Operations Manual EZDP-2156 Rev A

Electrical Signature Analysis

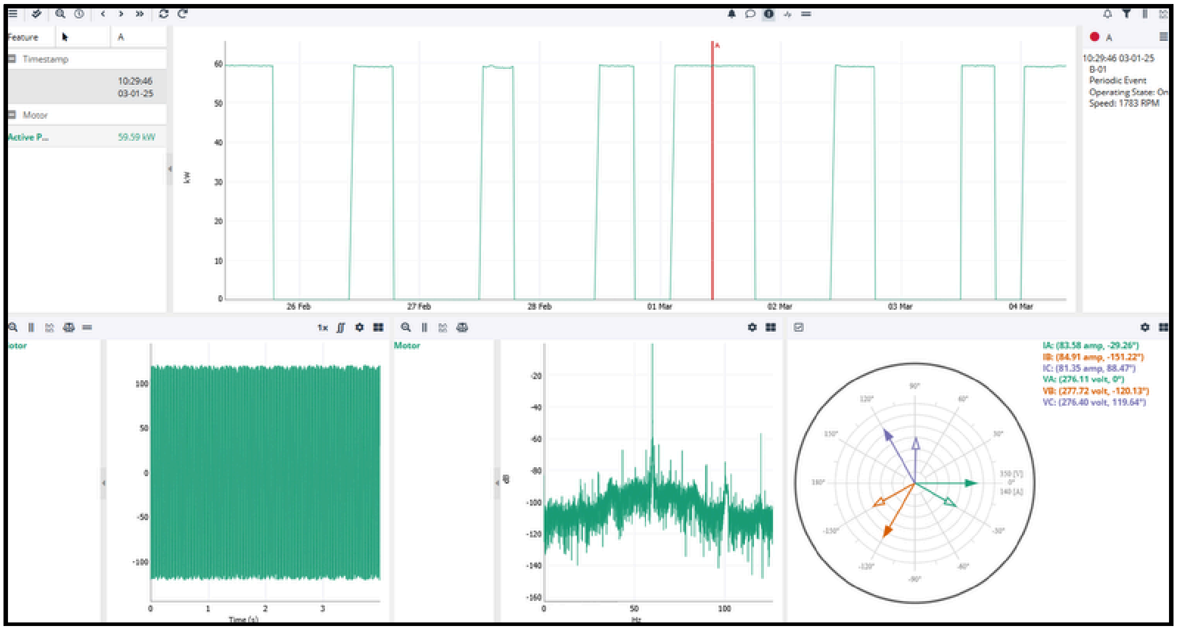

Table of Contents

Legal Information

Limited Warranty

This document is provided 'as is' and is subject to being changed, without notice, in future editions. Cutsforth reviews this document carefully for technical accuracy; however, CUTSFORTH MAKES NO EXPRESS OR IMPLIED WARRANTY AS TO THE ACCURACY OF THE INFORMATION WITHIN THIS MANUAL AS IT RELATES TO SPECIFIC INSTALLATION. THE CUSTOMER IS RESPONSIBLE FOR VERIFYING INSTALLATION AND OPERATING CONDITIONS AT EACH INSTALLATION LOCATION AND FOR EACH GENERATOR TYPE. Cutsforth warrants that its hardware products will be free of defects in materials and workmanship that cause the product to fail to substantially conform to the applicable Cutsforth published specifications for one (1) year from the date of invoice.

For a period of ninety (90) days from the date of invoice, Cutsforth warrants that (i) its software products will perform substantially in accordance with the applicable documentation provided with the software, and (ii) the software media will be free from defects in materials and workmanship. If Cutsforth receives notice of a defect or non-conformance during the applicable warranty period, Cutsforth will, in its discretion: (i) repair or replace the affected product, or (ii) refund the fees paid for the affected product. Repaired or replaced hardware will be warranted for the remainder of the original warranty period or ninety (90) days, whichever is longer. If Cutsforth elects to repair or replace the product, Cutsforth may use new or refurbished parts or products that are equivalent to new in performance and reliability and are at least functionally equivalent to the original part or product. You must obtain an RMA number from Cutsforth before returning any product to Cutsforth. Cutsforth reserves the right to charge a fee for examining and testing hardware not covered by the Limited Warranty.

This Limited Warranty does not apply if the defect of the product resulted from improper or inadequate maintenance, installation, repair, or calibration performed by a party other than Cutsforth; unauthorized modification; improper environment; use of an improper hardware or software key; improper use or operation outside of the specification for the product; improper voltages; accident, abuse, or neglect; or a hazard such as lightning, flood, or other act of nature.

THE REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND THE CUSTOMER'S SOLE REMEDIES, AND SHALL APPLY EVEN IF SUCH REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

WARNING REGARDING USE OF CUTSFORTH SHAFT MONITORING EQUIPMENT: CUSTOMER IS ULTIMATELY RESPONSIBLE FOR VERIFYING AND VALIDATING THE SUITABILITY AND RELIABILITY OF THE PRODUCTS WHENEVER THE PRODUCTS ARE INCORPORATED IN THEIR SYSTEM OR APPLICATION, INCLUDING THE APPROPRIATE DESIGN, PROCESS, AND SAFETY LEVEL OF SUCH SYSTEM OR APPLICATION. PRODUCTS ARE NOT DESIGNED, MANUFACTURED, OR TESTED FOR USE IN LIFE OR SAFETY CRITICAL SYSTEMS, OR ANY OTHER APPLICATION IN WHICH THE FAILURE OF THE PRODUCT OR SERVICE COULD LEAD TO DEATH, PERSONAL INJURY, SEVERE PROPERTY DAMAGE OR ENVIRONMENTAL HARM (COLLECTIVELY, "HIGH-RISK USES"). FURTHER, PRUDENT STEPS MUST BE TAKEN TO PROTECT AGAINST FAILURES, INCLUDING PROVIDING BACK-UP AND SHUT-DOWN MECHANISMS. CUTSFORTH EXPRESSLY DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY OF FITNESS OF THE PRODUCTS OR SERVICES FOR HIGH-RISK USES.

CUTSFORTH DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE OF OR THE RESULTS OF THE USE OF THE PRODUCTS IN TERMS OF CORRECTNESS, ACCURACY, RELIABILITY, OR OTHERWISE. CUTSFORTH DOES NOT WARRANT THAT THE OPERATION OF THE PRODUCTS WILL BE UNINTERRUPTED OR ERROR FREE. INCIDENTAL AND CONSEQUENTIAL DAMAGES, INCLUDING LOSS OF USE, ARE SPECIFICALLY EXCLUDED FROM THIS WARRANTY; THE MAXIMUM VALUE OF A WARRANTY CLAIM CANNOT EXCEED THE ORIGINAL VALUE OF THE ASSEMBLY OR COMPONENT.

Copyright

Patents

Please send patent information requests to patents@cutsforth.com.

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.

Please note that if the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

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.
- Always ensure proper installation of the holder assembly and shaft grounding rope.

ELECTRICAL DANGER

Before working on the generator, de-energize, lock out, and tag out all power sources to the generator, shaft, and accessory devices. Electric shock and death may result due to failure to heed this warning.

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.

WARNING

Cutsforth recommends that workers do not change Shaft Contact Assembly (SCA) meter ropes while the generator is energized and/or operational. It is recommended that meter ropes be inspected and if necessary, changed during outages when the generator has been secured. Since the SCA is generally installed in relatively close proximity to the collector/brush gear (energized equipment) and or other rotating hazards in this area of the generator, it may pose a risk to workers that may include but are not limited to the following:

- Risk of entanglement or rotational injury attempting to remove/insert a meter rope.
- Risk of electrical shock.
- Risk of creating a short circuit between energized parts and ground.

These conditions and limitations are to be carefully considered at the time of installation. It is recommended that procedures and policies be implemented by the end user so as to realize the full function of the monitoring system but avoid potential hazards. These conditions generally do not apply to the Shaft Grounding Assembly (SGA) equipment installation.

WARNING

Never mix different carbon brush grades or brushes from different manufacturers on the same unit.

LIFTING EQUIPMENT

For configurations that weigh more than 18 kg (40 lbs.), please utilize team lifting techniques to lift and move the equipment, including lifting with the legs, and avoid twisting while moving the equipment.

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.

Veuillez noter que si l'équipement est utilisé d'une manière non spécifiée par le fabricant, la protection assurée par l'équipement peut être compromise.

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;
- Toujours s'assurer que la structure de soutien et le câble de terre de l'arbre de la génératrice sont correctement installés.

RISQUES DE CHOC ÉLECTRIQUE

Avant de travailler sur la génératrice, désalimentez, cadenassez et étiquetez toutes les sources d'énergies liées à la génératrice, à l'arbre et aux appareils accessoires. L'opérateur s'expose à des risques de chocs électriques pouvant causer la mort s'il ne tient pas compte de cet avertissment.

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.

AVERTISSEMENT

Cutsforth recommande aux travailleurs de ne pas changer les câbles de mesure de l'ensemble de contact avec l'arbre (ECA) lorsque le générateur est alimenté et/ou opérationnel. Il est recommandé d'inspecter les câbles de mesure et, si nécessaire, de les changer pendant les arrêts, lorsque le générateur a été sécurisé. Étant donné que l'ECA est généralement installé relativement près du collecteur et des frotteurs (lesquels sont sous tension) ainsi que d'autres composantes rotatives, l'utilisation ou la manutention de l'ECA peut présenter des risques pour les travailleurs, qui peuvent inclure les éléments suivants, sans s'y limiter :

- Risques d'être blessé par des composantes rotatives ou d'être coincé dans celles-ci en tentant d'enlever ou d'insérer un câble de mesure;
- Risques de choc électrique;
- Risques de créer un court-circuit entre des composantes alimentées et la mise à la terre.

Ces conditions et contraintes doivent être attentivement prises en considération lors de l'installation de l'ECA. Il est recommandé que l'utilisateur final implémente des protocoles et des politiques visant à s'assurer que le système de surveillance puisse être utilisé en évitant les risques potentiels liés à celui-ci sans compromettre son efficacité. Ces conditions ne s'appliquent généralement pas lors de l'installation de l'ensemble de mise à la terre de l'arbre (EMTA).

AVERTISSEMENT

Ne jamais utiliser de frotteurs de différentes qualités ou venant de différents manufacturiers sur le même appareil.

ÉQUIPEMENT DE LEVAGE

Pour les configurations pesant plus de 18 kg (40 lb), veuillez recourir à des techniques de levage en équipe pour soulever et déplacer l'équipement — notamment en sollicitant les jambes — et évitez toute torsion du corps lors du déplacement.

1. Product Description

NOTE:

This manual is a guide for the operation of the Electrical Signature Analysis (ESA) 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.

1.1. Electrical Signature Analysis Overview

Cutsforth's Electrical Signature Analysis (ESA) system is a permanently installed, online motor monitoring solution that uses three-phase voltage and current signals to continuously detect potential motor faults and anomalies. The ESA toolkit within InsightCM™ computes features specific to electrical data and motors, extending beyond standard phasor and waveform analysis to provide a comprehensive picture of motor health.

A single ESA acquisition device can monitor up to nine motors connected to a single voltage bus. Installation near Motor Control Centers (MCCs) or switchgear minimizes cable lengths and associated installation costs.

1.2. Common Fault Modes Detected

The ESA system is capable of detecting and trending the following fault modes:

- Rotor bar damage
- Misalignment
- Eccentricity
- Mechanical looseness
- Stator faults
- Bearing faults
- Power quality issues

1.3. Leveraging Existing Infrastructure

The ESA system can make use of protective relay current transformers (CTs) and potential transformers (PTs) already installed in the facility to simplify installation and reduce signal-conditioning costs. Where CTs and PTs are not already present, direct measurements can be made with appropriately sized instrumentation that integrates into the ESA platform.

1.4. InsightCM™ Integration

All ESA 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 calculated by InsightCM™ can be transmitted to plant historians for integration into advanced pattern recognition (APR) models or other machine learning platforms.

The ESA viewers available in InsightCM™ include:

- Trend
- Waveform
- Spectrum
- High Resolution Spectrum
- Phasor Diagram
- Envelope (Amplitude Demodulation)
- Park Clarke
- Torque Waveform

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

2. Technical Specifications

2.1. IT System Requirements

2.1.1. Overall Architecture

The ESA system uses an InsightCM™ edge hardware device (cRIO) to acquire voltage and current 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 HTTP.

NOTE:

InsightCM™ and SystemLink are incompatible and must be installed on separate servers.

2.1.2. Server Hardware Requirements

The following table summarizes the minimum recommended server specifications. Cutsforth recommends using solid state drives (SSDs) to improve disk throughput and overall system performance.

System Scale	OS	Processor	RAM	Storage
Fewer than 10 monitoring devices	Windows 10 or 11 (64-bit Pro)	2.2 GHz, 4-core	16 GB	Single drive: 500 GB minimum
Fewer than 50 monitoring devices	Windows Server 2016, 2019, or 2022	2.2 GHz, 8-core	16 GB	OS drive: 250 GB; Data drive: 1 TB
More than 50 monitoring devices	Windows Server 2016, 2019, or 2022	3 GHz, 16-core	32 GB	OS drive: 250 GB; Data drive: 2 TB

2.1.3. Networking Requirements

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

2.2. ESA System Hardware Specifications

Table 1. Power Specifications

Parameter	Specification
Plant-Supplied Power	120 V, 60 Hz AC or 240 V, 50 Hz AC
Input Voltage Range	100 – 240 VAC
Input Frequency Range	50 – 60 Hz
Input Power Rating	150 W
Internal Circuit Breaker	120 V, 5 A
Current Draw (Normal)	Approx. 0.6 A
Input Wire Connection	DIN Screw-Down Terminal Block
Input Wire Size	26 – 10 AWG
Overvoltage Category	Category II

Table 2. Environmental Specifications

Parameter	Specification
Operating Temperature	-20 °C to 65 °C (-4 °F to 149 °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	2,000 m (6,500 ft)
Pollution Degree	2

Table 3. Enclosure Specifications

Parameter	Specification
Weight	15.88 – 27.22 kg (35 – 60 lbs.) depending on configuration
Indoor/Outdoor Use	Both
Enclosure Construction	Powder coated steel
Enclosure rating	UL 508A Listed Type 1, 2, 4, 4X, 12, 13 File No. E194432; IP65 and IP66

2.3. Product Certifications

Region	Category	Standard
North America	EMC	Conforms to FCC 15.107, 15.109 (2026) Class A; ICES-003 Issue 7 (2020) Class A
North America	Safety	UL 508A; CSA C22.2 No. 286
EU (CE)	EMC Directive 2014/30/EU	Tested to EN IEC 61326-1 (2021) Class A
UKCA	EMC 2016	Tested to EN 61326-1 (2021) Class A

3. System Components

3.1. ESA Acquisition Hardware

The ESA system consists of a cRIO (Compact Reconfigurable I/O) controller housed in a NEMA 4X-rated enclosure, equipped with the following I/O modules:

- Controller — one of the following, depending on the number of motors being monitored:
  - cRIO-9055 (4-slot controller)
  - cRIO-9058 (8-slot controller)
- NI-9242 or NI-9244 voltage bus input card (for potential transformer measurements)
- NI-9239 voltage input module (for voltage-output current sensors)
- Current sensors (clamp-on type, supplied by Cutsforth)

NOTE:

The specific enclosure and controller configuration are determined by the number of motors to be monitored and the site voltage class. Refer to the Installation Planning Guide (EZDP-2148) for full equipment lists and enclosure sizing.

3.2. Enclosures

Two standard enclosure sizes are available. The specific enclosure is selected based on the space requirements of the configured product:

Catalog Number	Dimensions (in.)	Dimensions (mm)
SNB-3746	20.0 × 16.0 × 8.0	508 × 406 × 203
SNB-3752	24.0 × 20.0 × 8.0	610 × 508 × 203

NOTE:

Enclosures are rated NEMA 4X, UL Listed Type 1, 2, 4, 4X, 12, 13, and IP65/IP66. Conduit holes are not pre-drilled; conduit sizing and placement are customizable per installation. Adequate sealing hardware should be used to maintain the enclosure ratings.

3.3. InsightCM™ Software

InsightCM™ is Cutsforth's application software for continuous condition monitoring. It runs on a customer-supplied server (see Section 5 for server requirements) and provides:

- An asset tree for organizing monitored motors and voltage buses
- Real-time and historical data viewing in multiple specialized viewers
- Automated fault feature extraction and trending
- Configurable alarming with optional email notification
- Integration with plant historians via standard protocols
- Data export for external analysis

4. Installation Overview

NOTE:

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 Electrical Signature Analysis Installation Planning Guide (EZDP-2148 Rev D).

4.1. Major Installation Steps

1. Mount the ESA System enclosure at the planned location on the strut rack or wall.
2. Install conduit between the ESA Monitoring System and each voltage bus pickup point.
3. Install conduit between the ESA Monitoring System and each current sensor pickup point. Current sensor cables may share conduit provided it is appropriately sized; current sensor cables must not be combined with PT cables.
4. Install conduit for 120/240 VAC power. Minimum circuit: 20 A, 120/240 VAC, free of non-linear loads. A circuit with isolated ground is recommended.
5. Install conduit and wire for the data connection. Cutsforth recommends Cat6a or fiber (fiber requires a media converter).
6. Connect the protective earth conductor per local electrical codes.
7. Install wire for 120/240 VAC supply per local electrical codes.
8. If required by local codes, install an external switch or circuit breaker near the equipment.

4.2. Conduit Layout Summary

Color	Conduit Run	Trade Size	Wire Description	Max Length	Supplied By
Blue	ESA Enclosure to InsightCM™ Server	3/4 in (2 cm)	Cat6a Cable or Fiber	Refer to cable specifications	Plant Electrical Contractor
Red	Plant Power to ESA Enclosure	3/4 in (2 cm)	120 VAC, 20 A dedicated	N/A	Plant Electrical Contractor
Purple	Current Sensor Output to ESA Enclosure	Per NEC / site spec	Shielded Twisted Pair	100 ft	Plant Electrical Contractor
Yellow	Voltage Bus Signals to ESA Enclosure	3/4 in (2 cm)	Shielded Twisted Pair	100 ft	Plant Electrical Contractor

5. System Configuration

NOTE:

Complete configuration of InsightCM™ devices and asset trees is performed within the InsightCM™ application. Refer to the InsightCM™ Setup and Configuration Manual (available at https://support.cutsforth.com) for full device configuration procedures. This section covers the ESA-specific configuration items required before monitoring can begin.

5.1. Motor Nameplate Information

Accurate configuration is the foundation of reliable ESA monitoring. Because every fault feature is calculated relative to the motor's rated operating point and scaled from the signals the device measures, the analysis is only as accurate as the configuration behind it.

The following nameplate fields are required before feature calculation can begin:

- Load and Load Unit (HP or kW)
- Nominal Frequency (50 or 60 Hz)
- Synchronous Speed (RPM)
- Full Load Speed (RPM)
- Rated Volts
- Full Load Amps (FLA)
- Service Factor
- Power Factor
- Full Load Efficiency

The following fields are optional but improve analytical accuracy and should be entered where available:

- Efficiency at 75% Load
- Efficiency at 50% Load
- Efficiency at 25% Load
- Number of Stator Slots
- Number of Pump Vanes / Fan Blades
- Number of Rotor Bars

Nameplate data can typically be found on: the motor nameplate, spare motor nameplate, motor/pump manuals, previous test reports, CBM/PdM databases and reports, and relay/protection documents.

NOTE:

Use the asset tree's invalid-configuration markers in InsightCM™ to confirm that no motor group is missing required nameplate information before placing assets into routine monitoring.

5.2. Instrument Transformer Ratios

The ESA device measures the stepped-down secondary signals from the potential transformers (PTs) on the voltage bus and the current transformers (CTs) on each motor phase. InsightCM™ must be told the ratio of each transformer so that it can scale these secondary measurements back to the true primary voltages and currents.

- CT ratio: Expresses primary-to-secondary current. For example, a 200:5 CT outputs 5 A on the secondary when 200 A flows in the primary.
- PT ratio: Expresses primary-to-secondary voltage. For example, a 4160:120 PT outputs 120 V on the secondary when 4160 V is present on the primary.

WARNING

If a CT or PT ratio is entered incorrectly, every voltage- or current-derived feature — RMS, power, power factor, percent load, and unbalance — will be scaled incorrectly even though the waveform shape appears correct. The entered ratios must exactly match the nameplates of the installed transformers.

5.3. Voltage Bus Wiring Configuration

When the voltage bus is created in InsightCM™, the associated PT sensors are added, and the wiring configuration must be defined to match the installation. Select the appropriate configuration:

- Wye or Delta bus topology
- Number of voltage sensors (typically two or three sensors per bus)

The selected configuration determines how phase-to-phase and phase-to-ground relationships are interpreted. Where multiple motors share a common voltage source, a shared voltage bus configuration can be created once and applied to each motor fed from that bus.

5.4. Commissioning Using the Phasor Diagram

After entering nameplate data, transformer ratios, and wiring configuration, verify the installation using the Phasor Diagram in InsightCM™ before placing the asset into routine monitoring.

With an induction motor, current should lag voltage. Confirm the following:

- The three voltage phasors are balanced in magnitude and spaced approximately 120° apart.
- The three current phasors are balanced in magnitude and spaced approximately 120° apart.
- Each current phasor lags its associated voltage phasor.
- The phase sequence is correct (A matched to A, B to B, C to C).

> NOTE:
>
> If a current phasor appears 180° out of phase with its associated voltage phasor, the current sensor polarity is reversed. This can be corrected in InsightCM™ by enabling the Reverse Polarity setting for that phase in the asset configuration page and pushing the updated configuration to the device — no physical field changes are required.

5.5. Alarm Threshold Guidelines

Alarm thresholds for ESA assets are based on a combination of industry standards, operational experience, and equipment-specific trend data. Thresholds should be reviewed and tuned periodically. The primary reference standard is ANSI/NEMA MG 1, Motors and Generators.

Parameter	Recommended Alarm Window	Notes
Voltage Unbalance	3% – 5%	Per NEMA MG 1, motors should be derated above 1% unbalance. Operating within 3%–5% is acceptable with derating.
Current Unbalance	5% – 8%	Provides early warning before current exceeds service-factor limit. Can indicate voltage unbalance or impending stator fault.
Torque Ripple	Greater than 10%	Excess torque ripple historically indicates developing driven-equipment issues such as pump problems.
Rotor Bar Sideband	Greater than -45 dB: low concern; greater than -40 dB: moderate; greater than -35 dB: high	Values are negative dB; less-negative is worse. Tune thresholds per asset and load class.

> NOTE:
>
> In addition to fixed thresholds, consider configuring deviation-from-baseline alarms. Once a representative healthy signature is established for an asset, alarms configured on statistical deviation from that baseline can detect small step changes earlier than traditional fixed-setpoint alarms.

5.6. Operating States

The ESA system uses configurable operating states to gate data collection and feature calculation based on motor load. The default operating states are:

State	Entry Condition	Data Collection	Notes
Off	% FLA less than 25%	Trend: every 5 min; Data set: once per hour	Full fault feature calculation not performed; motor not running under sufficient load.
Default (Running)	% FLA 25% to less than 200%	Trend: every 5 min; Data set: once per hour (3 sec, with 1 sec pre-trigger)	Normal monitoring state; full fault feature calculation is active.
Startup	% FLA 200% or greater	Single 30-sec data set (with 1 sec pre-trigger)	Captures full startup transient. Exits when % FLA drops below 110% for 5 sec or after 30 sec.

NOTE:

The minimum working current threshold (default 25% FLA) and maximum working current threshold (default 200% FLA) are configurable on the Device Properties tab in InsightCM™. The Rotor Bar Sideband feature returns -100 dB when the motor is below the minimum working current threshold.

6. Operation

6.1. Powering the ESA System On and Off

6.1.1. Powering On

1. Open the ESA enclosure door.
2. Locate the circuit breaker on the bottom DIN rail inside the enclosure.
3. Flip the circuit breaker to the ON (closed) position.
4. Close the enclosure door.

6.1.2. Powering Off

1. Open the ESA enclosure door.
2. Locate the circuit breaker on the bottom DIN rail.
3. Flip the circuit breaker to the OFF (open) position.
4. 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.

6.2. Interpreting the InsightCM™ Data Views

The ESA toolkit in InsightCM™ provides a set of specialized viewers for analyzing motor electrical signatures. Each view targets a different aspect of motor health. The sections below describe how to interpret each view and what to look for.

6.2.1. ESA Spectrum

The ESA Spectrum displays the frequency content of the motor current after a Fast Fourier Transform (FFT) converts the time-domain current waveform into amplitude versus frequency. The horizontal axis is frequency (Hz) and the vertical axis is amplitude, typically in decibels (dB).

The dominant feature is the line-frequency peak at the supply fundamental (50 or 60 Hz); fault information is carried in the smaller sideband and harmonic peaks distributed around and above it. Key interpretation guidelines:

- Sidebands spaced at twice the slip frequency (2·s·f) around the fundamental point to rotor bar problems.

- Peaks at multiples of running speed or at rotor-slot-pass frequencies indicate eccentricity.
- Elevated peaks at line-frequency harmonics (120, 180, 360 Hz, etc.) generally reflect supply or power-quality issues rather than mechanical faults.
- A rising sideband or harmonic amplitude over successive acquisitions is more significant than its absolute value — always evaluate the spectrum as a trend.

6.2.2. ESA Envelope Spectrum

The ESA Envelope Spectrum (amplitude demodulation) is derived by extracting the modulation envelope of the current signal and then applying an FFT to that envelope. This removes the large line-frequency carrier and reveals low-frequency modulations that are difficult to see in the standard spectrum, making this view especially useful for detecting mechanical faults.

Look for discrete peaks at characteristic defect frequencies — running speed and its harmonics, gear-mesh frequencies, or the calculated bearing defect frequencies (BPFO, BPFI, BSF, FTF). Peaks that grow over time and align with a known fault frequency for the asset are the most significant indicators. Broadband elevation of the envelope floor without distinct peaks usually indicates increased random load variation rather than a specific developing fault.

6.2.3. ESA Torque Waveform

The ESA Torque Waveform displays an estimate of the motor's instantaneous air-gap torque, computed from the measured three-phase voltage and current, plotted against time. A healthy motor driving a steady load produces a relatively flat, low-ripple trace. Interpret the waveform by relating the period of any repeating fluctuation to a mechanical event:

- Pulsations at the running-speed period suggest misalignment, imbalance, or a coupling problem.
- Pulsations synchronized to the driven equipment (pump vane-pass, fan blade-pass, or gear-mesh events) point to load-side disturbances.
- A growing torque ripple over successive acquisitions signals a worsening mechanical condition even when the average torque is unchanged.

6.2.4. Park Clarke

The Park Clarke view applies the Park/Clarke transform to the three-phase current, mapping the three currents onto two orthogonal axes (d–q) and plotting one against the other. For a healthy, balanced motor the resulting figure is a near-perfect circle centered on the origin. Interpret this view by examining the shape, thickness, and centering of the pattern:

- A circle distorted into an ellipse indicates current unbalance — often a sign of stator winding faults, voltage unbalance, or a connection problem.
- Thickening or fuzziness of the trace reflects modulation of the current by a developing fault.
- An off-center pattern points to a DC offset or sensor issue.

6.2.5. Phasor Diagram

The Phasor Diagram displays the magnitude and relative phase angle of each voltage and current phase as vectors on a polar plot. The three voltage phasors should be roughly equal in length and spaced 120°

apart, as should the three current phasors. For an induction motor, each current phasor should lag its associated voltage phasor. Interpret the diagram by checking three things:

- The three voltage and three current phasors are balanced in magnitude and evenly spaced.
- The phase sequence is correct.
- Each current phasor lags its associated voltage phasor (current should never lead).

NOTE:

A current phasor that appears to lead, or that sits approximately 180° from its expected position, indicates reversed current-sensor polarity on that phase. This can be corrected by enabling the Reverse Polarity setting for that sensor in the asset configuration — no field work is required.

6.3. Fault Mode Descriptions and Data Signatures

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

6.3.1. Rotor Bar Damage

Description: Cracked or broken rotor bars disrupt the rotor current and produce pole-pass sidebands around the line-frequency peak in the ESA Spectrum. The sidebands are spaced at twice the slip frequency (2·s·f) on either side of the supply fundamental, and their amplitude relative to the fundamental grows as more bars break. In InsightCM™ this appears as a rising Rotor Bar Sideband feature value (less negative dB) and as visible sideband peaks in the ESA Spectrum.

Recommended Action: Trend the Rotor Bar Sideband feature against its alarm threshold. Confirm the motor is running under sufficient load (above 75% FLA), since the feature is not calculated accurately at low load. If sidebands are growing, plan a rotor inspection or testing during the next maintenance window.

6.3.2. Misalignment

Description: Coupling or shaft misalignment cyclically loads the motor once per revolution, modulating the current and torque at running speed and its harmonics (1×, 2×, sometimes 3× RPM). It is most visible as peaks at running-speed multiples in the ESA Envelope Spectrum and as periodic ripple at the running-speed period in the ESA Torque Waveform. A 2× running-speed component is a common misalignment signature.

Recommended Action: Check shaft and coupling alignment using laser or dial-indicator methods at the next opportunity, and inspect the coupling for wear. Correlate the ESA findings with available vibration data to confirm the mechanical source before scheduling corrective alignment.

6.3.3. Eccentricity

Description: Eccentricity is a non-uniform air gap between rotor and stator, either static or dynamic. It produces peaks at the rotor-slot-pass frequencies and at running-speed sidebands around those slot harmonics in the ESA Spectrum. Growing peak amplitude over time indicates worsening air-gap variation.

Recommended Action: Verify mounting and check for soft foot, loose hold-down bolts, or a distorted base. Inspect bearings and bearing housings. Trend the relevant slot-pass peaks; rising amplitude warrants mechanical inspection.

6.3.4. Mechanical Looseness

Description: Looseness in the mounting, bearing housings, or driven-equipment connections allows components to move under load, producing irregular, often multi-harmonic content. It typically appears as a series of running-speed harmonics in the ESA Envelope Spectrum and as erratic or impacting fluctuations in the ESA Torque Waveform, frequently with a raised noise floor.

Recommended Action: Inspect and re-torque mounting bolts, hold-downs, and coupling fasteners. Check bearing housing fits and driven-equipment connections. Re-evaluate the ESA data after tightening to confirm the harmonic content has subsided.

6.3.5. Stator Faults

Description: Stator winding problems — turn-to-turn shorts, phase imbalance, or insulation degradation — unbalance the three-phase currents. In the Park Clarke view this distorts the normally circular pattern into an ellipse, and on the Phasor Diagram it shows as unequal current magnitudes or uneven phase spacing. Severe faults also raise line-frequency harmonic and odd-harmonic content in the ESA Spectrum.

Recommended Action: Confirm the imbalance is internal to the motor and not caused by supply voltage unbalance (check the voltage phasors first). If currents are unbalanced with balanced voltages, schedule insulation-resistance and surge testing of the stator windings. Treat a developing stator fault as high priority, as turn-to-turn shorts can escalate quickly.

6.3.6. Bearing Faults

Description: Bearing defects (outer race, inner race, ball/roller, or cage) modulate the current at characteristic bearing-defect frequencies (BPFO, BPFI, BSF, FTF). These are best seen as discrete peaks in the ESA Envelope Spectrum. Rising peak amplitude at a calculated defect frequency indicates a progressing bearing fault.

Recommended Action: Match any envelope-spectrum peaks to the calculated bearing-defect frequencies for the asset to identify which element is affected. Trend the amplitude and corroborate with vibration or temperature data where available. Plan bearing replacement and lubrication review according to how quickly the trend is advancing.

6.3.7. Power Quality Issues

Description: Power quality problems originate on the supply side — voltage unbalance, harmonic distortion, sags/swells, or rectifier/drive artifacts. They appear as elevated line-frequency harmonics (120, 180, 240, 360 Hz, etc.) in the ESA Spectrum and as unequal or unevenly spaced voltage phasors on the Phasor Diagram. Because the source is the supply, the same signature typically appears on multiple motors fed from the same bus.

Recommended Action: Examine the voltage phasors and voltage-side harmonics to confirm the issue is supply-related, and check whether other motors on the same bus show the same pattern. Investigate upstream sources such as drives, rectifiers, unbalanced loads, or loose connections. Address power quality at the source.

6.4. Day-to-Day Operational Workflow

6.4.1. Routine Daily Checks

On a daily basis, the operator should review the alarm status of all monitored motor assets in InsightCM™. A once-per-day check of the alarm dashboard is sufficient to catch developing conditions that trend slowly, such as rising rotor bar sidebands or a declining power factor.

NOTE:

Configure email alarm notifications in InsightCM™ so that the operator receives an immediate alert when an alarm triggers between scheduled daily reviews. Daily dashboard checks and email notifications together provide both routine oversight and prompt warning of acute events.

6.4.2. Following Major Overhaul or Motor Replacement

Following any major overhaul, motor replacement, rewind, or extended outage, verify the InsightCM™ configuration before relying on the alarm system:

- Confirm that the asset configuration — nameplate data, sensor mapping, and operating-state thresholds — still reflects the equipment as currently installed.
- Allow the motor to run under normal load to collect representative data.
- Review and reset alarm baselines after the work is complete. The motor's healthy signature may have shifted following an overhaul, so thresholds set against the previous baseline may produce false alarms or mask a real developing fault.

6.5. Forcing a Manual Data Acquisition

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

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

7. Maintenance and Troubleshooting

7.1. Fuse Replacement

Fuses protect the ESA system's instrument circuits. If a fuse is found to be blown during troubleshooting, replace it with an Eaton Bussmann KTK-1 fuse or equivalent 1 A, 600 V, fast-acting cartridge-style fuse.

ELECTRICAL DANGER

Before opening the enclosure or touching any internal components, de-energize, lock out, and tag out all power sources to the ESA enclosure. Failure to do so may result in electric shock and death.

To replace a fuse:

1. Open the ESA enclosure.
2. Locate the fuse holder containing the fuse requiring replacement.
3. Lift up on the fuse holder tab to open the fuse holder and expose the fuse.
4. Remove the old fuse.
5. Install the new fuse into the fuse holder, observing the correct orientation.
6. Close the fuse holder until it latches.
7. Close and latch the enclosure door.

NOTE:

A fuse should always be installed between the ESA system and the bus PT wiring. This provides selective coordination so that a fault on the ESA instrument circuit clears locally without affecting the plant's operational PT circuit.

7.2. 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.

7.3. Troubleshooting Common Issues

NOTE:

The guidance below assumes the InsightCM™ device (cRIO) is powered, online, and connected to the InsightCM™ server. If the device itself is unreachable, resolve the communication issue (see Section 10 — Communication Failures) before troubleshooting individual signals.

7.3.1. No Signal on a Voltage (PT) Input

A missing voltage signal with the device online usually indicates an open circuit on the PT side — most commonly a missing or blown fuse. Confirm that the fuse for the affected phase is present and intact, and replace it if necessary (see Fuse Replacement above). A fuse must be installed between the ESA system and the bus PT to provide selective coordination.

7.3.2. No Signal on a Current (CT) Input

Loss of a current signal points to an open circuit between the CT transducer and the cRIO input. To locate the break:

1. Place a voltmeter across the positive and negative leads close to the CT and measure the AC voltage. A healthy transducer under load will show a small AC signal.
2. If a signal is present at the CT, continue measuring along the cable run back toward the cRIO to find the point where the signal is lost.
3. Repair the open connection at the identified location.

7.3.3. Bad Phasor Readings

Incorrect phasor readings are typically caused by a current transducer that is either reversed in polarity or clamped onto the wrong phase. Use the phasor diagram to diagnose:

- If a current phasor sits approximately 180° from where it should be, the transducer polarity is reversed. Enable the Reverse Polarity setting for that sensor in the asset configuration and push the updated configuration to the device.
- If the current phasors are simply in the wrong order, reorder the current phase assignments in the InsightCM™ asset configuration so that each CT is associated with the correct phase.

7.3.4. Communication Failures

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:

1. Verify the physical link using an Ethernet cable tester to confirm the cable run from the cRIO to its endpoint is intact.

2. Confirm the network configuration of the cRIO — IP address and subnet — matches the network it is connecting to.
3. 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.

8. Communication Interfaces

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

- OPC-UA and PI AF/SDK/MQTT for data historian integration (for example, AVEVA PI)
- 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 motor asset, enable email notifications, and specify the recipient addresses and notification conditions. Ensure that the InsightCM™ server has been configured with valid outgoing email settings. Refer to the InsightCM™ User Manual for detailed configuration steps.

For information on data export, aging strategies, and historian integration, refer to the InsightCM™ User Manual available at https://support.cutsforth.com.

9. Frequently Asked Questions

Why does my phasor diagram show current leading voltage instead of lagging?

With induction motors, current should always lag voltage. If current appears to lead voltage on the phasor diagram, this typically indicates that the current sensor polarity is reversed for that phase. Correct this in InsightCM™ without going back into the field by enabling the Reverse Polarity setting for the affected phase in the asset configuration page and pushing the updated configuration to the device.

How do I verify that voltage bus signals are wired correctly after installation?

Compare the voltage signals reported in InsightCM™ against the values expected for the bus configuration. Determine the actual PT configuration in the field (Delta or Wye, and the number of PTs), calculate the expected voltage values for that arrangement, then open the asset in InsightCM™ and compare the reported RMS voltages and phasor relationships against your calculated expected values. Agreement confirms correct wiring; a mismatch indicates an incorrect wiring-configuration selection in InsightCM™ or a wiring error in the field.

What motor nameplate information is required before ESA monitoring can begin?

The following fields are required: Load, Load Unit (HP or kW), Nominal Frequency (50 or 60 Hz), Synchronous Speed (RPM), Full Load Speed (RPM), Rated Volts, Full Load Amps, Service Factor, Power Factor, and Full Load Efficiency. Optional fields that improve accuracy: Efficiency at 75%, 50%, and 25% load, Number of Stator Slots, Number of Pump Vanes or Fan Blades, and Number of Rotor Bars. This data can be found on the motor nameplate, spare motor nameplate, motor/pump manuals, previous test reports, CBM/PdM databases, or relay and protection documents.

The system is monitoring multiple motors on the same voltage bus. How do I confirm each motor's current sensors are mapped to the correct asset in InsightCM™?

The most reliable method is to validate reported values against a known plant reference. Compare the InsightCM™ current reading for each asset against the relay or historian reading for the corresponding motor — a close match confirms the mapping. Alternatively, if a motor can be safely started or stopped, watch the asset's live data in the InsightCM™ test panel while commanding that action; a signal that rises or drops in response to the command confirms the sensors are mapped to the correct asset.

How often does the ESA system collect data by default, and how can I change the collection frequency?

By default, the device collects a data set once per hour and collects trend values every 5 minutes during the Default (running) operating state. Data sets are 3 seconds in length including 1 second of pre-trigger data. These settings are configured on the Operating States tab of the Asset Configuration page in InsightCM™.

What does it mean when a motor asset shows an Off state?

The Off state is entered automatically when the motor's Percent Full Load Amps falls below 25% FLA, indicating the motor is not running or is running at very low load. The system continues to collect data sets once per hour and trend values every 5 minutes during the Off state, but full fault feature calculations are not performed. The system automatically exits the Off state when Percent Full Load Amps rises back above 25% FLA.

What happens to ESA data collection during a motor startup event?

When Percent Full Load Amps rises above 200% FLA, the system automatically enters the Startup operating state and collects a single 30-second data set (including 1 second of pre-trigger data) to capture the full startup transient. The system exits the Startup state when Percent Full Load Amps drops below 110% FLA for 5 seconds, or after 30 seconds have elapsed.

Can the ESA system monitor a motor that runs intermittently or at variable load?

Yes. The ESA system performs exceptionally well at monitoring intermittently operated motors, provided the operating states are configured appropriately. Data collection and fault feature calculation are gated by motor load (Percent Full Load Amps), so tuning the operating-state thresholds to the motor's duty cycle ensures that each startup transient, steady operating period, and shutdown are correctly captured. Capturing the shutdown event in particular provides valuable data for postmortem analysis of any trip events.

What is the minimum load a motor must be running at before the ESA system will calculate fault features?

By default, the device requires a motor current RMS value of at least 25% of Full Load Amps (FLA) to calculate most fault features. Below this threshold, the device calculates only the Percent Full Load Amps feature; other features return zero, and the Rotor Bar Sideband feature returns -100 dB. The minimum working current threshold is configurable on the Device Properties tab in InsightCM™.

What does the Rotor Bar Sideband feature measure, and what value should prompt concern?

The Rotor Bar Sideband feature reports the maximum magnitude, in decibels, of the rotor bar sideband harmonics referenced to the magnitude of the fundamental component in the spectrum. The value is negative; a less-negative (higher) value indicates sidebands that have grown closer in magnitude to the fundamental, which is worse. Starting alarm thresholds: above -45 dB is a low-level concern, above -40 dB is moderate, above -35 dB is high. The trend matters more than any single reading — a steadily rising value over successive acquisitions is the clearest sign of advancing cage damage. Always confirm the motor is running under sufficient load when interpreting the value.

How do I use ESA data to determine whether a high vibration reading is electrical or mechanical in origin?

Electrical faults tend to produce line-frequency-related content: elevated peaks at line-frequency harmonics (120, 180, 360 Hz, etc.) in the ESA Spectrum, current or voltage unbalance on the Phasor Diagram and Park Clarke views, or rotor bar sidebands spaced at twice the slip frequency. Mechanical faults instead appear at rotational and defect frequencies: peaks at running speed and its harmonics or at bearing-defect frequencies (BPFO, BPFI, BSF, FTF) in the ESA Envelope Spectrum, and torque pulsations synchronized to running speed in the Torque Waveform. If current unbalance matches a corresponding voltage unbalance, the cause is likely supply-side electrical; if current is unbalanced while voltage is balanced, the motor itself is the suspect.

What is a normal power factor range, and what does a declining power factor trend indicate?

For a typical AC induction motor running near full load, power factor generally falls in the range of approximately 0.75 to 0.90 lagging, with larger and higher-speed motors tending toward the upper end. Power factor is strongly load-dependent — it is highest near rated load and drops significantly as the motor is unloaded. A power factor that declines while load stays constant warrants attention; it can indicate developing winding problems, increasing unbalance, or a supply/power-quality issue, and it often coincides with a rise in current unbalance or line-frequency harmonic content.

What is the difference between a trend alarm and a spectral alarm for ESA assets?

A trend alarm monitors the scalar feature values calculated by the ESA system over time (such as Rotor Bar Sideband magnitude, Power Factor, or RMS current) and triggers when those values cross user-defined thresholds. A spectral alarm monitors energy level across the frequency range of a spectrum, allowing alarm envelopes to be set for specific frequency bands. Use trend alarms for monitoring calculated health indicators with clear threshold values, and spectral alarms for detecting changes at specific fault frequencies that may not yet be captured by a calculated feature.

Can I configure the ESA system to send email notifications when a fault alarm triggers?

Yes. InsightCM™ supports email alarm notifications. Navigate to the alarm rule for the relevant motor asset, enable email notifications, and specify the recipient addresses and notification conditions. Ensure the InsightCM™ server is configured with valid outgoing email settings. Refer to the InsightCM™ User Manual for detailed steps.

How do I export ESA trend data or waveform data from InsightCM™?

Navigate to the relevant asset in the Data Viewer, select the data range to export, and use the export option to save data to a CSV file. For system logs and event data, refer to the InsightCM™ User Manual for detailed export procedures.

How long does InsightCM™ retain ESA historical data, and how can I configure data aging?

InsightCM™ uses configurable aging strategies to manage data retention. The retention period depends on your aging strategy configuration and available server storage. Navigate to the Server Configuration section of InsightCM™ and review the Aging Strategies settings. Data you want to preserve permanently can be protected from aging. Refer to the InsightCM™ User Manual on aging strategies for full details. Cutsforth recommends using solid state drives to maximize disk throughput and storage performance.

10. Glossary

AWG	American Wire Gauge
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.
CBM	Condition based maintenance
cRIO	NI Compact Reconfigurable I/O Controller.
current transformer (CT)	A device used to measure alternating current (AC).
DC	Direct Current
DCS	Distributed Control System
ESA	Electrical Signature Analysis (ESA) is a permanently installed, non-intrusive, online monitoring system that uses three-phase voltage and current signals to detect potential faults and anomalies.
Fast Fourier Transform (FFT)	A method for converting a signal into its frequency components, allowing for a better analysis of that signal.
FLA	Full Load Amps — the motor current at rated load, as specified on the nameplate.
FTF	Fundamental Train Frequency — a bearing defect frequency calculated from bearing geometry and running speed.
InsightCM™	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
LOTO	Lockout/Tagout

MCC	Motor Control Center
NEMA	National Electrical Manufacturers Association
Park Clarke	A signal processing technique that transforms three-phase current signals onto two orthogonal axes (d–q), used in the ESA system to visualize current balance and detect stator faults.
PdM	Predictive maintenance
potential transformer (PT)	A type of instrument transformer used in power systems to reduce high voltages to safer, lower levels for measurement and protection purposes.
RMS	Root Mean Square. A method of measuring the voltage or current of an AC waveform calculated by *Xrms* = sqrt[(1/*n*) * (SUM(*Xn*))], where *X* is the array of samples acquired and *n* is the number of samples acquired.
slip frequency	The difference between the synchronous speed and the actual rotor speed of an induction motor, expressed as a fraction of synchronous speed.
waveform	A variable that changes with time, usually representing a voltage or current. Waveforms are graphed with time on the horizontal axis.