HUNTING KAPLAN TURBINE

A new 5 MW Kaplan unit had just been added to the small, remote 50 MW power system, where about two-thirds of the power was being supplied by five small hydro plants, and one-third by diesels fueled with high-cost oil. With the recent addition to the system and a drop in load due to the closure of a mine, the system operators were now in a position to shut down the diesels and lower the cost of power.

The diesel plant had four units, and only one was operating. It was shut down and for the first time in about 20 years the plant was silent. Shortly after the diesel shut-down, the operator in the system control center noticed that the system frequency was starting to wander up to about 61 cycles and then down to 59 cycles. Slowly the frequency deviation widened to plus or minus two cycles, the wander assumed a cyclic pattern and it became apparent that the system was hunting between 58 and 62 cycles. Concerned that the frequency deviation might increase, the system operator started a diesel, placed it on line, and shortly thereafter the frequency deviations ironed out to the normal half cycle. He then called the utility engineers to look into the problem.

Next day, in the presence of the utility engineers, the diesel was shut down, and the same frequency wander was observed. The hydro plants had not operated on frequency control since the diesel units had started up, twenty years ago, and as a consequence, the hydro plant operators had damped down the dashpot return times on the mechanical hydro governors, and changed the governor droop settings, all in an effort to keep the hydro plants on the base load, leaving the quick-response diesels to control the frequency - as a result, the system was far from an optimum setting, particularly when the diesels were off line, hence a wander about 60 cycles could be expected. A governor expert was brought in, the system was analysed with the aid of a computer program, and all hydro governor droop settings and dashpot return times readjusted to the optimum for frequency control. After this effort, all were surprised to observe that the hunting persisted whenever the diesels were off, particularly since the system was stable with the same hydro plants operating 20 years ago, prior to bringing the diesels onto the system.

To try and isolate the cause of the hunting, the hydro plants were each in turn shut down over a low load period at night, and to everyone's surprise, the new 5MW hydro plant equipped with an electronic governor was found to be the cause of the problem. With the new plant off line, the system was stable, even without the diesels. The turbine and governor manufacturers for the new plant were called in, the turbine and governor were checked, but nothing could be found to explain the hunting. The new unit was started up and the manufacturer's engineers observed the unit's operation as the system began to hunt - and after some time, it became apparent that when system frequency fell below 60 cycles, the governor would open the wicket gates by a small amount, and shortly thereafter the gates would close slightly and the reverse would occur on higher frequencies. The new unit appeared to be hunting at a frequency which apparently matched a natural hunting frequency in the system - in other words, a small kick from the unit at the right instant was all that was required to start the whole system hunting.

The unit was stopped, dewatered and the governor times checked. All were found to be as specified, with open and close times set at 4 seconds. However, the Kaplan blade angle open and close times were also set at 4 seconds, and it was realised that the hunting was caused by the blades, on an opening stroke, moving to a higher efficiency angle, which then called for the governor to slightly close the wicket gates. A phone call to the manufacturer's head office elicited the information that a Kaplan blade opening time should be set at four to six times the governor opening time, precisely to avoid hunting!. The runner blade opening and closing times were reset at 20 seconds, the unit placed on line and much to everyone's relief, the system operated as expected with only minor frequency deviations.

Lessons learned

In a post-mortem of the incident, the turbine manufacturer found that three other identical Kaplan units had been installed on other systems, all with runner blade movement times equal to the wicket gate movement times and none had exhibited the hunting tendency. However, the three other units were installed on large interconnected power systems with system capacities well over 1000 MW. The new Kaplan units were simply too small to affect the frequency. On a small isolated system, the small Kaplan unit was large enough to affect frequency, but this could not have been anticipated from past experience on a large system. And why was the blade time set close to the governor time? - perhaps this is a case which can be attributed to loss of experienced turbine designers on downsizing - there is not much written about Kaplan blade timings, only one or two lines in the odd text. However, the book "Hydropower Mechanical Design" published by HCI does have a warning on page 4-18 in a discussion on turbine dynamics, wherein there is the statement "If the blade timing is close to the timing of the gates, the movement of the blade may, in turn, result in a movement of the flow control point, and instability may result". Only an experienced Kaplan turbine designer would be aware of this characteristic.