Supplemental Pumps Pay Off During Low River Conditions

Author: Rich Wendel, PE, Plant Mechanical Engineer, Kansas City Board of Public Utilities
        Jason Eichenberger, Project Engineer, Burns & McDonnell
        Terry Larson, PE, Project Manager, Burns & McDonnell

Presented at: Electric Power 2009
Date: May 14, 2009

ABSTRACT

Low river levels are causing reliability problems with once-through circulating water pump systems at several coal-fired power generating plants sited along the Missouri and Mississippi Rivers. River bottom degradation and U.S. Army Corps of Engineers (USACE) river management practices make low river levels a likely ongoing problem, especially during the drought years being experienced in the Midwest.

This paper outlines circulating water pumping problems that have occurred at Kansas City Kansas Board of Public Utilities’ (KCKBPU) Quindaro Power Station due to historic low water levels in the Missouri River, as well as the steps taken to resolve these problems. Remedial design solutions that were either considered or implemented included installation of supplemental pumps, vacuum lift systems, suction scoops, a new river water intake, and converting to a closed-loop cooling tower system. This paper includes an in-depth discussion of the supplemental pump system placed into service in the fall of 2006 and now in operation on the Quindaro river intake.

The new supplemental pump system consists of four submersible axial flow pumps mounted on the front of the existing intake. The total flow capacity of the four supplemental pumps is around 200,000 gallons per minute (gpm), and this flow is discharged into the existing intake to maintain an acceptable wet well water level for the operation of the existing circulating water pumps. Other system components include an overhead monorail system to facilitate annual supplemental pump installation/removal and a floating ice deflector system. The supplemental pumps are installed and operated during winter months when river levels are low, and removed during the river navigation season when the USACE maintains higher river flows.

EXISTING CONDITIONS

The KCKBPU owns and operates the Quindaro Power Station along the Missouri River in Kansas City, Kan. Quindaro has two coal-fired generation units. Unit 1 has a rated capacity of 75 MW, while Unit 2 is rated for 135 MW. Degradation (scouring) of the Missouri River channel has caused reduced river stage elevations at the Quindaro Station intake structures.

Once-through cooling is used for both units, and cooling water is obtained through a common cooling water intake structure that houses four 50,000 gpm vertical pumps. The existing cooling water pumps require 8.5 feet of submergence. The bottom of the intake structure is at elevation 709.75 feet, so without any modifications, the pumps were only able to operate at an approximate elevation of 718.25 feet.

The existing intake was fitted with a partial supplemental pump system in 1991. The existing supplemental system had only been sized to provide reliable raw water supply to the adjacent city water plant (no longer in service) and to allow one unit to be operated at reduced load. The existing system included diesel-driven hydraulic pumps, and there were concerns about potential oil spills adjacent to the river. For these reasons, KCKBPU did not want to rely on this existing system that had never been used, only tested. A monorail system was installed with the earlier supplemental pumps but was not oversized. A center rotating crane...
Supplemental Pumps Pay Off During Low River Conditions

was installed when the intake was constructed to facilitate maintenance of the cooling water pumps and traveling screens.

The current configuration of the Quindaro intake and pumping systems do not provide reliable cooling water supply for Units 1 and 2 at low river stages during the winter months when the USACE may reduce discharge flows from Gavins Point Dam to 12,000 cubic feet per second (cfs). Assuming the addition of lower than average tributary contributions due to draught conditions, the flows at Quindaro could be expected to reduce to 14,000 gpm during the winter months. Historic mean annual discharge is around 31,000 cfs with a minimum discharge of 26,600 cfs required to maintain river navigation during the navigation season (April 1 through November 30). The river level was projected to drop to elevation 716.5 feet during extreme low winter flow conditions and the level could drop to elevation 714 in the event of an upstream ice jam occurring during extreme low flow conditions. These projections estimated that the river level could fall two to four feet below the submergence required for the existing circulating water pumps, impacting the reliability of the Quindaro Power Station.

STUDY PHASE

KCKBPU retained Burns & McDonnell to conduct a study to identify and evaluate alternatives to improve the operational reliability of the Unit 1 and 2 cooling water systems during low river flow periods. Effects of current and projected future river degradation were considered in the identification and evaluation of viable alternatives.

Alternatives that were considered in the technology selection study included the following:

- Construct new intake structure
- Convert plant to closed-loop cooling tower system
- Install supplemental pumps on front of the existing intake
- Install vacuum lift system
- Install vortex suppression system

The results of the technology selection study indicated that installing new supplemental pumps was the most economical alternative when considering life-cycle costs and total system reliability. The study concluded that cooling towers were not economically viable because of the following factors:
1. Site constraints would force the cooling towers to be sited further from the plant resulting in long and costly circulating water piping runs and associated pumping costs.
2. The same tight site constraints made it difficult to identify suitable piping corridors and tie-in locations making pipe installation expensive because of required sheet piling and decreased installation efficiency costs.
3. Outage requirements associated with such difficult tie-in would be long and expensive.
4. High electrical installation costs would be required to upgrade to the plant’s auxiliary electrical system to accommodate the cooling tower fans and larger circulating water pump motors.
5. Increased operation and maintenance costs associated with the water treatment system, tower fans, larger pumps and the towers themselves.

Constructing a new intake would be costly, difficult to permit and difficult to construct due to tight site constraints including an adjacent USACE flood control levee. With Section 316(b) compliance requirements still not finalized, investing in a new intake structure did not make sense.

Potential intake modifications considered for improving intake reliability during low river levels included installing a vortex suppression system consisting of a vortex suppression grating or plate, an upstream curtain wall, and sidewall fillets to improve flow characteristics to the existing pumps. However, the vortex
Supplemental Pumps Pay Off During Low River Conditions

Suppression system would not be sufficient to allow the pumps to operate during the extreme low river levels anticipated in the winter months.

Installing a vacuum lift system within the existing intake was also considered to reduce vortexing and pump cavitation problems associated with low river flows. The vacuum lift system involves the installation of sealed walls between the traveling screens and the circulating water pump. The walls would extend below the low water level in the sump and all portals would be sealed to create air-tight pump chambers. Vacuum pumps and associated piping would then be installed to apply a vacuum to the pump chambers and lift the water level in the pump chamber approximately 7 feet above the river level, enabling the intake to operate at low river levels where adequate pump submergence conditions would not have otherwise existed. The main reason the vacuum lift system was not selected as the preferred alternative is that the vacuum would likely be lost during extreme winter low flow conditions associated with an ice jam or plugged traveling screens, and there were concerns with restarting the system if lost during low flow conditions.

SUPPLEMENTAL PUMP SYSTEM DESIGN

The alternative selected in the study phase involves installing supplemental pumps on the front of the existing intake. The new supplemental pump system consists of four axial flow, submersible pumps (see Photo 1) each rated for 50,000 gpm. The submersible pumps are housed within fabricated pump cans and the bottoms of the pump cans are set at elevation 708.5 feet. The supplemental pumps should operate satisfactorily down to a river stage of elevation 716 feet on a continuous basis and could allow operation down to elevation 714.5 for short durations such as during an ice jam. Overall system cost was approximately $2.7 million.

Submersible, axial-flow pumps were selected because they can pump a large volume of water at low-head conditions and do not require a lot of submergence. The submersible pumps can be installed directly in the river without an extensive wet well system, and are relatively inexpensive to purchase and operate. Horizontal axial flow pumps mounted on barges were also considered but concerns about potential damage to the units by floating ice, getting warm water out to pumps to prevent the screens from freezing, providing access for maintenance, and providing power or fuel supply to the floating units drove the decision to go with the submersible pumps mounted off the intake.

The design of the supplemental pump system had to address the following concerns:
The space available to install the low head pumps in front of the existing intakes is limited. Pumping a large volume of water (200,000 gpm) into the front of the intake may create unacceptable hydraulic conditions for the existing pumps and cause possible cavitation problems. Debris and ice floating down the river may damage the supplemental pumps. Any construction in the river may affect river navigation and would require USACE approval. Maintaining the intake in service during construction of the improvements.

Since the supplemental pumps are only considered a short-term solution and are most likely to be operated only in the winter months when flows are reduced and ice jams are likely, they were designed to be removable and to only be used in the non-navigation months when release rates and the corresponding river levels are lowered. This non-navigation season generally occurs from December through March; however, the USACE has shortened the navigation season the last couple of years due to prolonged draught conditions. By designing the system to be removable and to generally be used only in the winter months, many of the concerns about floating debris plugging the pumps were alleviated, especially grass and leaves typically associated with spring and fall flows. Floating ice and slush ice became the primary concerns, so a modular, interconnecting barge system was installed in front of the intake to deflect floating ice away from the supplemental pumps (see Photo 2). The protective interconnecting barge system and its lateral support system to hold the barges during fluctuating river levels were also designed for relatively simple annual installation and removal. The barges also serve as an access platform if needed to reach the pumps while in service.

Using a temporary system also made permitting the system easier because the barges and pumps are removed during the navigation season, which is required by the USACE.

The design of the supplemental pumps system had many other challenges. The design had to be such that no permanent structure components were placed in the water that could catch logs or other debris during the navigation season. Hanging the heavy supplemental pumps off of the existing intake superstructure required innovative structural design work. The pump cans were mounted to slide plates that slid in a spare channel in front of the intake bar screens (see Photo 3). This system allowed for the supplemental pumps to be installed more easily and to be completely removed when not in service. The plate also serves as a weir to raise the water level in the intake in order to maintain adequate submergence for the existing circulating water pumps and to reduce turbulence around the pumps.
To facilitate pump installation and maintenance, a new monorail system was installed to allow the pump cans (with the pumps inserted) to be lifted and transported to dry land for maintenance and storage when not in use (See Photo 4).

CONSTRUCTION & OPERATION PHASE

The intake modifications necessary to allow for installation of the supplemental pumps were completed in fall 2006 (see Photo 5). An existing concrete mat left over from construction of the original intake had to be lowered to allow the pump cans to extend to the design elevation. Divers were brought in to remove the top of the concrete mat and dredging was performed between the intake and the main river channel to provide more water depth in front of the intake.

The supplemental pump system operated during the 2006 and 2007 non-navigation seasons. The river levels dropped to record lows in each of these two years to the point where the existing cooling water pumps would have been lost if the supplemental pumps had not been installed. The supplemental pumps did not have significant impeller damage during operation, which was a major concern during the design phase since there are no fine traveling screen systems to protect the pumps.

SUMMARY

The supplemental pump system has worked satisfactorily for two seasons, keeping the Quindaro intake system online during unprecedented low river levels in winter months. This is in spite of many design and operational challenges unique to river construction that had to be overcome to make the system a reality.