Lessons Learned

The Case of the Broken Governor Link Pin

All was quiet at the hydro plant, a two-unit facility with Francis turbines. The daytime operator was filling in his log book, noting that both units were operating between 80 and 85 percent of full load, their usual daytime winter peak.

Suddenly, there was a loud explosion, followed by a rattling sound. Looking out through the control room window into the power plant, the operator was amazed to see a stream of water emerge from the access passage in the concrete plinth supporting Unit 2's vertical axis generator. A second or so later, a jet of water shot up from the valve pit with such force that it impacted on the flat powerhouse roof and showered back over most of the powerhouse floor.

The operator, after a few seconds of bewildered paralysis, shut down Unit 2, and moved the turbine valve control to the closed position. Water continued to flow unabated. The operator then shut down Unit 1, and opened the main breaker in the adjacent substation to disconnect the power plant from the transmission line. A second attempt was made to close Unit 2's valve, to no avail. Water continued to flow out of the valve and turbine pits on Unit 2 with such a volume that the power plant was beginning to fill with water. The operator then decided it was time to shut down the station service power and leave the building. He attempted to leave the control room through a rear emergency exit door, only to be confronted with a steeply sloping ice glacier down to the river. Turning around, he ran through the sheet of water cascading off the roof and out into the yard, pausing only to open the main door by a meter to allow the water to flow out and on down into the river.

His next task was to shut off the flow of water to the power plant. The two units were connected through a short steel bifurcation to a tunnel, at the upper end of which there was an intake equipped with a simple bulkhead gate on a manual hoist. With two assistants, he drove to the intake and quickly found that the bulkhead gate would not close against flow, despite adding concrete blocks to increase the weight. It took several days to locate, rent, and bring a pile driver to the intake, which was used to pound the bulkhead gate closed.

After the water flow was shut off, a detailed inspection of the remains of Unit 2 was conducted to try to determine the accident's cause. The unit's steel spiral casing, which was partially embedded in concrete, was split apart at the top. The center section, along with the headcover, had lifted off the wicket gates, and the stay vanes had failed at the top intersection with the casing. The wicket gates, with no top support, had been lifted out of their lower bearings and thrown into the rotating Francis runner, which was totally destroyed. The split in the spiral casing continued upstream to the valve, distorting the valve casing and preventing the butterfly valve from closing.

But what had caused all this destruction? The split casing indicated a large overpressure. The only cause could be a "slam" closure of the wicket gates resulting in an instantaneous waterhammer. An examination of the governor revealed a missing pin in the levers and links connecting the oil servomotor to the turbine speed ring, which controls the wicket gates. Removal of the pin would free the wicket gates to close instantly.

But how had the pin been removed? It was a steel pin of 5 centimeters in diameter, with a flat flanged head. It was retained in place on the bottom by a washer and split cotterpin. It was reasoned that the only explanation was for the pin to have been installed upside down, which would have prevented it from falling free by the cotterpin. The unit was only two years old, and, over this time, the cotterpin must have worn through and broken, resulting in the pin falling out and causing the slam closure of the wicket gates. This failure scenario was confirmed when the operators mentioned that they had noted the presence of the cotterpin on the top of the pin when cleaning the governor.

I suspect that, after reading this far, you're asking "How could a simple pin in a linkage be installed upside down?" This was never satisfactorily answered. It is probable that the links were assembled upside down, and then attached to the governor and wicket gate speed ring. The important point here is that the utility purchased and installed the second unit, without the benefit of the manufacturer's supervision. The unit was small, with a runner throat diameter of less than 1.1 meters; hence, the utility reasoned that, with the experience from observing and participating in the erection of the first unit, erection of the second could be undertaken without assistance. Yes, it was installed without difficulty, but with one vital part placed incorrectly.

Unit 1 was back in operation within a month, after a dished head was temporarily bolted onto the bifurcation to replace the damaged valve on Unit 2. Cleaning up and drying out of the power plant and equipment was simple because no oil had contaminated the flood waters. However, due to the extensive damage, repairs and replacement of Unit 2 equipment required nine months.

Lessons learned: First, all power plants should have an emergency "backdoor" exit whereby an operator can exit the powerhouse without having to walk past the unit(s), and can use it in all circumstances. This power plant had such an exit, but it was no use in winter due to the steeply sloping, ice-covered rock immediately outside.

Second, when a plant is in a remote area and construction equipment is not readily available in an emergency, a wheeled gate capable of closing against flow may be needed instead of an intake bulkhead gate.

Third, any unit assembled on site should be inspected by its manufacturer prior to commissioning. In this case, a manufacturer's commissioning inspection likely would have caught the error and prevented the accident.

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