508 mV/in/s)	4.5 – 1000 Hz (± 3dB) (270 - 60,000 CPM)
Velocity	BN 330505	Piezo-electric	20 mV/mm/s (508 mV/in/s)	0.5 – 1000 Hz (± 3dB) (30 – 60,000 CPM)
Velocity	B&K VS-068	Coil	100 mV/mm/s (2.54 V/in/s)	10 – 2000 Hz (± 3dB) (600 – 120,000 CPM)
Velocity	B&K VS-068 (with linearization)	Coil	100 mV/mm/s (2.54 V/in/s)	1 – 2000 Hz (± 3dB) (60 - 120,000 CPM)
Acceleration	Metrix SV6300	CCS	3.94 mV/mm/s (100 mV/in/s)	2 – 8000 Hz (± 3dB) (120 – 480,000 CPM)
Acceleration	B&K AS-477	CCS	500 mV/g	0.2 – 14 Khz (± 3dB) (12 – 840,000 CPM)
Acceleration	B&K AS-062, AS-063	CCS	100 mV/g	1.5 – 13,000 Hz (± 3dB) (90 – 780,000 CPM)

6.4.2.1 VS-068 and VS-069 - Limitations

B&K Vibro VS-068 and VS-069 should not be used with VC-8000 and SETPOINT CMS software for applications below 10 Hz (600 CPM) – unless the CMS waveforms are disabled. Below 10 Hz, the VC-8000 provides linearization for the overall value of the signal; but the CMS waveforms are not linearized and will not be correct. This means that the time-base and spectrum plots in SETPOINT CMS software will not be correct.

B&K Vibro VS-068 and VS-069 can be used with VC-8000 and SETPOINT CMS software for applications above 10 Hz (600 CPM).

6.4.3 SETPOINT CMS Plots and Measurement Units

The sensor you select will determine the measurement (units) that will be available to you in the SETPOINT CMS software. For example, a velocity sensor will only show the non-filtered time-base waveform in velocity units. The filtered (1X) time-base waveform can be displayed in velocity or displacement units, depending on how the 1X measurement is configured in the VC-8000.

Table 6-5) Plots and Measurement Units

Measurements	Acceleration	Velocity
Connected Sensor	Acceleration	Velocity
Direct	Acceleration (or Velocity) Units	Velocity (or Displacement) Units
1X Amp	Acceleration (or Velocity) Units	Velocity (or Displacement) Units
2X Amp	Acceleration (or Velocity) Units	Velocity (or Displacement) Units
nX Amp	Acceleration (or Velocity) Units	Velocity (or Displacement) Units
Bandpass	Acceleration (or Velocity) Units	Velocity (or Displacement) Units
Orbit	Acceleration Units	Velocity Units
Time-base	Acceleration Units	Velocity Units
Spectrum	Acceleration (and Velocity) Units	Velocity (and Displacement) Units
Orbit 1X, 2X, nX Filtered	Same as 1X, 2X, nX Amp	Same as 1X, 2X, nX Amp
Time-base 1X, 2X, nX Filtered	Same as 1X, 2X, nX Amp	Same as 1X, 2X, nX Amp
Polar Plot	Same as 1X Amp	Same as 1X Amp
Bode Plot	Same as 1X Amp	Same as 1X Amp

6.5 Cost

Saving cost for the customer is important. However, please ensure that the customer understands the implications when selecting an accelerometer simply to reduce cost.

- Is it the right sensor for the application (frequency of interest, signal amplitude)?
- Is it the right sensor for the environment (noise)?
- Is it the right sensor for the protection system VC-8000?

7 Hydro Air Gap Channel

The Hydro Air Gap channel uses capacitive displacement sensors to assist in detecting generator faults such as dislocation of poles, loose rotor rims, deformed rim or center-line offset. The channel provides the following measurements:

Table 7-1) Hydro Air Gap channel – Measurements

Measurement	Description
Minimum Air Gap	The measured minimum gap updated each revolution. One revolution is determined by counting the detected poles in the sensor waveform. The UMM tracks the poles using a fixed triggering threshold (10.25 V) and fixed hysteresis (0.5 V) to detect the spaces between poles.
Bias	DC sensor bias voltage.
Rotor Profile (Sync) Waveform	The Rotor Profile waveform saves the lowest sampled value (minimum air gap) for each pole. All other samples are removed.
Asynchronous Waveform	The Asynchronous waveform is the raw, unprocessed signal from the sensor.

7.1 Options for Extending Hydro functionality

The VC-8000 Air Gap channel will meet the specifications for most Hydro applications, with Air Gap and Rotor Profile being the principle Hydro measurements, along with rotor and casing vibration.

To extend the VC-8000 Hydro functionality you can use the VI-6080 combined with Compass software. See **Table 7-2** for differences in the current SETPOINT (July 2021), and Compass software features for Hydro applications.

Table 7-2) Compass and SETPOINT differences (March 2024)

Measurement	VI-6080/Compass	VC-8000/SETPOINT CMS
Minimum Air Gap	x	x
Maximum Air Gap	x	x (CMS/PI only)
Average Air Gap	x	x (CMS/PI only)
Stator Offset	x	
Rotor Offset	x	
Stator Roundness	x	
Rotor Roundness	x	
Top/bottom stator difference	x	
Rotor Profile (Air Gap plot)	x	x
Stator Profile	x	x
Asynchronous Waveform	x	x

7.2 Background

There are several potential failure modes that are related to the physical configuration of hydro generators. Hydro units turn at relatively low speeds to extract maximum energy from the water head. This means many rotor poles are needed to generate electricity at line frequency, which results in generators having a large diameter with a small space between the stator and rotor (air gap).

Air gap variations will have a direct effect on the generator's mechanical, electrical and thermal balance. Even small variations for air gap can generate tremendous electromagnetic forces that could stress the bearings and structure.

There are many causes for air gap variations. For the rotor: dislocation of poles, loose rotor rims, deformed rim, or center-line offset are a few examples. For the stator: it could be deformation due to concrete growth, jammed hold-down bolts or core / frame separation.

7.2.1 AG Sensor Operation Principles

The air gap sensor is a capacitive sensor glued to the stator wall. Within the sensor there are two conductor plates that operate like an open capacitor. As a rotor pole passes in front of the sensor, the capacitance between the two plates increases, causing the circuit natural frequency to increase to the oscillator frequency, thus generating an output signal that is proportional to the distance between the rotor pole and stator.

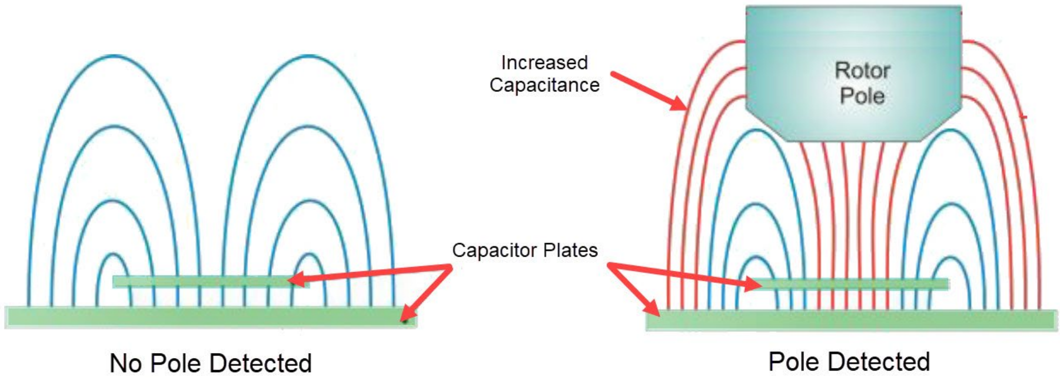


Figure 7-1) AG sensor operation

APPLICATION ALERT

UMM firmware 6.0 or higher is required for Hydro Air Gap channels.

7.2.2 How Many Sensors to Install

The air gap sensor measures the distance from the stator to each generator pole as it passes by. One sensor can only measure the distance at one location – where it is installed. Because the stator can deform in an irregular pattern, it is common to install multiple sensors; four, six, or eight sensors are the most common configurations.

Figure 7-2 shows how additional sensors provide increased accuracy. If one sensor (B) is installed at 0 Degrees (S-0), the minimum air gap will be (of course) detected at that location (B, S-0). With four sensors installed the minimum air gap is detected at sensor location (C, S-270), and with eight sensors at sensor location (D, S-315).

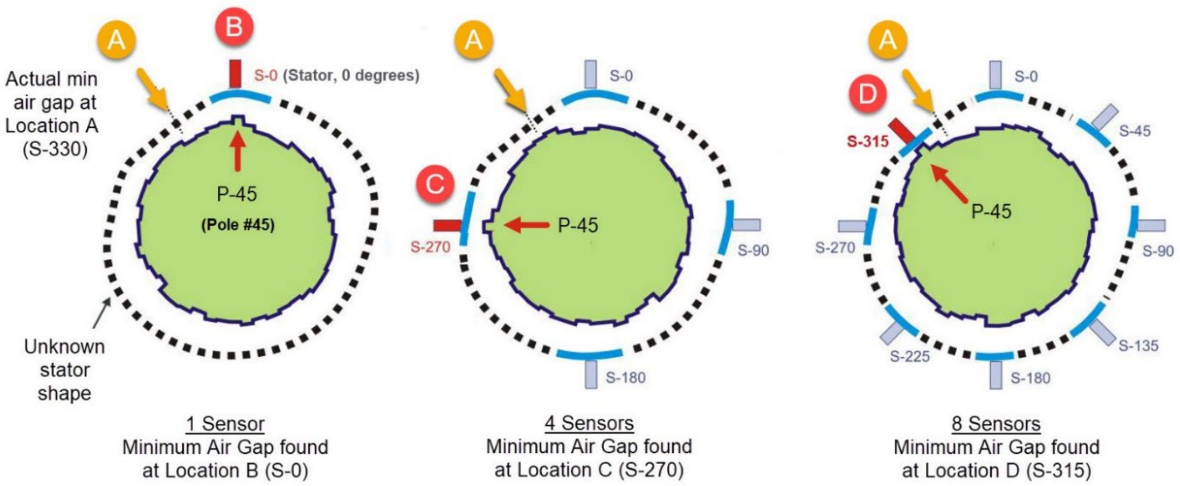


Figure 7-2) Minimum Air Gap, Number of Sensors

The number of sensors to install will be influenced by the size, the construction, and the age of the generator. For example, older generators may require more sensors due to segmented stator construction which would allow multiple portions of the stator to deform; Whereas newer construction may include a single-piece stator fabrication and so fewer sensors are needed.

Air gap monitoring is normally not so important if there is more than 2 mm to 3 mm nominal air gap per 1000 mm rotor diameter. If the generator height is greater than 1.6 m, two planes should be monitored, one on the top and one on the bottom, to detect geometrical variation along the vertical axis of the stator (ISO 19283 standard).

Remember, the Air Gap measurement is not a dynamic measurement and it is not a vector summation (like Smax, or an XY Orbit Plot). The Minimum Air Gap measurement is a position measurement (i.e. thrust, or eccentricity) and each sensor can only report the distance from the mounted location of the sensor to each rotor pole as they pass by.

7.3 Configure Hydro Air Gap

7.3.1 Rack Layout

The Hydro Air Gap channels can be installed in any UMM channel in the rack (they are not XY pairs). Air Gap channels in the same UMM will return rotor profile waveforms with the same timestamp. Air Gap channels in different UMMs are independent and rotor profile waveforms are not time-synchronized. In this case the Air Gap channels should be grouped together. Grouping the channels together will cause waveforms to be collected nearly at the same (within 1 sec).

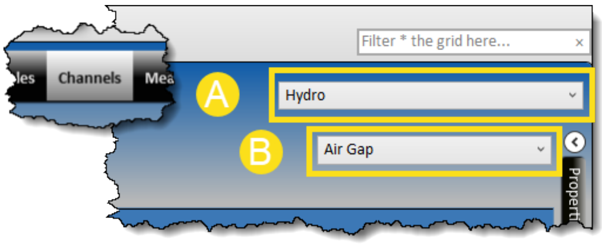
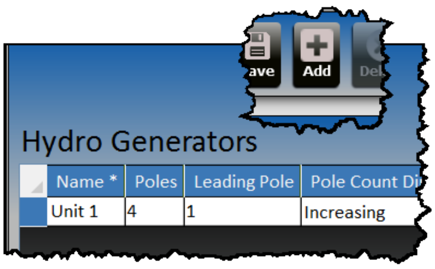
APPLICATION ALERT

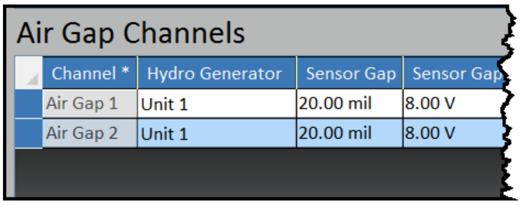
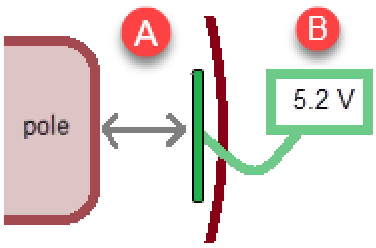
Air Gap channels for the same machine, but located in different UMM monitors should be grouped together using the Group Channels setting. This is enabled by default.

7.3.2 Hydro View

The Hydro Air Gap channel requires advanced configuration.
First, complete the standard configuration on the Channels tab (set the channel type, transducer, CMS data collection settings, etc.). Then, perform the following:

Table 7-3) Configuration, Hydro View

Instruction	Picture
First select the Hydro View and then select the Air Gap filter.	
Add and configure a hydro generator.	
Name	Assign a unique name to identify the hydro generator. This field is used in SETPOINT CMS software.
Poles	The number of generator poles. The VC-8000 uses this number to count the poles and determine the Minimum Air Gap per one revolution. This number is also used in SETPOINT CMS software on the Air Gap plot.
Tacho Pole	The pole that is in-line with the phase trigger notch. This parameter is used by the SETPOINT CMS software.

Instruction	Picture
Leading Pole (0 Deg Reference Pole)	The Leading Pole is the pole in-line with 0 degrees when the Tacho Pole passes the phase trigger (pulse occurs). The location of 0 degrees is determined by the customer (typically 0 degrees is upstream) If the phase trigger sensor is installed at 0 degrees. The Leading Pole and the Tacho Pole are the same pole. This number is used in the SETPOINT CMS software.
Pole Count Direction	The pole that follows the tacho pole determines the Pole Count Direction (increasing or decreasing). If the Tacho pole is pole 1, and the pole that follows is pole 2, the direction is increasing. This number is used in the SETPOINT CMS software.
Rotation Direction	The rotation direction (clockwise, or counter clockwise) is determined from this perspective: Standing above the generator looking down towards the turbine. Set the rotation direction on the Channels Tab, Phase Trigger View.
Associate the Air Gap channels to the generator and configure the sensor installation parameters.	
Sensor Gap (A) and Sensor Voltage (B) 	When the machine is stopped measure the following: Sensor Gap (A) is the physical distance between the sensor face and the pole in front of that sensor. Sensor Voltage (B) is the output voltage of the sensor when viewing that same pole. Note: This is a reference measurement, and it does not matter which pole is in front of the sensor when the measurement is taken. **If the value cannot be measured use a value from the sensor data sheet.**
Sensor Offset Distance	Measure the sensor thickness plus the adhesive thickness. The VC-8000 will add this value to the returned air gap value to provide the actual air gap between the stator and poles.
Scale Factor (mV/Unit)	Scale factor of the air gap sensor.
Unit	Scale factor units of the air gap sensor.
Max OK, Min OK	The voltage where the channel will go into Not OK.
Upper Trigger Level	The voltage level the sensor must exceed when viewing the spaces between the poles to indicate the end of a pole. This level is defaulted at 10.5V. See **Figure 7-11**.

Instruction	Picture
Lower Trigger Level	The voltage level the sensor must drop below when viewing the spaces between the poles to indicate the start of a pole. This level is defaulted at 10.0V. This value must be lower than the Upper Trigger Level. See **Figure 7-11**.
Averaging Revs	The number of revolutions averaged together for the Minimum Air Gap value.
Is On Secondary Plane	This indicates if an Air Gap sensor is on a different vertical plane from the primary sensors. This will allow the air gap sensor to have the same orientation as a sensor on the primary plane.

APPLICATION ALERT

When using custom Air Gap sensors with a range of 0-10 Vdc, set the Min OK Limit to 100 mV. This will drive the channel into Not OK if the sensor is disconnected or has lost power.

APPLICATION ALERT

UMM firmware 8.0 or higher is required to configure Upper Trigger Level, Lower Trigger Level and Averaging Revs.

7.3.3 Phase Trigger

A phase trigger is required for the VC-8000 Air Gap channel. However, the UMM calculates the Minimum Air Gap measurement by counting poles; If the Phase Trigger channel is Faulted, the Air Gap channel will remain OK and the Air Gap channel will still return a value.

A phase trigger is also required for the SETPOINT CMS Air Gap plot. If the Phase Trigger channel is faulted, the rotor profile waveform will not be returned.

7.3.4 Waveform Sample Rates

The Air Gap channel waveforms are used in the SETPOINT CMS software. They are not used for machinery protection.

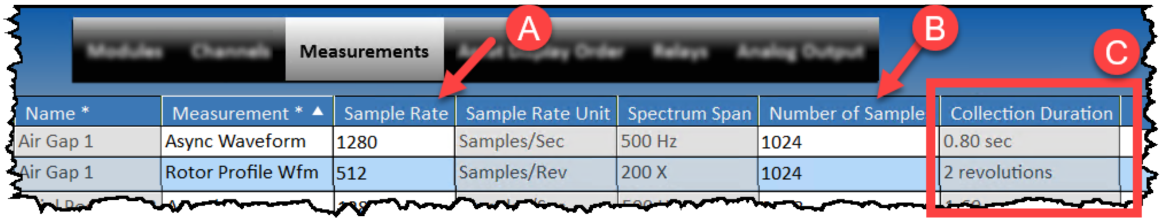


Figure 7-3) Waveform Data Collection

Best practice is to collect a waveform over 2 (or 4) revolutions with at least 10 samples per pole.

Asynchronous Waveform (Example)
Start by selecting the number of samples (See **Figure 7-3**). If the machine has 36 poles, the recommended Number of Samples (B) for one revolution should be (at least) 36 x 10 = 360 samples. For two revolutions we will need 720 samples. In this case, you would select 1024 samples (B). Next, select the sample rate. If the speed of the machine is 166.7 RPM, the time per one revolution is 0.36 seconds. To collect data for two revolutions the Collection Duration (C) must exceed 0.72 seconds. In this case you would select Sample Rate (A) = 1280 samples/sec. This will give a Collection Duration (C) of 0.8 seconds.

APPLICATION ALERT

To assist in trouble shooting and commissioning it is recommended to have a high sample rate and a large enough waveform to capture high resolution data for a single revolution.

Rotor Profile (Sync) Waveform (Example)
Notice that the Sample Rate (A) for the Rotor Profile Waveform is configured in Samples/Revolution. If the machine has 36 poles, we want to collect at least 36 x 10 = 360 samples (1 revolution); in this case, you would select 512 samples/revolution.
Select the Number of Samples (B) so that the Collection Duration (C) is 2 revolutions (or greater).

7.3.5 Waveform Collection

The Air Gap channel waveforms are used in the SETPOINT CMS software. They are not used for machinery protection.

Delta Time (Minutes)
The default setting of 20 minutes is acceptable for Air Gap channels.

Delta RPM
Leave the value at 10 RPM, which is the lowest setting.

I-Factor
This is the manual setting of the I-Factor threshold if Adaptive I-Factor is disabled or it is the minimum value if Adaptive I-Factor is enabled. Manually setting this value is an advanced topic and will not be covered here. We recommend enabling Adaptive I-Factor.

Adaptive I-Factor
Adaptive I-Factor should be enabled.
If too many waveforms are being collected, and Adaptive I-Factor is enabled, the Air Gap channel will adjust the setting automatically until the I-Factor is only triggered once during each Delta Time interval (i.e. 20 minutes). Note that the Adaptive I-Factor cannot decrease the I-Factor below the original setting. See more on I-Factor in the VC-8000 Operation & Maintenance Manual (S1079330).

Group Channels
All channels that are grouped will collect waveforms together if any one channel in the group is triggered to collect a waveform. The waveforms will not have the exact same time-stamp, but they are collected nearly at the same time (typically within 1 second).
Hydro Radial Vibration channels, Air Gap channels and Magnetic Flux channels should be grouped together. Velocity channels typically would not be included as they can be noisy and trigger too much data collection.

Boost Mode, Low Trigger (RPM), High Trigger (RPM)
Not for low speed machines. Leave at default values.

7.4 Compatible Sensors

The VC-8000 Air Gap Channel is designed for the B&K 2431 and the Meggitt LS 12x/ILS 73x families of sensors. However, any Air Gap sensor can be used if the sensor signal becomes greater than +10 Vdc when viewing the space between the poles.
The signal conditioner of some Air Gap sensor may have multiple outputs, such as Pole Profile, Rotor Profile, or Min Gap. Normally, you will connect the Pole Profile output to the VC-8000 Air Gap channel. The Pole Profile is the instantaneous value between the surface of the sensor and the rotor. The VC-8000 Air Gap channel expects a voltage input.

7.4.1 Sensor Power

Capacitive air gap sensors typically require +24 Vdc and require more current than can be supplied by the UMM. Power for air gap sensors must be supplied using an external power supply.

IMPORTANT

Capacitive air gap sensors require more current than can be supplied by the UMM. Supply the power for the air gap sensors using an external power supply.

7.4.2 Setting Ok Limits

If the Air Gap sensor has a range of 0 to +10 Vdc, set the Lower Ok Limit to 100 mV; This will detect an open circuit (0 V) or a sensor with no power (0 V). The Upper OK limit defaults to +18V.

7.4.3 Pole Detection

The Air Gap sensor (Pole Profile output) is typically a 0 to +10V (or 2 to +10 V) signal. The range of the sensor (i.e. 20 – 50 mm) will differ depending on the sensor part number. The Upper Trigger level is used to indicate the completion of a pole. The Lower Trigger Level is used to indicate the start of a pole.

Upper Trigger level is +10.5 V (Default)
The sensor output voltage must exceed +10.5 V when viewing the spaces between the poles. The UMM upper trigger level of 10.5 V triggers the completion of a pole. This voltage is configurable in newer versions of VC-8000 configuration software.

Lower Trigger level is +10.0 V (Default)
The voltage level the sensor must drop below when viewing the spaces between the poles to indicate the start of a pole. This voltage is configurable in newer versions of VC-8000 configuration software.

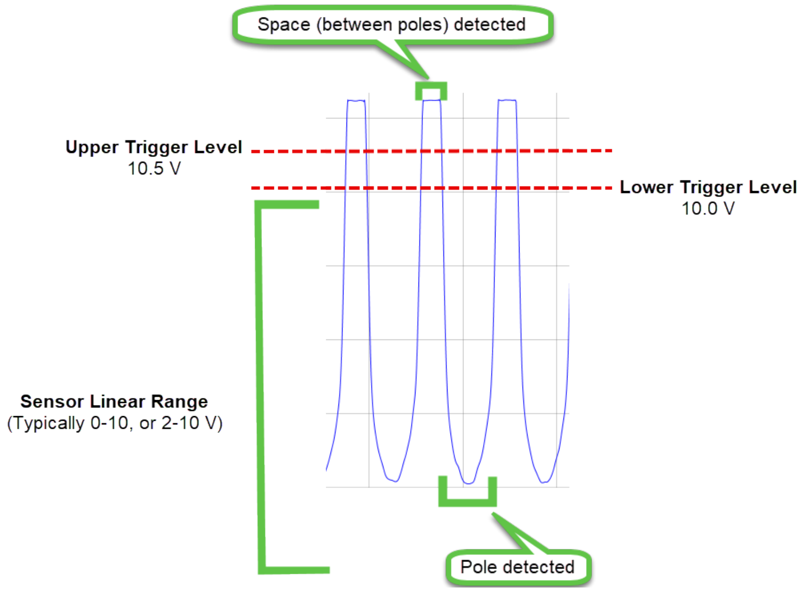


Figure 7-4) Typical Air Gap Sensor Signal

IMPORTANT

Upper and Lower Trigger levels are only configurable in UMM firmware 8.0 and greater.

IMPORTANT

The phase trigger pulse must happen within the Pole Detected region. If the phase trigger event happens in the space between poles, the Rotor Profile waveform will not be collected properly. Adjust the Upper and Lower Trigger Levels to ensure that the phase trigger pulse happens within the Pole Detected region.

7.5 Verify Air Gap Alarms

Simulate the Air Gap channel using a function generator (A) and a DC power supply (B) as shown in **Figure 7-5** The Minimum Air Gap measurement is calculated from the lower portion of the square wave (sensor viewing the pole); and the upper portion of the square wave (sensor viewing the space between the poles) must exceed 10.5 Vdc (see **Figure 7-4**).

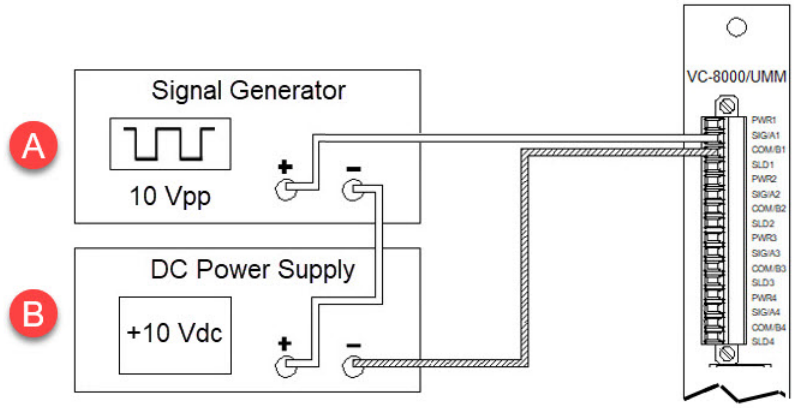


Figure 7-5) Test Air Gap alarms

A Phase Trigger channel is required to configure the Air Gap channel. However, since the Minimum Air Gap measurement uses "pole counting" to detect each revolution, you do not have to simulate the Phase Trigger channel to test the Minimum Air Gap alarms.
Calculate the input voltage as follows:

Equation 7.1) Input voltage – Distance (mm)

$$Distance\ (mm) = Abs\ ((Desired\ Air\ Gap\ Reading\ (mm) - Actual\ Gap\ (mm))$$

Equation 7.2) Input voltage – Input (Vdc)

$$Input\ (Vdc) = Sensor\ Gap\ (Vdc) - (Distance\ (mm) * Scale\ Factor\ (V/mm))$$

Where:

- Abs () = Absolute value
- Desired Air Gap Reading (mm) = The value to be simulated (i.e. 30 mm)
- Actual Gap (mm) = Sensor Gap + Sensor Offset Distance
- Sensor Gap (Vdc) = The voltage reading at the Sensor Gap (i.e. 6 Vdc)
- Scale Factor = Scale factor of the Air Gap sensor (i.e. 267 mV/mm)
- Input = The sensor voltage when viewing the pole.

Calculate the frequency of the input signal as follows:

Equation 7.3) Input signal – Frequency (Hz)

$$Frequency\ (Hz) = \left(\frac{Speed\ (RPM)}{60}\right) x\ Number\ of\ Poles$$

Example: Test an Air Gap channel with an Alert alarm

- Sensor Gap (sensor face to rotor pole) = 35 mm
- Sensor Gap (sensor face to rotor pole) Volts = 6.0 V
- Sensor Offset Distance = 5 mm
- Sensor Scale Factor = 267 mV/mm
- Actual Gap (stator to rotor) = 40.0 mm
- Poles = 36
- Machine Running Speed = 166.7 RPM
- Alert Alarm = 30 mm

To bring the channel into OK, set the function generator to a square wave at 10 Vpp. Set the DC power supply to +10 Vdc. This will give you an input signal oscillating from 5 Vdc to 15 Vdc.

Using **Equation 7.1** and **Equation 7.2** to compute the desired input voltage:

$$10\ mm = abs(30\ mm - \ 40.0\ mm)$$

$$3.3\ V = 6\ V - (10.0\ mm * \ 0.267 \frac{V}{mm})$$

Use **Equation 7.3** to calculate the input signal frequency. The machine speed is 166.7 RPM with 36 poles, so the frequency will be 100 Hz.

To simulate the alarm, adjust the DC power supply downward to +8.3 Vdc. This will move the input signal so that it is now oscillating from 3.3 Vdc to 13.3 Vdc (see **Figure 7-6**). The Minimum Air Gap measurement should read 30 mm.

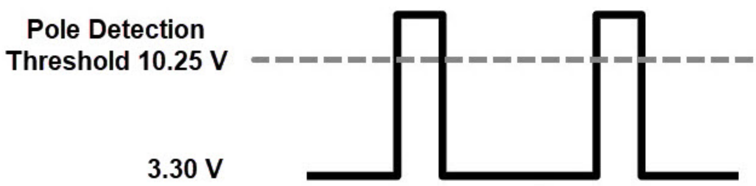


Figure 7-6) Signal Simulation (Minimum Air Gap)

7.6 SETPOINT CMS Air Gap Plots

The VC-8000 Air Gap channel provides a Rotor Profile waveform and an Asynchronous waveform to the SETPOINT CMS software. This data is used for the Asynchronous Timebase plot (A), the Rotor Profile Timebase plot (B), and the Air Gap plot (C) (see **Figure 7-7**).

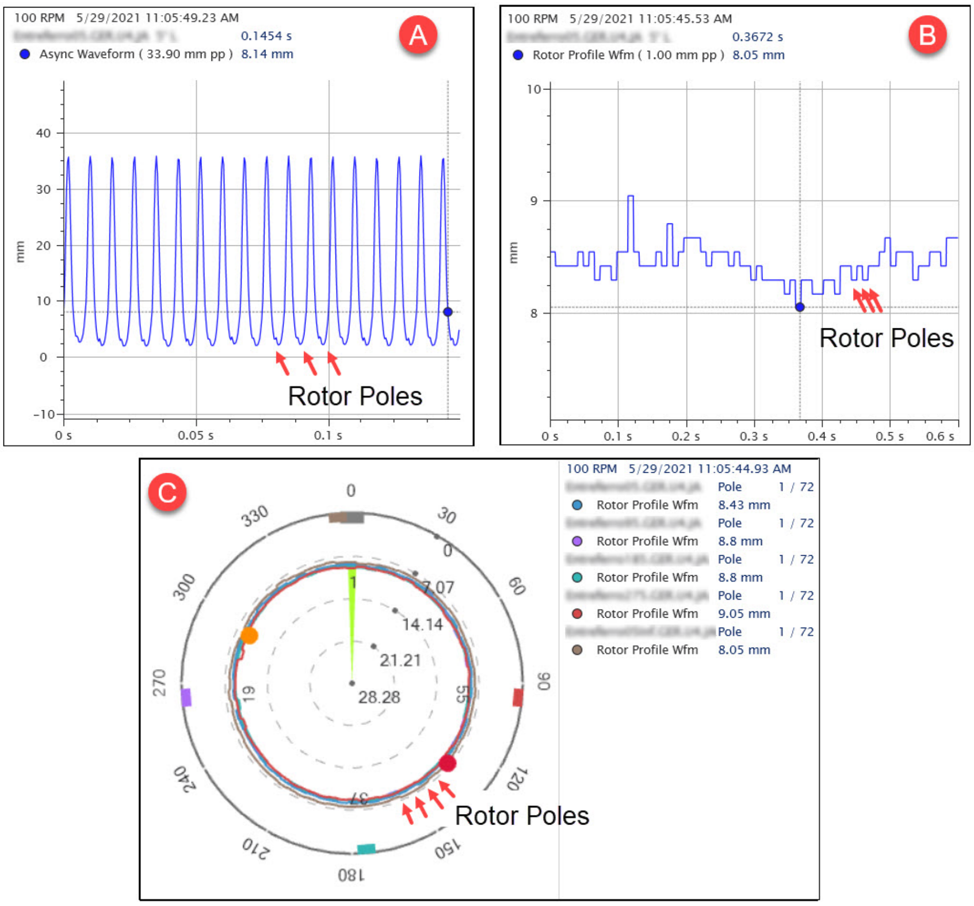


Figure 7-7) SETPOINT CMS Air Gap Plots

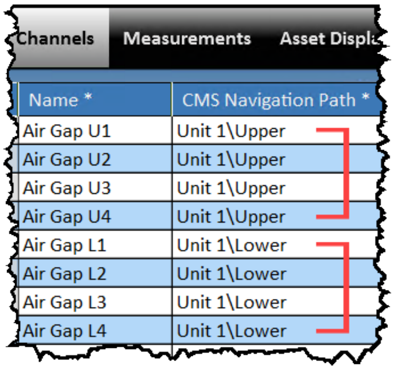
<u>Asynchronous Timebase Plot (A)</u>
This is the raw data samples from the Air Gap sensor.

<u>Rotor Profile Timebase Plot (B)</u>
The Rotor Profile waveform is constructed from the raw data samples. The waveform shows the minimum value from each pole over two (or more) revolutions. Typically, 1024 samples are taken each revolution of the generator (see Section 7.3.4).

<u>Air Gap Plot (C)</u>
The Air Gap plot for Sensor 1 (for example) is constructed from the Sensor 1 Rotor Profile waveform; It consolidates the two (or more) revolutions from the Sensor 1 Rotor Profile waveform into a single revolution for plotting; the minimum value at each pole is used.

7.6.1 Creating Multiple Air Gap Plots

Air Gap channels with the same CMS Navigation path are displayed on the same Air Gap plot. To place channels on separate plots, make the CMS Navigation path different for each channel (or group of channels). For example, if you have sensors on the upper and lower side of the generator, use a CMS Navigation path of “Unit 1\Upper”, for the upper channels, and “Unit 1\Lower” for the lower channels (see **Figure 7-8**).



Name *	CMS Navigation Path *
Air Gap U1	Unit 1\Upper
Air Gap U2	Unit 1\Upper
Air Gap U3	Unit 1\Upper
Air Gap U4	Unit 1\Upper
Air Gap L1	Unit 1\Lower
Air Gap L2	Unit 1\Lower
Air Gap L3	Unit 1\Lower
Air Gap L4	Unit 1\Lower

Figure 7-8) Air Gap groups

7.6.2 Differences from Compass Software

The CMS Air Gap plot is different than the Air Gap plot in previous version of B&K Vibro software. For example, the Compass CMS software always shows the rotor profile for sensor 1 alone; whereas the SETPOINT CMS software overlays all of the sensors on the Air Gap plot.

7.6.3 Verify the Air Gap Plot in SETPOINT CMS

To simulate the Air Gap plot the user must have a working knowledge of the SETPOINT PI Adapter software, and the SETPOINT CMS software. These topics are not covered in this manual.
Setup the simulation as shown in **Figure 7-9)** Simulate Air Gap plot. The signal generator (B) is optional but is highly recommended to see a full simulation. If it (B) is not used, the Rotor Profile waveform will be a straight line, and the Air Gap plot will be a perfect circle. Note: (C) and (D) can be in the same 2-Channel function generator, but (B) must be independent.

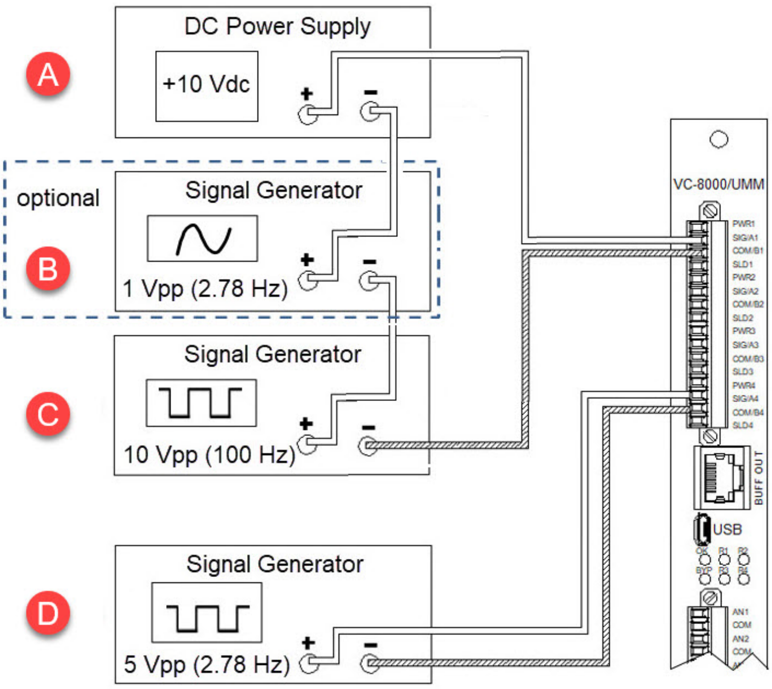


Figure 7-9) Simulate Air Gap plot

Example: Simulate an Air Gap channel with a Minimum Air Gap of 30 mm. The settings described here, are for convenience to make it easier to simulate the channel.

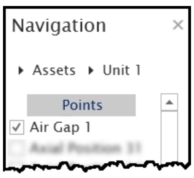
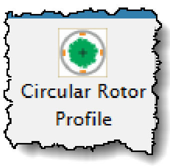
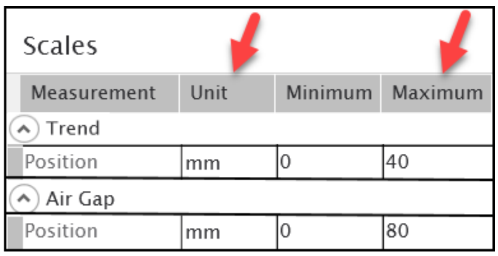
<u>Air Gap Channel</u>

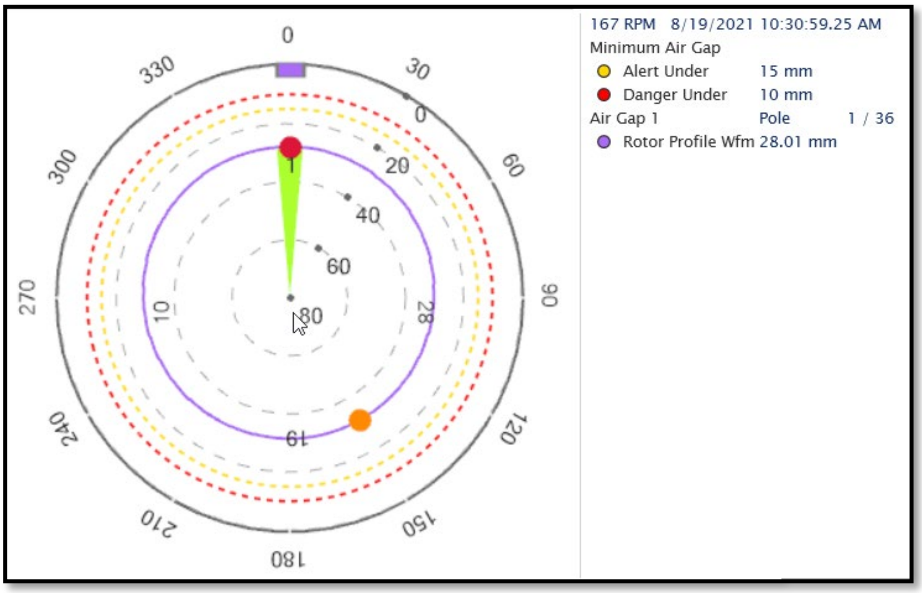
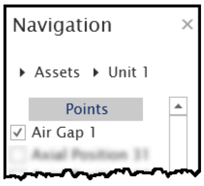
- Range = 0 - 40 mm (Alert = 15 mm, Danger = 10 mm)
- Orientation: 0 Degrees Left
- Machine Name: Hydro Generator 1
- Poles = 36 (166.7 RPM speed machine)
- Leading Pole = 1
- Pole Count Direction = Increasing
- Sensor Gap (sensor face to rotor pole) = 35 mm
- Sensor Gap Volts = 6.0 V
- Sensor Offset Distance = 5 mm
- Sensor Scale Factor = 267 mV/mm
- Delta Time (Minutes) = 1
- CMS Navigation Path = Unit 1
- Async Waveform = 1,280 samples/sec (1,024 samples) = 0.8 sec
- Rotor Profile (Sync) Waveform = 1,024 Samples/Rev (2,048 samples) = 2 Revs

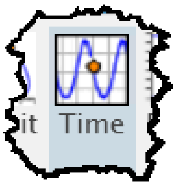
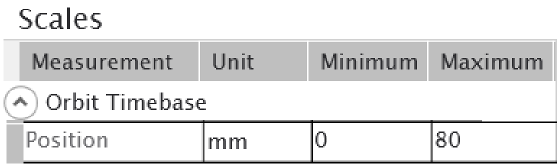
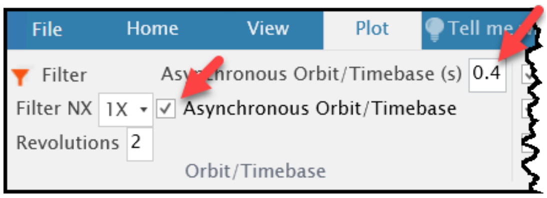
<u>Phase Trigger Channel</u>

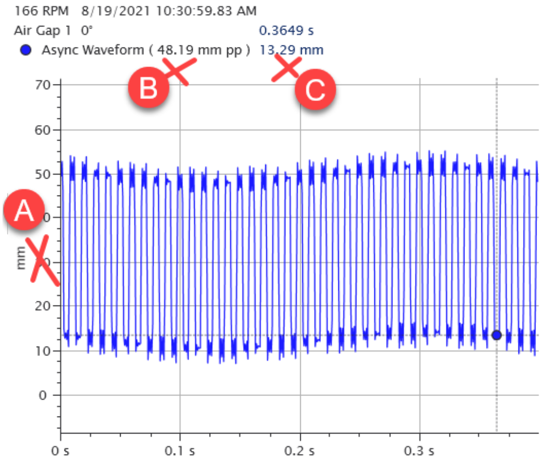
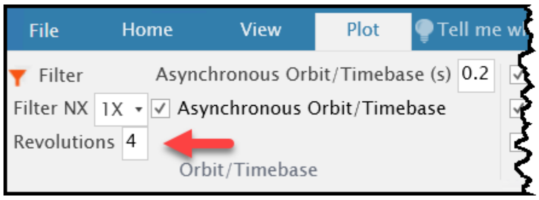
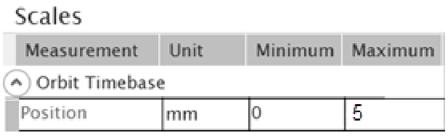
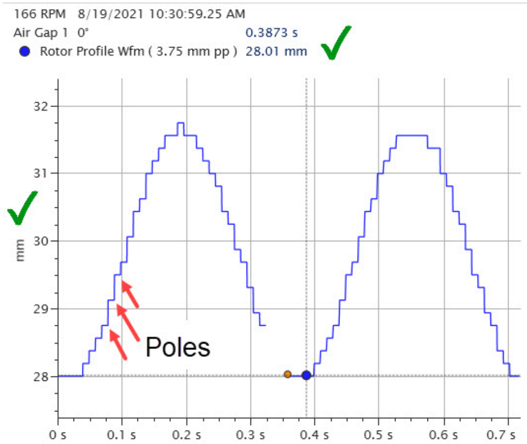
- Transducer Power = +18 V Proximity Switch
- Orientation = 0 Degrees Left
- Event Ratio = 1
- Direction of Rotation = Clockwise

Follow these steps to simulate and view the Air Gap plot:

Instruction	Picture
Set up the simulation as shown in **Figure 7-1**.	(A) +10 Vdc Offset (B) 1 Vpp (2.78 Hz) (C) 10 Vpp square wave (100 Hz) (D) 5 Vpp (2.78 Hz) Phase Trigger
In the SETPOINT CMS software: Select the Air Gap measurement in the Navigation pane. Select the Circular Rotor Profile plot from the Hydro ribbon.	 
Set the Trend manual scale to 0-40 mm Set the Air Gap manual scale to 0-80 mm Note: The Air Gap scale is increased to 80mm to make it easier to view the Air Gap plot.	

<table>
<tr><th>Instruction</th><th>Picture</th></tr>
<tr><td colspan="2">The Air Gap plot is shown here. Due to variations in the timing between the function generators your plot may appear slightly different. In general you should have an Air Gap plot with a minimum air gap of ~30 mm with max and min points ~180 degrees apart.

</td></tr>
<tr><td>In the SETPOINT CMS software:
Select the timebase icon</td><td>


</td></tr>
<tr><td>Set the manual scaling for the Position measurement (Orbit Timebase section) to 0-80 mm</td><td>
</td></tr>
<tr><td>On the Plot tab (Orbit/Timebase section)
Select to show the Async Orbit/Timebase
Set Async Orbit/Timebase = 0.4 seconds. This controls how much of the Async waveform is shown. If the machine is running at 166.6 RPM, 0.4 seconds is just over 1 revolution.</td><td>
</td></tr>
</table>

Instruction	Picture
The Asynchronous waveform is shown here. This plot shows the raw waveform coming from the sensor. The Y Axis (A) is not used. The two numbers reported on this plot (B) and (C) are also not used.	
On the Plot tab (Orbit/Timebase section) Set Revolutions = 2. This controls how many revolutions of the rotor profile waveform will be shown.	
Set manual scale to 0-5 mm (Orbit Timebase section).	
An exaggerated signal was used to generate this Rotor Profile waveform. The Rotor Profile waveform is the lowest filtered sample value (minimum air gap) for each pole. The pole measurements are varying between 28 mm and 31.7 mm (variation of 3.75 mm). This is the 1 Vpp sine wave that is riding on top of the square wave. A 1 V (sine wave) x 267 mV/mm (transducer scale factor) = 3.7 mm variation.	

7.6.4 Troubleshooting the Air Gap Plot

If the rotor profile waveform is not being shown in the CMS software:

- Check the status bar (A) of the Air Gap channel using the VC-8000 Maintenance software. Verify the status is OK (see **Figure 7-10**).
- Make sure the UMM is configured for the correct number of poles. If this is not correct, the Rotor Profile waveform will not be generated. See section 7.3.2.
- Temporarily modify the Delta Time setting to 0.25 minutes (Channels tab, CMS Framework view). This will force a waveform to be collected every 15 seconds and make troubleshooting easier.
- Using a high-resolution asynchronous waveform, determine appropriate upper and lower trigger levels. Adjust levels so that noise in the gap between poles will not trigger phantom poles (see **Figure 7-11**). You will need to convert the displayed gap to a voltage using the sensor scale factor.

For more information on the Air Gap plot see the SETPOINT CMS Instruction Manual (S1176125.002).

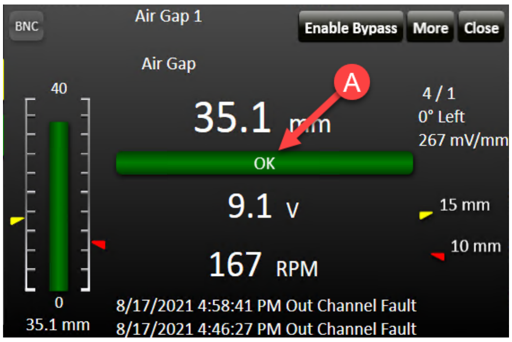


Figure 7-10) Status Bar

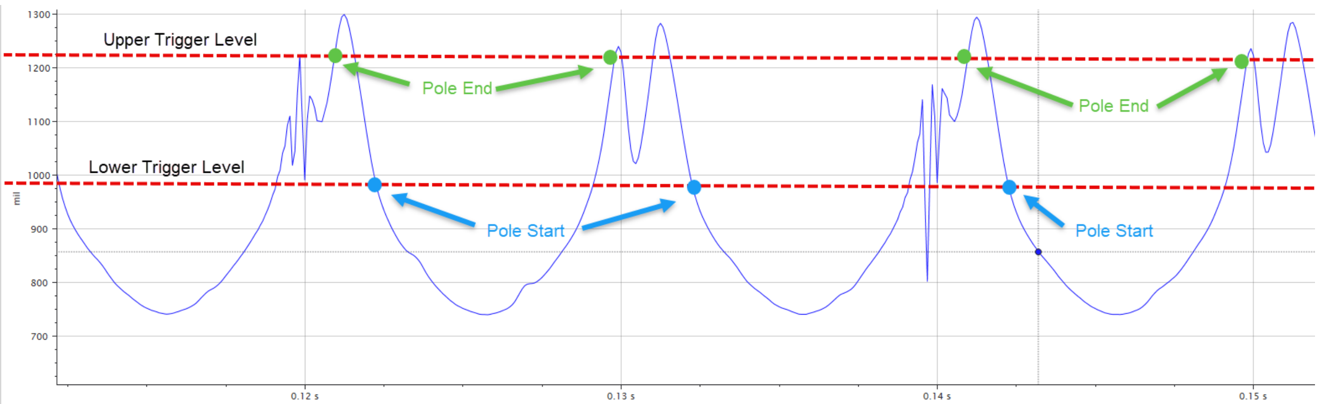


Figure 7-11) Selecting Trigger Levels

8 Magnetic Flux Channel

The Hydro Magnetic Flux channel uses Hall effect sensors to assist in detecting generator faults such as shorted pole coils and diagnostic of generator magnetic fields. The channel provides the following measurements:

Table 8-1) Magnetic Flux channel – Measurements

Measurement	Description
Minimum (primary)	The measured minimum Magnetic Flux updated each revolution.
Maximum	The measured Maximum Magnetic Flux updated each revolution.
Average	The measured average Magnetic Flux updated each revolution.
Profile (Sync) Waveform	The Profile waveform saves the lowest filtered value (minimum magnetic flux) for each pole. All other samples are removed.
Asynchronous Waveform	The Asynchronous waveform is the raw, unprocessed signal from the sensor.

8.1 Background

There are several potential failure modes that are related to the physical configuration of hydro generators. Hydro units turn at relatively low speeds to extract maximum energy from the water head. This means many rotor poles are needed to generate electricity at line frequency, which results in generators having a large diameter with a small space between the stator and rotor (air gap).

Monitoring a generator’s magnetic flux allows for the detection of turn to turn shorts in a rotor’s pole windings. This type of failure can lead to increased mechanical vibration and a drop in efficiency of the generator.

8.1.1 Magnetic Flux Sensor Operation Principles

The magnetic flux sensor measures the generated magnetic flux from the generator. The magnetic flux will alternate between positive and negative for each pole of the generator.

Figure 8-1) Raw Magnetic Flux Signal in Tesla

To process this data, the signal will be rectified so each pole can be directly compared.

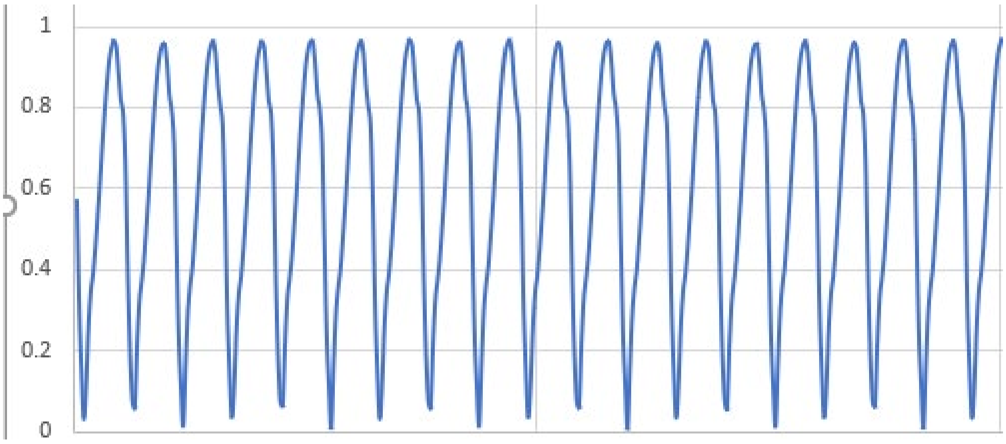


Figure 8-2) Rectified Magnetic Flux Signal

APPLICATION ALERT

UMM firmware 8.0 or higher is required for Magnetic Flux channels.

8.2 Configure Magnetic Flux

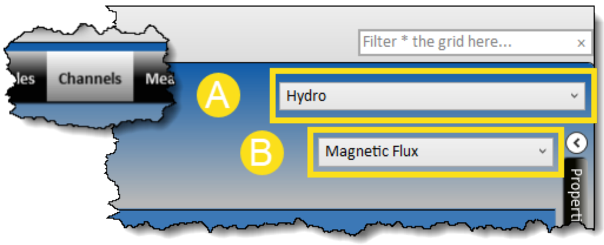
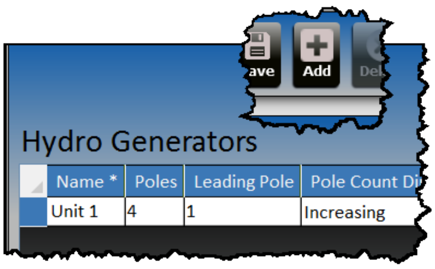
8.2.1 Rack Layout

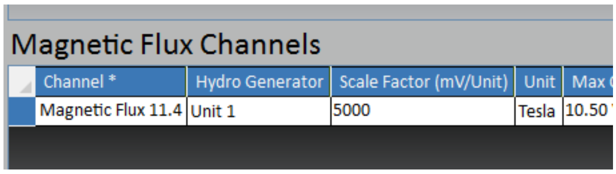
The Magnetic Flux channels can be installed in any UMM channel in the rack. There is generally one sensor per machine. It is recommended to group the Magnetic Flux channel with any Air Gap channels configured on the same machine.

8.2.2 Hydro View

The Magnetic Flux channel requires advanced configuration.
First, complete the standard configuration on the Channels tab (set the channel type, transducer, CMS data collection settings, etc.). Then, perform the following:

Table 8-2) Configuration, Hydro View

Instruction	Picture
First, select the Hydro View and then select the Magnetic Flux filter.	
Add and configure a hydro generator.	
Name	Assign a unique name to identify the hydro generator. This field is used in SETPOINT CMS software.
Poles	The number of generator poles. The VC-8000 uses this number to count the poles and determine the Magnetic Flux measurements once per revolution. This number is also used in SETPOINT CMS software for Hydro plots.
Tacho Pole	The pole that is in-line with the phase trigger notch. This parameter is used by the SETPOINT CMS software.
Leading Pole (0 Deg Reference Pole)	The Leading Pole is the pole in-line with 0 degrees when the Tacho Pole passes the phase trigger (pulse occurs). The location of 0 degrees is determined by the customer (typically 0 degrees is upstream) If the phase trigger sensor is installed at 0 degrees, the Leading Pole and the Tacho Pole are the same pole. This number is used in the SETPOINT CMS software.

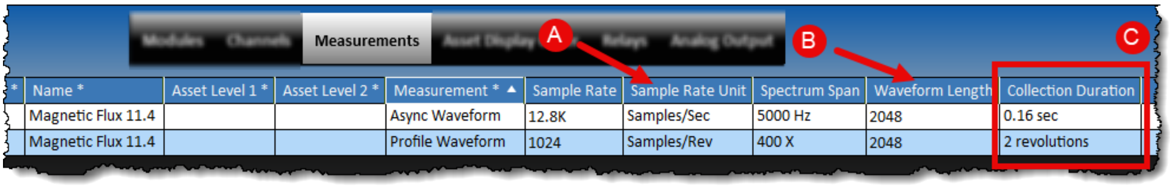
Instruction	Picture
Pole Count Direction	The pole that follows the tacho pole determines the Pole Count Direction (increasing or decreasing). If the Tacho pole is pole 1, and the pole that follows is pole 2, the direction is increasing. This number is used in the SETPOINT CMS software.
Rotation Direction	The rotation direction (clockwise, or counter clockwise) is determined from this perspective: Standing above the generator looking down towards the turbine. Set the rotation direction on the Channels Tab, Phase Trigger View.
Associate the Magnetic Flux channel to the generator and configure the sensor installation parameters.	
Scale Factor (mV/Unit)	Scale factor of the magnetic flux sensor.
Unit	Scale factor units of the magnetic flux sensor.
Max OK, Min OK	The voltage where the channel will go into Not OK.
Upper Trigger Level	The voltage level the sensor must exceed when viewing the spaces between the poles of the rectified signal to indicate the start of a pole.
Lower Trigger Level	The voltage level the sensor must drop below when viewing the spaces between the poles of the rectified signal to indicate the end of a pole. This value must be lower than the Upper Trigger Level.
Averaging Revs	The number of revolutions averaged together for all the Magnetic Flux values.

8.2.3 Phase Trigger

A phase trigger is required for the VC-8000 Magnetic Flux channel. However, the UMM calculates the Magnetic Flux measurements by counting poles; if the Phase Trigger channel is faulted, the Magnetic Flux channel will remain OK and the Magnetic Flux channel will still return all values.
A phase trigger is also required for the SETPOINT CMS Hydro plots. If the Phase Trigger channel is faulted, the profile waveform will not be returned.

8.2.4 Waveform Sample Rates

The Magnetic Flux channel waveforms are used in the SETPOINT CMS software. They are not used for machinery protection.



*	Name *	Asset Level 1 *	Asset Level 2 *	Measurement * ▲	Sample Rate	Sample Rate Unit	Spectrum Span	Waveform Length	Collection Duration
	Magnetic Flux 11.4			Async Waveform	12.8K	Samples/Sec	5000 Hz	2048	0.16 sec
	Magnetic Flux 11.4			Profile Waveform	1024	Samples/Rev	400 X	2048	2 revolutions

Figure 8-3) Waveform Data Collection

Best practice is to collect a waveform over 2 (or 4) revolutions with at least 10 samples per pole.

Asynchronous Waveform (Example)
Start by selecting the number of samples (See **Figure 8-3**). If the machine has 36 poles, the recommended Number of Samples (B) for one revolution should be (at least) 36 x 10 = 360 samples. For two revolutions we will need 720 samples. In this case, you would select 1024 samples (B).
Next, select the sample rate. If the speed of the machine is 166.7 RPM, the time per one revolution is 0.36 seconds. To collect data for two revolutions the Collection Duration (C) must exceed 0.72 seconds. In this case you would select Sample Rate (A) = 1280 samples/sec. This will give a Collection Duration (C) of 0.8 seconds.

APPLICATION ALERT

To assist in trouble shooting and commissioning it is recommended to have a high sample rate and a large enough waveform to capture high resolution data for a single revolution.

Profile (Sync) Waveform (Example)
Notice that the Sample Rate (A) for the Profile Waveform is configured in Samples/Revolution. If the machine has 36 poles, we want to collect at least 36 x 10 = 360 samples (1 revolution); in this case, you would select 512 samples/revolution.
Select the Number of Samples (B) so that the Collection Duration (C) is 2 revolutions (or greater).

8.2.5 Waveform Collection

The Magnetic Flux channel waveforms are used in the SETPOINT CMS software. They are not used for machinery protection.

Delta Time (Minutes)
The default setting of 20 minutes is acceptable for Magnetic Flux channels.

Delta RPM
Leave the value at 10 RPM, which is the lowest setting.

I-Factor
This is the manual setting of the I-Factor threshold if Adaptive I-Factor is disabled or it is the minimum value if Adaptive I-Factor is enabled. Manually setting this value is an advanced topic and will not be covered here. We recommend enabling Adaptive I-Factor.

Adaptive I-Factor
Adaptive I-Factor should be enabled.
If too many waveforms are being collected, and Adaptive I-Factor is enabled, the Magnetic Flux channel will adjust the setting automatically until the I-Factor is only triggered once during each Delta Time interval (i.e. 20 minutes). Note that the Adaptive I-Factor cannot decrease the I-Factor below the original setting. See more on I-Factor in the VC-8000 Operation & Maintenance Manual (S1079330).

Group Channels
All channels that are grouped will collect waveforms together if any one channel in the group is triggered to collect a waveform. The waveforms will not have the exact same time-stamp, but they are collected nearly at the same time (typically within 1 second).
Hydro Radial Vibration channels, Air Gap channels and Magnetic Flux channels should be grouped together. Velocity channels typically would not be included as they can be noisy and trigger too much data collection.

Boost Mode, Low Trigger (RPM), High Trigger (RPM)
Not for low speed machines. Leave at default values.

8.3 Compatible Sensors

The VC-8000 Magnetic Flux Channel was originally designed for the B&K EQ 2430 sensor. However, any magnetic flux sensor can be used with the custom transducer option.
The VC-8000 Magnetic Flux channel expects a voltage input.

8.3.1 Sensor Power

Magnetic flux sensors generally require an external bi-polar power supply.

8.3.2 Setting Ok Limits

Magnetic flux sensors have a bipolar voltage output such as +/- 10 V. Make sure the configured OK limits exceed the linear range of the sensor.

APPLICATION ALERT

Since the voltage output of a magnetic flux sensor goes between a positive and negative voltage, there is no way to detect an open or shorted sensor as the voltage will be detected as 0 V.

8.3.3 Pole Detection

The Magnetic flux sensor (Pole Profile output) is typically a -10V to +10V signal. This signal is rectifed internally to become a 0V – 10V signal.

Upper Trigger level is +1.0 V
The sensor output voltage must cross 0 V when viewing the spaces between the poles. The UMM upper trigger level of 1.0 V indicates the start of a pole. This voltage is configurable in the VC-8000 configuration software.

Lower Trigger level is +0.5 V
The voltage level the sensor must drop below when viewing the spaces between the poles to trigger the completion of a pole. This voltage is configurable in the VC-8000 configuration software.

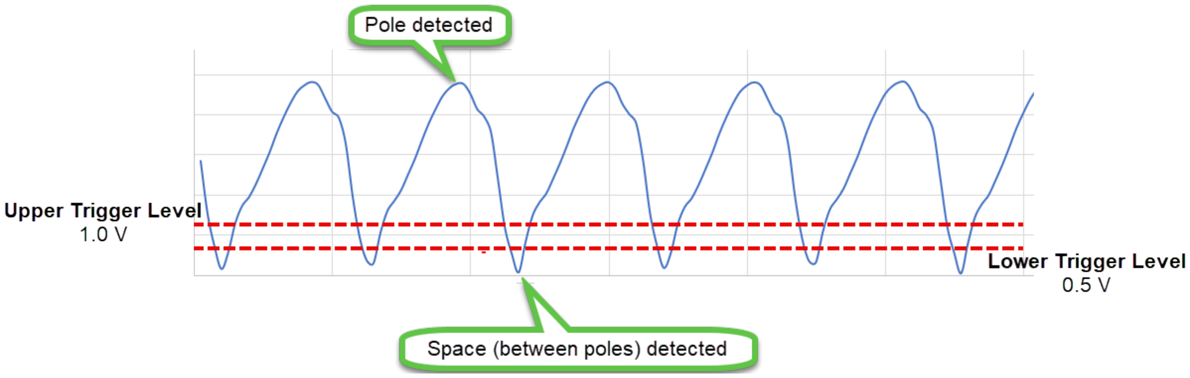


Figure 8-4) Typical Rectified Magnetic Flux Sensor Signal

IMPORTANT

The phase trigger pulse must happen within the Pole Detected region. If the phase trigger mark happens in the space between poles, the Profile waveform will not be collected properly. Adjust the Upper and Lower Trigger Levels to ensure that the phase trigger pulse happens within the Pole Detected region.

8.4 Verify Magnetic Flux Alarms

Simulate the Magnetic Flux channel using a function generator as shown in **Figure 8-5**. The Magnetic Flux measurements are calculated from the extremes of the sine wave (sensor viewing the pole); and the upper peaks of the sine wave (sensor viewing the space between the poles) must exceed 2.0 Vpp (see **Figure 8-4**).

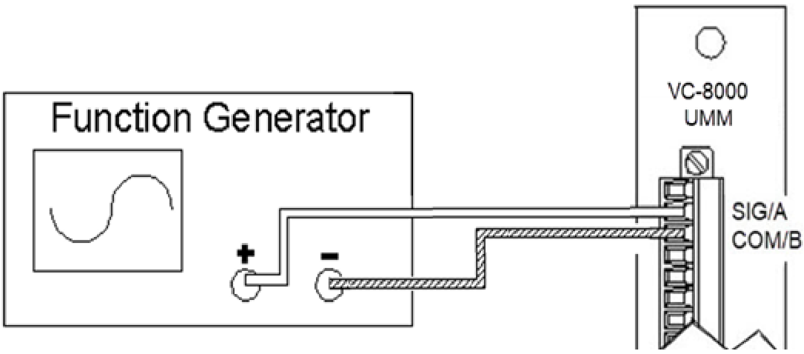


Figure 8-5) Test Magnetic Flux alarms

A Phase Trigger channel is required to configure the Magnetic Flux channel. However, since the Magnetic Flux measurements use “pole counting” to detect each revolution, you do not have to simulate the Phase Trigger channel to test the Magnetic Flux alarms.

Calculate the input voltage as follows:

Equation 8.1) Input voltage – Input (Vdc)

$$Input\ (Vpp) = 2.0 * \ (Desired\ Magnetic\ Flux\ Reading\ (Tesla)\ * Scale\ Factor\ (V/Tesla))$$

Where:

- Desired Magnetic Flux Reading (Tesla) = The value to be simulated (i.e. 1.0 Tesla)
- Scale Factor = Scale factor of the Magnetic Flux sensor (i.e. 5000 mV/Tesla)
- Input = The sensor peak to peak voltage seen by the poles.

Calculate the frequency of the input signal as follows:

Equation 8.2) Input signal – Frequency (Hz)

$$Frequency\ \ (Hz) = \left(\frac{Speed\ (RPM)}{60}\right) x\ Number\ of\ Poles$$

Example: Test a Magnetic Flux channel with an Alert alarm

- Sensor Scale Factor = 5000 mV/Tesla
- Poles = 48
- Machine Running Speed = 125 RPM
- Under Alert Alarm = 0.4 Tesla

To bring the channel into OK, set the function generator to a square wave at 6 Vpp. Set the DC power supply to 0 Vdc. This will give you an input signal oscillating from -3 V to +3 V.

Using **Equation 8.1** to compute the desired input voltage:

$$4.0\ Vpp = 2.0 * (0.4\ Tesla * \ 5.000 \frac{V}{Tesla})$$

Use **Equation 8.2** to calculate the input signal frequency. The machine speed is 125 RPM with 48 poles, so the frequency will be 100 Hz.

To simulate the alarm, adjust the AC amplitude down to 4.0 Vpp. This will decrease the magnetic flux value to 0.4 Tesla.

8.5 SETPOINT CMS Magnetic Flux Plots

The VC-8000 Magnetic Flux channel provides a Profile waveform and an Asynchronous waveform to the SETPOINT CMS software. This data is used for the Profile Timebase plot (A) and the Asynchronous Timebase plot (B) (see **Figure 8-6)** SETPOINT CMS Magnetic Flux Plots).

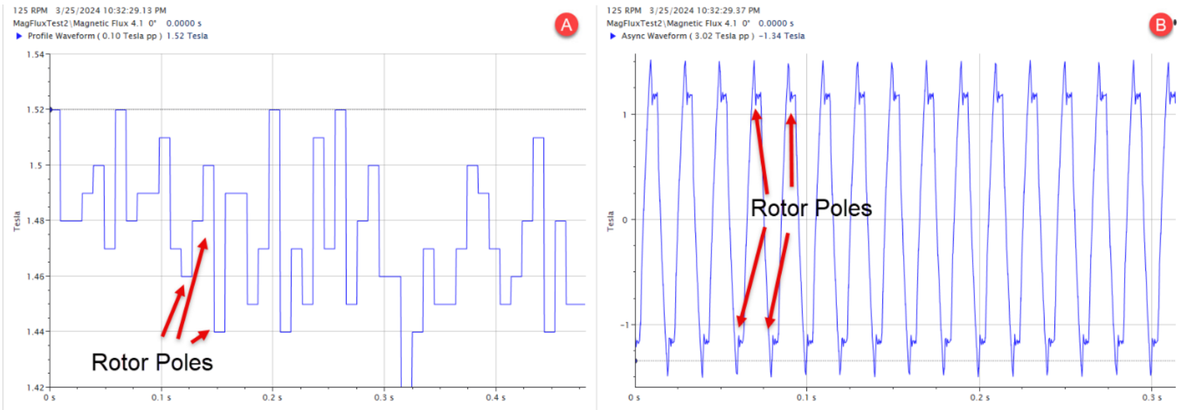


Figure 8-6) SETPOINT CMS Magnetic Flux Plots

Profile Timebase Plot (A)
The Profile waveform is constructed from filtered data samples. The waveform shows the minimum value from each pole over two (or more) revolutions. Typically, 1024 samples are taken each revolution of the generator (see Section 8.2.4).

Asynchronous Timebase Plot (B)
This is the raw data from the Magnetic Flux sensor.

8.5.1 Troubleshooting the Magnetic Flux Plot

If the rotor profile waveform is not being shown in the CMS software:

- Check the status bar (A) of the Air Gap channel using the VC-8000 Maintenance software. Verify the status is OK (see **Figure 8-7**).
- Temporarily modify the Delta Time setting to 0.25 minutes (Channels tab, CMS Framework view). This will force a waveform to be collected every 15 seconds and make troubleshooting easier.

For more information on the Hydro plots see the SETPOINT CMS Instruction Manual (S1176125.002).

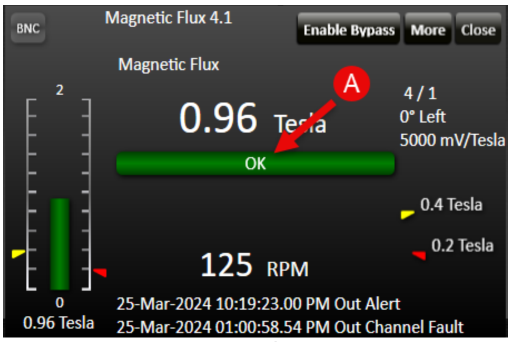


Figure 8-7) Status Bar

9 Machine-State Alarming

Machine-State Alarming allows alert and danger alarm levels to change, based on the operational state of the machine (i.e. Pump/Storage Hydro units). One alarm level is set when the machine is generating electricity (Machine-State A (Generating)), and another alarm level is used when the machine is pumping water back into the upper reservoir (Machine-State B (Pumping)).

The following sections describe how to configure Machine-State Alarming. This includes:

- Configure VC-8000 channels
- Create machine-states (Generating, Pumping)
- Configure the alarms

9.1 Configure VC-8000 Channels

Your VC-8000 channels should be fully configured before you define the machine-state logic. This includes channel types, the layout of the rack, and channel names. The machine-state alarms will be configured after the machine-state logic has been completed.
Control of the machine-state is done using the machine speed or a discrete input channel.

9.1.1 Phase Trigger (Speed) Channel

To use speed (or speed direction) as an input for machine-state alarming you will need to configure a Phase Trigger channel in the rack. Only Phase Trigger channels may be used for machine-state alarming. Tachometer channels are not shared down the back plane of the rack and they cannot be used for machine-state alarming.

9.1.2 Discrete Input Channel

To use a discrete contact as an input for machine-state alarming you will need to configure a Discrete Input channel in the rack as follows:

1. Add a Discrete Input channel (Channels Tab, Summary View). The Discrete Input channel can be in any location in the rack. When used to control machine-state logic, this channel will consume one group line (on the backplane). The discrete input channel will have a Min/Max scale of 0 to 1 and the units will be “On/Off”.

Type *	Name *	Minimum	Maximur	Unit	Su
Discrete Input	U1_State_Control	0	1	On/Off	
Discrete Input	U2_State_Control	0	1	On/Off	

Figure 9-1) Configure a Discrete Input Channel (use On/Off Units)

2. Configure the polarity of the Discrete Input channel (Channels tab, Contacts view) (see **Figure 9-2**). If the Polarity is “Active Closed (Logic Low)” the channel will display in the Maintenance software as 0 = On and 1 = Off. If the Polarity is “Active Open (Logic High)” the channel will display as 1 = On, and 0 = Off.

3. The fields Contact Function, and Group Name (see **Figure 9-2**) are not used for machine-state logic. These fields are for Bypass, Inhibit, and Trip Multiply control functions and are rarely used (See the VC-8000 instruction manual for more information).

Channel Type *	Name *	Contact Function	Group Name	Polarity
Discrete Input	U1_State_Control	None	None	Active Closed (Logic Low)
Discrete Input	U2_State_Control	None	None	Active Open (Logic High)

Figure 9-2) Set Polarity

4. Set the Clamp Value (see **Figure 9-3**). The Clamp value should be set to the value that corresponds to the "Off" position. For example, If the polarity is "Active Open (Logic High)" then 1 = On, and 0 = Off; Therefore the clamp should be set to 0. If the polarity is "Active Closed (Logic Low)" then 0 = On, and 1 = Off; Therefore the clamp should be set to 1. Modbus output values will clamp to this value when the channel is bypassed or faulted.

Name *	Measurement * ▲	Minimum	Maximum	Unit	Clamp
U1_State_Control	Digital State	0	1	On/Off	1
U2_State_Control	Digital State	0	1	On/Off	0

Figure 9-3) Set Clamp

9.1.3 Define Machine (Asset) Groups

Figure 9-4 shows a typical example of Machine (or Asset) groups. The field "Asset Level 1" is used to define two different machine train groups; Group 1 is Unit 1, and Group 2 is Unit 2.

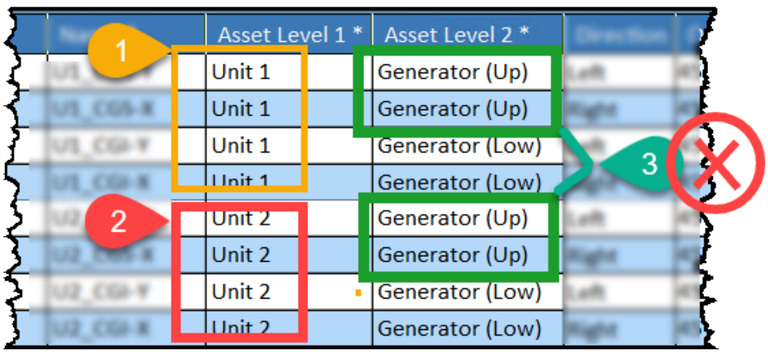


Figure 9-4) Define Machine Group

These two groups will be used (See 9.2.1) to define the channels (and alarms) that will be affected by the machine-state logic. Group 3 (Generator (Up)) should not be used as it defines a bearing location, and is common to both Unit 1, and Unit 2.

CAUTION

Machine groups are multi-purpose (i.e. machine-states, relay logic, and to organize display screens). Use caution when changing machine (asset) groups.

9.1.4 Temperature Channels (TMM)

The TMM does not have the ability to do machine-state alarming. If temperature is needed for machine-state alarming, the user must bring the temperatures into a UMM Process Variable channel using a transmitter (i.e. 4-20 mA).

9.1.5 Modbus and Machine-State Alarms

The configured alarm value of a channel can be read via Modbus. This value will change with the machine-state. For example, an alarm is configured for 250 µm (State = Pumping), and 300 µm (State = Generating). The alarm value is read in register 30001 (for example). When the machine state is Pumping, the Modbus register will read 250 µm. When the machine is Generating, the Modbus register will read 300 µm.

You can also verify the machine-state using Modbus (**Figure 9-5**). Each machine defined in the configuration has a unique ID number (A) shown in the Properties pane. The value of the register will contain the unique ID number of the machine-state (B). the Modbus map (C) will list the machines by their ID number.

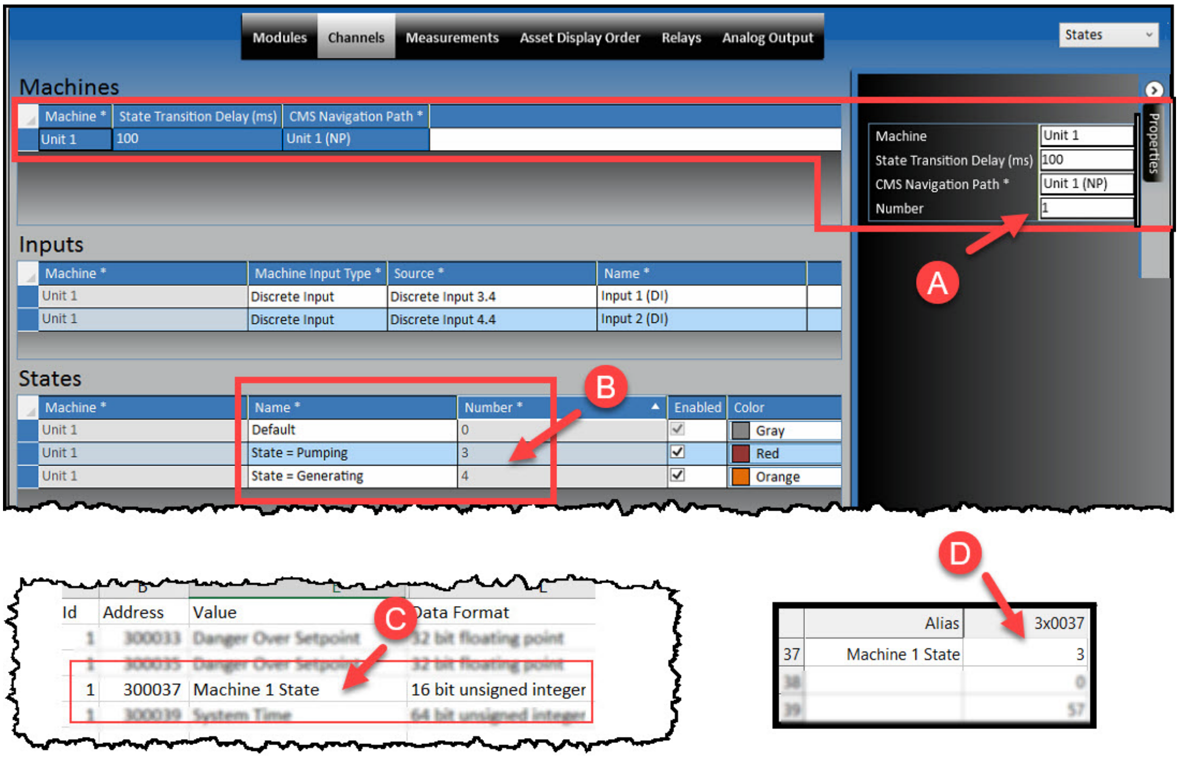


Figure 9-5) Machine Number (Modbus)

Read the Modbus register (D) to see the machine-state ID number. In the example here (**Figure 9-5**), register 30037 shows that the current machine-state for Machine 1 = 3 (Pumping).

9.2 Configure Machine-States

The machine-states, and logic are configured on the Channels tab, States view. Your basic rack configuration (channel names, channel types, and rack layout) should be completed before you configure machine-state logic.

9.2.1 Add a Machine

Follow these steps to add Machines for your machine-state logic (see **Figure 9-6**).

1. Select the Add button to add a machine group (Channel tab, States view). Select "Add" a second time to add a second machine group.
2. Select Add, Input from the menu. A new Input will be shown in the Inputs grid.

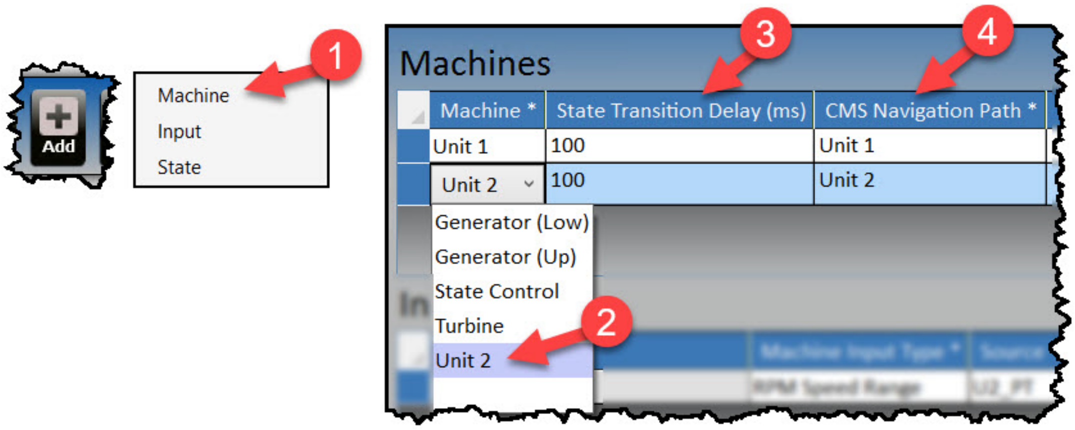


Figure 9-6) Add Machine

3. A State Transition Delay (ms) can be added if needed. This will cause a delay before the state is changed. For example, if a Discrete Input channel is used to change the state, and there is a 100 ms State Transition Delay configured, the new state will be activated 100 ms after the discrete input has activated.
4. Set the CMS Navigation Path similar to the CMS Navigation Path used for the signal channels (Channels tab, CMS Framework view). For example if the signal channels for Unit 1 have a CMS Navigation Path of "Unit 1\Generator", and "Unit 1\Turbine", the machine-state path for the machine-state should be "Unit 1". Make sure the spelling is the same.

9.2.2 Add Inputs

Follow these steps to add Inputs for your machine-state logic (see **Figure 9-7**).

1. Select the Machine (row). The Input will be added to this machine.
2. Select Add, Input from the menu. A new Input will be shown in the Inputs grid.
3. Select the Machine Input Type.

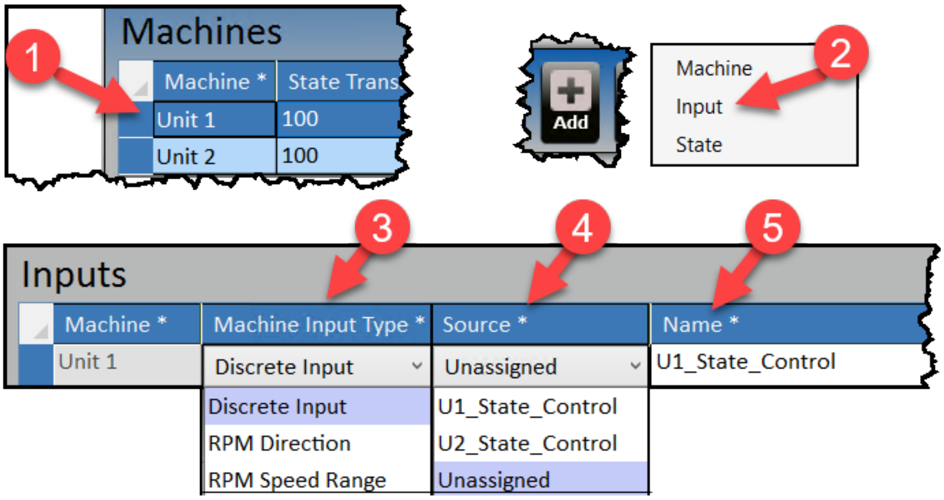


Figure 9-7) Add Inputs

4. Select a Source (this will be a Discrete Input channel, or a Phase Trigger Channel)
5. Provide a name for the Input.

9.2.3 Add States

Follow these steps to add States for your machine-state logic (see **Figure 9-8**).

1. Select the Machine (row). The State will be added for this machine.
2. Select Add, State from the menu. A new State will be shown in the States grid. Repeat this step to add an additional state. Best practice is to leave the Default state as is. For example, don't use it (or rename it) as one of your states.

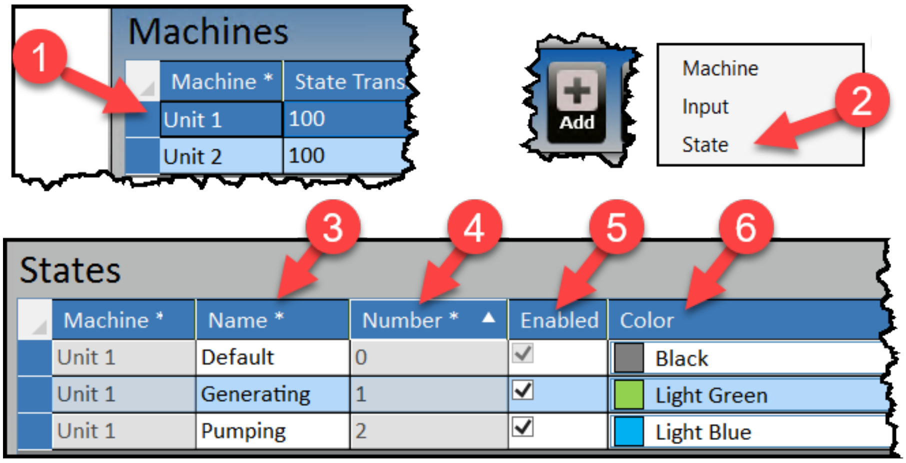


Figure 9-8) Add States

3. Name your states.
4. State number (used to define the state for Modbus queries, see Section 9.1.5).
5. Select to Enable (or Disable) each state. The Default state is always enabled.
6. Select a color for each state. The state color will be used on the VC-8000 display, in the VC-8000 Maintenance software, and in the SETPOINT CMS software.

9.2.4 Set Machine-State Definitions

Follow these steps to define the states for your machine-state logic (see **Figure 9-9**).

1. Select the machine.
2. Notice the definition type.
3. The Default machine-state is shown first. If none of the other machine-state conditions are met, the machine will go into the Default state.
4. Add parameters for the other machine-states here. For example in **Figure 9-9**, the Generating state requires the Discrete Input to be Active, and a speed from 275-325 RPM. To go into the Pumping state, the Discrete Input must change to Inactive and the speed must be 175-225 RPM. All other conditions will result in the Default state.

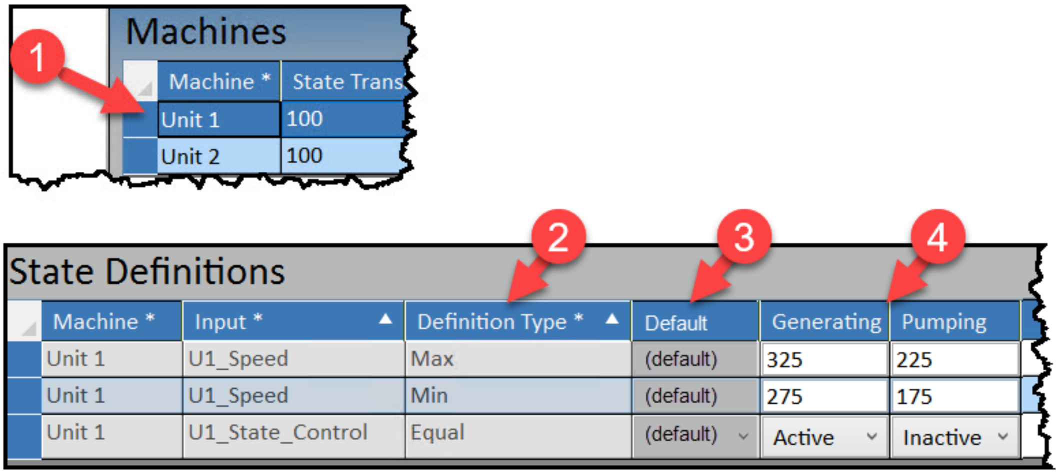


Figure 9-9) State Definitions

The Definition Types (**Figure 9-9**, Item 2) for each input are explained in the table below.

Table 9-1) Explanation of Definition Types

Input Type	Definition Type	Description
Discrete Input	Active	Discrete Input is "Active" (or "Inactive") as configured in the VC-8000. See section 9.1.2.
	Inactive	
RPM Speed Range	Max	RPM speed is below the Max value and above the Min value.
	Min	
RPM Direction	Accelerating	Associated machine speed is Accelerating, Decelerating, or in Steady State. See section 9.2.4.1 for more information.
	Decelerating	
	Steady State	
	Invalid Phase Trigger	Phase Trigger channel is Invalid (Not Ok)

9.2.4.1 Acceleration, Deceleration, Steady State Calculations

The Phase Trigger speed and the Phase Trigger Delta RPM setting are used to determine if the machine is Accelerating, Decelerating or in Steady State. For this instruction, the Accelerating State will be used as an example.

When the Phase Trigger becomes valid (see **Figure 9-10**), a speed reference is saved, and the machine-state equals Steady State (A). The speed is then checked every 40 msec. When the speed increases by the Delta RPM setting (Phase Trigger channel) the machine-state changes to Accelerating (B). If the speed value continues to increase, the machine-state remains Accelerating.

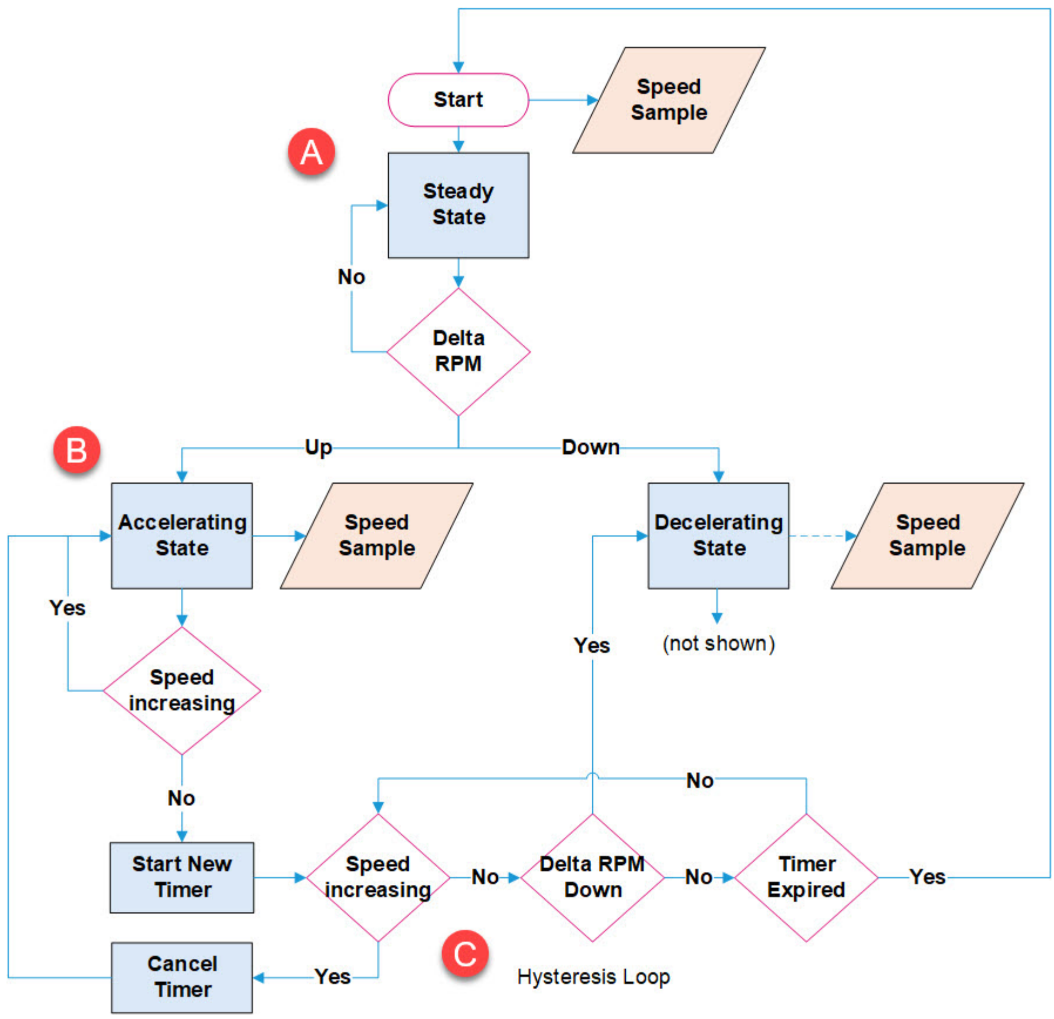


Figure 9-10) Machine Accelerating - State Evaluation

A hysteresis timer (C) prevents erratic machine-state changes. The timer is three shaft rotations, based on the last sample speed value, or 80 msec, whichever is longer. If the machine-state has stopped accelerating, the timer starts. When the timer expires, the state changes to Steady State. If the machine starts to accelerate again (before the timer expires) the timer is canceled, and the state remains Accelerating (B). **Figure 9-10** shows a simplified diagram of this process.

9.3 Configure Machine-State Alarms

Alarms for each machine-state are configured on the Measurements tab, Machine Name (i.e. Unit 1) view. **Figure 9-11** shows the Unit 1 machine with states Default, Generating, and Pumping. The name (i.e. Unit 1) will appear in the pull-down view after the machine-state has been configured (see 9.2.1).

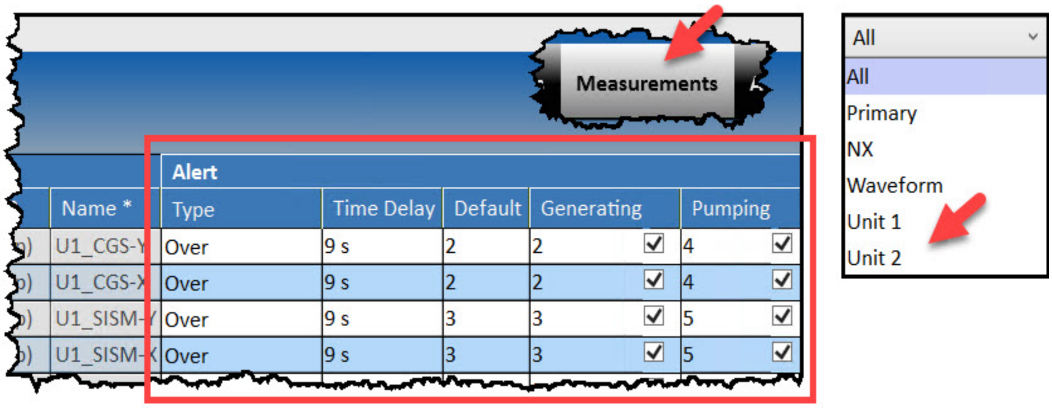


Figure 9-11) Machine-state Alarms

The Alarm Type can be Disabled, In Band, Out of Band, Over, or Under. The Alarm Type and Alarm Time Delay must be the same for all machine-states.

Notice in **Figure 9-11** that the Generating and Pumping state alarms can be disabled individually; The alarm for the Default State cannot be disabled individually; If the alarm for the Default State is disabled then all alarms for that channel are disabled.

9.4 Validate Machine-State Alarming

The following is a basic procedure for validating machine-state alarming. For this procedure the name of the machine is Unit 1, and the machine-states are Default, State A, and State B.

- Simulate the input that controls the machine-state (i.e. Discrete Input).
- Place Unit 1 in State A.
- Verify the machine-state by viewing the Maintenance software or the machine-state Modbus register.
- Simulate the vibration signal for the first channel on Unit 1 (i.e. Brg 1X Radial Vibration)
- Place the channel in OK (no alarms)
- Increase the input slightly above the Alert setpoint.
- Verify the channel is in Alert by viewing the Maintenance software or the channel status Modbus register.
- Increase the signal slightly above the Danger setpoint.
- Verify the signal is in Danger by viewing the Maintenance software or the channel status Modbus register.
- Decrease the input signal and reset any latched alarms (no alarms).
- Repeat for all channels on Unit 1.
- Place Unit 1 in State B.
- Verify the machine-state by viewing the Maintenance software, or the machine-state Modbus register.
- Repeat the Alert/Danger channel tests for State B.
- Place Unit 1 in the Default state (if applicable)
- Verify the machine-state by viewing the Maintenance software, or the machine-state Modbus register.
- Repeat the Alert/Danger channel tests for the Default state.

9.4.1 Documentation

For documentation of the machine-state validation, you can copy and paste the machine-state alarms from the VC-8000 Setup software into a spreadsheet. Simply click the mouse on the top left corner of the Measurements tab to select the full table and then copy the table by pressing CTRL-C. The column headers are not copied, and will have to be entered manually.

9.4.2 Trip Multiply Vs. Machine-State Alarming

Trip Multiply and Machine-State alarming are both used to modify protection alarms during operation of the machine. Trip Multiply is designed to be used for a brief period during a machine start-up and the functionality of Trip Multiply is defined by API 670. Machine-State alarms are for machines with multiple modes of operation where each mode could last for days or months.

The Trip Multiply and Machine-State features are not designed to be used together. However, Machine-State alarms could be used in place of Trip Multiply in a machine start-up scenario. A few differences between the two features are described below.

9.4.2.1 Trip Multiply (TM) Contact

The TM contact (on the RCM) will not affect Machine-State alarms. However, it will affect the default state alarm levels.

9.4.2.2 Modbus Registers

The current Machine-State configured setpoint can be read over the Modbus registers (see 9.1.5).

The current Trip Multiply setpoint value cannot be read over the Modbus registers. For example, if the Trip Multiply value is 2X, and the alarm is configured for 70 µm, the Modbus value will always read 70 µm, even when Trip Multiply is enabled.

9.4.2.3 VC-8000 Display

Machine-State setpoint values will update to the new values on the VC-8000 Maintenance Display when the machine-state changes. In contrast, when Trip Multiply is enabled the setpoint values on the screen do not change; the screen will only display that Trip Multiply is enabled.

9.4.3 Alarm Delays (Timers) and Hysteresis

Alarm Delays (Timers) are not reset when switching between states. When the current input exceeds the current alarm setting, the Alarm Delay timer starts. If a new machine-state is triggered the timer will stop - if the input is less than the new alarm setting; if the input is greater than the new alarm setting, the timer continues.

Likewise, if a channel is in alarm (State A) the alarm delay has already expired. Switching to State B will not require a new Alarm Delay timer to start. If State B is in alarm, the switch from State A to State B (also in alarm) will appear as a single continuous alarm, without interruption.

Hysteresis is not reset when switching states. For example, the alarm setting for State A is 250 µm; the alarm for State B is 300 µm. The current value is 295 µm. When the machine-state changes from State A (250 µm) to State B (300 µm) the alarm remains active, even though the current value (295 µm) is slightly below the current alarm setting (300 µm). To clear the alarm, the current value (295 µm) must go below the current alarm setting by more than the Hysteresis value.

9.5 Viewing States in SETPOINT CMS software

See the SETPOINT CMS software manual S1176125.002 / V08 (or later).

9.6 Troubleshooting States

The following errors are from the Channels Tag, States View.

Channel source assignment required.
Inputs: Make sure the input has been assigned a source (speed channel or discrete input).

Machine asset assignment required
The machine is 'Unassigned'. A machine is defined using the Asset Level 1 group names (Channels Tab, Summary View). After the machine groups are defined, then a machine can be selected.

Machine must have a CMS Navigation Path
See Section 9.2.1

Machine must have at least one state beyond the default state
See Section 9.2.3

The input source must be assigned to the associated machine.
If the selected machine group is Unit 1. The Discrete Input (or speed) channel must also be part of the group Unit 1. This assignment is made on the Channels Tab, Summary View. The Asset Level 1 group name must be Unit 1.

There are no distinguishing conditions between states
This is caused by overlapping state definitions. For example, one state is defined as 0-100 RPM and another state is defined as 90-200 RPM.

'*Machine Name*' Input source already made on another machine.
The Discrete Input (or Speed) channel can only be used as a control input for a single machine (i.e. Unit 1). You are trying to use it as an input on two machines (i.e. Unit 1 and Unit 2).

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