Measuring High-Frequency Bearing Currents with PEM's CMC Rogowski Probe

High-frequency bearing currents can rapidly damage modern motor systems through electrical discharge machining effects, particularly in VSD-driven applications.

PEM's **CMC** Rogowski technology provides purpose-built detection with optimised high-frequency response, enabling diagnostic identification and mitigation verification for marine propulsion systems, water treatment facilities and industrial applications, before catastrophic bearing failure occurs.

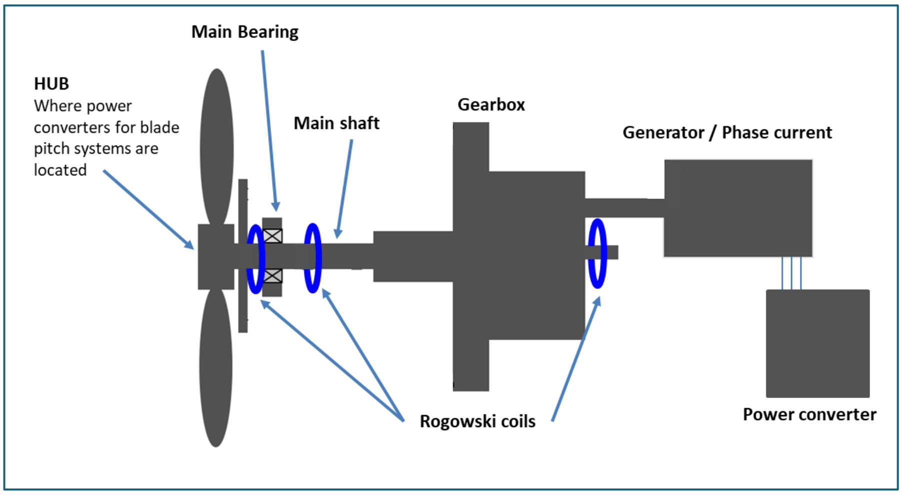

Figure 1. Rogowski coil positioned in a wind turbine drivetrain

About High-Frequency Bearing Currents

High-frequency bearing currents represent a significant threat to modern motor systems, particularly those driven by variable speed drives (VSDs). These transient currents flow through motor bearings due to capacitive coupling and electromagnetic effects, causing accelerated wear through electrical discharge machining (EDM). Unlike conventional mechanical wear, bearing damage from high-frequency currents can develop rapidly and lead to catastrophic failure within months of commissioning.

These currents are characterised by:

- Short-duration pulses with extremely fast rise times (ns range)
- Frequency components from 2-20 kHz (PWM carrier) extending to MHz range
- Amplitudes typically ranging from 0.5-40A depending on type and severity
- Intermittent occurrence patterns related to operating conditions
- Multiple conduction paths including circulating and common mode currents

Power Electronic Measurements

Spectral Signature

- Dominant peaks at PWM switching frequency (typically 2-20 kHz)
- Rich harmonic content extending into MHz range
- Non-continuous spectrum with discrete frequency components
- Significant energy in high-frequency bands (>100 kHz)
- Often coincident with drive switching transients

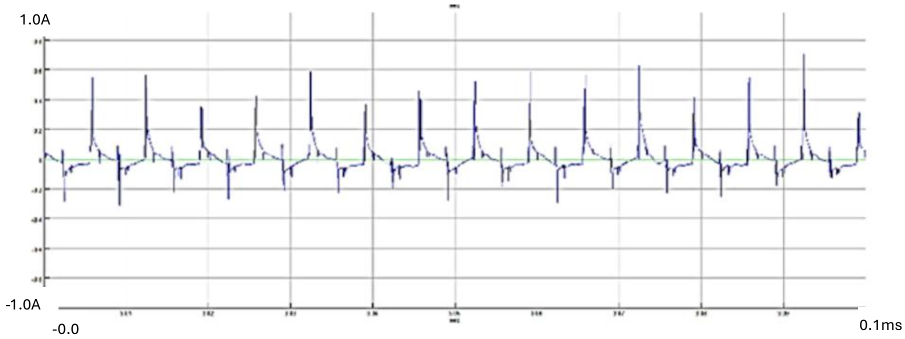

Figure 2. Waveform of bearing currents

Waveform Features

- Impulsive character with extremely fast rise times (<100ns)
- Short duration pulses (typically 0.1-2μs)
- High peak-to-average ratio
- Often clustered in time with operating condition dependency
- May show phase relationship to PWM switching events

Damage Mechanisms

High-frequency bearing currents cause distinctive damage through several mechanisms:

- **Electrical Discharge Machining (EDM)**: Localised melting and cratering of bearing surfaces
- **Material Transfer**: Metal particles removed from one surface and deposited on another
- **Lubricant Carbonisation**: High-temperature discharges create carbon particles in lubricant
- **Fluting Pattern Development**: Progressive formation of washboard-like ridges
- **Increased Vibration and Noise**: Leading indicators of developing damage

Technical Difficulties

Measuring high-frequency bearing currents presents unique challenges:

- **Transient Nature**: Short-duration pulses require high bandwidth measurement
- **Wide Frequency Range**: Need to capture components from kHz to MHz
- **Multiple Current Paths**: Different current types require different measurement points
- **Intermittent Occurrence**: Events may occur randomly based on operating conditions
- **High dI/dt**: Extremely fast current rise times challenge measurement systems

Variable Speed Drive Systems

- PWM Switching: Fast IGBT switching creates high dv/dt and common mode voltages
- Cable Length: Longer cables between drives and motors increase parasitic capacitances
- Drive Configuration: Certain control strategies increase common mode voltages
- Grounding Quality: Poor or high-impedance grounding exacerbates bearing current issues
- Switching Frequency: Higher switching frequencies increase bearing current risk

Marine Propulsion Systems

- Large Drive Power: High-power propulsion systems generate substantial common mode currents
- Complex Grounding: Vessel construction creates multiple ground paths
- Critical Operation: Bearing failures during voyage create significant safety and economic risks
- Environmental Factors: Marine conditions may affect insulation properties
- Limited Maintenance Access: Repairs at sea are difficult or impossible

Water Treatment Facilities

- Vertical Shaft Orientation: Creates unique current paths and bearing loading
- Continuous Operation: Extended running times allow damage progression
- Moist Environment: Potential for increased conductivity and insulation degradation
- Process Criticality: Failures impact essential public services
- Multiple Drive Systems: Facility-wide bearing current issues affect multiple asset

CMC: Technical Specifications

Core Technology

The CMC utilises specialised Rogowski coil technology specifically optimised for high-frequency measurement applications:

- **Measurement Principle**: Air-core inductive sensor producing an output voltage proportional to the rate of change of current
- **Signal Conditioning**: Precision integrator circuit with high-frequency optimisation
- **Electrostatic Screening**: Specially designed shielding to minimise capacitive coupling interference
- **Flexible Form Factor**
- **Long coils** up to several metres to encircle large machine shafts

- **Short, thin, coils for installation in tight spaces such as e-motors**
- **Non-Invasive Measurement**: No electrical connection or circuit breaking required

Performance Specifications

Parameter	Specification	Notes
Frequency Range	1.9 kHz into MHz range	Optimised for high-frequency transients, whatever the machine size and coil circumference
Sensitivity	200 to 50 mV/A	Linear across entire measurement range
Peak current ranges	30A to 150A peak	Maximum measurable current
Noise	<4 mV peak-to-peak	With coil closed and no current
Peak dI/dt	16 kA/μs	Maximum rate of change of current
LF (-3dB) Bandwidth	1.9 kHz	Low frequency (-3dB) cut-off to attenuate large fundamental power frequency currents and magnetic fields.
Accuracy	±1% of reading	For conductor central in coil

Physical Specifications

Coil and cable

Parameter:	Available Options:
Coil Circumference	100mm to 1000mm standard lengths (longer available on request, up to 7000mm)
Cable Length	4m standard (2.5m and longer available on request)
Coil Cross-Section	Large coils > 500mm - 8.5mm diameter (14mm with protective sleeve)- standard CMC range Shorter coils < 500mm - 3.5mm diameter
Battery Type	4 x AA 1.5V alkaline (B option)
Battery Life	Approximately 25 hours continuous operation
Operating Temperature	0°C to +40°C (integrator), -20°C to +90°C (coil and cable)
Storage Temperature	-20°C to +85°C
Dimensions	183mm × 93mm × 32mm (integrator housing)

Electronics enclosure

Parameter:	Notes
Power Supply	Battery powered (external power adaptor optional)
Output Connector	BNC socket (supplied with 0.5m BNC:BNC cable)
Input Impedance Requirement	>100kΩ (1MΩ oscilloscope input recommended)
Output Voltage	±7.5V peak maximum
LED Indicators	Power status

Certification & Compliance

- Electromagnetic Compatibility: EN 61326-1:2013
- Safety: EN 61010-1:2010
- Environmental: RoHS and REACH compliant
- Quality: ISO 9001:2015 certified manufacturing

Contact Information

Power Electronic Measurements Ltd
Nottingham, UK
Email: info@pemuk.com
Telephone: +44 (0) 115 946 9657
Website: www.pemuk.com