ROV-Based Inspection of Hydropower Penstocks

Inspecting steel penstocks without dewatering, downtime, or sending personnel into the pressurised bore

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Understanding the Penstock

A penstock is the large-bore steel pipe that carries water from a reservoir down to the turbines of a hydroelectric power plant. It runs from the intake gate at the reservoir to the main inlet valve at the powerhouse, often over a length of several hundred metres and a diameter of several metres. The water inside it moves under a significant hydraulic head, the pressure built up by the vertical drop from reservoir to turbine, which can range from a few bars to well over sixty.

In a plant with several generating units, each unit is usually fed by its own penstock. These pipes are among the most heavily loaded structures in the plant. The steel wall is what holds the pressure, and the thickness of that wall is what governs whether the structure is safe. Everything about penstock inspection comes back to one question: is the wall still sound.

The Inspection Challenge

A penstock degrades in ways that are invisible from the outside and dangerous if missed.

The steel wall thins over time through corrosion and abrasion. Deposits build up along the invert. Cracks, pitting, or localised wall loss can develop at points that carry no outward sign until the structure is opened or, in the worst case, until it fails under pressure. Because the consequences of a penstock failure are severe, regulators require periodic internal inspection. The difficulty is that inspecting the inside of a penstock has traditionally meant one of two things, and both are costly.

The first option is dewatering. The penstock is drained and the generating unit it feeds is taken out of service for the full duration of the inspection. For a plant that earns its revenue by generating, removing a unit from service is an expense operators avoid wherever they can.

The second option is sending personnel into the drained pipe. This places people inside a confined, water-marked steel tube hundreds of metres long, accessed through gate openings at depth, with the hazards that come with confined-space entry. It is slow, it is risky, and the coverage achievable per entry is limited.

There is a further problem that neither option solves well. A visual inspection alone, however careful, cannot confirm structural integrity. Knowing that the wall looks intact is not the same as knowing how thick it still is. Without quantitative wall-thickness measurement at defined positions along the pipe, an inspection produces a description of the surface, not a verdict on the structure. The asset's condition does not wait for a convenient shutdown, and the methods available have not matched the frequency that responsible maintenance asks for.

ROV-Based Inspection: An Alternative Methodology

A remotely operated vehicle inspects the penstock from the inside while the operator stays outside it, and without the pipe being dewatered.

The vehicle is deployed from the dam top at the intake gate and navigates the full bore under its own power, from the intake gate down to the main inlet valve. It carries a multi-sensor payload, because no single sensor answers every question a penstock inspection has to answer.

Profiling sonar generates continuous cross-sectional profiles of the pipe along its length. This measures the actual internal diameter, detects any deformation or geometric change, and builds a dimensional record of the bore over the full run. An ultrasonic thickness probe measures the steel wall thickness at defined clock positions, the 12, 3, 6, and 9 o'clock points, at set chainages along the pipe, and compares those readings against the design drawings. This is the measurement that turns a visual survey into a structural assessment. A high-definition camera records the condition of the internal surface, the coating, and any visible defects.

All of this data is streamed live to a control station at the surface, so the engineer in charge watches the survey as it happens rather than waiting for a vehicle to be recovered and footage reviewed. The inspection data can then be position-tagged and processed into an interactive software report that sits alongside the conventional hard-copy deliverable, giving the asset owner a georeferenced record of the pipe's condition that can be acted on and compared against future inspections.

The result is a complete internal inspection, visual and quantitative, carried out without draining the penstock, without taking the unit offline for a personnel entry, and without placing anyone inside the pressurised structure. Because the same method can be repeated on a schedule, each inspection adds to a condition record over time, which changes the question from "is there a problem now" to "how is this pipe changing across inspection cycles."

Case Study: Inspection of an Operational Hydropower Facility

A large multi-unit hydroelectric project in India operates several generating units, each fed by an individual steel-lined penstock. The project includes four penstocks, which vary from 400 to 486m in length and are approximately 6.45 metres in diameter, operating under a water head of

about 140 metres. The operator required a comprehensive internal inspection of all the penstocks, with high-definition videography, profiling-sonar three-dimensional data, and ultrasonic thickness measurements at defined positions in order to access the present conditions of the penstock.

The inspection of the penstocks was completed within five days. The ROV was deployed from the dam top and navigated through each penstock to perform a comprehensive underwater inspection without the need for dewatering or personnel entry.. ROV was integrated with multiple underwater sonars including profiling sonar for continuous cross-sectional mapping and ultrasonic thickness gauge for wall thickness measurements at specified chainage and position. All inspection data including live video and sonar feeds, transmitted in real time to the surface control station, enabling the engineer in charge to monitor the inspection continuously. A comprehensive inspection report including hard copy documentation and digital report was submitted to support maintenance planning and asset integrity management .

Conclusion

A penstock is a structure where the cost of a missed defect is high and the cost of conventional inspection is also high, which is why so many penstocks are inspected less often than they should be. ROV-based inspection removes that trade-off. Configured with the right sensor payload, profiling sonar for geometry, ultrasonic measurement for wall thickness, and high-definition video for surface condition, it produces a complete internal assessment without dewatering, without downtime for personnel entry, and without putting anyone inside the pipe. Carried out on a schedule, it builds the condition history that turns penstock maintenance from a reactive exercise into a planned one.

To discuss an inspection programme for hydroelectric penstocks, contact EyeROV at info@eyerov.com or +91 6282 355 107.

About EyeROV

EyeROV (IROV Technologies Private Limited) is India's first indigenous manufacturer of commercial underwater ROVs, headquartered in Kochi, Kerala. EyeROV designs, manufactures, and operates underwater inspection systems for the oil and gas, hydropower, defence, maritime, and infrastructure sectors across India and international markets.

This whitepaper is prepared by EyeROV (IROV Technologies Pvt. Ltd.) based on field deployments conducted in India. Client and project details have been withheld.