Broken turbine headcover bolts.

By

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Tom and George were sitting at the “coffee shop” set up on the generator floor of the large low-head 4-unit powerplant. They were enjoying a late evening coffee break from installing new control cables for the governors. Suddenly there was a rumble, the floor shook, and a loud explosion preceded the sound of rushing water. George ran over to the stairway leading down to the turbine floor between Units 1 and 2, where he was astonished to see white water rushing past. Turning to Tom behind him, he yelled “Something’s burst – trip the headgates”.

Tom ran up to the control room, only to meet Bruce, the plant operator coming down the stairs, where he repeated the instructions. Together they ran into the control room and pressed the large red emergency close buttons for the headgates. George entered the control room and advised that the plant had flooded to tailwater level, with oil in the water and that station service power should be shut off to all levels below the generator floor. The control panel, awash with red lights, indicated that Unit 1 had started to trip from excessive vibration, and that the wicket gates had failed to close. On the other three units, the wicket gates had closed normally. The phone rang, Bruce answered and advised central control that there had been a serious accident, probably on Unit 1, the powerhouse was flooded, and that oil appeared to be floating on the water within the powerhouse.

Equipped with flashlights and waders, Tom and George attempted to investigate the accident, only to discover that the water was too deep. Preparations were made for a more thorough investigation in the morning. Next day, a couple of inflatable boats were launched, but all that could be determined – from the direction in which cabinets and other equipment had been hurled, was to confirm that the burst had occurred in Unit 1. The repair crew arrived, and installed the draft tube gates. The powerhouse submersible sump pumps were used to dewater the plant, after by-passing the controls at turbine floor level, which were submerged.

With the plant dewatered, a thorough inspection was undertaken. Damage to Unit 1 was severe. The turbine headcover had ripped open, apparently from failure of the outer headcover studs. One side had remained in place, while the other side wad lodged up against the lower generator bracket. About half of the wicket gates had lifted with the headcover, were bent, and lodged against the upper ring of the stay vanes. Governor piping had been sheared apart by the headcover, and the servomotors were destroyed, hence the oil leak. The 6.5m diameter runner blades had severely scored the throat ring, the generator bearing pads and stator windings were severely damaged, but fortunately, with the generator guide bearing remaining intact, and the runner acting as a crude bearing, the rotor had not contacted the stator.

On the lower floors, the force of the rushing water had pushed anything not securely bolted down, along the floor to smash against the far wall at Unit 4. Walls, floor and everything else was covered with a thin layer of oil. The floor was extremely

slippery. Very fortunately, there were no injuries. Earlier, during the day of the accident, a large crew had been working in the lower floors replacing water piping. In the evening, the electricians had been on their coffee break – it was a miracle that no lives were lost.

But what had happened. The investigation was long and extensive. Fortunately, the 25-year old records of the installation and commissioning work were still available. From these and the SCADA data, along with an examination of the ruptured parts, it was concluded that the break had initiated at the outer studs connecting the headcover to the stay vane ring. About 13% of the studs had cracked through, and the surfaces were found to be well rusted. Another 51% had rusted fatigue cracks and fast fracture failures. The cracked and failed studs were grouped together, around the upstream half of the headcover.

The stay vanes in the area below the cracked studs had a history of vibration, and had been reinforced with cross-vanes a few years after the plant was commissioned. The installation records indicated that the studs may not have had the correct torque applied. At the time of the rupture, the unit had been operating at near speed-no-load, and the break occurred when the unit started to load, and the wicket gates moved open. This was the “straw that broke the camel’s back” adding one more load cycle to the headcover, on failed studs, with adjacent studs on the verge of fatigue failure, and failure occurred.

Cleanup and repairs required 18 months for Unit 1. The other units were returned to service earlier, after installing larger studs on the headcovers.

Lessons learned.

There are many. The first, and most obvious, is to install submersible dewatering pumps with all controls and power routed to a cubicle above tailwater flood level. Another lesson is to split the station service power, to power floors above tailwater in a separate circuit from floors below. It required some time to cut circuits to the lower floors, before lighting and heating could be restored.

But the principal lesson is to regularly check any bolts or studs under stress. At this plant, the headcover is split in two, with the outer headcover only removed when the wicket gate bearings need repairs. And this had never been necessary. Only the inner headcover was lifted on runner removal. As a result, the outer headcover bolts had never been removed nor checked, and this is the usual practice in powerplants. It would be a simple precaution to check such bolts about once every five years. If the bolts had been checked, the broken studs would have immediately been found, and an investigation started. In fact, except for two, all the broken studs were found and matched to the pieces in the bolt holes, from which it was deduced that the broken studs could have easily been lifted out by hand!

Immediately after the incident, the utility started a practice of torque-checking a small percentage of all headcover bolts and studs every few years.

A description of the incident was included at the last minute during a hydro conference coincidentally held a few days after the accident. It was revealing to see many of the attendees walk out to call their offices, and instruct their staff to start checking bolts.