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March 28, 1989

Mr. Lee H. Sheldon
Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208-3621

Subject: Completion of Contract DE-AC79-86BP64922,
Services Provided By Portland General Electric
To Evaluate Woodward Governor Index Test Box

Dear Mr. Sheldon,

Per this letter we are transmitting the final report which is intended to fulfill and satisfy all obligations of Portland General Electric regarding the subject contract and "Statement of Work" dated September 23, 1986. The report includes an overview of our experience on the project in addition to detailed analysis of all phases of recorded test data. As you know, evaluation of the Index Test Box was a joint effort between BPA, PGE, and The Woodward Governor Company.

In summary, we feel the evaluation proved that the Woodward Index Test Box provides an accurate, relatively simple alternative to conventional methods of completing index tests on Kaplan Turbines.

Sincerely,

Gary Hackett

Gary W. Hackett
Sr. Staff Engineer
Hydro Production
Contract & License Admin.

Attachments: Complete original report plus three copies

c: F. H. Lamoureaux w/o Attach.
Carolyn A. Richardson, BPA Contract Specialist w/o Attach.
D. R. Miller w/Attach.
Terry Bauman, Woodward Governor w/Attach
C. Hilbrick, City of Portland w/Attach

GWH/jw
M2/gwh/464

FINAL REPORT

Evaluation of Woodward Index

Test Box On

Portland Hydro Unit 2

September 1987 to February 1989

BPA Contract DE-AC79-86BP64922
With Portland General Electric Company

Report Assembled By: Gary Hackett

March 10, 1989

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Background

The index test box evaluation was completed on a 16,300hp, 12,500kVA Kaplan turbine-generator which was installed in 1982. The unit is owned by the City of Portland although it is operated and maintained by the Portland General Electric Company. The turbine was manufactured by The Fuji Company and the governor was supplied by Woodward Governor Company. The evaluation project was a joint effort of BPA, PGE, and Woodward.

Initial Setup

In order to use the index test box at PHP-2, it was necessary to remove the existing 2-D electro-mechanical cam and replace it with a 3-D electronic cam. It was also necessary to install several new input parameters to the Woodward Index Test Box.

The test box requires headwater level, tailwater level, gate position, blade angle, flow, and power inputs. To obtain the headwater level, we added a pressure transducer to the existing penstock taps. The blade angle was measured by adding a remote position transducer to the restoring shaft on the oil head. All the other inputs were readily available without the addition of transducers.

Operation

Overall, the index test box was very easy to use. The program was loaded using an IBM PC-compatible computer which takes about one-half hour to load.

The touch screen on the index test box provides a clear indication of each stage of a test. It shows samples and averages as each of the six inputs is sampled. When the blades move, it gives present value and desired value of voltage corresponding to the blade angle, as well as the percent above or below the on-cam position. After a blade movement, the box waits for conditions to stabilize before proceeding with the testing.

During this waiting period, all inputs must remain stable within user-defined limits for a fixed period of time. The screen has a counter which tells the operator how long conditions have been stable and which input was outside the limits if the count is not reached. When a test is complete, the operator is informed that the EPROM is being programmed. The screen then returns to a selection that allows the operator to either change the test parameters or start another test using the same parameters. All of the test parameters can be easily changed from the touch screen. Overall, the operators found the test box easy to use and to understand.

Comments and Suggestions

The plant we used for the test, for the most part, has a very constant headwater level, so we were not able to test the operation at widely varying heads. A major advantage of using a 3-D cam over a 2-D cam is the ability of the 3-D cam to take net head into consideration in determining the optimum blade-gate relationship. The index test box would prove even more valuable in optimizing a plant which operates with a varying head. We experienced a few problems during the testing, many of which were expected, as this was the first field test of the device. The original program had to be modified at the beginning as it was too large to be loaded onto the EPROM. An isolation amplifier was added when a Woodward serviceman noticed the box was causing a ground on a terminal that should have been floating. Woodward corrected these problems, and the index test box is now operating properly.

Overall, from an operational point of view, we were satisfied with the performance of the box.

Major Events Which Occurred During This Evaluation

Preliminary installation work consisted of mounting an RVDT and a junction box on the oil head, installing and calibrating the headwater transducer, and running circuits from each of these devices to the index test box which was accomplished before the Woodward engineers arrived on site.

Woodward engineer Terry Bauman and serviceman John Firnett were on site from September 14-18, 1987. During this time, they removed the mechanical 2-D cam assembly, blade tilt mechanism, floating lever, and adjustable restoring link. Then they installed the new electronic 3-D cam assembly, blade tilt assembly, vibrator assembly, power supply, and rack assembly. They also calibrated and adjusted all of the newly installed equipment. The test was then delayed as the unit could not be operated due to lack of water.

On October 9, still prior to operation, the newly installed power supply failed due to output transistors burning out. Our technician spent approximately 5 man-days troubleshooting the power supply problems, which appeared to be intermittent. After several trips to the shop and calls to Woodward, we isolated the problem to a "crowbar" circuit in the power supply. Woodward sent us a new power supply which we installed.

Bryan Walters from Woodward came out for the unit start-up on December 4, 1987. We felt it was necessary to have a Woodward serviceman on site because the unit had not been tested since the modifications were made in September. Bryan recalibrated the 3-D cam and adjusted the blade and gate cables to give accurate indication on the governor dials. He then ran new blade-gate curves and the unit was started without any problem.

December 11, Terry Judkins and Bert Evans (both with PGE) recalibrated the new headwater transducer, watt transducer, and the RVDT at the oil head. While they were at the plant, an operator pointed out a rapid movement of the gates. The gates would move approximately 5 percent above the on-cam position then 5 percent below the on-cam position, then settle back to the correct position. The whole movement took about 1 second. This problem had not existed before Woodward completed their governor modifications.

From December 14-18, Terry Bauman and John Firnett from Woodward were on site to start the index testing. Terry ran the inputs to the test box while John worked on finding the "glitch" (gate movement) mentioned above. John checked and cleaned the pilot valve, checked and cleaned the SSG, regapped the SSG sensor, and put some of the control wiring in conduit. We checked several of the modules for proper calibration and rechecked all of the new wiring as well as much of the original wiring in the governor control circuits. None of these changes solved the oscillating wicket gate problem. John noted that the SSG was grounded, but since many are designed to be grounded, didn't think it was a problem. Nobody at Woodward had any more ideas on how to find the "glitch".

Terry Bauman tried to load his program into the index test box, but found that the program was too large to fit on the EPROM. Terry and John returned to Wisconsin with the understanding that John would get more information and give us recommendations on solving the "glitch", and Terry would rewrite part of his program to use less space so we could load it onto the EPROM.

John Firnett called (approximately January 6, 1988) with some items to check in trying to locate the "glitch". We put a recorder on the power amp output, lifted a wire from terminal MA-19 to isolate the speed circuits, checked the output of all of the modules, and finally put a transient recorder on several signals. Woodward thought the problem was in the speed sensor card. We were unable to locate a spare card, but we needed one to determine if that was the problem. Woodward agreed to send a serviceman, at no charge, if a new speed sensor card didn't solve the problem. We purchased a new speed sensor card, but it didn't solve the problem.

Terry Bauman then sent a disk with the revised program on it. PGE loaded the program and tried to run a test, but couldn't get the program to record data on a disk. We received two more disks over the next several days and were finally able to start taking data.

On January 22, 1988, Dick Halderson from Woodward came out to work on the "glitch". After two days of testing, Dick removed the conduit running from the SSG to a junction box on the grounded portion of the unit. This removed the ground from the SSG and the "glitch" stopped. While Dick was testing various circuits looking for the "glitch", he noticed that the index test box was causing a ground on the 3-D cam at a point that should not have been grounded. He called Terry Bauman and after trying to clear the ground, told us to stop testing until we heard from Terry.

On January 31, Terry Bauman called. He had designed an isolation amplifier to be installed between the test box and the 3-D cam rack. Bryan Walters, from Woodward, came out on February 2 to install the isolation amplifier.

In February, the operator noted that at low power the unit would produce a power surge when a test was run. This was due to a program change that had been made earlier. The index box was releasing control to the governor when the blade-gate relationship was far from the on-cam position. At low power, the gates had to open wide to maintain a fixed power level when the blades were moved flat. When the test box released control to the governor, the blades would move to a position to match the wide-open gate, resulting in a power surge.

Terry Bauman modified the program to correct the problem amd to assure that the test box waits until the blade is within 5 percent of the on-cam position before releasing control to the governor. There is also a manual override available on the touch screen if the operator wants to release control before the 5 percent off-cam angle is reached.

On April 27, Lee Sheldon from BPA brought two members of his staff to the plant and we conducted a manual index test. The results of the manual index test (Attachment 1) were compared to the results obtained by the index test box (Attachment 2). It appears, from initial examination, that the unit is operating at near-peak efficiency throughout most of its range; however, at higher power levels, it could be improved by approximately 3 percent.

After this time, the bugs were worked out of the test procedure and the test box collected data without any problems. We continued running tests at some of the lower and mid-range power levels to fill in some gaps in the data after which the EPROM was sent to Woodward for analysis and development of a new control chip. The new control chip was received from Woodward in February of 1989 and installed to control the unit at optimum efficiency. The test box was disconnected and made available for testing other units.

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