

5. Overpumping Protective Systems

5.1 Upper Reservoir Water Level Monitoring and Control System As Installed

Originally, the upper reservoir water level monitoring and control system used a floating “skate” for water level monitoring and float operated switches for emergency backup pump shutdown and alarm. In 2000, the original skate system, encoder, and chart recorder were replaced with a differential pressure level transmitter, Programmable Logic Controller (PLC), and a digital level indicator at the upper reservoir. As part of the upper reservoir liner project in 2004, all of the earlier systems were replaced with pressure transducers for water level monitoring and control and conductivity probes for emergency backup pump shut down and alarm.

The 2005 water level monitoring and control system uses three 0-100 psi pressure transducers lowered into the reservoir to approximately Elev. 1500 and enclosed in a protective HDPE pipe. These transducers produce an electrical signal proportional to pressure. The three electrical signals are converted to pressure (feet of water) and then into upper reservoir water surface level. All three signals are sent to Taum Sauk power plant, Bagnell Dam control center and St. Louis control center where their average value is displayed as reservoir water level and is also used to calculate volume display values. Individual level signals from the transducers can also be displayed at these locations.

A programmable logic controller (PLC) automatically initiates shut down of the first pump at an indicated water level of Elev. 1592 and automatic shut down of the second pump at Elev. 1594. At Elev. 1594.2, automatic shut down is initiated for both pumps if they have not shut down already. Prior to October 2005, the pump shutdown levels were Elev. 1594 and Elev. 1596 respectively. The reason for these level changes is discussed in Section 7.

There is also a penstock pressure gauge (transducer) located in the power plant which can be used to provide an indication of upper reservoir water level during static conditions. This instrument is not used for this purpose during operation of the pump/turbines since a correction would be needed to account for velocity head and head loss in the water conduit to the upper reservoir. In addition, the pressure range of the penstock gauge (transducer) is about 900 feet compared to about 235 feet for the upper reservoir pressure transducers. Since the accuracy of pressure gauges and transducers is typically given as a percent of full scale reading, the penstock pressure gauge (transducer) is not as accurate as the upper reservoir pressure transducers for determining water level.

An upward adjustment of 0.4 ft. to the pressure transducer readings was made in the PLC code on September 27, 2005 in response to visual observation of reservoir level at Panel 72 compared to transducer indications. In addition, on October 7, 2005, lateral displacement of the transducers protective pipe was

observed. AmerenUE staff recognized that the transducer displacement was producing reservoir level indications lower than actual levels. In response, the pump automatic shutdown level was lowered from Elev. 1596 to Elev. 1594 “_____ so that we won’t pump over the reservoir walls.” (a quote from internal correspondence).

5.2 Emergency Water Level Protection Backup System As Installed

This system, commissioned in the fall of 2004, uses five Warrick conductivity probes with associated relays. Figure 5-1 is a diagram of the system as designed (11/01/2004). One of the probes is placed near the bottom of the upper reservoir and serves as the reference probe for the other four probes. The Hi and the Hi-Hi probes were placed at Elevations 1596.0 and 1596.2 respectively in November 2004. The top of the parapet at the probe location is Elev. 1598.

When water reaches the Hi probe, a circuit is completed through the water to the reference probe or other grounded metal objects to operate the associated Hi relay. A similar circuit is completed when the water reaches the Hi-Hi probe to operate the associated Hi-Hi relay. The remaining two conductivity probes, Lo and Lo-Lo, are located near the reservoir bottom and are used for backup shutdown in the generating mode of operation to prevent vortex formation at the intake or draining of the reservoir.

As shown in Figure 5-1, operation of either the Hi relay or the Hi-Hi relay provides a signal to the plant to stop the pumps and activate an alarm. AmerenUE reported that the Hi and Hi-Hi probes were tested at commissioning in the fall of 2004 as follows:

“First, the probes were circuit-checked to ensure that they would activate the pump shutoff signal and the alarm. Second, the probes were placed in water to simulate their operation in the upper reservoir. The pump shutoff signal at the plant was concurrently monitored to verify that the probes properly activated the pump shutoff signal and alarm when the probes were placed in water. Third, once the upper reservoir was filled, the Hi and Hi-Hi probes were immersed in the reservoir to confirm that the probes properly activated the pump shutoff signal and alarm.”

In December 2004, the PLC logic was changed so that both relays had to be energized for sixty seconds to provide a signal to stop the pumps and activate an alarm. In addition, both the Hi and Hi-Hi probes were reportedly raised to Elevations 1596.7 and 1596.9 respectively as shown on Figure 5-2. These changes were documented in comments within the PLC code and as revision 15 to drawing 8303-P-26648.

During the post-breach interview process, AmerenUE’s Vice President of Power Operations expressed the opinion that the Hi and Hi-Hi probes may never have

been set at Elevations 1596.7 and 1596.9 as recorded on electrical drawing 8303-P-26648 Rev. 15 and as noted in comments in the associated PLC program. He noted that the probe cables had only two tape bands on each one and that they were separated by 18 inches, the distance between the original probe elevations and the final as found elevations.

The tape bands were apparently used to reference the probe elevation with respect to the top of the protective pipe. There were no marks on the cables to indicate that the probes were ever set at intermediate elevations. The question of when and why the Hi and Hi-Hi probes were raised to the post-breach as found elevations is an interesting one, but it does not affect the analysis of the cause for the reservoir breach.

The alarm output is initiated by the Hi-Hi- probe and not the Hi probe. This is contrary to normal alarm and trip practice which gives an alarm first followed by a trip if the parameter being measured continues changing in an unsafe direction. Vibration, pressure, level, and temperature are parameters that are often monitored by two sensors; one to provide an alarm function and the second to provide the trip or shutdown function.

Figure 5-3 (02/15/2005) shows a logic change requiring both, rather than either, the Hi and the Hi-Hi probe to be wet for sixty seconds in order to initiate a pump shutdown.

5.3 Overpumping Protection Response on December 14, 2005

5.3.1 Response of Water Level Monitoring and Control System

As noted above, both units were in the pumping mode in the early morning of December 14, 2005. At 04:39, Unit #2 was shut down automatically at an indicated upper reservoir water level of Elev. 1591.6. At 05:15, Unit #1 was shut down manually by the Bagnell Dam control center operator in accordance with instructions from St. Louis control center to shutdown just shy of where it would shut down automatically (Elev. 1594). At that time, the reservoir level reading was Elev. 1593.7. The automatic shut down of the first pump and the non-automatic shut down of the second pump is consistent with level information from the pressure transducers and the automatic shut down elevations described above.

Since the reservoir overtopped and the top of the parapet wall at its lowest point is at Elev. 1597, it is clear that the actual water level exceeded the indicated Elev. 1593.7 and that the pressure transducer signals were in error.

5.3.2 Response of Water Level Protection Backup System

No shutdown or alarm was produced from the conductivity probe backup system on December 14, 2005.