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Lessons Learned

When Governors Govern

After two years of hard work, all was ready to commission a two-unit Kaplan hydro facility adjacent to a remote town. The town's residents eagerly anticipated the electricity to be generated by the hydro facility. They had been purchasing power generated using oil-fired diesel generators, which resulted in high electric utility bills. The system was commissioned without difficulty, and the diesels were shut down. All went well for a few hours, until the hydro plant shut down!

A check of the hydro plant instrumentation indicated that the system frequency had dropped below 90 percent of synchronous frequency. This resulted in actuation of the under-frequency relays, which caused the hydro plant to disconnect from the grid. The plant engineers were puzzled, because all instrumentation and controls had been thoroughly checked during commissioning. By process of elimination, it was decided that something must be wrong with the governors. These were checked, and open and close times verified at an effective four seconds. They appeared ready for service. Nothing had been found to explain the shutdown, so the units were started and connected to the grid. The diesels were shut down. Again the hydro plant disconnected a few hours later due to under-frequency.

This time the engineers decided that there must be something fundamentally wrong with the governors. An expert from the governor manufacturer was flown to the site to test the governors. A minor adjustment was made to the dashpot return time, but nothing could be found to explain the shutdowns. It was decided to restart the units and to maintain a close watch on the instrumentation.

The same shutdown was again experienced a few hours after start up. (By this time, comments from the residents had become unprintable.) This time, the operator watching the kilowatt output meters had observed a sudden increase in load on the generators immediately prior to the shutdown. The governor expert, sitting patiently beside the governors, reported that the governors started to open the wicket gates of both units, and after a few seconds, reversed direction to close the wicket gates to the speed-no-load position at about 20 percent gate opening. (This was in the days before multi-channel recorders.)

This indicated that a major load was being dumped suddenly onto the system, with the load being sufficiently large to cause the frequency to drop below 90 percent of synchronous frequency. No one could imagine where this load was coming from; the town load was entirely residential, with some commercial and no industrial load. Accordingly, it was decided to run the diesels and conduct an inspection of all commercial loads. Nothing was found until the engineers arrived at the hospital, where the oil-fired hot water boiler had been converted to electricity with a 4,000-KW heating element.

In order to increase the load on the hydro plant, the utility had provided a very attractive rate for secondary energy to the hospital as an inducement to convert the boiler to dual energy. The sudden imposition of a 4,000-KW load onto the grid was simply too much for the 11,000-KW power plant. The governors could not act fast enough to prevent a large drop in frequency. The problem was overcome by dividing the element into four 1,000-KW units and adding a timer to delay actuation of each unit by 60 seconds. No further problems were encountered.

Large frequency deviations are usually associated with small isolated hydro systems, where governors do govern. At hydro plants connected to large systems, the governors rarely move the wicket gates during normal operation, output is steady, and frequency drifts slowly up and down around synchronous frequency, with a deviation of less than one-tenth of a cycle. On rare occasions, there is a major disruption to the system caused by a transmission line overload or an outage of a power plant. On such occasions, the disruption to the power supply causes a major frequency drop that can result in a cascading failure to spread over the entire interconnected system, as happened recently in the western United States.

With small hydro systems, frequency variations are common, and, depending on the nature of the load, can vary by two or three cycles around synchronous frequency. The worst type of load for a small system is an electric arc furnace where the make-break load is irregular and can create havoc. Even a small 10-MW arc furnace can bounce around a 100-MW system, particularly if the furnace is near other loads and far from the power plant. If arc furnaces are the major load on a hydro system, the resulting frequency variations are often so large as to render the electric power useless for other loads. Other causes of major frequency variations are electric-powered open pit mine shovels and hoists on deep mines.

The lesson learned: the nature of the load must be taken into account when designing a hydro plant, since a hydro plant governor cannot respond instantaneously to variations in load. An improvement in response to load change can be achieved by shortening governor time and increasing generator inertia. But there are limits to both.

Another approach to limiting frequency variations is to use electronic controls to even out the load by switching in hot water heaters when there is a drop in load. Or a motor-generator connected to a large flywheel can be installed to act as an energy battery.

A third alternative is to keep a diesel running on a predominantly hydro system. The fast acting diesel governor can smooth out the frequency variations more effectively than relatively slow hydro plant governors.

At present, there is a major increase in the construction of small hydro facilities around the world. Where the hydro systems are isolated and built to supply an industrial demand, the nature of the load must be taken into account in the design of the hydro plant.

— By James L. Gordon, B. Sc., hydropower consultant. Please send your stories of events, both serious and amusing, to HRW *so that we all can learn from — and hopefully avoid — accidents, errors, and omissions in future hydro-related work.*