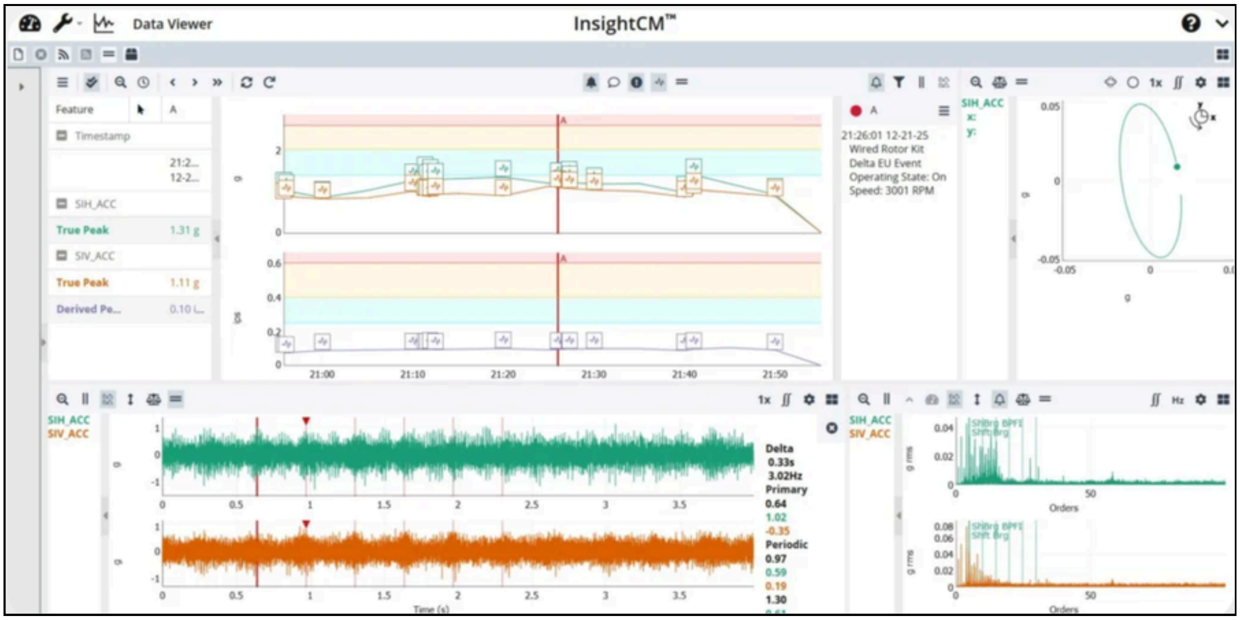
# Operations Manual

# EZDP-2159 Rev –

## Wired Vibration Monitoring



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# Safety Information

## Safety Information [English]

Following is important safety information. For safe installation and operation of this equipment, be sure to read and understand all cautions and warnings.

### Safety Conventions

NOTE:

Additional information.

ELECTRICAL DANGER

Indicates an action or specific equipment area that can result in personal injury or death from an electrical hazard if proper precautions are not taken.

CAUTION

Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury or equipment damage.

WARNING

Indicates a hazardous situation that, if not avoided, could result in death or serious injury.

ROTATING PART CAUTION

Indicates possible injury from rotating parts.

DANGER

Indicates a hazardous situation that, if not avoided, will result in death or serious injury.

### General Safety Instructions

ELECTRICAL DANGER

Only qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid injury should work with Cutsforth products. Among the many considerations are the following:

- Avoid contact with energized circuits.
- Avoid contact with rotating parts.
- Never install any component that appears not to be functioning in a normal manner.

ROTATING PART CAUTION

High-voltage and rotating parts can cause serious or fatal injury. Installation, operation, and maintenance of this product must be performed only by qualified personnel, in accordance with all applicable safety regulations and guidelines.

# Consignes de Sécurité [Français]

Les informations qui suivent sont essentielles afin d'assurer la sécurité de l'utilisateur lors de l'installation et de l'opération de l'équipement. Assurez-vous de bien lire et de comprendre tous les avertissements et mises en garde qui suivent.

## Conventions de Sécurité

NOTE:

Informations supplémentaires.

RISQUES DE CHOC ÉLECTRIQUE

Indique que l'action ou la partie de l'équipement concernée peut mener à des blessures par électrisation ou à la mort par électrocution si les précautions adéquates ne sont pas prises.

MISE EN GARDE

Indique la présence d'une situation dangereuse qui, si elle n'est pas évitée, pourrait mener à des blessures mineures à modérées ou à des dommages matériels.

AVERTISSEMENT

Indique la présence d'une situation dangereuse qui, si elle n'est pas évitée, pourrait mener à des blessures sévères ou à la mort.

MISE EN GARDE : PIÈCE ROTATIVE

Indique la présence de pièces d'équipement rotatives pouvant causer des blessures.

DANGER

Indique la présence d'une situation dangereuse qui, si elle n'est pas évitée, pourrait mener à des blessures sévères ou à la mort.

## Consignes de Sécurité Générales

RISQUES DE CHOC ÉLECTRIQUE

L'utilisation des produits Cutsforth n'est recommandée qu'aux professionnels qualifiés qui savent comment reconnaître la présence de risques de choc électrique ainsi que les consignes de sécurité à suivre pour éviter les blessures liées à ces risques. Lesdites consignes de sécurité incluent, sans s'y limiter :

- Éviter tout contact avec des circuits alimentés;
- Éviter tout contact avec des pièces d'équipement rotatives;
- Ne jamais installer de composante ne paraissant pas fonctionner normalement;

### MISE EN GARDE : PIÈCE ROTATIVE

Les pièces d'équipement rotatives et sous haute tension peuvent causer des blessures sévères ou fatales. L'installation, l'opération et la manutention de ce produit ne doivent être faites que par des professionnels qualifiés et en respectant toutes les règles et consignes de sécurité applicables.

# 1. Product Description

This manual is a guide for the operation of the Wired Vibration Monitoring system. It does not cover all details or variations in equipment, nor does it consider every possible contingency. If you have questions not addressed in this manual, contact Cutsforth Engineering Support. support.cutsforth.com

## 1.1. Wired Vibration Monitoring System Overview

The Cutsforth Wired Vibration Monitoring System provides continuous, high-fidelity insight into the mechanical health of rotating and reciprocating assets. By capturing and analyzing vibration amplitude, frequency, and waveform patterns over time, the system enables early detection of developing faults such as imbalance, misalignment, bearing defects, looseness, gear wear, cavitation, resonance and more.

Designed to monitor a wide range of equipment, including motors, pumps, compressors, turbomachinery, and generators, the system offers users a detailed understanding of machine behavior during all operating conditions. This early visibility helps prevent failures, reduce unplanned downtime, and improve overall equipment reliability.

At the core of the system is InsightCM™, Cutsforth's multi-physics monitoring platform. InsightCM delivers high-resolution waveform capture, automated mechanical fault detection, and trend analysis, correlating vibration data with temperature, electrical, and process inputs to provide a comprehensive view of asset condition. Standard diagnostic tools include time waveform, spectrum, full spectrum, Bode and orbit plots, waterfall displays, envelope spectrum, and shaft-centerline analysis.

The system supports a wide range of sensors, including accelerometers, velocity probes, proximity probes, speed sensors, and other dynamic sensors, ensuring compatibility with diverse machinery types and applications. High-fidelity 24-bit acquisition and intelligent edge processing optimize data accuracy while minimizing bandwidth and storage requirements.

## 1.2. Common Assets Monitored

- Motors
- Pumps
- Compressors
- Turbomachinery
- Generators
- Balance of Plant Equipment

## 1.3. Common Fault Modes Detected

- Imbalance
- Misalignment
- Bearing defects
- Mechanical looseness
- Gear wear/eccentricity
- Cavitation
- Resonance or structural vibration
- And more

## 1.4. InsightCM Integration

All vibration data is managed, displayed, and analyzed within Cutsforth's InsightCM condition monitoring software. InsightCM is a Cutsforth-developed application providing full access to waveforms, multi-sensor technology inputs, enterprise software connectivity, and analytics packages. Feature data calculations by InsightCM can be transmitted to plant historians for integration into advanced pattern recognition (APR) models or other machine learning platforms.

The data viewers available in InsightCM for vibration assets include:

- Time Waveform
- Spectrum
- Full Spectrum
- Bode Plot
- Orbit Plot
- Waterfall
- Envelope Spectrum
- Shaft-Centerline
- Feature Trending

For more information on InsightCM features, visit the InsightCM user manual at support.cutsforth.com.

# 2. Technical Specifications

## 2.1. IT System Requirements

### 2.1.1. Overall Architecture

The Wired Vibration Monitoring system uses an InsightCM edge hardware data acquisition device (cRIO) to acquire vibration signals at the field level. Processed data and extracted features are transmitted via TCP over an Ethernet network to the InsightCM server application, which provides data storage, trending, alarming, and data-viewer access. The server can be connected to the plant historian and to business-network users via HTTPS.

### 2.1.2. Server Hardware Requirements

InsightCM requires a dedicated server. If NI SystemLink is present on the target machine (for example, from a previous NI deployment), install InsightCM on a different server, as the two products cannot share a machine.

Cutsforth recommends using solid state drives to improve disk throughput.

| Proof of Concept | Standard Deployment | Enterprise |
|---|---|---|
| ▪ Windows 11, 64-bit Professional<br>▪ 2.2 GHz, 4-core processor<br>▪ 16 GB RAM<br>▪ One physical hard drive for OS, program installation, and storing data files—At least 500 GB disk space | ▪ Windows Server 2016, 2019, 2022, or 2025<br>▪ 3 GHz, 16-core processor<br>▪ 32 GB RAM<br>▪ Two physical hard drives:<br>  ▪ For OS and program installation—At least 250 GB disk space<br>  ▪ For storing data files—At least 2 TB disk space | Contact your Account Manager or put in a request here: cutsforth.com/contact-us/ |

### 2.1.3. Networking Requirements

A fast or gigabit Ethernet connection (100 Mbps or 1000 Mbps) is required between the InsightCM server and the Wired Vibration Monitoring devices. It is also preferable for the server to be connected to the site data historian to enable process data integration.

## 2.2. Hardware Specifications

### 2.2.1. Power Requirements

| Parameter | Specification |
|---|---|
| Plant-supplied power source | 120 V, 60 Hz or 240 V, 50 Hz |
| Input voltage range | 85 – 264 VAC |
| Input frequency range | 47 – 63 Hz |
| Input power rating | 150 W |
| Maximum power consumption | 120 W |
| Internal circuit breaker | 120 V, 5 A |
| Input wire connection type | DIN, Screw-Down Terminal Block |
| Input wire size | 26 – 10 AWG |
| Overvoltage category | III; per EN62368, EN61558, EN50178, EN60664-1, EN62477-1 |

### 2.2.2. Environmental Specifications

| Parameter | Specification |
|---|---|
| Operating temperature | -40 °C to 60 °C (-40 °F to 140 °F) |
| Storage temperature | -40 °C to 85 °C (-40 °F to 185 °F) |
| Operating humidity | 10% RH to 90% RH, non-condensing |
| Storage humidity | 5% RH to 95% RH, non-condensing |
| Maximum altitude | 5,000 m (16,400 ft) |

## 2.3. Enclosure Specifications

| Parameter | Specification |
|---|---|
| Catalog number | SNB-3746 |
| Dimensions | 20.0 in. × 16.0 in. × 8.0 in. (508 mm × 406 mm × 203 mm) |
| UL listing | UL 508A Listed Type 1, 2, 4, 4X, 12, 13 — File No. E194432 |
| IP rating | IP65 and IP66 |
| Construction | Powder coated steel; RoHS compliant |

Conduit holes are not pre-drilled. Conduit sizing and hole placement are customizable per installation.

# 3. System Components

## 3.1. Acquisition Hardware

The Wired Vibration Monitoring system consists of a cRIO (Compact Reconfigurable I/O) data acquisition device housed in a NEMA 4X-rated enclosure. The controller and input card selection depends on the quantity and type of signals being monitored.

Controller options (supplied by Cutsforth):

- cRIO-9055 — 4-slot device
- cRIO-9058 — 8-slot device
- cRIO-9047 — 8-slot device

Input card options (supplied by Cutsforth, based on signal type and quantity):

- NI-9229
- NI-9230
- NI-9232
- Optional Static Input cards

The specific controller and input card configuration are determined by the number of assets to be monitored and the sensor types. Up to 32 signal inputs can be connected to a single Wired Vibration Monitoring system, provided cable lengths remain within specified limits. Refer to the Installation Planning Guide (EZDP-2153) for full equipment lists.

## 3.2. Supported Sensors

The system is compatible with the following sensor types. Sensors may be supplied by Cutsforth or provided by the plant:

- Accelerometers (IEPE or voltage-output)
- Velocity probes
- Proximity probes (eddy-current, for fluid-film bearing machines, requires a proximity driver)
- Tachometer inputs (required for Bode plots, orbit plots, and order-tracked spectra)
- Other dynamic sensors providing dynamic voltage signals

## 3.3. InsightCM Software

InsightCM is Cutsforth's application software for continuous condition monitoring. It runs on either a customer-supplied server (see Server Hardware Requirements (page 9) for server requirements) or a Cutsforth hosted cloud instance and provides:

- An asset tree for organizing monitored equipment and sensors
- Real-time and historical data viewing across multiple specialized viewers
- Automated fault feature extraction and trending
- Configurable alarming with optional email notification
- Integration with plant historians via PI AF SDK, MQTT, and TCP/IP
- Programmatic data integration with REST API
- Data export for external analysis

# 4. Installation Overview

This section provides a high-level installation summary. For complete installation details, conduit layout drawings, strut rack specifications, and enclosure mounting dimensions, refer to the Wired Vibration Monitoring Installation Planning Guide (EZDP-2153).

## 4.1. Major Installation Steps

- Mount the Wired Vibration Monitoring system enclosure at the planned location.
- If not already installed, install vibration sensors at the desired locations on equipment to be monitored.
- Install conduit and run shielded signal cabling between the vibration sensors and the monitoring system enclosure. Maximum cable length is dependent on the sensor, frequency range of interest, and power supplied by the input card.
- Install conduit and run cable for AC power input to the monitoring system enclosure. Minimum circuit: 20 A, 120/240 VAC, free of non-linear loads. A circuit with an isolated ground is recommended.
- Install conduit and run cable for the data connection. Cutsforth recommends Cat6a or fiber (fiber requires a media converter). Refer to cable specifications for recommended maximum cable lengths.
- Ensure the plant's InsightCM server is set up and ready to communicate with field equipment prior to Cutsforth commissioning.

## 4.2. Conduit Layout Summary

| Color | Conduit Run | Trade Size | Wire Type | Max. Length | Supplied By |
|---|---|---|---|---|---|
| Blue | Monitoring Enclosure to InsightCM Server | ¾ in. (2 cm) | Cat6a or Fiber | Refer to cable specifications | Plant Electrical Contractor |
| Red | Plant Power to Monitoring Enclosure | ¾ in. (2 cm) | 120/240 VAC, 20A dedicated circuit (isolated ground preferred) | N/A | Plant Electrical Contractor |
| Yellow | Vibration Sensor(s) to input modules in the Enclosure | ¾ in. (2 cm) | Shielded signal cabling | Depends on sensor, frequency of interest, and input module | Plant Electrical Contractor |

# 5. Configuration

Complete device configuration steps are covered in the InsightCM user manual. This section provides the key configuration inputs required before vibration monitoring and analysis can begin for a new asset.

## 5.1. Required Asset Configuration Fields

The following information must be entered in InsightCM before vibration monitoring analysis can begin for a new asset:

- Asset name and description
- Machine type (motor, pump, compressor, fan, gearbox, turbine)
- Running speed (RPM) required for calculating fault frequencies
- Sensor type per channel (accelerometer, velocity probe, or proximity probe)
- Sensor sensitivity (Imperial or Metric Units)
- Sensor location and orientation (drive-end/non-drive-end; horizontal/vertical/axial)
- Measurement direction
- Scaling information for other dynamic sensors as needed

## 5.2. Optional (Recommended) Configuration Fields

The following fields are not required but significantly improve fault detection capability:

- Bearing model number or geometry data (FTF, BSF, BPFO, BPFI) for each monitored bearing — required to enable bearing defect frequency feature tracking
- Number of gear teeth for each gear stage (for gearbox monitoring)
- Number of impeller vanes or fan blades (for vane/blade pass frequency tracking on pumps and fans)
- Tachometer channel assignment — required for Bode plots, orbit plots, and order-tracked spectra
- Integration setting per channel (none, single, or double — used to convert acceleration to velocity or displacement in software)
- High-pass and low-pass filter settings appropriate to the sensor type and fault frequencies of interest

## 5.3. Entering Sensor Sensitivity

Sensor sensitivity is entered on the channel configuration page for each monitored sensor in InsightCM. The correct value is found on the sensor manufacturer's calibration certificate or datasheet supplied with the sensor; it is also commonly printed on the sensor body.

| Sensor Type | Typical Sensitivity |
|---|---|
| IEPE accelerometers | Nominal 100 mV/g (10.2 mV/m/s2); use the actual calibrated value from the certificate, not the nominal value |
| Velocity probes | Typical 100 mV/in/s (3.94 mV/mm/s) |
| Proximity probes | Typically 200 mV/mil (7.87 V/mm) for standard eddy-current systems |

Retain calibration certificates for all installed sensors and store them with the asset documentation so values can be verified or re-entered if the configuration is lost.

## 5.4. Asset-Type Configuration Guidelines

The core configuration steps are the same for all asset types. The following differences apply:

| Asset Type | Configuration Notes |
|---|---|
| Motors | Configure for radial and axial measurements at drive-end and non-drive-end bearings. Set running speed to the synchronous or full-load speed. If the motor drives a pump or fan through a coupling, also configure the driven-equipment bearing locations. |
| Pumps | Configure radial and axial measurement channels to detect cavitation and hydraulic imbalance. |
| Compressors | Configure for both radial and axial measurements. For reciprocating compressors, running speed corresponds to crank speed; fault frequencies include piston pass and valve frequencies. |
| Turbomachinery / fluid-film bearing machines (generators, steam turbines, large compressors) | Configure proximity probe pairs at each bearing for orbit and full-spectrum analysis. Configure a tachometer/keyphasor channel for phase-referenced measurements, Bode plots, and shaft-centerline tracking. Enable gap voltage (DC) monitoring for shaft-centerline plots. |
| Gearboxes | Configure sensors at or near each gear mesh location where possible. |

## 5.5. Verifying Configuration After Setup

After completing asset and device configuration, use the Force Trigger function to acquire a test data set and verify the following:

- Each channel shows a live signal in the Data Viewer with an amplitude in a reasonable range for the sensor type and machine condition. A flat, near-zero waveform on a running machine indicates an open circuit or an unpowered IEPE sensor.
- The spectrum shows a clear 1× running speed peak at the expected frequency (e.g., a 1800 RPM machine should show a peak at 30 Hz). A spectrum with only broadband noise may indicate an incorrect running speed entry or a sensor issue.
- For proximity probe channels, the DC gap voltage is within the linear range of the probe driver (typically -8 to -18 V for a standard 200 mV/mil system).
- The device status shows Online in InsightCM with a configuration status of Ok and no update-required warnings.

## 5.6. Configuring Operating States

Operating states for vibration assets are configured on the Operating States tab of the Asset Configuration page in InsightCM. Each operating state defines when the device collects data and which features are calculated.

The transition trigger is typically based on overall vibration amplitude of a designated reference channel, or on a digital or analog process input (running status signal, motor current, or speed signal from the plant DCS). When a tachometer channel is present, speed can also be used as the trigger.

The most common configuration uses two operating states:

- On — The default operating state is active when vibration or speed exceeds a defined minimum threshold. Configured with a periodic collection interval (typically once per hour for routine monitoring) and a file length appropriate to the lowest fault frequency of interest, typically capturing 10 rotations of the highest speed shaft.
- Off — The operating state is active when the machine is stopped. The device continues to collect data at a reduced interval.

If startup or shutdown transients are of interest, Run-Up and/or Coast-Down states can be added, triggered by a rising or falling speed, to capture transient data for Bode plot analysis.

For meaningful spectral analysis, the machine must be running at a minimum of approximately 50% of rated speed and under representative load conditions. At very low speeds, vibration amplitudes are small, fault frequencies shift to values that are difficult to resolve, and signal-to-noise ratio is poor.

# 6. Alarm Threshold Guidelines

## 6.1. Overall Vibration Level Alarms

Overall vibration severity limits are defined in ISO 10816-3 (for industrial machines above 15 kW) and the successor standard ISO 20816. For general industrial machines in the 600 to 3600 RPM range on rigid mountings, the zone boundaries from ISO 10816-3 are:

| Zone | Velocity RMS | Assessment |
|---|---|---|
| Zone A | Up to 0.09 in/s (2.3 mm/s) RMS | New machine; acceptable |
| Zone B | 0.09 to 0.18 in/s (2.3 to 4.5 mm/s) RMS | Acceptable for long-term operation |
| Zone C | 0.18 to 0.28 in/s (4.5 to 7.1 mm/s) RMS | Alarm — not suitable for long-term continuous operation |
| Zone D | Above 0.28 in/s (7.1 mm/s) RMS | Danger — risk of damage |

For machines on flexible mountings, zone boundaries are approximately double the rigid-mounting values. For acceleration measurements, a common starting point for general industrial machines is an alert at 0.5 to 1.0 g RMS and a danger alarm at 1.0 to 2.0 g RMS for the 10 to 1000 Hz range. These values should be tuned to the specific asset.

## 6.2. Feature-Based and Spectral Band Alarms

Spectral band alarms and feature-based alarms complement overall level alarms by detecting developing faults at specific frequencies before the overall level is significantly affected.

## 6.3. Baseline / Deviation-from-Baseline Approach

A baseline/deviation approach is strongly recommended as a complement to fixed absolute thresholds and in many cases provides earlier, more asset-specific warning of developing faults.

To establish a baseline:

- After commissioning and verifying the machine is in a known healthy condition, collect representative data across at least several weeks of normal operation covering the full range of typical load and temperature conditions.
- Configure baseline-referenced alarms in InsightCM on the alarm rule for any calculated feature or spectral band, triggering when the current value deviates from the stored baseline by a defined amount (for example, a 30% rise in a spectral band, or a 20% increase in overall velocity).
- Review and update baselines after any maintenance event that changes the machine’s vibration characteristics (bearing replacement, realignment, balance correction, overhaul).

A practical approach is to use fixed ISO-based absolute thresholds as the safety net and baseline-relative alarms as the early-warning layer.

# 7. Operation

## 7.1. Powering the System On and Off

### 7.1.1. Powering On

- Open the Wired Vibration Monitoring enclosure door.
- Locate the circuit breaker on the bottom DIN rail inside the enclosure.
- Flip the circuit breaker to the ON (closed) position.
- Close the enclosure door.

### 7.1.2. Powering Off

- Open the Wired Vibration Monitoring enclosure door.
- Locate the circuit breaker on the bottom DIN rail.
- Flip the circuit breaker to the OFF (open) position.
- Close the enclosure door.

ELECTRICAL DANGER

Before opening the enclosure for any reason other than operating the circuit breaker, de-energize, lock out, and tag out all power sources to the enclosure. Exposure to energized conductors inside the enclosure can cause electric shock and death.

## 7.2. Forcing a Manual Data Acquisition

To initiate an immediate data acquisition outside the normal scheduled interval:

- Navigate to the Device Configuration page in InsightCM.
- Select the desired device.
- Open the Action menu and select Force Trigger.
- Wait several seconds for the acquisition to complete.
- Navigate to the Data Viewer to confirm data has been collected.

## 7.3. Interpreting the InsightCM Data Views

InsightCM provides a set of specialized viewers for analyzing vibration signatures. Each view targets a different aspect of machine health. The sections below describe how to interpret each view.

### 7.3.1. Time Waveform

The time waveform displays raw vibration amplitude plotted against time, as measured directly by the sensor. The horizontal axis is time and the vertical axis is amplitude in the sensor's engineering unit or for certain sensors, accelerometers or velocity probes, may be integrated.

A healthy machine running at steady load typically produces a relatively consistent, periodic trace. Periodic bursts or spikes repeating at a rate that matches a known machine frequency indicate a mechanical event loading the sensor at that rate. The time waveform is particularly useful for identifying impacting faults (bearing defects, looseness), because discrete impacts are visible as sharp transient spikes before they become prominent in the frequency domain.

### 7.3.2. Spectrum

The spectrum (also called the frequency spectrum or FFT spectrum) converts the time waveform into the frequency domain, displaying amplitude on the vertical axis against frequency on the horizontal axis. Each peak represents a repeating event in the machine at that frequency.

Read the spectrum by comparing peak locations to known fault frequencies for the asset: running speed (1×), its harmonics (2×, 3×, etc.), bearing defect frequencies (BPFO, BPFI, BSF, FTF), gear mesh frequency, and blade/vane pass frequency. As with all vibration views, the trend of a peak's amplitude over successive acquisitions is more meaningful than any single reading.

### 7.3.3. Full Spectrum

The full spectrum (two-sided or 2-channel spectrum) is generated from two orthogonal channels—typically the horizontal and vertical transducers at the same bearing location—and displays both forward (positive frequency) and reverse (negative frequency) vibration components. For a healthy, symmetric rotor, the forward components should have higher amplitude than the reverse components.

A dominant forward peak at 1× indicates imbalance or misalignment. A dominant reverse peak, or an asymmetric ratio between forward and reverse, is characteristic of rotor rub, fluid-film instability (oil whirl or oil whip), or anisotropic bearing stiffness. This view is primarily used for turbomachinery on fluid-film bearings.

### 7.3.4. Bode Plot

The Bode plot displays vibration amplitude and phase angle plotted against machine speed (RPM), generated from data collected during a machine run-up or coast-down. The most important feature to identify is a critical speed, a speed at which vibration amplitude peaks sharply and phase shifts by approximately 180 degrees, indicating the machine is passing through a resonant frequency.

> This view requires a tachometer or keyphasor input to provide the speed reference signal.

### 7.3.5. Orbit Plot

The orbit plot displays the actual path traced by the shaft centerline as it rotates, by combining simultaneous measurements from two orthogonal proximity probes at the same bearing location. A healthy rotor produces a slightly elliptical orbit centered near the bearing center.

A thin ellipse indicates directional stiffness or misalignment. A figure-eight or multi-lobed pattern indicates a sub-synchronous instability such as oil whirl, or the presence of a rub. This view is applicable to machines supported on fluid-film (sleeve) bearings.

### 7.3.6. Waterfall

The waterfall display presents a series of spectra collected over time or across a range of machine speeds, stacked in a three-dimensional arrangement. When plotted against speed, structural resonances appear as vertical ridges at fixed frequencies while running-speed harmonics appear as diagonal lines that shift with speed. When plotted against time at constant speed, the waterfall shows how the spectrum evolves as a fault develops.

### 7.3.7. Envelope Spectrum

The envelope spectrum is derived by bandpass-filtering the raw signal around a high-frequency resonance, demodulating the envelope of that filtered signal, and applying an FFT to the envelope. This view is the most sensitive tool for detecting early-stage rolling-element bearing defects.

Read the envelope spectrum by looking for discrete peaks that match calculated bearing defect frequencies for the asset: BPFO, BPFI, BSF, and FTF. Peaks at these frequencies, particularly sidebands around them spaced at shaft running speed, indicate that the corresponding bearing element is producing repetitive impacts—characteristic of developing spalling or fatigue damage.

### 7.3.8. Shaft-Centerline

The shaft-centerline plot tracks the average position of the shaft within its bearing clearance over time, using the DC (average) component of the proximity probe signal. During a normal run-up, the shaft traces a characteristic arc from its rest position (at the bottom of the bearing) to its running position (lifted by the oil film).

A shaft running very close to the clearance boundary indicates an abnormally loaded or misaligned bearing. A shaft that migrates significantly from its established running position—without a corresponding change in load or speed—can indicate bearing wear, changing alignment, or oil film degradation.

# 8. Fault Mode Descriptions and Data Signatures

The following sections describe each monitored fault mode, its appearance in InsightCM data views, and the recommended response.

## 8.1. Imbalance

*Description*

Imbalance occurs when the mass distribution of a rotating component is not symmetric about its rotational axis, causing a centrifugal force that loads the bearings once per revolution. In the vibration spectrum, imbalance is characterized by a dominant peak at 1× running speed. On the time waveform it produces a clean sinusoidal signal at running speed. In the full spectrum, imbalance shows as a dominant forward-direction component at 1×. Vibration amplitude increases with the square of running speed, so imbalance becomes more significant at higher speeds.

*Recommended Action*

Trend the 1× amplitude and phase over successive acquisitions. A rising 1× amplitude not accompanied by changes at harmonics or other frequencies points to increasing imbalance—which can be caused by material buildup, erosion, or a missing balance weight. If the 1× amplitude increases suddenly rather than gradually, check for loss of a balance weight or mechanical damage to the rotor. Plan a balance correction at the next available outage.

## 8.2. Misalignment

*Description*

Misalignment occurs when the centerlines of coupled shafts are not collinear—either offset (parallel misalignment), angularly misaligned, or both. The classic vibration signature is an elevated 2× running speed component, often comparable to or larger than the 1× component, frequently accompanied by elevated 1×. Angular misalignment tends to produce strong axial vibration at 1× and 2×; parallel misalignment tends to produce radial vibration primarily at 2×. A 180-degree phase difference across the coupling in the axial direction is a strong indicator of angular misalignment.

*Recommended Action*

Trend the 1× and 2× amplitudes and their ratio over time. A rising 2× component, particularly if axial vibration is also elevated, warrants a coupling and alignment inspection at the next maintenance opportunity. Verify alignment using laser or dial-indicator methods. Inspect the coupling for wear, cracking, or element failure. Correlate with recent maintenance work—misalignment often appears or worsens after equipment is reassembled or a baseplate is disturbed.

## 8.3. Bearing Defects

*Description*

Rolling-element bearing defects—spalling or fatigue damage to the outer race, inner race, rolling elements, or cage—generate repetitive impacts at characteristic frequencies: BPFO (ball pass frequency, outer race), BPFI (ball pass frequency, inner race), BSF (ball spin frequency), and FTF (fundamental train frequency). Early-stage bearing damage is best detected in the envelope spectrum, where these frequencies appear as discrete peaks before the defect is severe enough to show in the standard spectrum.

*Recommended Action*

Calculate bearing defect frequencies for each monitored bearing using bearing geometry data and current running speed, and enter these into InsightCM to enable feature tracking. Monitor the envelope spectrum and trend the amplitude at each defect frequency. A rising trend at BPFO or BPFI, particularly with sidebands spaced at running speed, indicates a progressing defect. Corroborate with bearing temperature data—a rising temperature alongside growing defect frequency amplitude indicates accelerating degradation and should shorten the replacement planning horizon.

## 8.4. Mechanical Looseness

*Description*

Mechanical looseness encompasses conditions in which components that should be rigidly connected have excessive clearance, including loose foundation bolts, loose bearing housing fits, loose rotor components, and loose or cracked structural elements. The classic signature is a series of running-speed harmonics (1×, 2×, 3×, and higher) with a relatively elevated noise floor. Sub-harmonic content at ½× or ⅓× running speed is also characteristic of certain looseness conditions. The time waveform often shows a clipped or truncated appearance.

*Recommended Action*

Inspect and re-torque all foundation bolts, hold-down hardware, and bearing housing fasteners. Check bearing housing fits for fretting corrosion or wear. Verify structural connections—grouting, base plate, sole plates—are intact. Re-evaluate the spectrum after tightening to confirm harmonic content has subsided. Looseness that persists after tightening may indicate a structural crack or worn bearing housing requiring repair.

## 8.5. Gear Wear/Eccentricity

*Description*

Gear faults, including tooth wear, pitting, cracking, and eccentricity, produce vibration at gear mesh frequency (GMF), which is the product of the number of teeth on a gear and its rotational speed. Healthy gears produce a peak at GMF with small sidebands. As gear condition degrades, the GMF amplitude increases and sideband structure becomes more complex. Eccentricity specifically produces prominent sidebands at GMF ± 1× shaft speed of the eccentric gear.

*Recommended Action*

Calculate the gear mesh frequency for each gear stage and configure these as reference frequencies in InsightCM. Trend the GMF amplitude and its sidebands over time. A growing GMF amplitude or expanding sideband structure indicates degrading gear condition. If GMF amplitude increases suddenly, inspect for lubrication issues, contamination, or overloading. Oil debris analysis is a valuable complementary tool for confirming gear wear before opening the gearbox.

## 8.6. Cavitation

*Description*

Cavitation occurs in pumps and hydraulic machinery when local fluid pressure drops below vapor pressure, causing vapor bubbles to form and collapse violently. In the vibration spectrum, cavitation appears as a broad elevation of the noise floor at high frequencies, often without distinct discrete peaks, yet blade pass frequencies may be present. Cavitation is distinguished from other high-frequency sources by its strong correlation with process conditions: it intensifies when suction pressure decreases, flow rate moves away from the pump's best efficiency point (BEP), or NPSH margin is reduced.

*Recommended Action*

Confirm the diagnosis by correlating vibration data with process parameters—suction pressure, flow rate, and NPSH available. Address the root cause at the process level: increase suction pressure, reduce flow restriction on the suction side, bring the operating point closer to BEP, or reduce fluid temperature to increase NPSH margin. Cavitation causes rapid erosion of impeller surfaces and should be corrected promptly. If process conditions cannot be changed, inspect the impeller for pitting damage at the next opportunity.

## 8.7. Resonance or Structural Vibration

*Description*

Resonance occurs when an excitation frequency—such as running speed, a harmonic, or a blade/vane pass frequency—coincides with a natural frequency of the machine or supporting structure, amplifying the vibration response. In the spectrum, resonance appears as an abnormally high amplitude at or near a structural natural frequency; the peak does not shift with speed and is often broad. On a Bode plot, resonance appears as a distinct amplitude peak accompanied by a phase shift of approximately 180 degrees as the machine passes through the critical speed.

*Recommended Action*

Use a Bode plot or variable-speed sweep to determine whether the high-amplitude frequency shifts with speed (suggesting a running-speed harmonic) or remains fixed (suggesting a structural natural frequency). If resonance is confirmed, options include changing the excitation frequency, changing the natural frequency of the structure (by adding mass or stiffness), or adding damping. Consult a structural dynamics or rotor dynamics specialist before making structural modifications. As an interim measure, avoid operating continuously at a speed where excitation and natural frequency coincide.

# 9. Day-to-Day Operational Workflow

## 9.1. Routine Checks

| Frequency | Action |
|---|---|
| Daily | Review the alarm status dashboard in InsightCM for all monitored assets and confirm no active alarms or warning-level conditions are present. Configure email alarm notifications so any new alarm triggers an immediate notification. |
| Weekly | Spot-check trend data for key features (overall velocity or acceleration level, 1× amplitude, and any active bearing defect frequency amplitudes) for critical assets to confirm values are stable and not drifting toward alarm levels. |
| Monthly | Review the spectrum and waveform data for each monitored machine and compare against the previous review period for new peaks or changes in spectral content. |

Configure email alarm notifications in InsightCM so that equipment experts, equipment owners and/or operators receive immediate alerts when an alarm triggers between scheduled reviews. Daily dashboard checks and email notifications together provide both routine oversight and prompt warning of acute events.

If alarms are configured properly, weekly and monthly checks may not be necessary.

## 9.2. Following Major Overhaul or Equipment Replacement

Following any major overhaul, component replacement, realignment, balance correction, or extended outage, complete the following before relying on the alarm system:

- Verify the asset configuration in InsightCM still accurately reflects the installed hardware, sensor mapping, and operating-state thresholds.
- Allow the machine to run under normal load to collect representative post-maintenance data.
- Review the post-maintenance spectrum against the pre-maintenance baseline to confirm the fault condition has been resolved.
- Update alarm baselines to reference the new post-maintenance healthy condition.

The machine's healthy signature may shift following an overhaul. Thresholds set against the previous baseline may produce false alarms or mask a real developing fault if not updated.

# 10. Maintenance and Troubleshooting

## 10.1. Enclosure Cleaning

Clean the exterior of the enclosure as needed to remove excess buildup of dust, debris, or other contamination.

- Ensure the enclosure door is shut while cleaning to prevent contact with internal components.
- Use a non-conductive, non-residue cleaner (for example, 70% isopropyl alcohol / 30% water mixture) and a soft cloth that will not scratch the enclosure surface.

## 10.2. Sensor Calibration

Vibration sensors used in industrial condition monitoring do not require routine periodic recalibration, but calibration should be verified when:

- A sensor is replaced
- Anomalous readings are suspected
- A mechanical event (impact, flooding, or fire) occurs that may have damaged the sensor

Verification is performed by comparing the sensor output on a calibrated shaker table. It can also be helpful to compare the sensor against a known reference using a calibrated back-to-back reference accelerometer, or by confirming DC gap voltage for proximity probes is within the expected linear range at the installed gap. For IEPE accelerometers, the presence of a DC bias voltage on the signal line while the sensor is powered confirms the sensor is receiving constant-current excitation; a loss of bias voltage indicates a wiring or power supply fault.

> The NI C Series input modules (NI-9229, NI-9230, NI-9232, etc.) are factory-calibrated and do not require field calibration under normal operation.

## 10.3. Troubleshooting Common Issues

### 10.3.1. No Signal on an Accelerometer, Velocity Probe, or Proximity Channel

For accelerometers and velocity probes:

- Confirm the sensor cable is fully seated at both the sensor connector and the terminal block inside the cRIO enclosure.
- For IEPE sensors (most industrial accelerometers), verify the constant-current supply is active by measuring DC bias voltage on the signal line. A healthy IEPE circuit shows approximately 8 to 12 VDC bias; zero volts indicates a broken wire, failed connector, or unpowered IEPE supply. InsightCM offers an open/short IEPE circuit indicator.

- Inspect the cable for physical damage along its run, particularly at the sensor connection (subject to vibration fatigue) and at conduit entry points.

For proximity probes:

- Verify the gap voltage is within the linear range of the driver (typically -8 to -18 V for a standard 200 mV/mil system).
- Confirm the proximitor/driver module is powered and its OK LED is illuminated.

### 10.3.2. Signal Appears Noisy or Erratic

The most common causes and corrective actions are:

| Cause | Corrective Action |
|---|---|
| Grounding issues | Verify the sensor cable shield is grounded at one end only to eliminate ground loops. |
| Cable routing near power conductors | Separate sensor signal cabling from power wiring per the Installation Planning Guide. |
| Loose connectors | Reseat and inspect all connectors at the sensor and terminal block for corrosion or partial seating. |
| Improper sensor mounting | Verify mounting torque or adhesive bond. A sensor not rigidly mounted picks up rocking or resonance artifacts rather than true machine vibration. |
| Proximity probe contamination | For proximity probes, erratic DC gap voltage indicates probe tip or target surface contamination or damage. |

### 10.3.3. Device Shows Offline in InsightCM

Loss of communication with the cRIO device is most often caused by poor Ethernet termination or by port blocking or firewall rules. Troubleshoot in the following order:

- Verify the physical link using an Ethernet cable tester to confirm the cable run from the cRIO to its endpoint is intact.
- Confirm the network configuration of the cRIO, IP address and subnet, matches the network it is connecting to.
- If cabling and network settings are both confirmed correct, contact the facility's IT group to verify that no firewall or port blocking is preventing the cRIO from communicating with the InsightCM server.

# 11. Communication Interfaces

The Wired Vibration Monitoring system integrates with InsightCM software over a standard Ethernet network. InsightCM in turn supports the following interfaces for exporting data to external plant systems:

- AVEVA PI AF SDK, MQTT for data historian integration (for example, OSIsoft PI, AVEVA Historian)
- TCP/IP communications for InsightCM edge device management

For alarm notifications, InsightCM supports outgoing email. To configure email notifications, navigate to the alarm rule for the relevant asset, enable email notifications, and specify the recipient addresses and notification conditions. Ensure the InsightCM server is configured with valid outgoing SMTP email settings.

For information on data export, aging strategies, and historian integration, refer to the InsightCM User Manual and the InsightCM application notes available at support.cutsforth.com.

# 12. Frequently Asked Questions

The waveform looks normal but the spectrum shows unexpected peaks. What are the most likely causes?

The most common causes are: (1) Electrical interference—peaks at line frequency (50 or 60 Hz) and its harmonics indicate electrical noise coupling into the signal, typically from unshielded or improperly grounded sensor cables near power conductors. (2) Structural resonances—peaks at fixed frequencies that do not shift when machine speed changes. (3) Vibration from adjacent machines transmitting through the structure. (4) Loosely mounted sensors resonating at a lower frequency than their rated resonant frequency. (5) Aliasing—if the sampling rate is not appropriate for the highest frequency of interest, verify anti-aliasing filter and sample rate settings.

How do I know if a bearing defect frequency peak is from a bearing fault versus electrical noise or a structural resonance?

Three diagnostic checks help distinguish a true bearing fault: (1) Confirm the peak falls at a calculated bearing defect frequency (BPFO, BPFI, BSF, or FTF) for the specific bearing. (2) Check for sidebands—a true bearing fault in the envelope spectrum typically produces sidebands spaced at running speed; electrical noise and resonances do not. (3) Check whether the peak shifts with machine speed—bearing defect frequencies scale with RPM, while structural resonances remain fixed regardless of speed.

How long does the system retain historical data, and how do I configure data aging?

InsightCM manages data retention through configurable aging strategies set on the Server Configuration page. There is no single fixed default retention period—effective retention depends on the aging strategy configuration, data collection rate, and server storage capacity. For typical systems, waveform data retention is on the order of months to over a year, while trend/feature data is typically retained for several years. Navigate to Server Configuration in InsightCM and select Aging Strategies to review or modify settings. Individual data files can be protected from aging to preserve records of significant events.

How do I export vibration trend data or waveforms from InsightCM?

To export trend or feature data, navigate to the relevant asset in the Data Viewer, select the features and time range to export, and use the export function to save the data as a CSV file. To export waveform files, navigate to the asset in the Data Viewer, select the data set of interest, and use the download option. For bulk export or automated reporting, refer to the InsightCM User Manual for historian integration options including the tag-based output for AVEVA PI Historian or MQTT for other historians.

Can the system monitor assets that run intermittently or at variable speed?

Yes. The system is well suited to monitoring intermittently operated and variable-speed assets. For intermittent assets, configure the operating state trigger so the system enters the running state only when the machine is operating. For variable-speed assets, InsightCM supports order-based analysis and speed-normalized features when a tachometer input is configured. If no tachometer is available, restrict trend comparisons to data collected within a narrow speed band by using operating state speed thresholds.

### What is the difference between a trend alarm and a spectral alarm for vibration assets, and when should I use each?

A trend alarm monitors scalar feature values (such as overall velocity RMS, 1× amplitude, or a bearing defect band amplitude) and triggers when values cross user-defined absolute thresholds or deviate from a stored baseline. Use trend alarms for overall health indicators referenced to standards or asset baselines. A spectral alarm monitors energy across defined frequency bands and is more sensitive to localized frequency-domain changes. Use spectral alarms when you want to monitor energy at specific fault frequencies independently of the overall level. The recommended approach is to use both: trend alarms on overall level and key scalar features as the primary health indicator, and spectral band alarms on known fault frequencies as an early-warning layer.

### Can I configure the system to send email notifications when an alarm triggers?

Yes. InsightCM supports email alarm notifications. To configure them, navigate to the alarm rule for the relevant vibration asset, enable the email notification option, and specify the recipient addresses and notification conditions. Ensure the InsightCM server has been configured with valid outgoing SMTP email settings in the Server Configuration section.

### What does it mean when an asset shows an “Off” state, and will the system still collect data?

The Off state is entered automatically when the system determines the asset is not running, based on the operating state trigger configured for that asset. During the Off state, the device continues to collect data at the interval defined for the Off operating state, but vibration-based fault feature calculations are not performed. The system automatically transitions back to the Default (running) state when the trigger threshold is exceeded again. If an asset shows Off state unexpectedly while the machine is known to be running, check the operating state trigger configuration—the amplitude or speed threshold for the running state may be set too high, or the reference channel may have a fault.

### What is a normal approach to setting up alarm thresholds for a new asset?

Start with fixed absolute thresholds based on ISO 10816/20816 overall velocity limits as a safety net. In parallel, collect baseline data over several weeks of normal operation and configure deviation-from-baseline alarms in InsightCM as the early-warning layer. Review and refine both sets of thresholds after the first few months of operation once the asset’s normal behavior is well characterized.

# 13. Glossary

| | |
|---|---|
| AC (Alternating Current) | An electrical power supply in which current periodically reverses direction. Required for powering the monitoring system enclosures. |
| acceleration | A measure of how quickly vibration velocity changes over time, commonly used in vibration analysis to assess fault severity in rotating machinery. |
| accelerometer | A sensor that measures vibration acceleration and is commonly used for monitoring high frequency machine faults such as bearing defects. |
| APR (Advanced Pattern Recognition) | A machine-learning or statistical modeling method that uses historical sensor data to detect abnormal asset behavior and predict developing failures. InsightCM can send feature data to plant historians for use in APR models. |
| asset tree | A hierarchical representation of plant equipment inside InsightCM. Used for organizing devices, configuring monitoring, and associating data with specific assets. |
| Bode plot | A visualization showing vibration amplitude and phase relative to machine speed; used for diagnosing resonance, imbalance, and rotor dynamic behavior. |
| BPFI | Ball Pass Frequency Inner Race — a bearing defect frequency calculated from bearing geometry and running speed. |
| BPFO | Ball Pass Frequency Outer Race — a bearing defect frequency calculated from bearing geometry and running speed. |
| BSF | Ball Spin Frequency — a bearing defect frequency calculated from bearing geometry and running speed. |
| cavitation | A damaging condition in pumps caused by vapor bubble formation and collapse, detectable through high-frequency vibration patterns. |
| cRIO | NI Compact Reconfigurable I/O Controller. |
| displacement | A vibration metric representing how far a component moves from its resting position; often used for low-frequency machinery such as large turbines. |
| edge processing | Local (in-enclosure) computation that reduces network bandwidth and storage needs by filtering, compressing, or analyzing data before sending it to InsightCM. |

| | |
|---|---|
| envelope spectrum | A specialized vibration analysis tool used for early detection of bearing faults by demodulating high-frequency impacts. |
| FTF | Fundamental Train Frequency — a bearing defect frequency calculated from bearing geometry and running speed. |
| full spectrum (2-channel spectrum) | A frequency-domain plot that includes both forward and reverse vibration components; essential for diagnosing rotating-equipment issues such as imbalance or oil whirl. |
| gear mesh frequency | A characteristic vibration frequency related to gear tooth engagement; deviations can signal gear wear or eccentricity. |
| IEPE | Integrated Electronics Piezo-Electric—a standard for accelerometers that have built-in signal conditioning powered by a constant-current supply on the signal cable. |
| imbalance | A common rotating-equipment fault where mass is unevenly distributed around a rotor, causing elevated vibration at running speed. |
| InsightCM™ (ICM) | InsightCM™ is application software for condition monitoring with full access to waveforms, multiple sensor technology inputs, enterprise software connectivity, and analytics packages. |
| I/O | input/output |
| keyphasor | An electric pulse derived from a point on a rotating shaft that serves as a zero phase reference for finding imbalance on a rotor. |
| misalignment | A fault occurring when coupled machine shafts are not properly aligned, causing elevated vibration at 1× and 2× running speed. |
| NEMA rating | A North American standard classifying enclosure protection levels against environmental conditions. |
| orbit plot | A visualization showing the actual motion path of a rotating shaft using two orthogonal proximity probes; used for high-end turbomachinery diagnostics. |
| peak-to-peak (P-P) | A vibration measurement representing the total displacement between the maximum and minimum values of a waveform cycle. |
| proximity probe | A non-contact sensor used to measure shaft position and displacement in rotating machinery such as turbines and generators. |
| resonance | A condition where machine natural frequencies amplify vibration response; often revealed through frequency sweeps and Bode plots. |

| | |
|---|---|
| sensor bias / bias voltage | A constant voltage applied to certain vibration sensors (e.g., IEPE accelerometers) to power internal circuitry. |
| shaft-centerline plot | A polar chart used to visualize shaft orbit movement relative to bearing clearance; critical for large rotating machinery diagnostics. |
| spectral analysis | The process of converting vibration waveforms into frequency-domain plots to identify characteristic fault signatures. |
| time waveform | A raw, time-domain vibration signal used to identify impacts, looseness, and transient machine behavior. |
| trending | The process of recording and analyzing changes in data over time to detect abnormal patterns or emerging failures. |
| velocity | A vibration measurement representing the speed of movement over time; commonly used to assess overall machine health and compliance with ISO 10816/20816 guidelines. |
| waterfall display | A three-dimensional plot of spectra collected over time or speed; used to track how frequency content changes as a fault develops or as machine speed varies. |