Operations Manual
EZDP-2064 Rev B

Rotor Flux Monitoring

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1. About Cutsforth

Cutsforth specializes in developing innovative new technologies and services to support the power generation industry. Cutsforth's patented EASYchange® brush holder design, online truing service, InsightCM™ condition monitoring software, and patented shaft grounding and monitoring systems have been installed across the globe in generators of all sizes and in nearly every industry application, including nuclear, natural gas, coal, wind, and hydroelectric.

Cutsforth's knowledge and commitment to excellence drives our innovative solutions for the changing needs of the power industry. Whether it is a quick response to a critical situation or a new way of solving an old problem, our commitment to quality ensures that our customers receive best-in-class products and services—Cutsforth is the Power of Innovation.

Cutsforth, Inc. started back in 1991 as a small company focused primarily on making replacement brush holders for generators and exciters. Today, after 30+ years in business, Cutsforth's experience and innovative designs have brought its best-in-class excitation brush holder and shaft grounding replacements and collector ring services to some of the world's largest power companies.

1.1. Cutsforth Products

- EASYchange® Removable Brush Holders
- EASYchange® Brush Condition Monitoring
- Cutsforth Shaft Grounding Systems
- Rotor Flux Monitoring
- Electro-Magnetic Interference Monitoring
- InsightCM™ Condition Monitoring Software

1.2. Cutsforth Field Services

Cutsforth provides comprehensive product installations for all product offerings as well as on-site training after the installation. We work efficiently during your outage to ensure a smooth upgrade to our innovative solutions such as Product Installations, Online Collector Ring and Commutator Truing, Spiral Groove Restoration, and Consulting and Emergency Services.

1.3. Cutsforth Automation and Control Services

Cutsforth provides comprehensive Automation and Control services which include data historian integration, InsightCM™ integration, DCS logic, engineered drawings and much more. This further complements our turnkey monitoring system installations.

2. Legal Information

2.1. 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.

2.2. Copyright

2.3. Patents

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

3. Safety Information

3.1. 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.

3.1.1. 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.

3.1.2. 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.

3.2. 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.

3.2.1. 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.

3.2.2. 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.

4. Rotor Flux Monitoring System

The Rotor Flux Monitoring system tracks the magnetic flux within a generator. Variances in magnetic flux indicate deterioration of winding insulation. Whether a result of thermal wear, large variation on load, contamination, or other causes, the impact to efficient generation is significant. Imbalances within the rotor damages insulation, which in turn degrades the generator's output capacity and increases vibrations, further damaging the insulation, which ultimately leads to a forced outage. Once the monitoring system collects the rotor flux data from the probe, the 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.

4.1. Key Specifications

Rotor Flux:

- 0-10 V 0-Pk
- Signal acquisition rate: 50kS/

Isolation: 1500 V

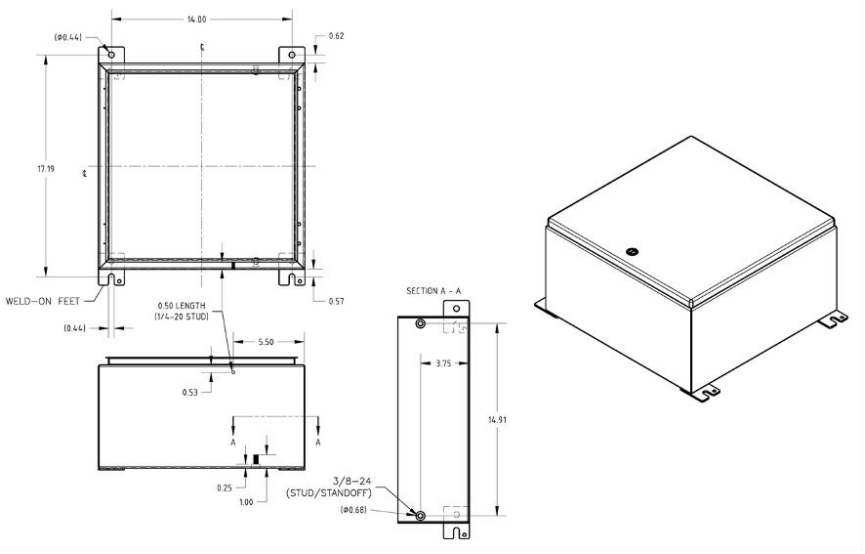
Accuracy: ± 1 V and 5% of current in specified range

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

4.2. Technical Specifications

4.2.1. Monitoring System Enclosure

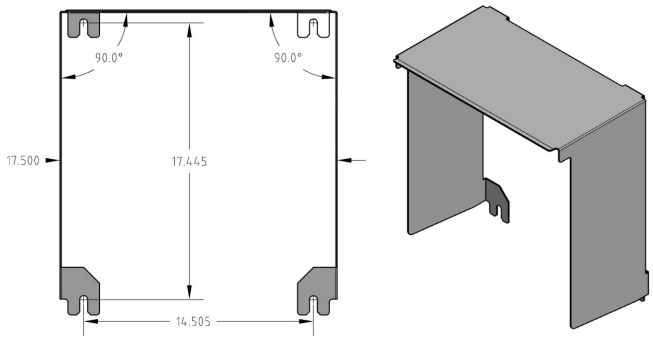
Catalog Number	Dimensions (in. (mm))	Stainless Steel Type
CSD16168SS6-MODS	16.0 (406) x 16.0 (406) x 8.0 (203)	316



Specifications:

▪ UL 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	▪ VDE IP66 ▪ IEC 60529, IP66 ▪ Meets NEMA Type 3RX requirements

EXMC-002: Optional sunshield for outdoor installations



4.2.2. 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

4.2.3. 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

4.2.4. 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)

4.2.5. 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)

5. Rotor Flux Monitoring System Setup

5.1. Rotor Flux Monitoring Overview

The data and waveforms collected by the Cutsforth Rotor Flux 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 Rotor Flux 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 Rotor Flux 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™

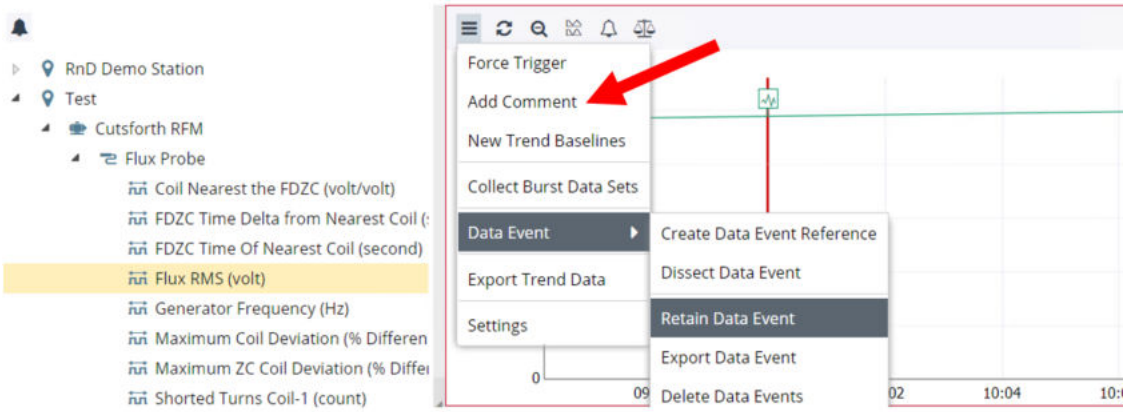
This section covers the viewing of rotor flux data in InsightCM™. For assistance with getting your Rotor Flux Monitoring System connected to and communicating with InsightCM™, refer to the InsightCM™ Setup and Configuration manual on the Cutsforth Support webpage at https://support.cutsforth.com, or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

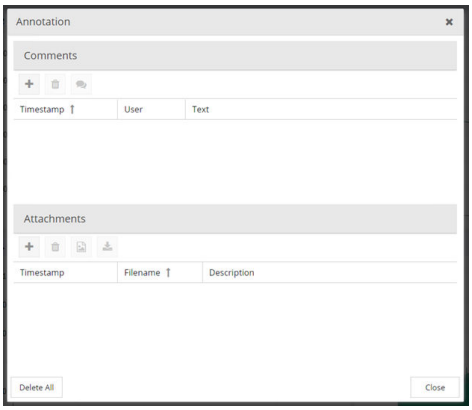
5.2.1. Collect RFM Baseline Waveforms

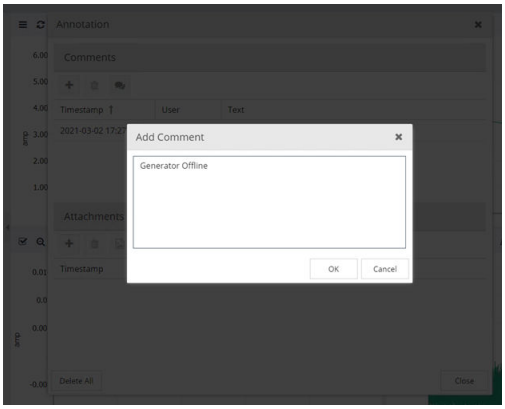
Monitoring for RFM conditions and alarms can only be operational when the generator is online or false faults will be registered. To do this, you must collect baseline waveforms according to these instructions to be able to accurately determine how to set the generator ON operating state.

1. 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

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

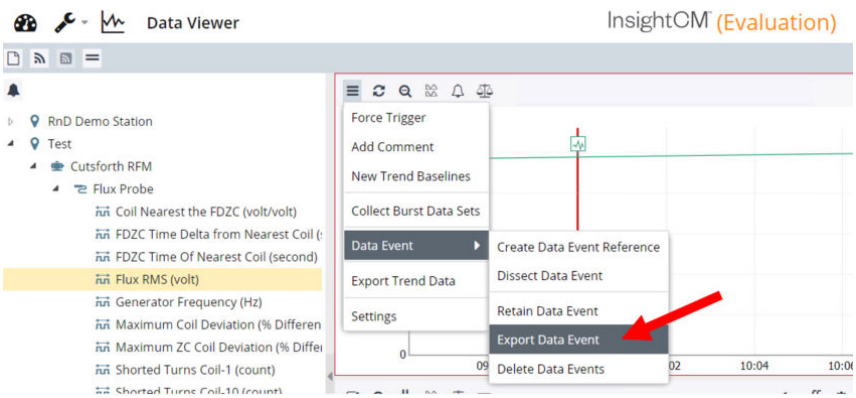






3. Save these waveforms so they are never deleted by selecting **Data Event** > **Retain Data Event**.

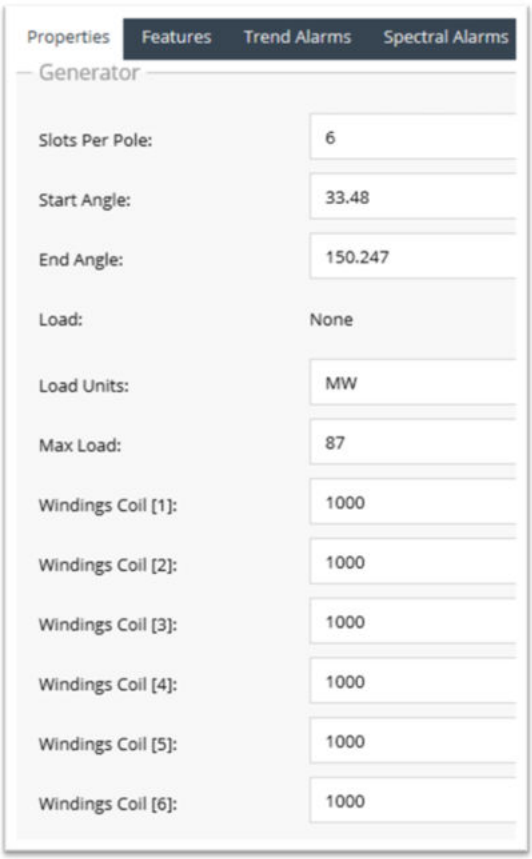
   Note that these four waveforms will possibly NOT be properly analyzed or display properly in the system at this time from the default waveform processing settings. Export these waveforms and send them to support@cutsforth.com for analysis at which time we will advise on each individual setting required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

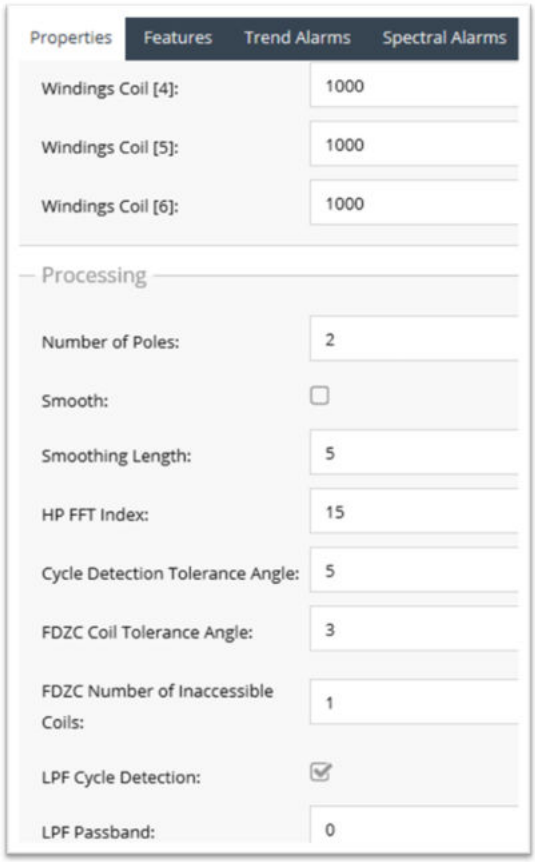


5.2.2. Define Unit and Signal Processing Properties

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 16), and send the resulting TDMS files to Cutsforth for analysis. For proper interpretation, Cutsforth must have:

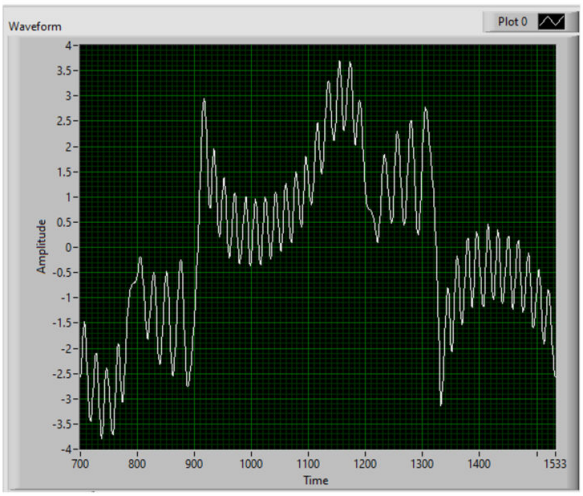
- The TDMS exports of the four waveforms collected
- The number of Poles
- The number of Slots per Pole
- The number of Windings per Coil
- The MW's capability of the unit



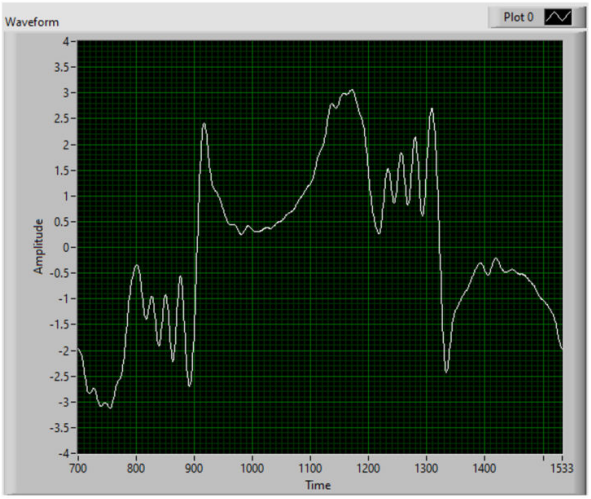


5.2.2.1. Property Definitions

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 ΔY/ΔX 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:

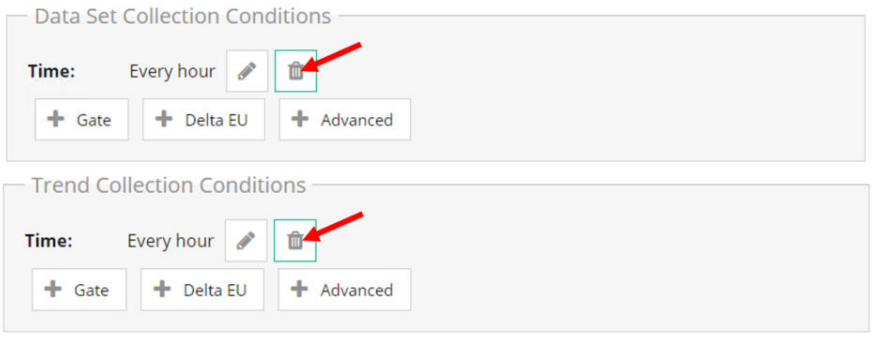
- LPFPassband = (AngRange / 360) / NumWiggles

For the signal above, with NumWiggles = 2 * NumCoils = 2 * 8 = 16, and 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

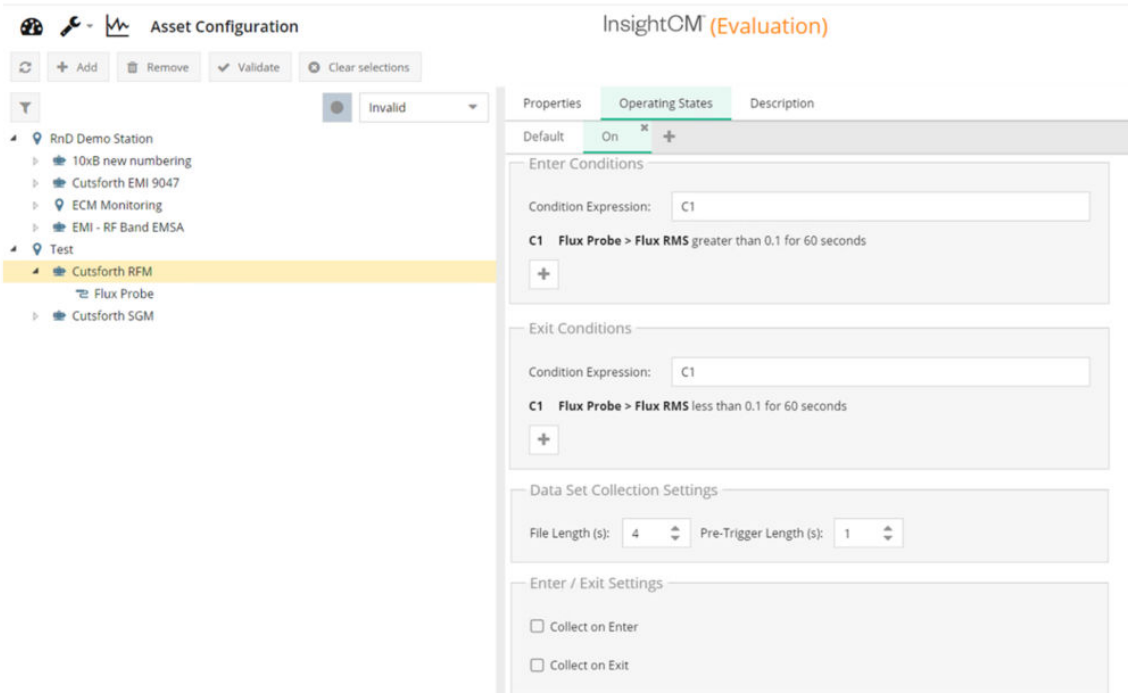
1. Remove the instructions for the system to collect waveforms when in the Default operating state.



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.

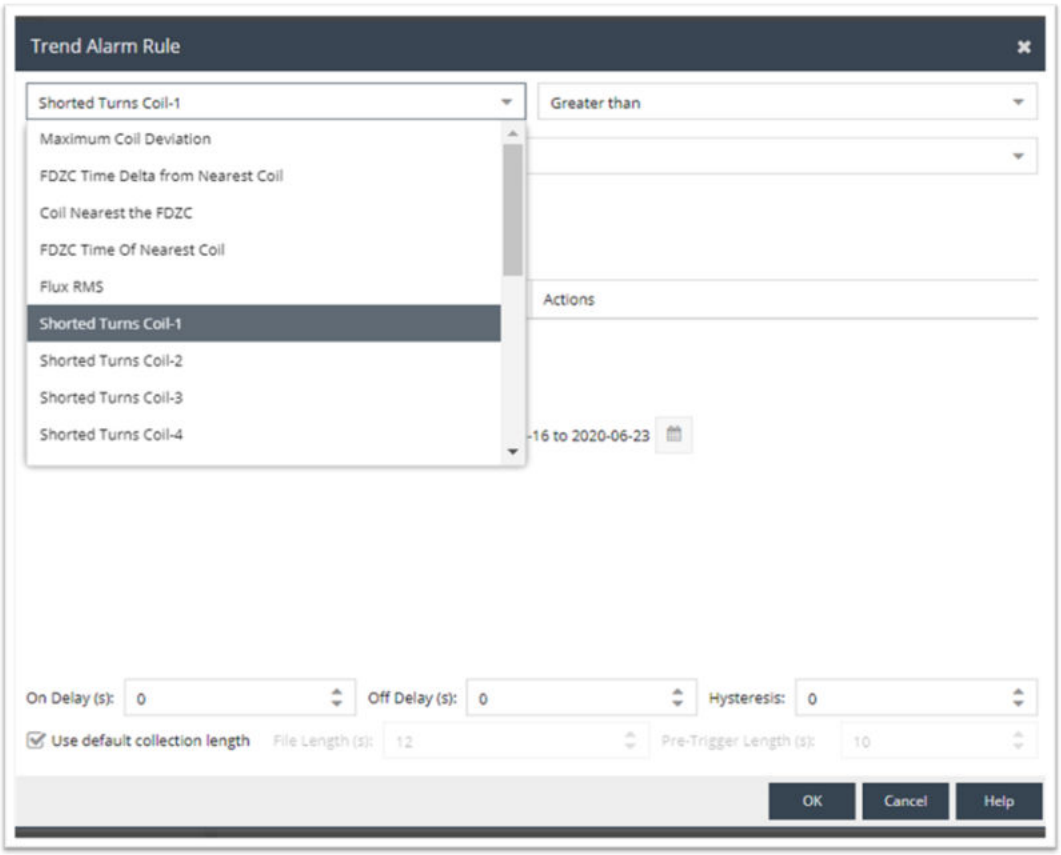
When the generator is offline, the Flux RMS amplitude will be low, and when the generator is online, this level will rise abruptly. The level for the ON state should be such that the RMS signal is produced by an online generator and that it is stable for at least a minute before collecting and analyzing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

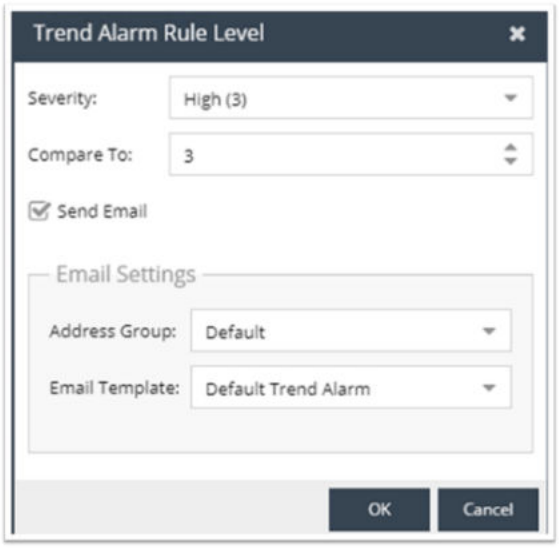
It is initially recommended that trend lines be set to collect every 15 minutes and that waveform sets be analyzed every 4 hours.

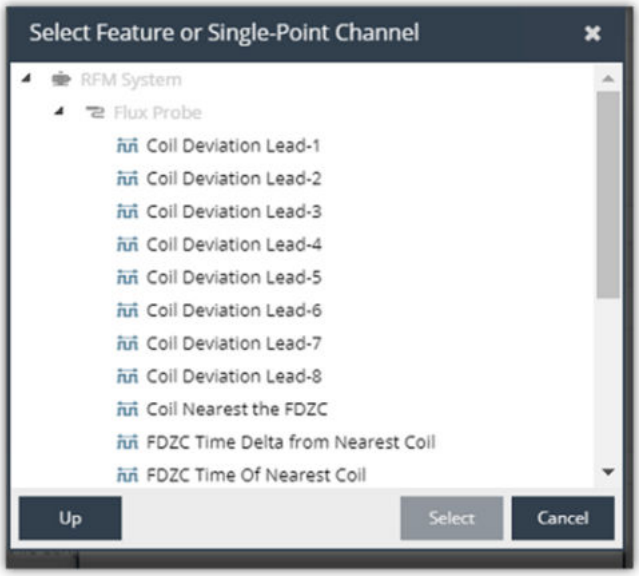


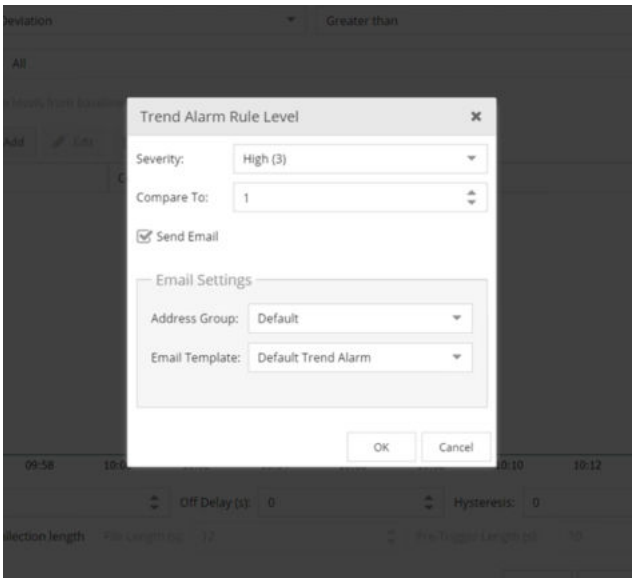
5.2.4. Alarm Management

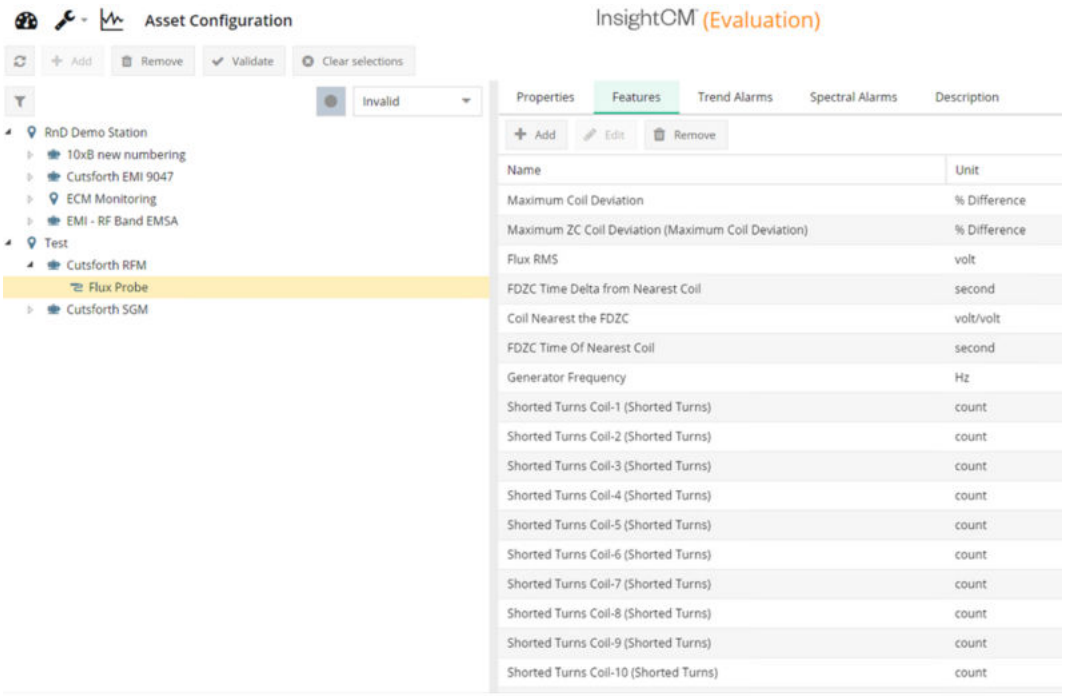
If the Cutsforth RFM template was used to create the asset, then the default alarms will be set such that when the number of shorted turns on any coil becomes greater than one, an alarm is triggered. It may be desired to change this such that an alert occurs when less than one turn is shorted, or more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











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. Glossary

extrema	The largest and smallest value of the waveform within a given range.
Fast Fourier Transform (FFT)	A method for converting a signal into its frequency components, allowing for a better analysis of that signal.
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.
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.
keyphasor	An electric pulse derived from a point on a rotating shaft that serves as a zero phase reference for finding imbalance on a rotor.
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.
rotor flux	The magnetic fields created by the generator windings.
Rotor Flux Monitoring System (RFM)	A Cutsforth product that detects variances in the magnetic flux within a generator that indicate deterioration of winding insulation.
rotor flux probe	A sensing device which measures the rotor flux and provides a signal output.
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.
waveform	A variable that changes with time, usually representing a voltage or current. Waveforms are graphed with time on the horizontal axis.