Field Performance Test Experience using Ultrasonic Transit Time Flow Measurement in Penstock

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Abstract

This paper will present the results of a successful turbine performance test at Powell River Generating Station using acoustic flow measurement techniques. The paper will present a new application for flow and efficiency field measurement for turbine performance contractual guarantee tests using temporarily installed insertion flow meters with 8 cross paths.

Powell River Generating Station is located within Catalyst Powell River Pulp Mill site approximately 3 km north of the town of Powell River, British Columbia. The power plant is owned and operated by Power River Hydro LLC. The station has one Francis turbine operating under a rated net head of 50 m (gross head of 52 m). The hydroelectric station was commissioned in 1912 by Catalyst Paper Mill, then was acquired by Brookfield renewable 2001. Unit # 1 was upgraded in 2016-2017 with new turbine runner.

This paper will describe an application to measure the turbine flow and efficiency using acoustic flow meters without spending the capital to purchase and install the acoustic flow-meters. The application is as accurate as permanently installed acoustic flowmeters and can be used for stations with multiple units without the permanent installation of the acoustic flow-meters. This methodology is suitable for contractual guarantees field tests and operation optimization field performance tests for a hydroelectric turbine with a penstock that is suitable for pressure-time method or the acoustic method. The owners who do not intend to install permanent acoustic flow measurement devices can utilize this methodology for field tests in an economic manner.

The paper will describe the test preparation, test setup, actual tests, test results, and uncertainties.

1. Introduction

Industry experience has shown that some permanently installed Acoustic Transit Time flow measurement devices stop working after 5 to 9 years. This is mainly due to failures of the flow measurement controllers in which they become faulty and need replacement or upgrade. Often times, since this equipment is not critical to station operation, owners do not carry out the needed upgrade or maintenance. For existing turbine units that have never undergone performance testing, executing turbine performance testing is best practice to establish existing performance and condition. This pre-upgrade performance can be used to establish accurate requirements and economics prior to executing the upgraded turbine project. For the upgraded unit, the post-upgrade performance testing is used to verify manufacturing guarantees, establish as-built performance and creating accurate operating tables. This performance is usually compared to post-upgrade performance for economic analyses and to determine the new turbine as built performance to verify if the turbine manufacturer contractual guarantees have been achieved.

The Powell River generating station was originally placed into service in 1912 and is situated within the Catalyst Powell River Pulp Mill project site approximately 3 km north of Powell River, off Marine Drive (Highway 99). The Station is fed through 440 m of penstock from its origin at the Powell River dam. The single supply penstock leads to G1 and discharges into a common tailrace shared with the adjacent G5 prior to discharging to the Pacific Ocean. The tailwater level is tidally influenced.

A test at the Powell Mill plant was initiated through discussions between Powell River Energy Inc. (PREI) and BC Hydro associated with PREI's proposed plant upgrades. PREI retained BC Hydro Engineering to conduct pre- turbine upgrade efficiency tests on three of its units. During the time of this test, the original five units were reduced to only three operating units. Later the number of units is reduced to a single unit, however at the time of these tests, three units were operational and tested.

In 2004, Rittmeyer Risonic 2000 acoustic transit time flow meter instrumentation was installed with 8 cross-paths.

BC Hydro carried a pre-upgrade performance test on Unit 1 using the 8 cross path Acoustic Transit Time flowmeter installation in March of 2006. The BC Hydro test report indicated that the test was in accordance with IEC 60041 (73 test runs). After the test, the Rittmeyer flowmeter was removed out of service including the transducers, controller, cables and transducer holes on the penstock were capped (16 penetrations).

Following completion of the Unit 1 overhaul and runner replacement in 2016-2017, a post-upgrade performance test was carried out by HydroPower Performance Engineering (HPPE)[1] on March 8-10, 2019. The purpose of this test was to confirm the Manufacturer's Contractual Guarantees and determine the overall unit and turbine operating characteristics after the unit upgrade (and compare against contractual guarantees). The acoustic method was used to compute the turbine performance. The post-upgrade performance test will establish a performance benchmark for the upgraded unit.

2. Performance Test Objectives

The performance testing objectives for the post-upgrade testing conducted in March of 2019 are as follows:

2.1. Confirm the Manufacturer's Contractual Guarantees
2.2. Determine the overall unit and Turbine operating characteristics and Water to Wire Performance at High and Low Tide.

3. Performance Test Preparation

The steps undertaken to prepare and execute the test are summarized briefly below:

3.1 Prepare test procedure that was approved by all stakeholders.
3.2 Prepare all measurement instruments required for the performance tests (generator output, head water level, tailwater level, draft tube exit pressure elevation, pressure elevation at turbine entrance, scroll case differential pressure, servomotor stroke, and wicket gate angle opening).
3.3 Preparation for flow measurement:
- 3.3.1 Design and fabricate adapters to fit in the existing penstock holes to insert KGS-HPPE acoustic instruments (Deltawave made by Systec-Controls – Germany). Refer to Figures 1 – 3 below for photos of the plugged penstock instrument taps and the new adapters for field measurements.
- 3.3.2 Unit shutdown and dewatered, install scaffolding to install the adaptors, valves, instruments, and verify measurements and survey.
- 3.3.3 After installing all 16 acoustic instruments (8-cross paths), measurement was made between the instruments and pipe diameters to determine our instrumentation parameters for the flow measurements and determine the differences between our measurements and the previous BC Hydro survey. See Figures 4 and 5 for details on the layout of the instruments.
- 3.3.4 Check instrument signals, direction, signal quality.
- 3.3.5 Remove scaffolds and close up the hatch to penstock.
- 3.3.6 While the unit is shut down and dewatered, inspect piezometer taps, measure cross-section area at piezometers at the turbine entrance, calibrate stroke and gate, install power-meters to measure generator output.
- 3.3.7 Using an acoustic transit time flowmeter in exactly the same setup will reduce the systematic uncertainties.
- 3.3.8 Water up the unit, then under static conditions, test the acoustic quality and acoustic velocities between each path.

[1] HPPE was acquired by KGS Group in September 2022.

Figure 1: Plugged Acoustic Instrument Penstock Tap.

Figure 2: Adapter and Valve Installed on the Original Acoustic Instrument Tap.

Figure 3: Acoustic Instrument Installed Through the Valve.

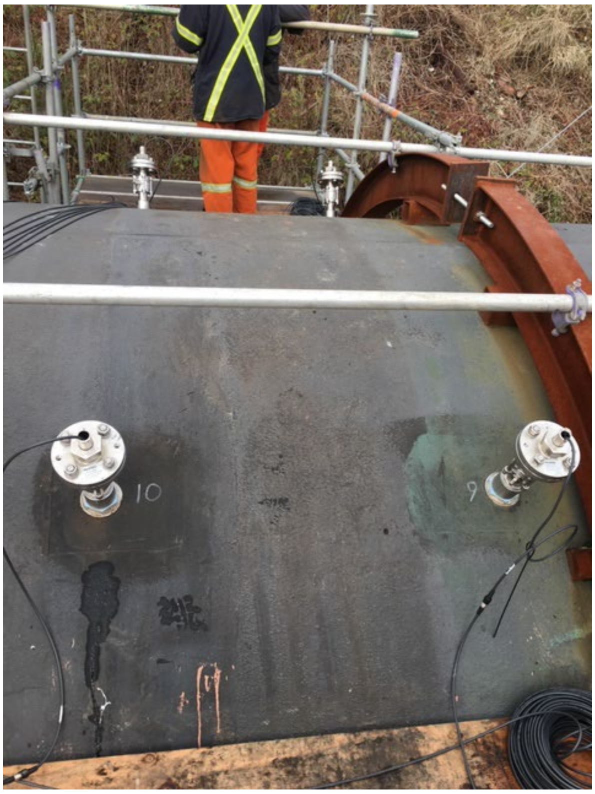

Figure 4: Acoustic Instruments Installed on Penstock.

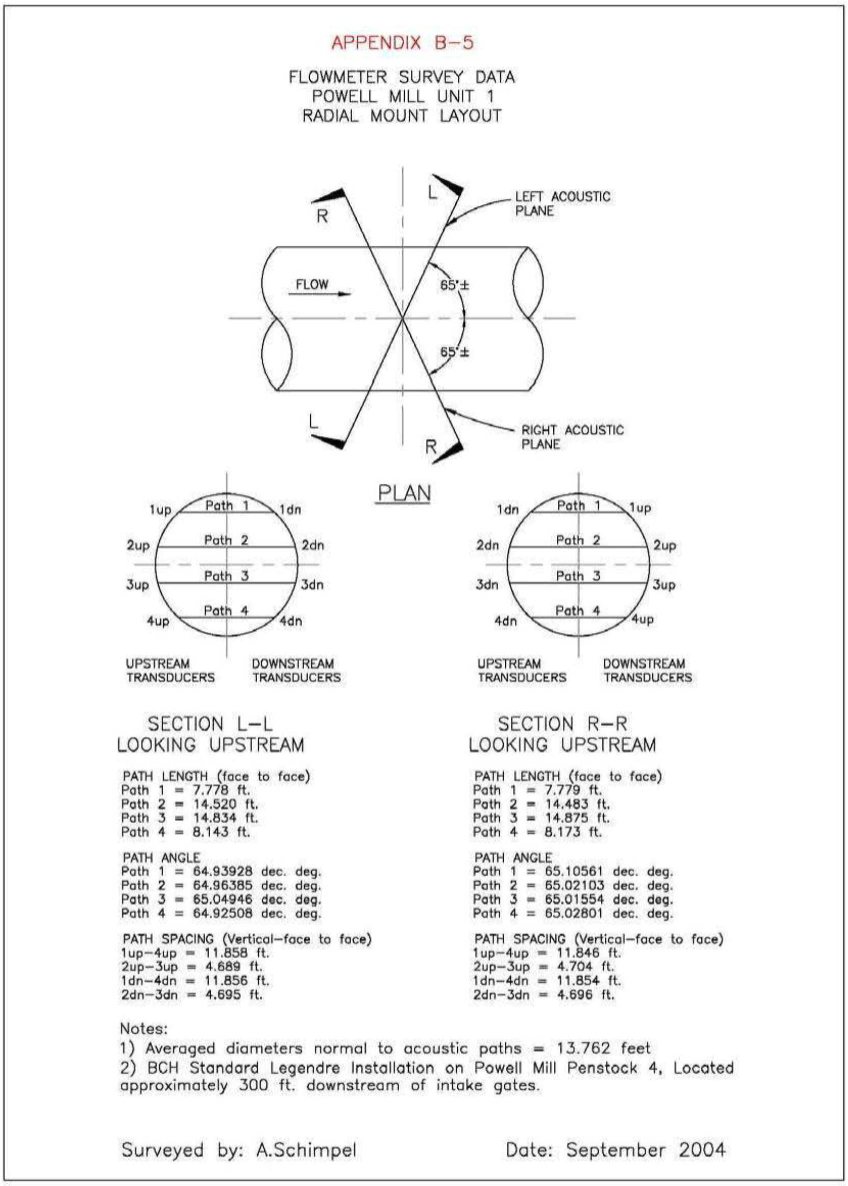

Figure 5: Acoustic Transit Time Survey of the Rittmeyer Transducer Installation from 2004 (Source: BC Hydro, 2004).

4. Performance Tests

Two Performance tests were carried out at tail water high tide and also at low tide. Average water level results were based on averaging the high tide and low tide heads. The tide changes multiple times a day and the tests correspondingly alternated between high and low tide scenarios. The tests were carried out between March 9 to March 11, 2019. 42 test runs were conducted under high tide conditions, and 43 test runs were conducted under low tide conditions.

5. Performance Test Results

The test results presented in Figure 6 show the high tide, low tide, and average head test results compared to the turbine manufacturer guarantees. Interpretation of the testing results is provided in the following section.

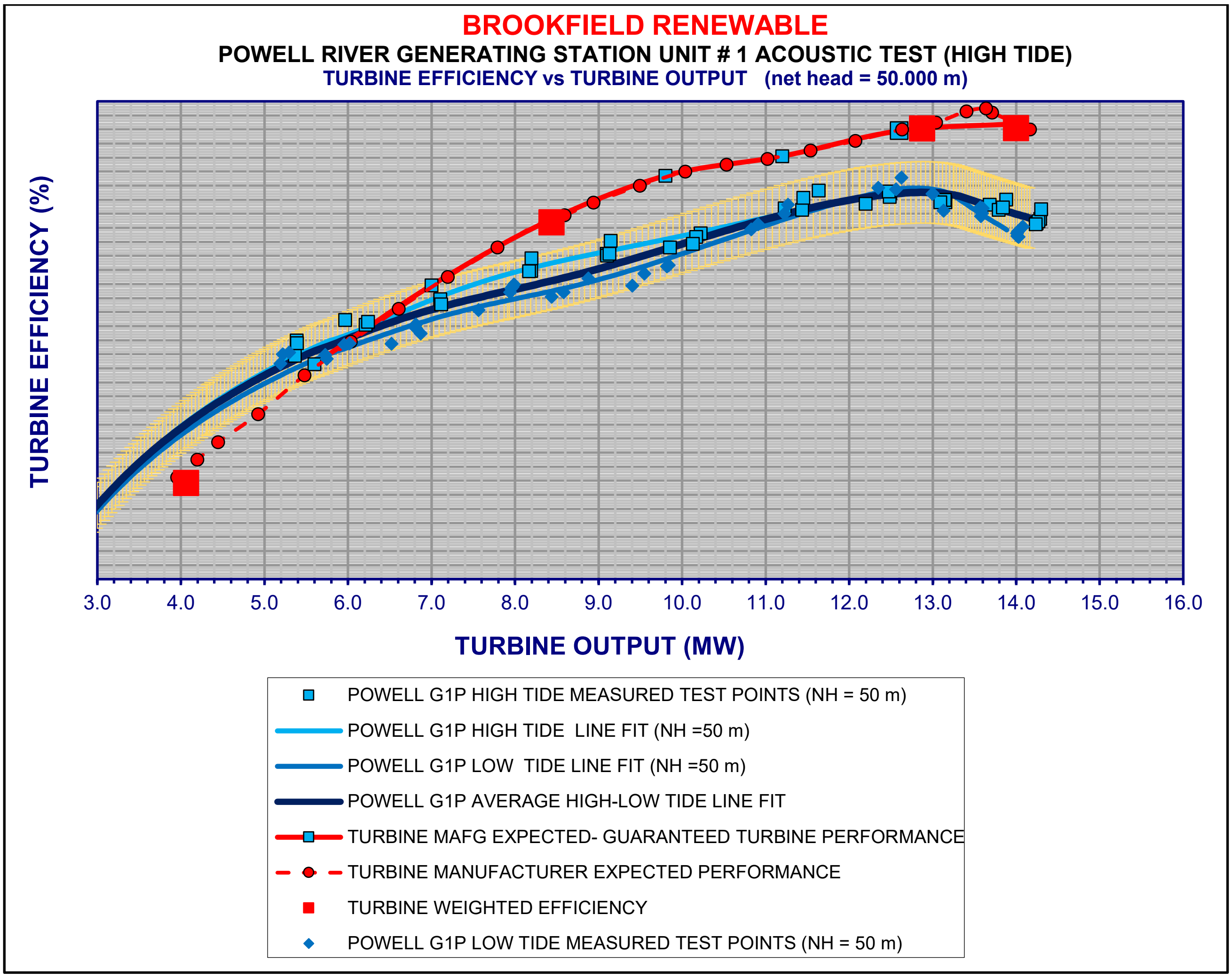

Figure 6: Test Results and Comparison between Actual Turbine Results VS. Turbine Manufacturer Expected Performance and Contractual Weighted Efficiency Guarantees.

6. Performance Test Conclusions

The conclusions from the March 8-10, 2019 tests on the overhauled unit are summarized as follows:

6.1. The turbine results showed that the turbine manufacturer did achieve the contractual guarantees for maximum power output of 14.0 MW. The unit produced 14.181 MW at the rated net head of 50.0 m. This was an overall capacity gain of 2.53%.
6.2. The turbine test results showed that the turbine manufacturer did not achieve the contractual guarantees for turbine efficiency, turbine weighted average efficiency, and the unit weighted average efficiency.
6.3. The performance test determined that the turbine efficiency at rated turbine output of 14.0 MW with difference of (-6.32%). The performance test determined that the turbine efficiency at rated turbine output of 14.0 MW with difference of (-4.22%).

The turbine test weighted average efficiency was lower than the turbine manufacturer guarantee with a difference of (-4.32 %).

7. Acknowledgements

7.1 Thanks to the management and the staff of Brookfield Renewable for their support to complete the test successfully.
7.2 Thanks to Systec-Controls for their assistance in the design and technical support for the instrumentation setup and reviewing the measurement parameters.

8. References

7.1. IEC 60041
7.2. BC Hydro 2006 Performance Test