RECLAMATION

Managing Water in the West

Project Planning Synopsis

(P5 and P6 Impellers, Stator Cores and Windings)

John W. Keys III Pump-Generating Plant Modernization Project for System Flexibility and Balancing Reserves

(Keys Modernization Project)

U.S. Department of the Interior
Bureau of Reclamation
Grand Coulee Power Office

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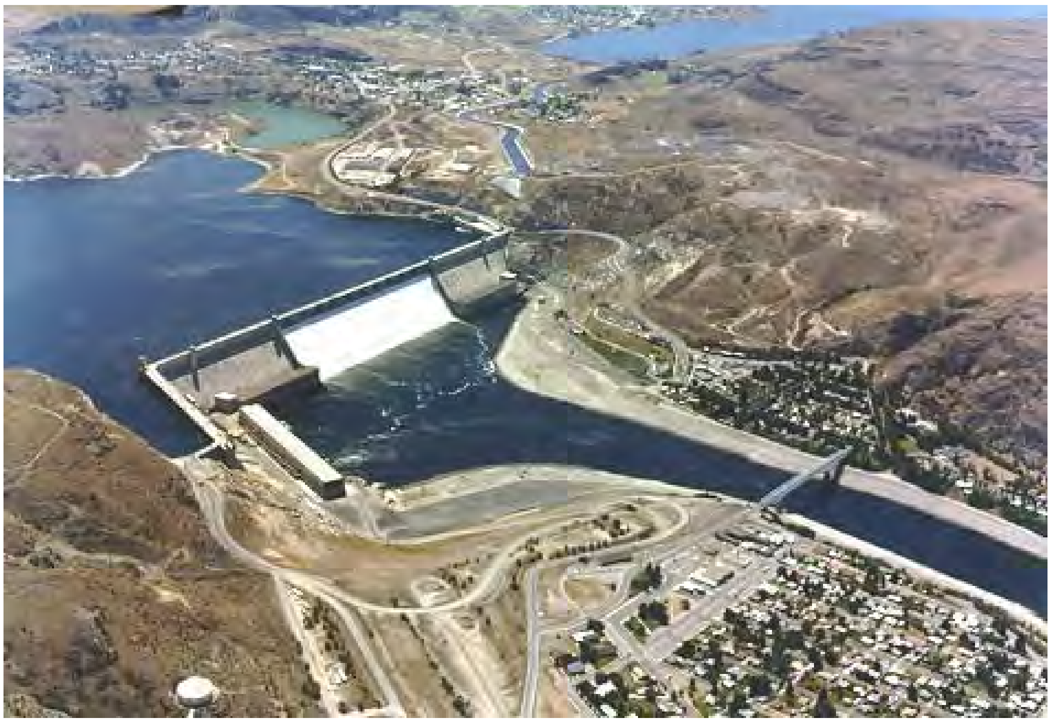
Project Synopsis for P5 and P6 Impellers, Stator Cores and Windings – April 2012



Executive Summary:

This document provides an overview of the John W. Keys III Pump/Generating Plant (Keys PGP) and potential changes to operation at Banks Lake. Any proposed changes to the existing facilities would not be allowed to adversely affect the authorized purposes of the Columbia Basin Project (CBP) and meeting irrigation deliveries will remain the primary purpose of the Keys PGP. Information contained within this document was obtained from Reclamation's *Appraisal Level Technical Evaluation for Modernization of John W. Keys III Pump Generating Plant* dated March 2011. The Bonneville Power Administration (BPA) funded the project investigation in coordination with the Bureau of Reclamation's (Reclamation's) Pacific Northwest Regional Office, Grand Coulee Power Office (GCPO), and the Technical Service Center (TSC).

Banks Lake is an off-river storage impoundment that receives water from Lake Roosevelt behind Grand Coulee Dam on the Columbia River. Pumping from Lake Roosevelt to Banks Lake began in 1952 with six pumps installed, P1 through P6. The six pump/generating (PG) units were added later; PG7 and PG8 were constructed in the mid 1970s, and PG9 through PG12 were complete by the early 1980s. As more and more wind generation is being added to the power system, pumped storage has been identified as a potential source for balancing reserves and a potential method for energy storage from wind power generation during low demand periods for

use at some later time for load scheduling. Because of its age and condition, the Keys PGP is somewhat limited in its support of wind integration. However, extensive rehabilitation and upgrades to the plant equipment could be implemented to improve reliability, flexibility, and efficiency of hydro-operations, thereby adding support for wind power generation.

In Phase I of Reclamation's Modernization Appraisal Study, existing information was compiled to examine the possibilities given current operational and environmental limitations. Minor facility improvements and major expansions were identified. It was determined that additional capability and faster response times are obtainable, but would require improvements and enhancements to existing equipment. Minor plant improvements would involve newer in-kind replacement of outdated or unreliable equipment. Major plant enhancements would involve upgrading or redesigning equipment to increase capacity and response time.

Under Phase II, the TSC conducted a technical evaluation of the previously identified potential enhancements. Appraisal level cost estimates were performed for the majority of the items. Economic studies will be conducted at a later date, as deemed necessary. This document addresses the proposed work associated with the governors, exciters, protective relays, and controls.

Background:

John W. Keys III Pump Generating Plant (Keys PGP) is one of the few large pump generation facilities in the western United States that has potential pump storage / wind integration capacity. This will require much rehabilitation and improvement to the existing facility. BPA has identified that additional balancing reserves for wind and load are required and will increase in the near future. Since the Keys PGP facility serves multiple purposes, competing obligations limit the power reserves that are available to support the addition of wind energy. The need to provide full irrigation supply to the CBP takes precedence, so wind integration modifications shall not limit Reclamation's capability or responsibility to deliver water to the irrigation districts. The main components needed to achieve this balance are the John W. Keys III Pump Generating Plant, Lake Roosevelt and Banks Lake, a feeder canal into Banks Lake, and irrigation obligations.

Lake Roosevelt and Banks Lake. Lake Roosevelt is operated for multi-purpose needs including irrigation water supply, municipal and industrial water supply, flood control, power generation, recreation, salmon recovery, and resident fishery. At maximum lake elevation of 1290 feet, Lake Roosevelt holds over 9,000,000 acre-feet of water. Water from Lake Roosevelt irrigates about 670,000 acres of land. The constraints for operation of Lake Roosevelt are based on flood control, irrigation delivery, and flows for downstream fisheries.

Banks Lake is also operated for multiple objectives. These include irrigation, resident kokanee fishery, recreation, and peaking power generation. The level of Banks Lake is operated generally in the top 5 feet during the fall and winter and in the top 2.5 feet in the spring and summer to best meet these multiple objectives. A 5-foot drawdown of Banks Lake is required in the month of August to support Columbia River in-stream flows. A minimum lake elevation of 1208 feet at Lake Roosevelt is required for pumping water into Banks Lake.

Feeder Canal. After being pumped from Lake Roosevelt up through the discharge pipes, water flows through a 1.6-mile feeder canal into Banks Lake. The feeder canal is capable of being operated at any elevation of Banks Lake at or below 1570 feet. In the feeder canal, a weir structure and check structure provide the backwater required to keep pump/generator unit discharges primed for all operating levels and reduce the velocity in the canal when the water surface elevation in Banks Lake is low, thereby eliminating hazards to the canal lining.

The maximum flow in the canal with the 12 Keys PGP units pumping at 270 feet, minimum dynamic head, is slightly over 21,000 ft^3/s. During generation, the reverse flow through each of the pump-generators is approximately 2,400 ft^3/s, for a maximum flow of 14,400 ft^3/s with six units generating.

Irrigation Obligations. Operation of Keys PGP is typically driven by water diversions with the flexibility to vary the lake elevation in Banks Lake by 5 feet. On average, five pumps are required to run continuously throughout the peak irrigation season to meet irrigation water demands, and more than five pumps are required at times. In order to take advantage of lower demand on the power system, it is beneficial to schedule most of the pumping to occur at night when possible. However, if any units are out of service for repair or maintenance, additional pumping to Banks Lake may be required during high load periods.

Reclamation has a contractual obligation to deliver water to irrigate the CBP as congressionally authorized. The Keys PGP must be operated to deliver the full irrigation water requirement to the CBP as measured at Mile 0.2 of the Main Canal at Dry Falls Dam. Diversion for the currently developed portion of the Project is certificated for 2.9 million acre-feet.

John W. Keys III Pump-Generating Plant. Keys PGP consists of six pumping units and six PG units. The six pumping units (P1–P6) are each rated at 65,000 horsepower (hp). PG units 7 and 8 are each rated at 67,500 hp in the pump mode and 50,000 kilowatts (kW) in the generating mode. PG units 9 through 12 are each rated at 70,000 hp in the pump mode and 53,500 kW in the generating mode. Since 1996, the entire plant has been used extensively to help meet the requirements and flexibility demanded of the power system. The majority of pumping for irrigation purposes now takes place during light load hours. During high pumping periods, pumping power loads can be as much as 600 megawatts (MW). Shutdown and reversal of the PG units allows generation of as much as 300 MW. The flexibility to adjust the power system load by up to 900 MW (-600 to +300 MW) provides significant operational flexibility. Operation of the Keys PGP in the generation mode also allows for power sales during heavy load conditions and maximizes revenue opportunities. Due to the increased starting and stopping of the pump and PG units, plant equipment, particularly circuit breakers, could require more frequent overhaul and refurbishment. Likewise, costs associated with plant maintenance could significantly increase with the use of the plant for power system peaking.

P1 through P6 may be operated as pumps any time Lake Roosevelt elevation is above 1208 feet. One of the significant limitations to a rapid start of P1 through P6 is that these pumps require generators G1 through G3 in the left powerhouse to be used in a "soft start" sequence to put the pumps on line. The full startup process is described later under *Pump Start Optimizations (P1–P6)*, p. 22. Another important limitation occurs if Lake Roosevelt level is below approximately 1210 feet. At this level, G1 has insufficient power capability to accelerate the pumping units to sufficient speed to lock them into the grid. If pumping is required at this time, G1, P1, and P2 must be operated as electrically islanded from the grid and the units operated asynchronously. In order to prevent this from happening, P1 and/or P2 are started before the level drops below 1210 feet and remain running continuously until operations knows they will not be needed to support irrigation or the Lake Roosevelt level recovers above 1210 feet. This procedure eliminates the capability to load follow. Across-the-line start capability may partially remedy this.

The PG units in pump mode (PG7–PG12) are started across the line at full voltage by closing their associated circuit breakers. These units take less than60 seconds to synchronize with the grid. Due to the design of their runners, the PG units do not have as wide an operating level in the pumping mode as do the pumping units. If Lake Roosevelt is below the PG minimum operating level, the units reach their "dead head" pumping limit resulting in water not rising high enough in the penstocks to go over the siphon invert. That point is at Lake Roosevelt level 1240 feet for PG9 through PG12 and 1263 feet for PG7 and PG8.

The PG units can also be used as generators. PG7 through PG9 are connected to the grid via one phase reversal switch and one transformer. PG10 through PG12 are likewise connected to the grid via their own phase reversal switch and transformer. These switches must be moved from the pump to generator position in order to switch unit operating modes. Visual verification is required to ensure that all switch contacts have closed before operations can resume. Once switched, the associated units can be started as generators and brought online. Unlike pumping where the load is fixed, the generator's output is variable. These units typically generate at their maximum efficiency point, which varies slightly dependent on net head. The maximum generation available from all six PG units is limited by the elevation of Banks Lake. At 1568 feet, all six PG units are available for power generation. As Banks Lake approaches its lower elevation level of 1563 feet, only three units are available for generation. Reversal of plant operations from pumping to generating is limited to approximately 1 hour in order to protect the fish that tend to congregate in the feeder canal during pumping operations.

Current maintenance schedules generally have one or two units out of service at a time due to major maintenance requirements and system upgrades. This eliminates the availability of roughly 100 MW of pumping and/or generation depending on which units are out of service. Enhanced planning could take into account system needs and be used to schedule some of these activities to times when regulating services are in low demand. There might be some flexibility in maintenance plans to have greater unit availability during the peak wind season when system reserves are required. However that timing must also be coordinated with irrigation pumping requirements.

Proposed Impeller and Stator Core Replacements, Rewinds for P5 and P6:

Starting with P1 in the early 90's, one impeller has been replaced approximately every five years. The reason for replacing the impellers is to replace or fix worn and damaged parts, gain higher efficiency, and attempt to minimize vibrations throughout the discharge lines. The new impellers have nine blades instead of seven, which changes the natural frequency of the units, ultimately decreasing the vibration amplitudes by 40%. Impeller replacements have been performed on units P1 through P4, with P3 being the last one completed. Per the overhaul schedule, the impeller for P5 has been funded and is currently on schedule for replacement during the current rate period.

Implementation of a Stator Core and Winding Replacement Program in the early 90's includes replacement of the core laminations and stator windings with materials of modern design and construction. This work has historically been completed after the impeller replacement during separate outages. Similarly to the impeller replacements completed to date, an average of one unit has been replaced every five years. With P1 through P4 stator core and winding replacements now complete, the same is necessary and due to be addressed for P5 and P6. P5 and P6 were installed in the early 50's and tests indicate a deterioration of the insulation. Fretting and moisture have caused core lamination insulation problems on all of our cores designed by Westinghouse which lead to heating and loss of efficiency. One factor making the availability of pumps more useful to the Northwest power grid is that they are used in load factoring. This use increases the number of on/off cycles and attendant thermal cycling of the stator and rotor, therefore reducing expected useful life.

With the modernization plans for the Keys Pump Generation Plant to integrate wind power in conjunction with the pumping operations, opportunities to incorporate the P6 impeller project were looked at during the P5 Impeller Replacement Value Engineering Study. Cost benefits were modest, but time savings of schedule and consideration of timing with respect to the new Irrigation rate period matched up with the timing of the completion of the P5 impeller project. Also, the overall schedule for the anticipated Keys Modernization Project is on an aggressive path, requiring the need for multiple contractors to share a limited work space simultaneously. Space within the plant is limited, so a reduction in the number of contractors working at the same time and subsequent reduction in number of unit outages would be beneficial. By combining the stator core and rewind components with the impeller replacements, logistic and schedule challenges are reduced.

Impeller work

The principal components of the work to replace the impellers include: Fabricate P6 in replica with P5 impeller, and utilize test results from one hydraulic pump model; pre-tear down readings, disassembly, and component disposition reports; furnish and deliver stainless steel vertical pump impellers; furnish new motor/pump shaft coupling bolts and nuts; furnish new head cover bolts and nuts; furnish upper and lower stationary wear rings; furnish new mechanical seals; inspect guide bearings (pump, upper and lower motor) and motor thrust bearings; lead abatement of paint and recoat pump components; recoat pump components, spiral case, diffuser ring, diffuser ring vanes, metal parts of suction tube, lower cover, all air, oil and water piping in the pump pit, pump pit liner, pump guide bearing barrel, supports and cover, and interior and exterior surfaces of head cover; on-site machine upper and lower wear ring seats; re-assemble all new and refurbished equipment: impeller, mechanical seal, stationary wear rings and any other equipment removed in disassembly; shaft work to accommodate the new mechanical seal; alignment; pre-operational testing, checkout of rehabilitated equipment by Contractor.

Several items recognized in the specifications have been identified as "Optional Items." These include: rebabbitt and machine pump guide bearings; rebabbitt and machine motor lower guide bearings; rebabbitt and machine motor upper guide bearings; rebabbitt and machine motor thrust bearing shoes; and rehabilitate thrust bearing; spare set of upper and lower wear rings.

Stator Core and Winding work

Disassemble and dispose of existing core and winding on P5 and P6; provide a full set of core laminations and stator windings with modern design and construction, rated at the same horsepower and speed rotation that currently exist.

Implementation considerations

It is preferred that this project be solicited as a single contract that would include P5 and P6 impeller replacements and P5 and P6 stator core and winding replacement. Based on the criticality of mechanical disassembly and reassembly, a mechanical contractor should be the lead on this project.

Testing for asbestos and lead paint; Identifying safety equipment and procedures for the various projects

The Contractors performing work on any existing equipment need to be aware that there is a possibility that they could encounter asbestos or lead paint on some of the existing components. Typically this is not an issue for components manufactured after 1980. However, these units were completed prior to that year in most part and therefore it is incumbent upon the Contractors doing work that impacts existing equipment to test and be prepared with appropriate safety equipment, procedures, and trained staff to handle and dispose of the hazardous material.

Coordinating NEPA/Section 106 Activities and obtaining any permits required for the projects

NEPA compliance needs to be considered for all activities associated with the modernization. Impacts to the environment need to be defined and addressed appropriately. Additionally, the

Grand Coulee Power Office facilities are considered part of a Historically Significant Area. As such, any activity that could impact the overall appearance of the area could have an adverse effect and should be avoided if possible and mitigation for the action applied if the action is unavoidable.

Developing hazardous waste handling requirements

All construction contracts associated with the project will include a requirement that all hazardous waste shall be handled and disposed as required by the applicable regulations. Certain wastes are the responsibility of the Contractors and others are the responsibility of Reclamation. These need to be identified and manifested and handled and disposed of correctly.