‘Balancing’ a Generator at a Hydro Electric Plant

Just two years after installation of a new turbine-generating unit at the 93-MW Thompson Falls hydro project, PPL Montana LLC noticed increasing vibration values on the generator guide bearing. After several unsuccessful attempts to correct the problem, plant personnel adjusted the clearance on the guide bearings. Since that work was completed, the unit has operated within acceptable vibration values.

Discovering the problem

The Thompson Falls project on the Clark Fork River in Montana began operating in 1917 with six turbine-generating units. At that time, capacity of the project was 40 MW.

In July 1993, PPL Montana began construction on a second, underground powerhouse that would contain a single 53-MW unit. This unit was added to meet growing electricity demand and to better utilize the flow of water coming down the river. The new turbine is a four-bladed, vertical-shaft Kaplan unit manufactured by Kvaerner Turbine AB. The generator, manufactured by Sade Vigesa, is cooled by eight water-cooled radiators.

The new unit was equipped with four vibration proximity probes, two at the generator guide bearing and two at the turbine guide bearing, as well as one axial vibration probe on the rotor shaft. The probes were supplied by Bently Nevada. PPL Montana installed the probes to obtain baseline vibration readings on the new turbine-generator and determine if the unit needed balancing. The probes also would allow on-line condition monitoring of the unit’s vibration.

Values from these probes are imported into multiple systems, including: a Zero Outage On-line Monitoring (ZOOM) system supplied by VibroSystM; a readout display in the control room, supplied by Bently Nevada; and the plant control system (PCS) computer.

PPL Montana also installed an air gap monitoring system from VibroSystM on the unit to provide baseline readings of the generator air gap during start up and initial operation. The system also is being used for continuous condition monitoring of the true dynamic shape of the rotor and stator, along with the generator air gap.

Commissioning began in September 1995, and the unit began commercial operation in December 1995.

During start up, values measured by the five vibration probes were in the 3-4 mil range on both the generator and turbine guide bearings. Based on these readings, PPL Montana personnel determined that neither the turbine nor generator needed balancing.

After two years of operation, vibration values on the generator guide bearing began to creep up. By 2000, these values were around 10 mils and climbing. Over this same time period, the turbine guide bearing vibration did not show much change.

Because the diametrical clearance for this generator guide bearing was 10 mils, the alarm point on the PCS originally was set at 7.5 mils. (Industry practice says to limit vibration in a bearing to 75 percent of the diametrical clearance.) Over the years, PPL Montana consulted with the generator manufacturer and repeatedly moved up the vibration limit. The vibration limit was increased to 8 mils in 1998, 10 mils in 2000, and then 12 mils in 2001.

Measurements of diametrical clearance (see arrow) on the generator guide bearing on a unit at 93-MW Thompson Falls revealed the clearance had doubled over seven years of operation. Adjusting the bearing back to the original clearance solved a problem with extreme vibration.

During this time, the air gap monitoring system was producing alarms that indicated the unit was approaching minimum air gaps. PPL Montana attributed part of the air gap problem to a lack of clearance between the stator shell and some of the stator hold-down bolts. This clearance condition prevented thermal expansion at these locations, which caused the generator stator to become egg-shaped during operation. This decreased the air gap between the rotating rotor and stator.

Attempting multiple solutions

PPL Montana tried or considered many methods to solve the problem with the generator guide bearing vibration.

PPL Montana initially thought the cause of the vibration problem was due to the stator becoming more egg-shaped. Plant personnel surmised that as the rotor rotated and the field poles came closer to the stator in places and farther away in others, the magnetic forces were stronger when closer and weaker when farther away. This situation could cause a

vibration problem. In September 2000, PPL Montana returned the rotor to circularity. However, the vibration values continued to climb.

Next, PPL Montana consulted VibroSystM personnel, the original generator erector (Brian Young with Hydro Help), and the generator manufacturer. Young and VibroSystM personnel suggested PPL Montana attempt to balance the rotor by adding a prescribed amount of weight at a calculated specific location. During annual maintenance performed in 2001, plant personnel attempted many "balance shots" on the rotor. Each attempt at balancing involved adding a different amount of weights to the rotor to change the vibration. This requires many mini-outages because the generator must be taken off line to a complete stop, the weight applied, and then the unit put back on line to determine if there is any difference in vibration. However, no significant improvements could be made in the vibration readings. At this time, the vibration values were 10 to 12 mils.

Because extra water was coming down the river and the generator was needed, PPL Montana decided to run the unit for another year. This would give personnel time to plan for the following year's maintenance outage. Although there were some risks with running the machine for another year with such high vibration, PPL Montana closely monitors bearing temperature, and an alarm indicates when temperature rises above a specific value. PPL Montana also consulted with the generator manufacturer.

Adjusting the guide bearing clearance

During the next year's maintenance outage, PPL Montana decided to inspect the generator guide bearing.

PPL Montana asked Young to be on site during this work, which was performed in September 2002. Plant personnel removed the cover from the guide bearing and removed one guide bearing pad for inspection. No problems were found. The guide bearing showed normal wear patterns, and the journal still looked like new.

The next step was to check the clearance between the bearing pads and the journal on the generator shaft. To avoid losing the original center established during construction and to keep the shaft from moving when readings were taken, Young blocked the shaft. Readings were taken using a feeler gauge between the adjusting stud and the back side of the pad, around the entire bearing assembly. This particular bearing had ten pads, so four were used to block the shaft and the other six were measured. Based on these measurements, Young determined that the diametrical clearance had increased to about 20 mils, or double from the original installation.

Plant personnel then adjusted the bearing back to the original clearance of 5 mils per side or 10 mils total diametrical clearance. This was accomplished by loosening the lock nut and adjusting the stud that pushes on the bearing pads. The unit was put back on line, and

immediately the vibration dropped drastically, back to what originally was recorded during start up and commissioning of the unit in 1995 - 3 to 4 mils.

Before deciding that the problem had been solved, Young wanted to ensure that the unit did not have a balance problem that was being masked by tightening up the clearance. He placed a dial indicator between the upper bracket that held and supported the generator guide bearing and the concrete wall that encased the generator barrel. The dial indicator showed a maximum of 1 mil of movement, so Young determined that the high vibration values had indeed resulted from the bearing clearance increasing and allowing the shaft journal to skate around within the bearing opening.

Results to date

Since September 2002, the generator vibration has not increased and is still reading in the 3-4 mil range.

PPL Montana used this method of adjusting the generator guide bearing again in 2001, when vibration checks performed on Unit 1 at the 198-MW Kerr project during an index test showed vibration of 10 mils or greater. Again, PPL Montana adjusted the generator guide bearings on that generator in October 2003. The company brought Young in to assist with the problem. In a similar fashion, PPL Montana adjusted the bearing back to the original specification based on the original equipment manufacturer's drawings. When personnel from PPL Montana and Stan Bognatz with M&B Engineered Solutions checked the unit's vibration again in 2006, it was down to 3 mils.

Based on these experiences, PPL Montana learned that when vibration starts trending up, it is time to schedule a bearing inspection and clearance check. While there might be other reasons for an increase in unit vibration, it seems prudent to check the clearance on the bearings earlier rather than later.

by Gary W. Peterson, Senior Hydro Engineer, PPL Montana LLC