Canal Flow Control Improvement in Central Valley
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Abstract:

The Friant-Kern and Madera Canals provide vital irrigation water to the Central Valley of California. Friant Power Authority (FPA) operates and maintains three powerhouses at Friant Dam, which is owned by the US Bureau of Reclamation. The original Hitachi mechanical positioner systems (circa 1983) were extremely complex, controlling not only the Kaplan turbine but multiple bypass valves to maintain flow. In 2003, FPA began suffering outages due to controller problems, which were extremely difficult to diagnose because of the complexity of the system and poor support from the manufacturer. In 2005, FPA embarked on a major controls upgrade to upgrade and simplify both systems, convert them to full governors, and integrate the functions of several other unit monitoring systems. This paper discusses the project, profiles the controls before and after, and summarizes the operational improvements and reliability gains realized.

Introduction

Friant Power Authority (FPA) owns and operates three powerhouses at Friant Dam 15 miles north of Fresno, California. Friant Dam was completed on the Upper San Joaquin River in 1942 by the United States Bureau of Reclamation (USBR) and created Millerton Reservoir. The dam is still owned and operated by the USBR and provides irrigation water to the Friant-Kern and Madera canals and maintains the water flow in the river. The three powerhouses were built in 1985 by a newly formed Friant Power Authority.

The powerhouses utilize the head to produce a total of 32.1 MW of generation. Friant has a 19.9 MW synchronous generator with a bulb turbine with variable blades and two automatically operated synchronous bypass valves. Madera has a 9.9 MW synchronous generator with a bulb turbine with variable blades and one automatically operated synchronous bypass valve. The River Outlet powerhouse has an induction machine capable of 2.3 MW and does not have a bypass valve. Overall, the water flow in the canals is of paramount importance, and power is a byproduct. The bypass valves at Friant and Madera are critical to the continued operation of the powerhouses themselves. In the event of a unit shutting down, the water that had been flowing...
through the unit must be automatically transferred to the valves and the total flow must remain constant. As an additional safeguard, all three powerhouses have valves that can be manually operated by the USBR that allows water to completely bypass each powerhouse.

**Definition of the Problem**

The existing Hitachi Hydraulic Controller is an exceedingly complicated mechanical positioning device that does no actual speed governing. It is a complex combination of mechanical actuators, hydraulic sequencing valves, links, levers, motors, cams and walking beams that, primarily, control the position of the wicket gates according to operator setpoint. In the event of turbine shutdown, these mechanisms automatically operate the synchronous bypass valves to assure that downstream flow to the canal is maintained at all times. The mass of link, levers, cams and other mechanical devices made the units difficult to maintain and support and parts were difficult to obtain. FPA had experienced several instances where water was available for generation but they could not get the turbines up and running for hours or days at a time. This lost revenue was a powerful incentive to update the systems. Additionally, the controller was solely a mechanical positioner and did not provide speed control. This made the unit very difficult to put on-line.

*Hitachi Hydraulic Controller*

One of the few pieces of modern equipment, an electronic 3D Cam, controlled the mechanical blade angle positioning subsystem according to stored curves and actual net head signal. A recent study indicated that the gate/blade relationship could be modified to improve efficiency. The existing equipment made these modifications very difficult.

The main control room is located at the Friant powerhouse. While some controls for the Madera unit were available in the main control room, several others were not. This required the operators to travel 2.5 miles through several gates to address issues at Madera. While at the Madera plant, the operators had no information as to the status of the Friant or River Outlet units.

The existing obsolete Rochester annunciator panels were difficult to repair and/or change. Several windows no longer worked and others had text that had been modified by hand.
Rochester Annunciator Panels

Explanation of the Solution

Unit Control

The solution required many layers, and included providing unit controllers, remote operation and new plant monitor panels. First, the unit controllers would be replaced. The new unit controller consists of Electro Hydraulic Interface (EHI), electronic speed and feedback devices, interposing relays, dual power supplies and two Programmable Logic Controllers (PLC’s). The Main PLC controls the gates and blades of the unit and automatically transfers the flows between the unit and bypass valves as needed. In the event of a fault in the Main PLC system, an additional bypass valve control was required. The Backup PLC will take control and operate the bypass valves to maintain the required flow.

Mechanical Interface

The mechanical portion of the conversion was perhaps the most difficult. The goal was to remove all unnecessary mechanical devices and connect the new electrical/hydraulic interface as simply as possible. The EHI blocks are mounted on simple metal platforms to allow access for tubing and then connected to the distributing valves with stainless steel tubing. The blocks consist of interface block, proportional valves and shutdown solenoids. The EHI’s also have Linear Variable Differential Transformer (LVDT) and signal conditioner to provide temporary feedback from the distributing valve to each proportional valve. All of the bypass valves, two at Friant and one at Madera, were provided with specially constructed EHI’s with duplicate components to allow independent control in the event of a failure. Using this design technique, the system was simplified significantly, reducing the number of components that would require adjustment and reducing potential failure points while providing back up control in the event of a rare failure.
Electrical Interface

The electrical interface consisted of devices that allowed the PLC to interface with external plant devices and unit hydraulics. This portion of the conversion was also kept as simple as possible to minimize points of failure. The main control board electronics consisted of interposing relays, signal isolators, power supplies, speed sensor modules and the PLC’s. Additionally, a local HMI was provided at each unit for controlling and monitoring unit operation, viewing alarm history and performing diagnostics. Switches were also provided near the HMI for local control.

Unit Controllers

Two PLC’s were provided for control. The Main PLC is the primary controller and is designed to run the generator, including the gates and blades, and both bypass valves. The greatest benefit of using PLC controls as opposed to the original mechanical controls is the ability to move the complicated mechanical schemes to the software. Once the software is operating properly, it will always operate properly. Software does not bind or break. The primary controller is used to start the unit in speed control and run on-line in either speed control with droop or positioning control. It adjusts the blade angle with respect to the gate position and net head level to use the least amount of water for the greatest amount of generation. The optimization is based on a recent set of curves for the unit. These curves are easily modified to maintain optimal generation.

The Backup PLC is designed to run the bypass valves only. The switching between the controllers may be accomplished automatically or manually. The control is switched automatically in the event of a significant failure on the Main PLC. The manual switch is
used primarily for maintenance. The backup controller is always monitoring the flows and the bypass valve positions. In the event of a fault on the main, the backup controller will energize the supplementary portion of the bypass valve EHI and continue to control with a “bumpless” transfer.

**Annunciator Panels**

The annunciator panels, three at Friant, two at Madera and one at River Outlet, were replaced with plant monitors consisting of a single PLC and one 10” touch screen at each site. Special panels were set in place of the existing annunciators for wire termination in order to utilize as much of the existing wire as possible. New wire was run from the panels to the PLC’s.

The PLC’s collected not only alarm information but are also used to replace an obsolete temperature monitoring system. The HMI system was designed to operate similarly to the existing annunciators. New alarms are still shown blinking and an audible alarm will sound for each new alarm. The audible alarm can be silenced and the blinking alarms acknowledged. Once acknowledged, the alarm will remain lit until the condition is cleared.

The main difference between the original annunciators and the new screen is the amount of real estate required. Rather than have all alarms immediately visible, the new screen consists of one main screen that is broken down into categories. If there is an alarm, the specific category light will blink red. The specific alarms may be viewed by touching the category. The category will remain lit until the specific alarm is cleared. Once the alarm is cleared the category will turn green.

Connected via fiber optics, the annunciator PLCs have information as to the status of the other plants. This allows the operator to be notified if there is an alarm condition at one plant while working at another.
The Server/HMI or central PC workstation gathers information from all three of the plant monitor PLC’s and both main unit PLC’s and will, in the future, collect information from the Basler DEC 300 Excitation systems. Because of the long distance and the amount of information and control required, a new fiber optic system using ring technology was installed through the dam to provide a very reliable communication path between powerhouses. Included in each of the three plant monitors is a fiber optic Ethernet switch that collects information from the five PLC’s. The main switch is located at Friant and connects the central PC workstation and printer. A dial up connection to this workstation allows remote monitoring of all the plants and enables technicians to remotely troubleshoot problems through the PC workstation.

The workstation consists of a PC with dual flat screen monitors and a color printer. The primary purpose of the workstation is to allow the operators to view information from all of the controllers at one convenient location. The system also allows operation of both Friant and Madera units. (Note: This feature is disabled from the dial-up connection for security). Alarms and significant events are readily accessible. Historical logging is also provided and can be used for trend analysis. Multiple screens are provided to view different types of information. The main screen displays generic information about each plant. Several more screens are used for viewing unit specific information and for control of Friant and Madera units.
Conclusion

The replacement system achieved the original goals to significantly reduce maintenance and increase reliability and generator efficiency. Additional benefits include increased understanding and enhanced operation for all involved in operation of the facilities. Canal flows are very stable and have improved water flow deliveries to the Central Valley.

Author

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