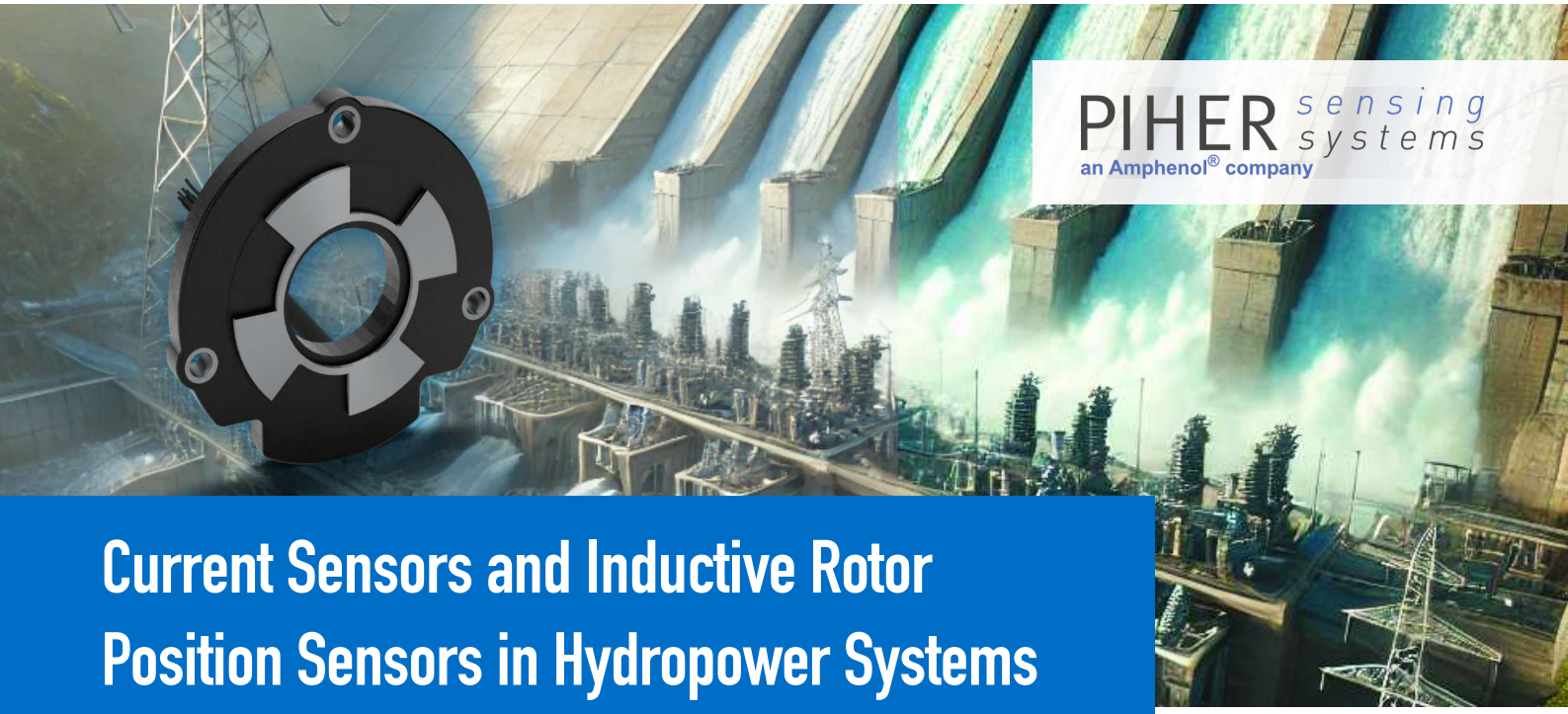


Current Sensors and Inductive Rotor Position Sensors in Hydropower Systems

As we strive for sustainable energy solutions, hydropower has emerged as a cornerstone of our efforts to reduce reliance on fossil fuels. Central to the operation of hydroelectric power plants are power converters and generators, which require precise monitoring and control to operate efficiently and safely.

The integration of high-accuracy current sensors and inductive rotor position sensors significantly enhances the performance, efficiency, and safety of hydropower systems. By providing precise real-time data, these sensors enable better control and monitoring, leading to improved operational outcomes.

Current Sensors in Hydropower Converter Systems

Power converters in hydropower systems are responsible for converting electrical energy from one form to another, typically from alternating current (AC) to direct current (DC) and vice versa. Accurate current monitoring within these converters is essential for:

■ Power Flow Control: Ensuring the efficient transfer of energy between the generator and the grid.

■ Protection Mechanisms: Detecting overloads, short circuits, and other fault conditions to prevent equipment damage.

■ Efficiency Optimization: Adjusting the converter's operation to match load demands and minimize energy losses.

Types of Current Sensors Used

Three-phase sensors are commonly used in hydropower generators due to their inherent three-phase nature. They provide measurements for each phase of the generator's output, offering a more comprehensive understanding of the system's operation. These can be:

■ Hall Effect Sensors: Utilize the Hall effect principle to measure magnetic fields produced by current flow.

■ TMR Sensors: are designed to offer high accuracy, wide dynamic range, and robust isolation, making them ideal for hydropower applications.

Integration into Control Loops.

Current sensors are typically installed in the generator's stator winding or output cables to measure the current flowing through these components.and are integrated into the converter's control system to provide real-time feedback. This feedback allows to:

■ Fault Detection: Identifying abnormal current levels quickly to activate protective measures.

■ Load Balancing: Ensuring equal distribution of current across multiple phases or converter units.

Ways to Improve Converter Efficiency Using Current Sensors

■ Accurate Current Measurement

Enhanced Precision: High-quality current transducers offer exceptional accuracy, allowing for precise control of the converter's output.

Optimized Switching: Accurate measurements enable fine-tuning of switching elements in the converter, reducing switching losses.

■ Improved Control Algorithms

- Adaptive Control: Precise current data allows for the implementation of advanced control strategies, such as vector control or direct torque control.

- Dynamic Response: Quick detection of current changes enables the system to respond rapidly to load variations, maintaining optimal performance·

Piher's current sensors are non-invasively placed around the conductor carrying the current. They use magnetic induction to measure the current without interrupting the circuit. This is a common method due to its convenience and safety.

■ Fault Detection and Prevention

- Early Fault Identification: Immediate detection of overcurrents or short circuits helps prevent damage to the converter and associated equipment.

- Protective Actions: Triggering of protective measures like circuit breakers or alarms to mitigate faults.

■ Load Balancing and Harmonic Reduction

- Phase Balancing: Accurate current measurements ensure equal load distribution across all phases, reducing stress on the system.

- Harmonic Minimization: Precise control reduces harmonic distortion, improving power quality and reducing losses.

Benefits of High-Accuracy Current Sensors

■ Enhanced Efficiency: Accurate current measurements enable optimal converter performance, reducing energy losses.

■ Improved Safety: Rapid fault detection protects equipment and personnel from electrical hazards.

■ System Reliability: High-quality sensors contribute to the longevity and reliability of the overall system.

KEY REQUIREMENTS FOR CURRENT SENSORS USED IN HYDRO POWER SYNCHRONOUS GENERATORS	
Supply voltage	Must handle the full range of currents generated, including normal operation and overload conditions.
Accuracy	High precision to ensure accurate monitoring and control of generator output.
Bandwidth/Frequency Response	Adequate to capture the fundamental frequency and harmonics present in the generator's current waveform.
Insulation Voltage/Isolation	High insulation levels to withstand the generator's operating voltages and prevent electrical hazards.
Environmental Conditions	Reliable operation under varying temperatures, humidity, and potential exposure to water or oil common in hydro plants.
Mechanical Dimensions	Compact and suitable form factor to fit within existing generator assemblies without modifications.
Safety Requirements	Features like overcurrent protection, fault detection, and fail-safe operation to protect equipment and personnel.
Response Time	Fast response to detect and react to current changes swiftly, crucial for protective relaying and system stability.
Power Consumption	Low energy usage to minimize impact on overall system efficiency and reduce operational costs.
Durability and Reliability	Robust construction to ensure long-term performance with minimal maintenance over the generator's lifecycle.

Inductive Rotor Position Sensors in Power Generators

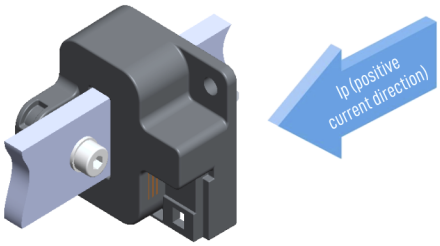
In hydro power generation systems, precise monitoring of the rotor's position, direction, and speed is essential for maximizing efficiency and ensuring reliable operation.

Inductive hign speed position sensors deliver high-accuracy feedback on these parameters while serving as a **cost-effective alternative to conventional resolvers and encoders.** Uniquely, these sensors are inherently **immune to stray magnetic fields** common in the electromagnetically noisy environments of hydro power plants, eliminating the need for additional shielding. This immunity not only simplifies the installation process but also reduces maintenance requirements and overall system complexity.

By providing accurate rotor position data without susceptibility to electromagnetic interference,

In summary, inductive sensors enhance the reliability and performance of hydro power generators, leading to reduced downtime and optimized energy production.

The HCSP-1BS busbar-mount current sensor is non-intrusive. It is designed to let the busbar pass through it freely.



In hydropower generators, the rotor's position is critical for efficient energy conversion and synchronization with the power grid. Inductive rotor position sensors detect the position, direction an speed of the rotor without physical contact, using electromagnetic induction principles.

Knowing the exact rotor position allows for:

■ Optimal Magnetic Flux Alignment: Maximizing the electromagnetic interaction between the rotor and stator.

■ Synchronization (alternating current): matches the frequency, phase and voltage of a generator or other source to an electrical grid in order to transfer power.

■ Vibration Analysis: Detecting mechanical issues early by monitoring positional anomalies.

Key Features of Inductive Position Sensors include:

■ Non-Contact Measurement: Reduces wear and maintenance requirements.

■ High Accuracy: Provides precise position data essential for control systems.

■ Robustness: Operates reliably in harsh environments with high temperatures and vibrations.

■ Immune to stray fields, no shielding required.

■ Cost-effective alternative to conventional resolvers and encoders.

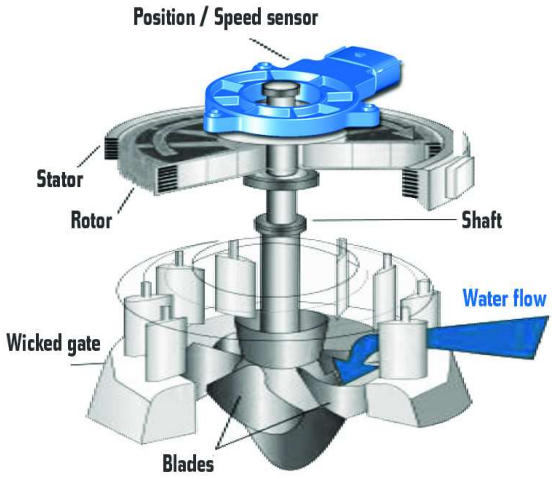
TECHNOLOGY COMPARISON		
	Inductive Position Sensors	Resolvers
Weight	< 30g	> 200g
Typical height	< 10mm	> 25mm
Sealing	Up to IP69K, IP67	IP5X
Direct angle output	Yes	No (converter needed)
ASIL support	Yes (ASIL D on sensor level)	No (only on system level)
BOM / raw material impact	Low	High
Assembly cost	Low	High
Power consumption	Low	High
Working Temperature	-40°C to +160°C	-55°C to +150°C

Integration with Control Systems

Feedback Loop: Position data is fed into the generator's control system to adjust excitation and load sharing.

Protective Functions: Detects abnormal positions that may indicate mechanical faults, triggering alarms or shutdowns.

Performance Optimization: Enhances efficiency by maintaining optimal rotor-stator alignment.



Benefits of Inductive Rotor Position Sensors

■ High speed: Up to 600.000 (el) rpm speed.

■ Reduced Maintenance: Non-contact design minimizes mechanical wear.

■ Enhanced Safety: Early detection of mechanical issues prevents catastrophic failures.

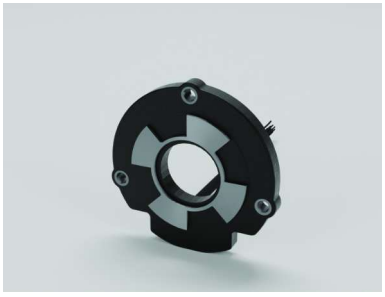
■ Synchronization (alternating current): matches the frequency, phase and voltage of a generator or other source to an electrical grid in order to transfer power.

The integration of high-accuracy current sensors and inductive rotor position sensors significantly enhances the performance, efficiency, and safety of hydropower systems. By providing precise real-time data, these sensors enable better control and monitoring, leading to improved operational outcomes.

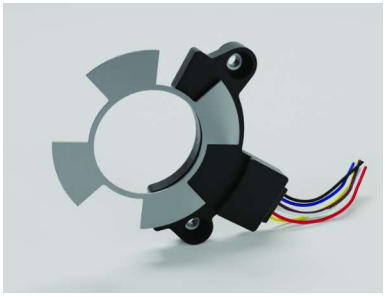
e-Motor Rotor Position Sensors

Inductive high-speed sensors for precise motor control

End-of-shaft



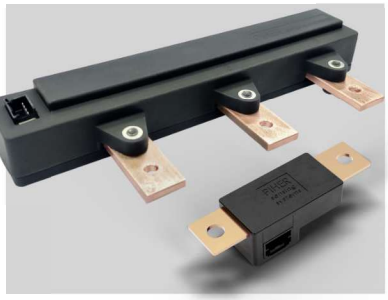
Through-shaft



Arc / segment

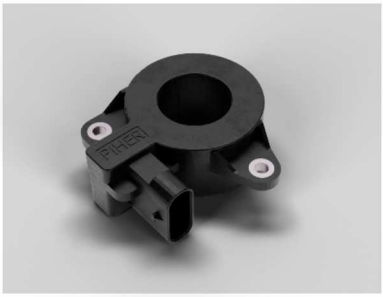
Current Sensors

Accurate measurement for battery management and inverters



TMR Coreless Current Sensorss

Busbar mounted Current Sensors



Through-hole wire mount

CURRENT SENSORS

INDUCTIVE SENSORS

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