

Operations Manual EZDP-2089 Rev E Generator Field Monitoring



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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.

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. The Cutsforth Generator Field Monitoring System

Cutsforth's Generator Field Monitoring System is a multifunctional monitoring system where Shaft Ground Monitoring and Rotor Flux Monitoring work together in real time, providing waveform resolution up to 1 million samples per second. The system measures grounding current and shaft voltage at the drive end bearing of the generator and exciter voltage at the output end of the generator shaft as well as the rotor flux density signal waveform collected from the generator's hall effect sensor, when one exists. The system features manual test points within the monitoring enclosure that allow for the measurement of any signal acquired by the system with hand-held equipment. This data is then ported directly into Cutsforth's InsightCM™ online asset monitoring software for viewing and alarm setting in the control room or any authorized remote location.

1.1. Key Specifications

Voltage:

- ± 100 V DC
- 0-70.7 V RMS
- 0-100 V 0-Pk

Current:

- ± 30 A DC
- 0 -21.21 A RMS
- 0 -30 A 0-Pk

Isolation: 1500 V

Accuracy: ± 1 V and 5% of current in specified range

Operating Temperature: -40°C to 70°C (-40°F to 158°F)

Signal Acquisition Rates:

- Shaft voltage and ground current are measured at 1 million samples per second at 14-bit resolution with the current sensor having a 500 kHz bandwidth sensor.

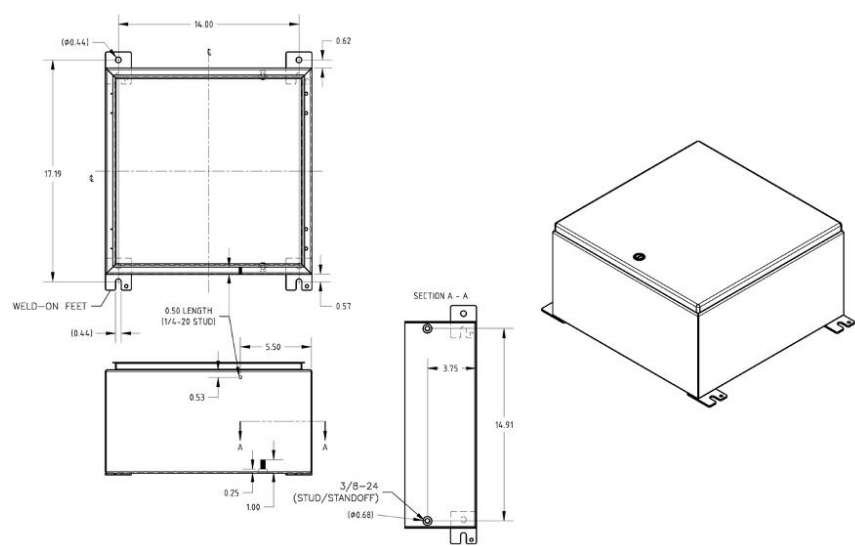
1.2. Proper Generator Field Monitoring System Installation Required

All descriptions in this manual assume that the Generator Field Monitoring System is connected via signal wires to Cutsforth's proprietary shaft grounding and voltage sensing hardware, with rope wear indicators installed on the generator shaft.

1.3. Technical Specifications

1.3.1. Monitoring System Enclosure

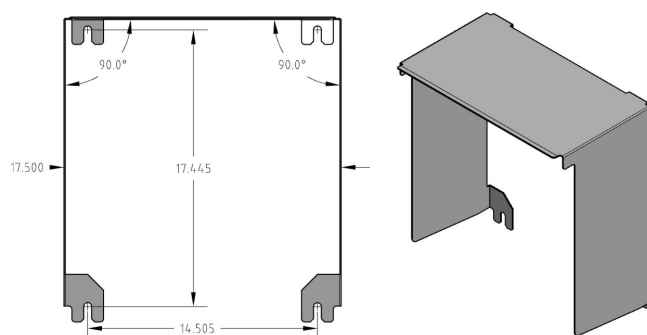
Catalog Number	Dimensions (in. (mm))	Stainless Steel Type
CSD16168SS6-MODS	16.0 (406) x 16.0 (406) x 8.0 (203)	316



Specifications:

- | | |
|---|---|
| <ul style="list-style-type: none"> UL 508A Listed; Type 3R, 4, 4X, 12; File No. E61997 cUL Listed per CSA C22.2 No 94; Type 3R, 4, 4X, 12; File No. E61997 NEMA/EEMAC Type 3R, 4, 4X, 12, 13 CSA File No. 42186: Type 4, 4X, 12 | <ul style="list-style-type: none"> VDE IP66 IEC 60529, IP66 Meets NEMA Type 3RX requirements |
|---|---|

EXMC-002: Optional sunshield for outdoor installations



1.3.2. AC Power Supply Requirements

Plant-supplied Power Source	120 V, 60 Hz AC or 240 V, 50 Hz AC
Circuit Breaker	Internal 120 V, 5 A
Circuit Draw Under Normal Usage	Approximately 0.6 A

1.3.3. Digitizers

NI-9215

Range	± 10 V
Sample Rate	100 kS/s
Resolution	16-bit
Manufacturer's Datasheet	http://www.ni.com/pdf/manuals/373779a_02.pdf

Safety Standard

This product is designed to meet the requirements of the following standards of safety for electrical equipment for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1

1.3.4. Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

EN 61326 (IEC 61326)	Class A emissions; Basic immunity
EN 55011 (CISPR 11)	Group 1, Class A emissions
AS/NZS CISPR 11	Group 1, Class A emissions
FCC 47 CFR Part 15B	Class A emissions
ICES-001	Class A emissions
CE Compliance	Meets the essential requirements of applicable European Directives, as amended for CE marking, as follows: 2006/95/EC, Low-Voltage Directive (safety); 2004/108/EC, Electromagnetic Compatibility Directive (EMC)

1.3.5. Environmental

Storage Temperature	-40 °C to 85 °C (-40 °F to 185 °F)
Operating Temperature	-40 °C to 70 °C (-40 °F to 158 °F)
Storage Humidity	5% RH to 95% RH, noncondensing
Operating Humidity	10% RH to 90% RH, noncondensing
Maximum Altitude	5,000 m (16,400 ft)

2. Installation

This section describes the installation of the Generator Field Monitoring System. Before beginning the installation, thoroughly review the Generator Field Monitoring System Installation Planning Guide (EZDP-2090).

2.1. Inside the Box

	Generator Field Monitoring System (GFM)
	Shaft Grounding Assembly (SGA) plus installation hardware
	*Shaft Contact Assembly (SCA) plus installation hardware
	Signal cable (J1) – SGA to Generator Field Monitoring System
	Signal cable (J2) – SGA to Generator Field Monitoring System
	*Signal cable (J3) – SCA to Generator Field Monitoring System
	Shaft Grounding/Contact Ropes
	Additional items as indicated on order

*If SCA was ordered

2.2. Installation Overview

1. [Mount the Generator Field Monitoring System enclosure. \(page 14\)](#)
2. [Mount the Power Supply Enclosure. \(page 16\)](#)
3. [Connect the signal cables from the Shaft Grounding hardware \(and Shaft Contact hardware, if installed\) to the Generator Field Monitoring System. \(page 17\)](#)
4. [Run power cabling from the Power Supply Enclosure to the Generator Field Monitoring System. \(page 19\)](#)

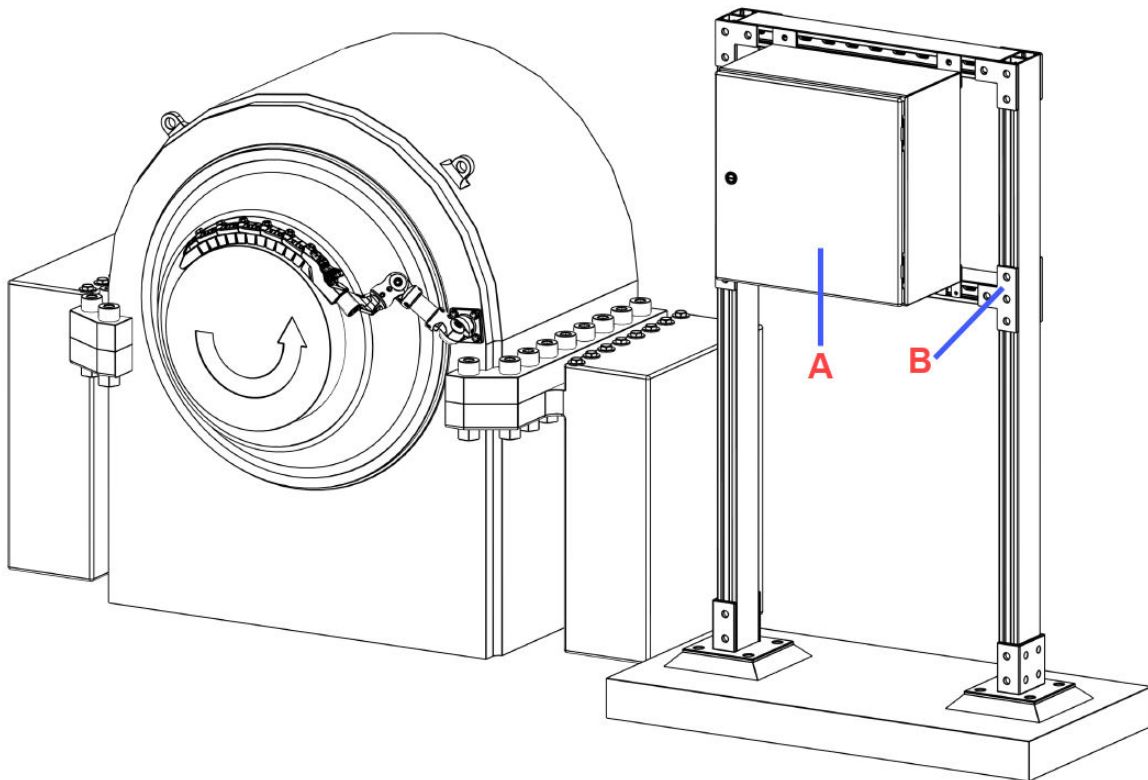
5. [Run plant power to the Power Supply Enclosure. \(page 20\)](#)
6. [Connect the data output from the Generator Field Monitoring System to the plant server. \(page 20\)](#)

2.3. Placement and Mounting of the Generator Field Monitoring System Enclosure

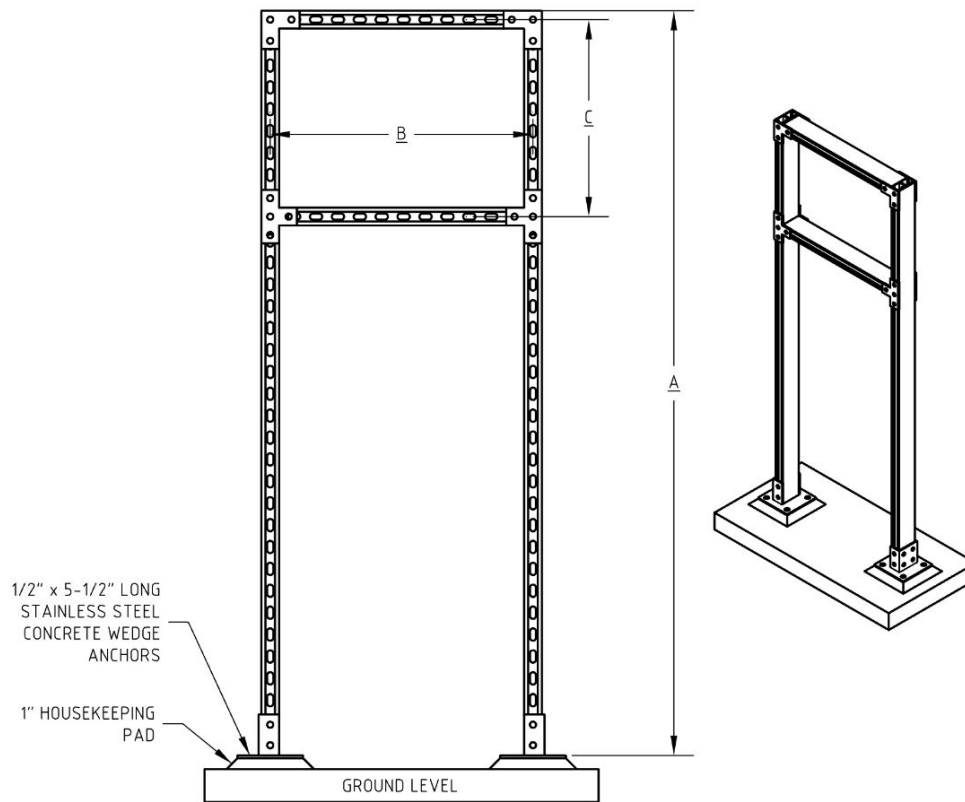
This section covers the placement and mounting requirements for the Generator Field Monitoring System enclosure.

The Generator Field Monitoring System **(A)** is designed to be mounted using a strut channel rack **(B)**. The enclosure should be mounted at the drive end of the generator and as close to the Shaft Grounding Assembly as possible to minimize the run length of the signal cables, while:

- Maintaining operator safety
- Meeting the requirements outlined in the Installation Planning Guide (EZDP-2090), to minimize the run length of the signal cables



2.3.1. Recommended Strut Rack Design

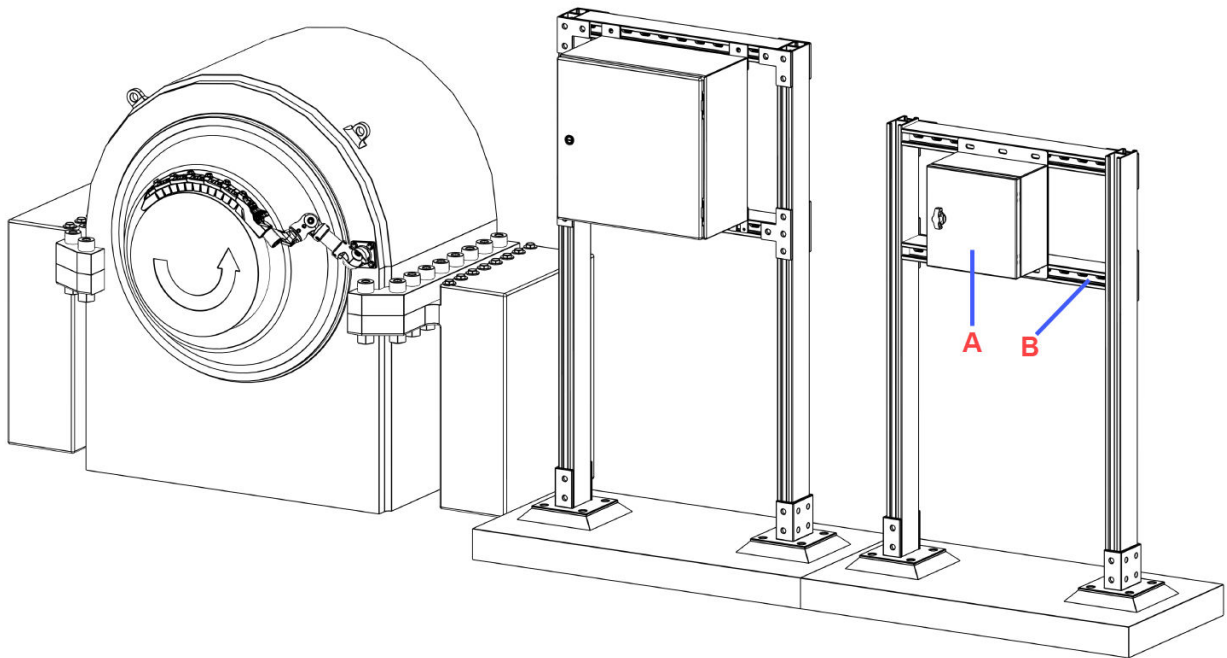


A (in (cm))	B (in (cm))	C (in (cm))
68 (173)	24 (61)	Refer to enclosure mounting feet dimensions

2.4. Placement and Mounting of the Power Supply Enclosure

This section covers the placement and mounting requirements for the Power Supply Enclosure.

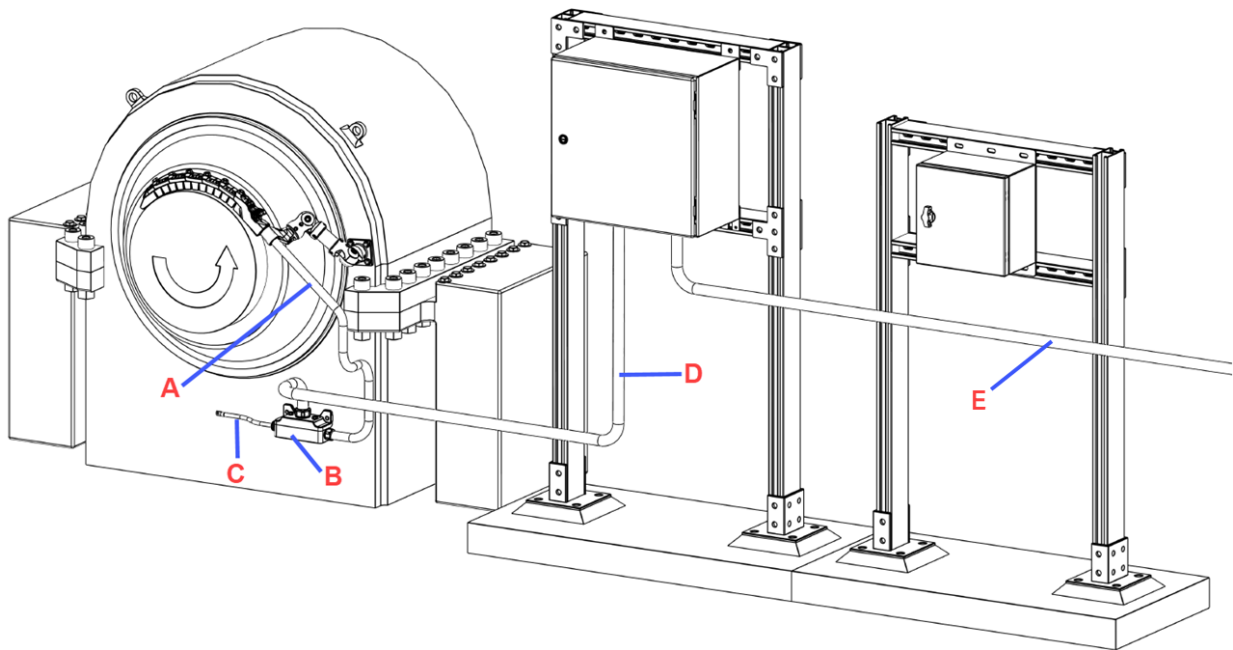
The Power Supply Enclosure (A) is designed to be mounted using a strut channel rack (B). If desired, the Power Supply Enclosure can be mounted to the same strut channel rack as the Generator Field Monitoring System. Cabling traveling between the monitoring system enclosure and the Power Supply Enclosure must not exceed 25 feet in length.



2.5. Routing the Signal Cables from the Shaft Assemblies

This section covers the requirements relating to the routing and termination of the Shaft Grounding Assembly (SGA) and Shaft Contact Assembly (SCA) signal cables.

1. Connect the supplied Ethernet signal cables **(D)** to the SGA Junction Box **(B)** attached to the SGA cable whip **(A)**.
2. [Only if Shaft Contact Assembly is installed] Connect the supplied Ethernet signal cable **(E)** to the SCA Junction Box (not shown) in the same manner as the SGA.
3. Connect the other end of the Ethernet signal cables **(D)** to the Generator Field Monitoring System according to the associated wiring diagram(s).
4. Drill and tap a 5/16"-18 hole in the unit case near the Shaft Grounding Assembly junction box **(B)** for the ground wire connection. Route the 8 AWG ground wire **(C)** from the junction box **(B)** to unit case ground. Verify that the ground wire termination point will maintain proper electrical connection; remove any paint, rust, or other, contaminants from the location of the 5/16"-18 hole.



2.6. Routing the Signal Cable from the Rotor Flux Probe

The location of the rotor flux probe may vary from generator to generator. Cutsforth will rely on the plant to locate the rotor flux probe and/or its signal pick-up point. It is recommended that the total length of the rotor flux signal cables (A), from the rotor flux probe to the Generator Field Monitoring System, be kept at or below 100 ft.

2.7. Routing the Power Cable from the Power Supply Enclosure to the Generator Field Monitoring System

This section covers the requirements relating to the routing and termination of the DC power cabling from the Power Supply Enclosure to the Generator Field Monitoring System.

The Power Supply Enclosure has an internal enclosed AC/DC converter which has an output of 24V, 5A DC (120W). The output of this power supply should be wired to the input of the Generator Field Monitoring System using the Cutsforth-supplied 16 AWG, shielded, twisted-pair cable (A). The cabling should be run to the monitoring system enclosure in liquid-tight conduit.

2.8. Running Plant Power and Data Connections

This section covers the power requirements for the Power Supply Enclosure and the data connections for the Generator Field Monitoring System.

The Power Supply Enclosure has an internal enclosed AC/DC converter which requires a power input of 85-264 V and 5 A AC at 50 or 60 Hz. The power input cabling **(A)** should be run to the Power Supply Enclosure in liquid-tight conduit.

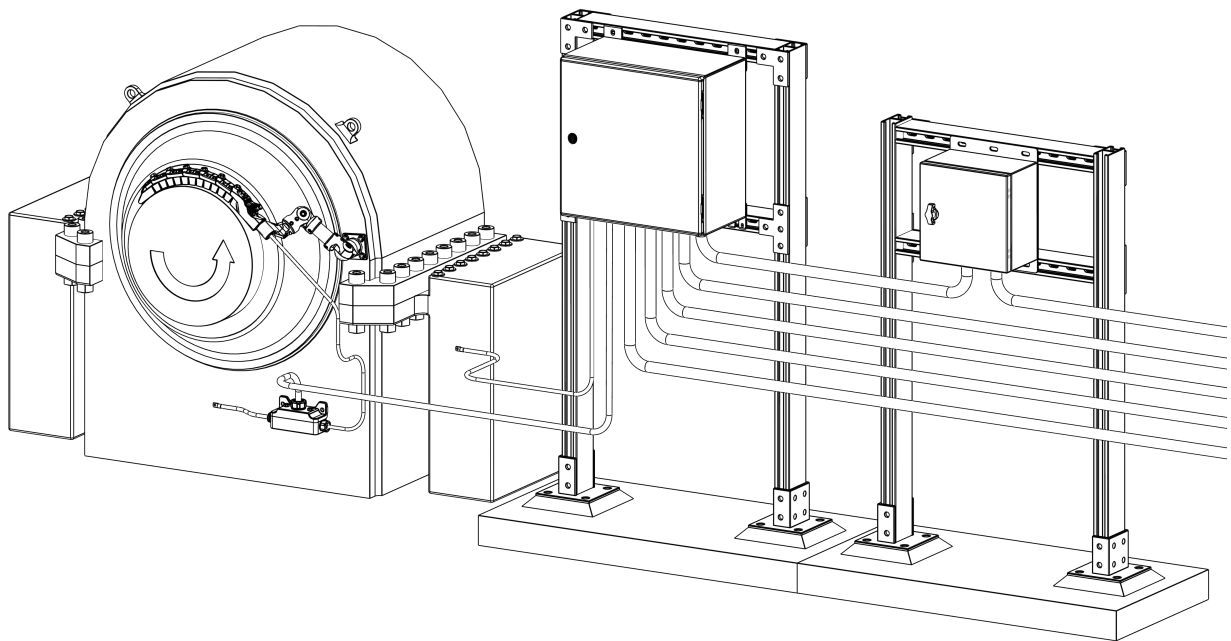
Cutsforth recommends a CAT6a cable for the data output from the Generator Field Monitoring System to the control room **(B)**. The data output cabling should be run to the control room in liquid-tight conduit.

Where flexible conduit is used, Cutsforth recommends the use of type HCX high-temp flexible metallic conduit (LFMC).

2.9. Terminate Enclosure Case Ground Wire

This section covers the requirements related to the termination of the enclosure case ground wire.

The Generator Field Monitoring System is supplied with a length of 12 AWG ground wire (A). This wire should be used to bond the GFM enclosure case to the unit case ground, ideally the same structure to which the main 8 AWG ground wire is terminated, if possible.



3. Shaft Ground Monitoring (SGM) Setup

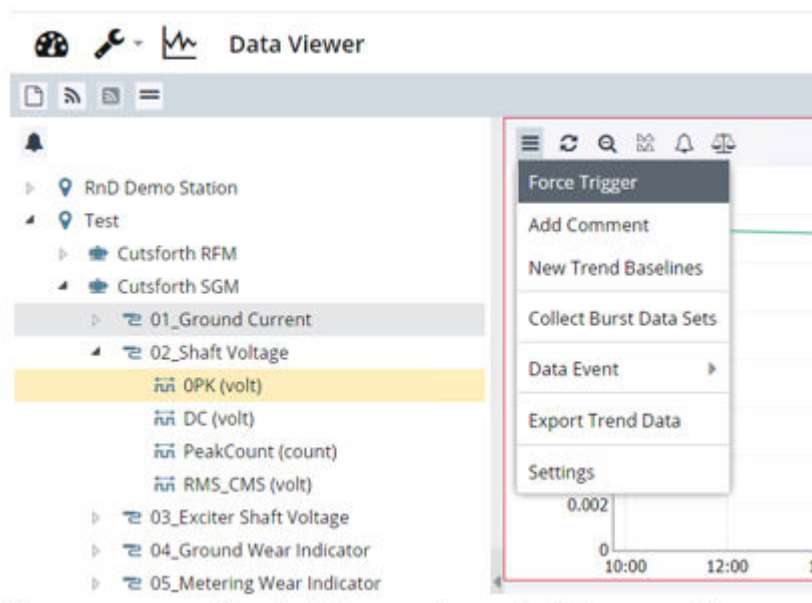
Refer to the InsightCM Setup and Configuration manual on the Cutsforth Support webpage at <https://support.cutsforth.com> for instructions regarding how to configure devices, assets, alarms and operating states in the monitoring server system. Add the device using the template provided for your device to assure initial sensor configurations and alarm levels are at their recommended starting values. Once the device is initially configured use the following guidelines to set Shaft Grounding specific parameters.

3.1. Collect SGM Baseline Waveforms

Monitoring for grounding conditions and alarms can only be operational when the generator is online or false faults will be registered. To do this, you must collect baseline waveforms according to these instructions to be able to accurately determine how to set the generator ON operating state.

Using the Force Trigger action on the InsightCM Data Viewer page, collect the following four baseline waveform sets:

- Force Trigger just prior to the generator spinning up on turning gear
- Force Trigger during spin up just prior to the generator coming online
- Force Trigger just after the generator comes online and is at lowest load
- Force Trigger when the generator is at normal operating load



Note: Annotate and save these waveforms so they are never deleted.

From the Data Viewer screen:

1. Click the action menu button (icon with three horizontal lines).
2. Click **Add Comment**.
3. After you have added your comment, click the action menu button again, expand the Data Event list, and select **Retain Data Event**.



3.2. Define an ON Operating State

An operating state within InsightCM™ is a parameter that allows you to define alarms and data collection frequency when in that specific operating state.

The first step is to remove the instructions in the default operating state to collect any waveforms while in the default state. In order to do this, click the Delete icon in the Data Set Collection Conditions and Trend Collection Conditions.

3.3. Create an ON Operating State

There will be a noticeable step up in the ground current 0-PK and shaft voltage 0-PK levels between the SGM baseline waveforms previously collected.

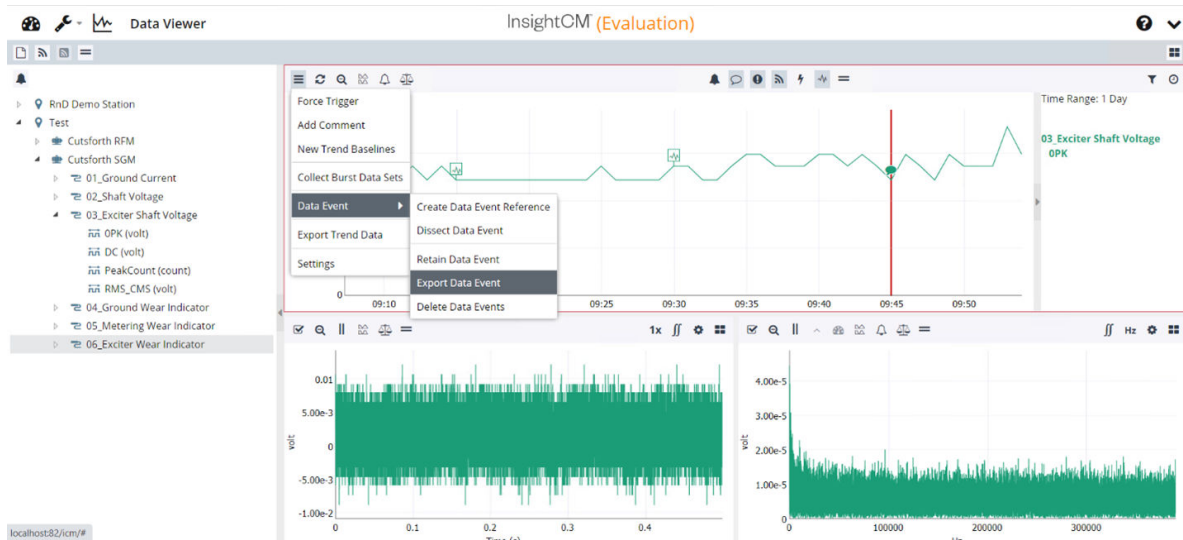
1. Enter the rules needed to enter the ON operating state so that when both current and voltage 0-PK values have stepped high enough to indicate that the generator is online and stayed at that level for at least 60 seconds.
2. Set the rules so that the system will exit the ON operating state (and return to default) when both of these values have dropped below the level where the generator is online.

The screenshot shows the 'Asset Configuration' window for 'InsightOM (Evaluation)'. The 'Operating States' tab is active, and the 'On' state is selected. The 'Enter Conditions' section contains two conditions: C1 (01_Ground Current > 0PK greater than 3 for 60 seconds) and C2 (02_Shaft Voltage > 0PK greater than 3 for 60 seconds). The 'Exit Conditions' section contains the same two conditions: C1 (01_Ground Current > 0PK less than 3 for 60 seconds) and C2 (02_Shaft Voltage > 0PK less than 3 for 60 seconds). The 'Data Set Collection Settings' section shows 'File Length (s): 4' and 'Pre-Trigger Length (s): 1'.

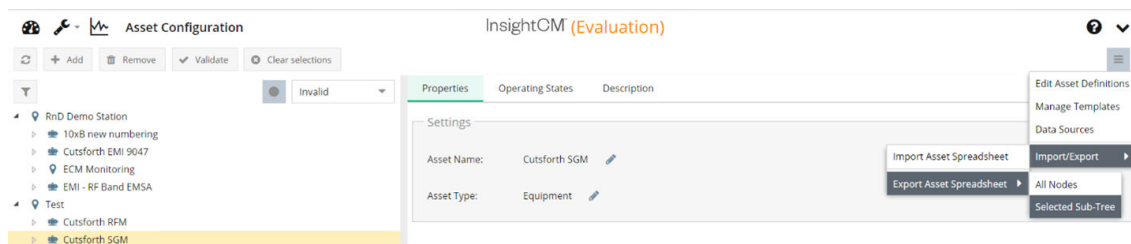
3. Initial recommendations are to set the ON state waveform Data Set Collection Conditions to occur once every 4 hours and the Trend Collection Conditions data to update once every 15 minutes.

The screenshot shows the 'Asset Configuration' window for 'InsightOM (Evaluation)'. The 'Operating States' tab is active, and the 'On' state is selected. The 'Data Set Collection Settings' section shows 'File Length (s): 4' and 'Pre-Trigger Length (s): 1'. The 'Enter / Exit Settings' section has checkboxes for 'Collect on Enter' and 'Collect on Exit'. The 'Data Set Collection Conditions' section shows 'Time: Every 4 hours' with buttons for 'Gate', 'Delta EU', and 'Advanced'. The 'Trend Collection Conditions' section shows 'Time: Every 15 minutes' with buttons for 'Gate', 'Delta EU', and 'Advanced'.

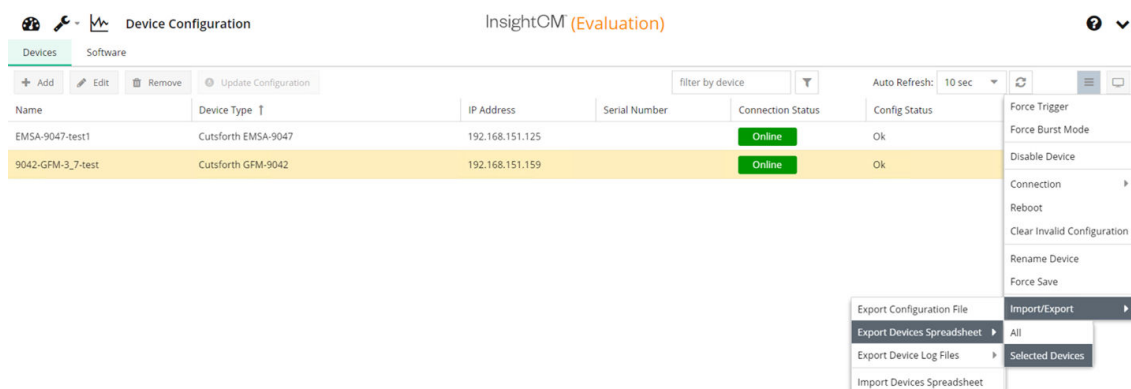
4. The system will come with a default set of alarm levels set, which may need adjusting. Once the generator is operational, select the four baseline trend points collected above from the trend line and select **Data Event > Export Data Event** to export and save the TDMS file for each dataset.



5. Export the Asset and Device configuration spreadsheets:
 - a. From the Asset Configuration screen, press the action menu button (icon with three horizontal lines) in the upper-right, and select **Import/Export > Export Asset Spreadsheet > Selected Sub-Tree**.



- b. From the Device Configuration screen, press the action menu button in the upper-right, and select **Import/Export > Export Devices Spreadsheet > Selected Devices**.



- c. Send the information collected above to support@cutsforth.com to request review and advice regarding status and alarm settings and any attention to waveforms that may be recommended.

The screenshot shows the 'Trend Alarm Rule' configuration window. Red arrows point to the following fields:

- RMS_CMS** (Variable)
- Greater than** (Comparison Operator)
- Operating State: On** (Dropdown)
- Severity ↑** (Dropdown, currently set to High (3))
- Compare To** (Value, currently set to 10)
- Actions** (Dropdown, currently set to Email)

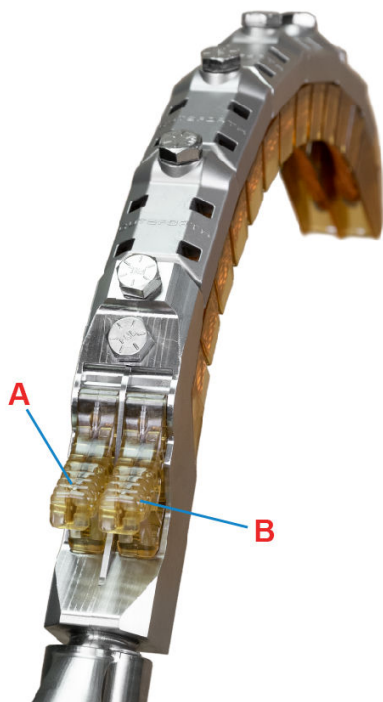
Other visible fields and controls include:

- ☐ Auto-configure levels from baseline
- Levels** section with **Add**, **Edit**, and **Remove** buttons.
- Set Baseline** button and date range **2021-02-23 to 2021-03-02**.
- ☐ Show baseline
- On Delay (s):** 0, **Off Delay (s):** 0, **Hysteresis:** 0
- ☒ Use default collection length, **File Length (s):** 12, **Pre-Trigger Length (s):** 10
- OK**, **Cancel**, and **Help** buttons at the bottom.

4. Shaft Ground Monitoring (SGM) Troubleshooting

4.1. About the Shaft Grounding Assembly (SGA)

The SGA contains two ropes. Both ropes provide grounding and are named as indicated in the figure below. The grounding rope **(A)** acts as the primary direct connection between the generator shaft and the unit case, and the metering rope **(B)** connects the shaft to the unit case through a small resistor to facilitate measuring shaft voltage in addition to providing a secondary connection to ground. The metering rope **(B)** also provides temporary primary grounding when the grounding rope **(A)** is being replaced or is not connected to the shaft for any reason.



4.2. Monitoring Test Points



ELECTRICAL DANGER

Only qualified electrical personnel should take measurements at the remote test points. For any of the test points on the faceplate, use a hand-held voltmeter, oscilloscope, clamp-on ammeter, or other appropriate testing device. Always follow proper electrical safety procedures.

The test points in the monitoring system connect directly to the following sensor locations:

- "Shaft Voltage" is connected directly to the SGA's meter rope on the shaft.
- "Exciter Shaft Voltage" is connected directly to the SCA's meter rope on the shaft (if SCA is installed).
- "Signal Ground" is connected to the unit case grounding location and is the ground reference for both the shaft voltage and Wear Indicator test points.
- Each Wear Indicator test point is connected to a resistance-based wear indicator circuit. A 5V DC reading at the test point indicates a rope in good condition, whereas a voltage close to 0V DC indicates a worn rope in need of replacement.
- Ground Current + and - are connected to the output of the ground current sensor on the grounding wire.



Monitoring must be powered on for ground current and wear indicator statuses to be measurable at the test points. All shaft voltage readings are direct connections and can be taken regardless of whether the monitoring system is powered on or off.

4.2.1. Ground Current Test Points

Please note, the ground current test points are connected to the output of the current sensor located at the grounding location so the monitoring system must be powered on to take measurements at the ground current test points.

To measure current flowing to ground from the shaft, place the positive and negative probes of a scope or hand-held meter on the "Current +" and "Current -" test points, respectively. Refer to the following table to convert the resulting voltage reading to the associated ground current value.

4.2.2. Shaft Voltage Test Points

To read the shaft voltage, place the positive probe of the hand-held device on the Shaft Voltage or Exciter Shaft Voltage test point, and place the negative probe on the Signal Ground test point. The resulting voltage or waveform read at this point represents the shaft voltage at the associated metering rope location. The Shaft Voltage test points do not require power, so valid measurements can be taken even if the monitoring system is powered off.

4.2.3. Wear Indicator Test Points

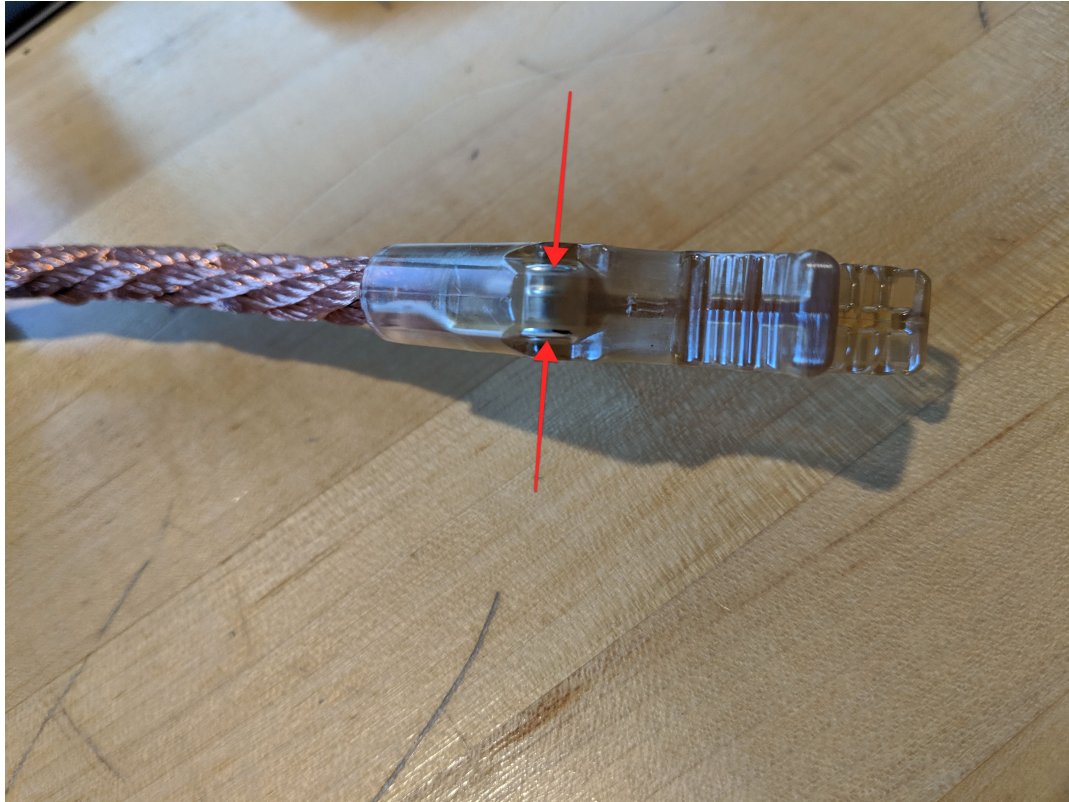
The wear indicator test points are connected to a powered, resistance-based wear indicator circuit, so the monitoring system must be powered on to take measurements at the wear indicator test points.

To take measurements at the wear indicator test points, place the positive probe of a scope or hand-held meter on the desired rope wear indicator test point, and place the negative probe on the "Signal Ground" test point. Refer to the following table for interpretation of measurements:

Meter Reading (V DC)	Rope Status
5 ± 1	Pass (Rope OK)
0 ± 1	Fail (Replace Rope)

4.2.3.1. Rope Fault Troubleshooting Recommendations

Using a voltmeter set to measure resistance, measure between the wear indicator contact and the outer rope contact on the underside of the rope grip to confirm whether or not the rope needs replacement. See the image below:



- If 500 Ohms or greater resistance is measured, the rope does not require replacement.
- If less than 500 Ohms is measured, the rope requires replacement, even if it may not look like it.

If the above recommendation does not resolve the issue, contact Cutsforth Support.

4.3. Advanced Troubleshooting

4.3.1. Possible Grounding Fault Indicators

Every generator has its own distinct set of normal operating conditions. Normal conditions on one generator may be alarming on another, even if the two units are of the same type. Plant personnel responsible for monitoring the systems should be familiar with normal average and peak levels for each unit.

A change in a unit's waveform output can be a powerful indicator that something requires attention within the generator or the grounding system.

The conditions listed in this topic may be fault indications. This is not a comprehensive list, but rather it is intended to draw attention to scenarios that can warrant further investigation.

- [Grounding Current Steps Down and Shaft Voltage Steps Up \(page 30\)](#)
- [Average and/or Zero-to-Peak Grounding Current Steps Down \(page 30\)](#)
- [Average or Zero-to-Peak Shaft Voltages or Grounding Currents Step Up \(page 31\)](#)
- [Average and-or Zero-to-Peak Shaft Voltages or Currents Trending Up or Down Over Time \(page 31\)](#)
- [Questionable Readings \(page 31\)](#)

4.3.2. Grounding Current Steps Down and Shaft Voltage Steps Up

If a significant step down in grounding current takes place in conjunction with an increase in shaft voltage **this could indicate a potential loss of grounding and should be investigated immediately**. Inspect the grounding assembly, grounding rope, and shaft surface for potential deterioration of the grounding rope-to-shaft connection.

4.3.3. Average and/or Zero-to-Peak Grounding Current and Shaft Voltage both Step Down

If you notice an unusual step down in grounding current and shaft voltage occurs, it may be a significant event:

- Has something else contacted the shaft, or has a bearing lost insulation allowing alternate paths to ground?
- Is the rope-to-shaft contact of good integrity to allow current to flow freely when voltage is present?

When grounding current and voltage are markedly lower than what is normally seen on the generator and no correlating operating condition exists to explain it, the grounding hardware should be evaluated to ensure that the generator shaft is grounded.

Baseline measurements are crucial for identifying events of concern. Baseline readings should be known for generator online status, turning gear status, offline status, and at differing load levels for comparisons when questions arise.

4.3.4. Average and/or Zero-to-Peak Shaft Voltages or Grounding Currents Step Up

Typically, shaft voltages and grounding currents on the generator increase or decrease in amplitude along with generator output levels and other operating conditions. Soon after installing, you should capture what normal readings are for your generator at different loads. Knowing the difference between your generator's grounding system's readings at lowest and highest generator outputs helps you to fine tune your monitoring system's thresholds so that you are not triggering snapshots and alarms at levels that are potentially just normal periods of greater demand.

"If shaft cleaning does not resolve the higher levels while taking the above into consideration, share the waveforms you are seeing with Cutsforth so we can compare against our library of waveforms which may indicate other possible problems occurring in the generator that are being detected by the grounding monitoring waveforms.

4.3.5. Average and/or Zero-to-Peak Shaft Voltages or Currents Trending Up or Down Over Time

Trending values on the generator can be a powerful diagnostic tool. If your challenge is poor rope-to-shaft contact tracking, the trend will help to know if steps at remediation are effective or not before alarming takes place. If your waveforms are showing, for example, that there are shorts in the stator winding insulation, trending the amplitude and frequency of the problem signature over time and at various unit loads can help give insight as to whether the condition is getting worse and at what load does the condition first appear now vs. time past when the condition was first identified.

4.3.6. Questionable Readings

If you have questions concerning the integrity of shaft voltage or current measurements:

1. Clean the shaft surface, and inspect the shaft grounding hardware.
2. Collect another set of waveforms to compare.

If you have concerns:

- Record a snapshot or set threshold levels so they capture the events in question in a waveform view.
- Record the date and time along with generator load and vibration trends along with known generator problems that exist.

Cutsforth can then help you connect with professionals experienced in shaft diagnostic and root cause analysis.

5. Rotor Flux Monitoring System Setup



Any unit with more than 2 poles requires a keyphasor input into the GFM system.

Keyphasor input signals must have one pulse per shaft rotation.

5.1. Rotor Flux Monitoring Overview

The data and waveforms collected by the Cutsforth Generator Field Monitoring System can be used to determine the level of deterioration in the insulation of the rotor windings that result in shorted winding turns.

Damage to the winding insulation leads to:

- Increased demand on excitation systems
- Imbalances in the rotor field
- Increased vibration
- Degradation of flux field integrity
- Reduced generator capacity
- Increased risk of rotor ground fault
- Potential unexpected generator failure or forced outage

Advance knowledge of insulation failure and real-time feedback of the extent of the damage helps the plant determine the best course of action for potential continued operations and planned vs. unplanned maintenance activities.

The Cutsforth Generator Field Monitoring System acquires signals from the generator's existing rotor flux sensor at over 50kHz. The rotor flux waveform is then analyzed to determine the following:

- The beginning and end of each rotation cycle
- Which coil is closest to flux density zero cross
- The flux density peak amplitude value of each coil
- The percent deviation between the leading and lagging peak amplitude value of each coil

5.1.1. Rotor Flux Technical Overview

This section offers a brief technical overview of the rotor flux capabilities of the Cutsforth Generator Field Monitoring System:

- Rotor flux signals processed in real time.

- Peak voltage amplitude of each coil is identified as waveforms are processed.
- Monitoring system plots the Flux Density Curve (FDC) and identifies the Flux Density Zero Crossing (FDZC). (The FDZC is the point at which the integral of the flux waveform is zero volts, which affords the greatest sensitivity to detecting a shorted turn in a coil.)
- Deviation in voltage between poles is calculated in real time.
- Deviation in voltage between poles is calculated for coil nearest the FDZC and reports the numbers of shorted turns on that coil.
- A high-speed waveform and full feature set is captured each time the FDZC aligns with a different coil.
- Total flux in Volts RMS is calculated and displayed.
- Offers multi-feature alarming. (For example, total flux and number of shorted turns on FDZC coil.)

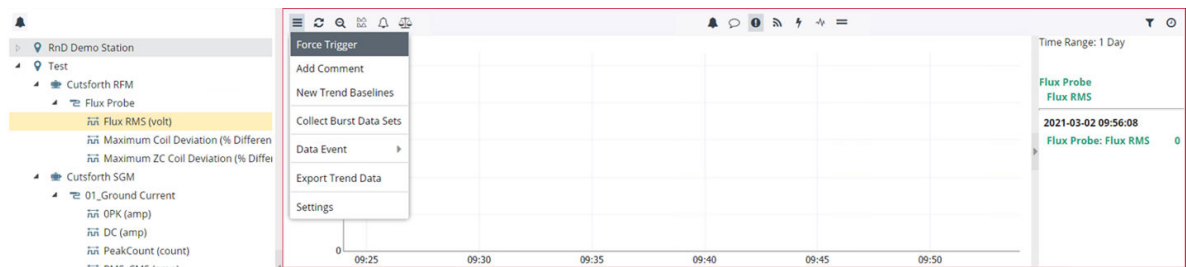
5.2. Rotor Flux Monitoring in InsightCM™

This section covers the viewing of rotor flux data in InsightCM™. For assistance with getting your Generator Field Monitoring System connected to and communicating with InsightCM™, refer to the InsightCM™ Setup and Configuration manual on the Cutsforth Support webpage at <https://support.cutsforth.com>, or contact Cutsforth Support if further assistance is needed.

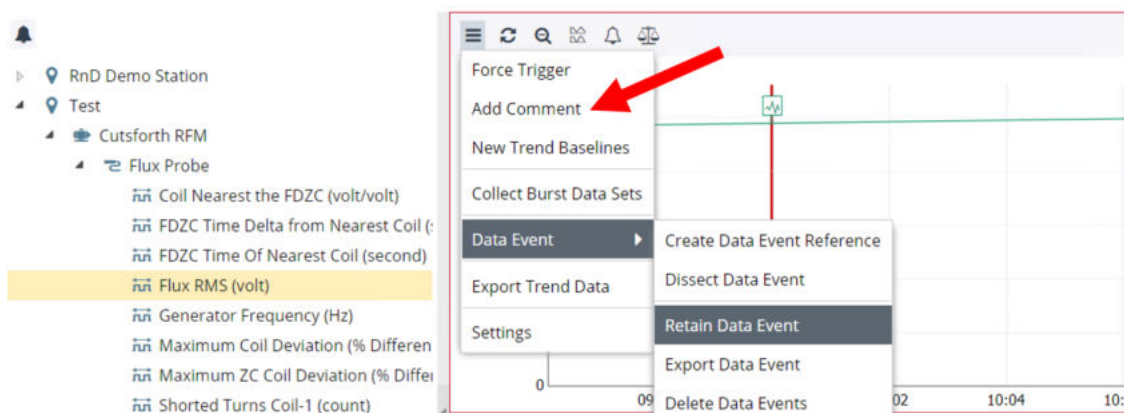
5.2.1. Collect RFM Baseline Waveforms

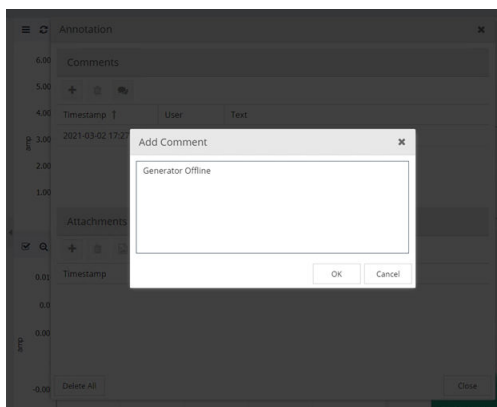
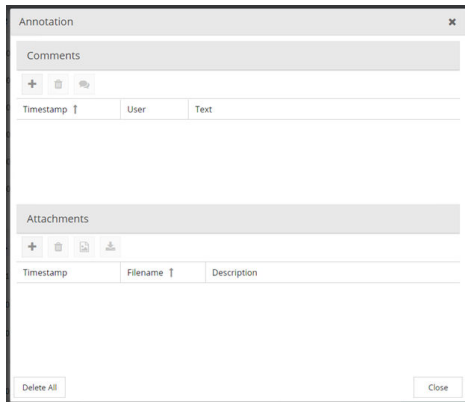
Monitoring for RFM conditions and alarms can only be operational when the generator is online or false faults will be registered. To do this, you must collect baseline waveforms according to these instructions to be able to accurately determine how to set the generator ON operating state.

- From the InsightCM Data Viewer page, click **Force Trigger** to collect the following baseline waveform sets:
 - Force Trigger just prior to the generator spinning up on turning gear
 - Force Trigger during spin up just prior to the generator coming online
 - Force Trigger just after the generator comes online and is at lowest load
 - Force Trigger when the generator is at normal operating load



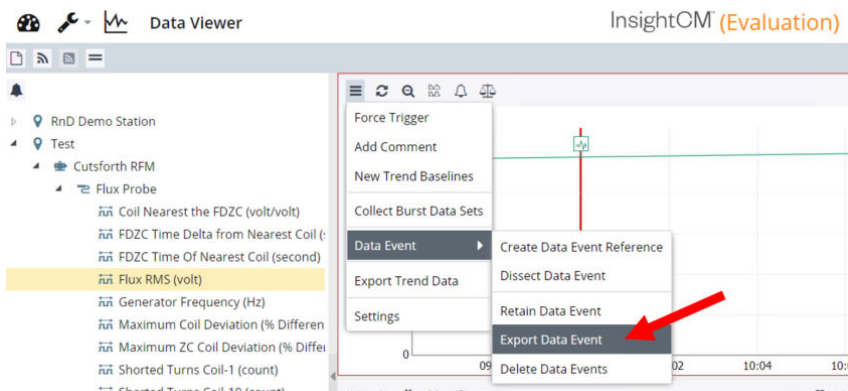
- Annotate the waveforms by clicking **Add Comment**.





3. Save these waveforms so they are never deleted by selecting **Data Event > Retain Data Event**.

Note that these four waveforms will possibly NOT be properly analyzed or display properly in the system at this time from the default waveform processing settings. Export these waveforms and send them to support@cutsforth.com for analysis at which time we will advise on each individual setting required on the Signal Processing Properties tab of InsightCM.



5.2.2. Define Unit and Signal Processing Properties

Cutsforth offers many user-definable RFM parameters so that analytics and calculations are specifically tailored to the unique flux signal that each generator produces. It is difficult to advise what the settings might be for any given unit. On first power up, it is advised to perform the waveform collection steps referred to in [Collect RFM Baseline Waveforms \(page 34\)](#), and send the resulting TDMS files to Cutsforth for analysis. For proper interpretation, Cutsforth must have:

- The TDMS exports of the four waveforms collected
- The number of Poles
- The number of Slots per Pole
- The number of Windings per Coil
- The MW's capability of the unit

Properties
Features
Trend Alarms
Spectral Alarms

Generator

Slots Per Pole:

6

Start Angle:

33.48

End Angle:

150.247

Load:

None

Load Units:

MW

Max Load:

87

Windings Coil [1]:

1000

Windings Coil [2]:

1000

Windings Coil [3]:

1000

Windings Coil [4]:

1000

Windings Coil [5]:

1000

Windings Coil [6]:

1000

Properties
Features
Trend Alarms
Spectral Alarms

Processing

Windings Coil [4]:

1000

Windings Coil [5]:

1000

Windings Coil [6]:

1000

Number of Poles:

2

Smooth:

☐

Smoothing Length:

5

HP FFT Index:

15

Cycle Detection Tolerance Angle:

5

FDZC Coil Tolerance Angle:

3

FDZC Number of Inaccessible Coils:

1

LPF Cycle Detection:

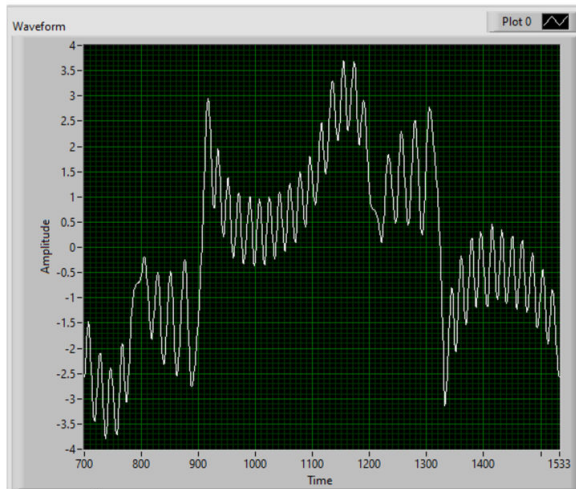
☒

LPF Passband:

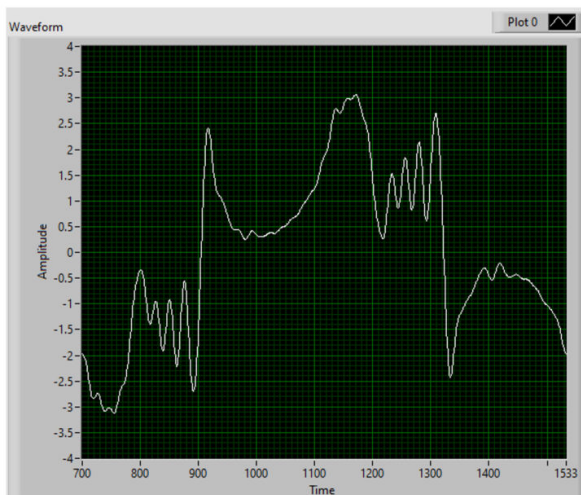
0

5.2.2.1. Property Definitions

Number of Poles	The number entered in this field indicates the quantity of poles in the generator. A typical generator has 2 poles. Some have 4 poles.
Smooth	If the signal is excessively noisy, check this flag, and smoothing will be applied to the measured flux signal to reduce the noise.
Smoothing Length	If the Smooth flag is checked, the signal is smoothed with a filter that is Smooth Length points long.
HP FFT Index	To help separate the flux wiggles from the lower frequency power cycle signal, the 'HP FFT Index' specifies the frequency above which a high-pass filter is applied to the flux signal. The frequency is specified as the number of cycles per power period. For example, a value of 20 means that frequencies below 20 cycles per 1/60 of a second (for 60 Hz generation) are removed by this high-pass filter. As another example, a value of 1 means one cycle in 1/60 second, which is the power frequency of the generator.
Cycle Detection Tolerance Angle	After the cycle is detected, the positive-going flux wiggles should reside between the 'Start Angle' and 'End Angle' of the power cycle. (The negative-going flux wiggles must fit between this range after adding 180 degrees.) Any wiggles outside this region are rejected. Since the cycle detection start index has some "jitter", this tolerance angle is used to allow that angle window to expand a little on both sides by this tolerance angle. This tolerance angle should never be more than about half the angular cycle length of a flux wiggle. For example, if 12 wiggles (due to 6 coils) occur between the 'Start Angle' and 'End Angle', which for example might span 150 degrees, then each wiggle spans about 13.636 degrees (from 150/11), so this tolerance angle should not be more than 13.636/2 or about 6.8 degrees.
FDZC Coil Tolerance Angle	Capturing the flux signal when the FDZC is near a coil position implies that a tolerance of that position is necessary, since the chance of the FDZC being exactly on a coil position is small. When the FDZC is at a coil position +/- this tolerance angle, the flux signal is captured.
FDZC Number of Inaccessible Coils	Since the FDZC position may never reach coils 1 and 2 at full load, this number allows the flux signal to capture the coil amplitude deviations when the FDZC is at this number plus 1. For example, if the number of inaccessible coils is 2, then when the FDZC is at coil 3, the results for coil 2 and 1 are also captured.
LPF Cycle Detection	If this flag is set to true (checked), then the LPF is applied.
LPF Passbands	As mentioned above, some flux waveforms have structure that can confuse MJCD method. If the frequency of the wiggles is faster than any other structure, a lowpass filter can remove the wiggles and focus on the rest of the structure. The utility of the MJCD is to find a maximum of the $\Delta Y/\Delta X$ values that is close to the "between" region as this parameter walks along the waveform so that the cycle start can be placed in this region. The following figures show the effect of this lowpass filter. The first example is from an LGE coal-fired generator. Note that the amplitude of the wiggles in the "between" region are about the same as the flux wiggles.



Applying the LPF to the signal with a passband of 0.022 results in the following signal.



Note that the flux wiggles are essentially eliminated and the overall background structure of the wiggles is preserved. The $\Delta Y/\Delta X$ value has a very distinctive maximum at the center of the "between" region.

A good starting value of the LPF Passband is computed as follows:

- $\text{LPFPassband} = (\text{AngRange} / 360) / \text{NumWiggles}$

For the signal above, with $\text{NumWiggles} = 2 * \text{NumCoils} = 2 * 8 = 16$, and $\text{AngRange} = 150 - 32 = 118$, the LPFPassband is $(118 / 360) / 16 = 0.0205$.

Adjusting this value slightly up or down can help improve the detection of the wiggle extrema.

5.2.3. Define the ON Operating State

1. Remove the instructions for the system to collect waveforms when in the Default operating state.

The image shows two panels: 'Data Set Collection Conditions' and 'Trend Collection Conditions'. Both panels have a 'Time:' dropdown set to 'Every hour' and a trash icon with a red arrow pointing to it, indicating removal. Below the 'Time' dropdown are three buttons: '+ Gate', '+ Delta EU', and '+ Advanced'.

2. Create an ON operating state based on the Flux Probe RMS level as recommended by Cutsforth as a result of analyzing the TDMS waveforms collected on first power.

When the generator is offline, the Flux RMS amplitude will be low, and when the generator is online, this level will rise abruptly. The level for the ON state should be such that the RMS signal is produced by an online generator and that it is stable for at least a minute before collecting and analyzing waveforms.

It is initially recommended that trend lines be set to collect every 15 minutes and that waveform sets be analyzed every 4 hours.

The image shows the 'InsightOM (Evaluation)' Asset Configuration interface. The left sidebar shows a tree view with 'Cutsforth RFM' selected. The right panel shows the 'Operating States' configuration for 'On' state. It includes 'Enter Conditions' (C1: Flux Probe > Flux RMS greater than 0.1 for 60 seconds), 'Exit Conditions' (C1: Flux Probe > Flux RMS less than 0.1 for 60 seconds), 'Data Set Collection Settings' (File Length (s): 4, Pre-Trigger Length (s): 1), and 'Enter / Exit Settings' (Collect on Enter, Collect on Exit).

5.2.4. Alarm Management

If the Cutsforth RFM template was used to create the asset, then the default alarms will be set such that when the number of shorted turns on any coil becomes greater than one, an alarm is triggered. It may be desired to change this such that an alert occurs when less than one turn is shorted, or more if a unit already has an existing set of shorted turns present on any given coil.

The screenshot shows the InsightCM (Evaluation) Asset Configuration window. The left sidebar lists the asset hierarchy: RnD Demo Station > 10x8 new numbering > Cutsforth EMI 9047 > ECM Monitoring > EMI - RF Band EMSA > Test > Cutsforth RFM > Flux Probe. The main panel shows the 'Trend Alarms' tab with a table of configured alarms.

Trend	Aut...	Operator	Levels	Operating State	Hys...	On ...	Off ...	Actions	Def...
Shorted Turns Coil-1		Greater than	3: High (3)	On	0	0	0	Yes	Yes

The 'Trend Alarm Rule' dialog box is shown. It contains a list of available metrics on the left, including 'Shorted Turns Coil-1', 'Maximum Coil Deviation', 'FDZC Time Delta from Nearest Coil', 'Coil Nearest the FDZC', 'FDZC Time Of Nearest Coil', 'Flux RMS', and 'Shorted Turns Coil-2' through 'Shorted Turns Coil-4'. The 'Shorted Turns Coil-1' metric is selected. The comparison operator is set to 'Greater than'. The 'Actions' section is empty. At the bottom, there are input fields for 'On Delay (s): 0', 'Off Delay (s): 0', and 'Hysteresis: 0'. There is also a checkbox for 'Use default collection length' and fields for 'File Length (s): 12' and 'Pre-Trigger Length (s): 10'. The dialog has 'OK', 'Cancel', and 'Help' buttons at the bottom right.

Trend Alarm Rule Level

Severity: High (3)

Compare To: 3

☒ Send Email

Email Settings

Address Group: Default

Email Template: Default Trend Alarm

OK Cancel

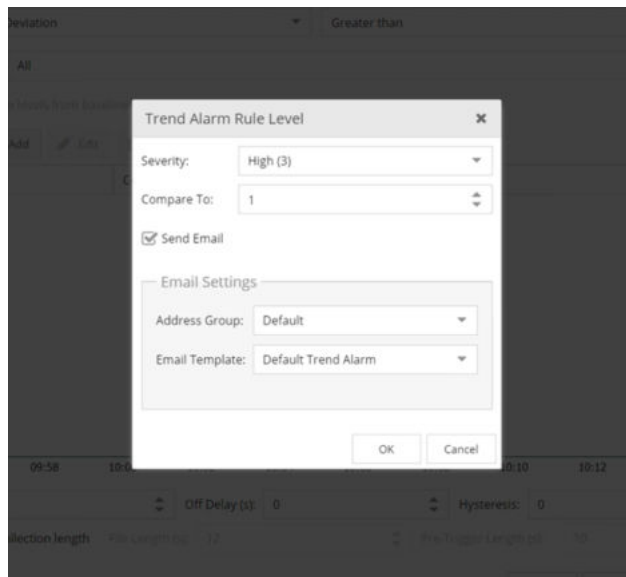
Select Feature or Single-Point Channel

RFM System

Flux Probe

- Coil Deviation Lead-1
- Coil Deviation Lead-2
- Coil Deviation Lead-3
- Coil Deviation Lead-4
- Coil Deviation Lead-5
- Coil Deviation Lead-6
- Coil Deviation Lead-7
- Coil Deviation Lead-8
- Coil Nearest the FDZC
- FDZC Time Delta from Nearest Coil
- FDZC Time Of Nearest Coil

Up Select Cancel



Asset Configuration

🔄 ➕ Add 🗑️ Remove ✓ Validate 🧹 Clear selections

🔍 Invalid

- 📍 RnD Demo Station
 - 🔧 10x8 new numbering
 - 🔧 Cutsforth EMI 9047
 - 📍 ECM Monitoring
 - 🔧 EMI - RF Band EMSA
- 📍 Test
 - 🔧 Cutsforth RFM
 - 🔧 **Flux Probe**
 - 🔧 Cutsforth SGM

InsightCM (Evaluation)

Properties	Features	Trend Alarms	Spectral Alarms	Description
➕ Add ✎ Edit 🗑️ Remove				
Name	Unit			
Maximum Coil Deviation	% Difference			
Maximum ZC Coil Deviation (Maximum Coil Deviation)	% Difference			
Flux RMS	volt			
FDZC Time Delta from Nearest Coil	second			
Coil Nearest the FDZC	volt/volt			
FDZC Time Of Nearest Coil	second			
Generator Frequency	Hz			
Shorted Turns Coil-1 (Shorted Turns)	count			
Shorted Turns Coil-2 (Shorted Turns)	count			
Shorted Turns Coil-3 (Shorted Turns)	count			
Shorted Turns Coil-4 (Shorted Turns)	count			
Shorted Turns Coil-5 (Shorted Turns)	count			
Shorted Turns Coil-6 (Shorted Turns)	count			
Shorted Turns Coil-7 (Shorted Turns)	count			
Shorted Turns Coil-8 (Shorted Turns)	count			
Shorted Turns Coil-9 (Shorted Turns)	count			
Shorted Turns Coil-10 (Shorted Turns)	count			

5.2.5. Rotor Flux Data Viewer

The InsightCM™ Data Viewer screen layout is fully customizable according to the user's preference and also allows the viewer to observe multiple data points in both graphical and numerical form at the same time.



6. Calibration and Preventive Maintenance



ELECTRICAL DANGER

Calibration and maintenance is to be conducted only by qualified electrical and monitoring systems personnel.



ELECTRICAL DANGER

Follow all plant safety and lock-out/tag-out requirements before accessing the equipment referenced in these procedures.

6.1. Visually Inspect and Clean Generator Field Monitoring System Electrical Components

PM Need: Required

Frequency: Annually

Action: Using a compressed-air duster approved for electronics, blow all dust and debris off the electrical components inside the Generator Field Monitoring System.

6.2. Check Current Sensor, Voltage Sensor, and System Performance

Calibration Need: Advised

Frequency: Annually, as outage schedule permits, or if measurements suggest readings are inaccurate.

7. Reference Information

This section provides detailed technical information on the Generator Field Monitoring System capabilities and legal information.

7.1. Monitored Lines and Bandwidths

Standard Data Collection

Monitored Line	Bandwidth	Attenuation Ratio
Ground Current	1 MS/s or 222 kHz	30 A : 10 V
Shaft Voltage	1 MS/s or 222 kHz	100 V : 10 V
Exciter Shaft Voltage	1 MS/s or 222 kHz	100 V : 10 V
Rotor Flux	100 kS/s or 22.2 kHz	100 V : 10 V

7.2. How Average and Peak Values Are Calculated

- Average voltages and currents are calculated on the samples taken during each snapshot as the sum of $(x)/N$, where x is the array of samples acquired, and N is the number of samples.
- Zero-to-peak voltages and currents are calculated on the samples taken during each 0.02 second period by the following formula:

$$\max(x) - \min(x)$$

- The longer-term averages are calculated by accumulating averages for the specified period. They are then reset in preparation for the next calculation. The formula used is as follows:

$$NewAverage = \frac{(PreviousSampleCount * PreviousAverage) + NewSampleAverage}{PreviousSampleCount + 1}$$

7.3. Related Documents

Document Name	Document Number
Shaft Grounding System Operations Manual	Series 1: EZDP-2007 Series 2: EZDP-2035 Series 3: EZDP-2068
Generator Field Monitoring System Installation Planning Guide	EZDP-2090
Generator Field Monitoring System Wiring Diagram	Refer to Product Part Number (e.g., EAMA-002, EAMA-201)
InsightCM Installation Manual	Refer to the InsightCM installation instructions on the Cutsforth Support Webpage
Activating InsightCM Server License	Refer to the InsightCM licensing instructions on the Cutsforth Support Webpage

8. Glossary

attenuation	The reduction of the amplitude of a signal due to excessive cable length.
AWG	American Wire Gauge
DC average	The average of the DC component measurements during a sample period as calculated by $\sum X/n$, where X is the array of samples acquired and n is the number of samples.
DCS	Distributed Control System
extrema	The largest and smallest value of the waveform within a given range.
flux density integral zero cross (FDZC)	The FDZC is the point at which the integral of the flux waveform is zero volts, which affords the greatest sensitivity to detecting a shorted turn in a coil.
flux	Rate that an electric field flows through a given area, proportional to the number of electric field lines going through a virtual surface.
flux density	The amount of flux passing through a defined area that is perpendicular to the direction of the flux.
Generator Field Monitoring System	A Cutsforth product which monitors shaft voltages, shaft currents, and rotor flux signals and provides real-time data and analytics through Cutsforth's InsightCM™ software.
ground conductor	8 AWG, green ground conductor that carries the shaft current to the unit case ground location.
ground current	The electrical current between the shaft and the unit case ground through the ground conductor.
ground rope	The left rope in the Shaft Grounding Assembly, which provides the primary path to unit case ground through the 8AWG ground conductor.
impedance	The resistance to change in the current of a circuit.
lag	An alternating current that reaches its maximum value up to 90 degrees later than the voltage that produces it.
lead	An alternating current that reaches its maximum value up to 90 degrees ahead of voltage that produces it.

LOTO	Lockout/Tagout
meter rope	The right rope in the Shaft Grounding Assembly which provides a shaft contact point at which shaft voltage readings are taken.
rotor flux	The magnetic fields created by the generator windings.
rotor flux probe	A sensing device which measures the rotor flux and provides a signal output.
oscilloscope resolution	A measurement that describes the granularity of a waveform (like the resolution of a photograph).
RMS	
Shaft Grounding Assembly (SGA)	A Cutsforth product designed to provide a best-in-class ground connection, as well as a shaft contact point at which shaft voltage can be measured.
shaft voltage	The voltage potential between the shaft and the unit case ground as measured by the metering rope.
shorted turns	Shorted turns result when insulation fails between windings in a rotor winding of a generator. Shorted turns limit the load a generator can produce. Shorted turns may result in failures leading to outages.
signal cable	Shielded cable that carries the voltage signals from the SGA and the SCA to the monitoring system.
unit	The equipment monitored by the Cutsforth monitoring system.
unit case ground	The lower half of the turbine case, generator case, or coupler case near the Shaft Grounding Assembly to which the shaft can be grounded.
voltage divider	A component that reduces the voltage in a circuit by a predetermined ratio.
zero-to-peak	A measurement of a signal calculated by $ \max(x) $ or $ \min(x) $, whichever is greater, during a given period of time, where x is the array of samples acquired during that period.