Final Technical Report

City of North Little Rock Electric Department – Murray Hydro Facility

Project Title: Recovery Act: Hydroelectric Facility Improvement Project – Replacement of Current Mechanical Seal System with Rope Packing System

DOE Award Number: DE-EE0002674

Project Period: 01/2010 – 02/2013

Principal Investigator: Jessica Stephens, 501.992.4089, jstephens@nlr.ar.gov

Recipient Organization: The North Little Rock Electric Department, 1400 W Maryland Ave, North Little Rock, AR 72120

Other Organizations: Hydro Consulting and Maintenance Services
Garver Engineers and Consultants, Inc.

Date of Report: May 29, 2013

Acknowledgment, Disclaimer and Proprietary Data Notice

Acknowledgment: This report is based upon work supported by the U.S. Department of Energy under Award No. DE-EE0002674.

Disclaimer: Any findings, opinions, and conclusions or recommendations expressed in this report are those of the author and do not necessarily reflect the views of the Department of Energy.

Proprietary Data Notice: If there is any patentable material or protected data in the report, the recipient, consistent with the data protection provisions of the award, must mark the appropriate block in Section K of the DOE F 241.3, clearly specify it here, and identify them on appropriate pages of the report. Other than patentable material or protected data, reports must not contain any proprietary data (limited rights data), classified information, information subject to export control classification, or other information not subject to release. Protected data is specific technical data, first produced in the performance of the award, which is protected from the public release for a period of time by the terms of the award agreement. Reports delivered without such notice may be deemed to have been furnished with unlimited rights, and the government assumes no liability for the disclosure, reproduction or use of such reports.

Contents

List of Acronyms.....	4
List of Figures	5
Executive Summary.....	6
Introduction	8
Background	9
Results and Discussion	10
Accomplishments.....	12
Conclusions	15

List of Acronyms

ARRA: American Recovery and Reinvestment Act

DOE: Department of Energy

IMD: Intake Maintenance Device

PTFE: Polytetrafluoroethylene, Teflon

List of Figures

Figure 1: Kilowatt Hour production for March 2013

Figure 2: Kilowatt Hour production for April 2013

Figure 3: Total system load versus kilowatt hour production for April 2013

Figure 4: System total load for April 2013

Executive Summary

On January 27, 2010 the City of North Little Rock, Arkansas received notification of the awarding of a Department of Energy (DOE) grant totaling \$450,000 in funding from the American Recovery and Reinvestment Act (ARRA) under the Project Title:

Recovery Act: Hydroelectric Facility Improvement Project – Automated Intake Clearing Equipment and Materials Management.

The purpose of the grant was for improvements to be made at the City's hydroelectric generating facility located on the Arkansas River. Improvements were to be made through the installation of an intake maintenance device (IMD) and the purchase of a large capacity wood grinder.

The wood grinder was purchased in order to receive the tree limbs, tree trunks, and other organic debris that collects at the intake of the plant during high flow. The wood grinder eliminates the periodic burning of the waste material that is cleared from the intake and reduces any additional air pollution to the area. The resulting organic mulch has been made available to the public at no charge.

Design discussion and planning began immediately and the wood grinder was purchased in July of 2010 and immediately put to work mulching debris that was gathered regularly from the intake of the facility. The mulch is currently available to the public for free.

A large majority of the design process was spent in discussion with the Corps of Engineers to obtain approval for drawings, documents, and permits that were required in order to make changes to the structure of the powerhouse.

In April of 2011, the City's Project Engineer, who had overseen the application, resigned and left the City's employ. A new Systems Mechanical Engineer was hired and tasked with overseeing the project. The transfer of responsibility led to a re-examination of the original assumptions and research upon which the grant proposal was based. At that point, the project went under review and a trip was booked for July 2011 to visit facilities that currently had an IMD installed.

This further study of facilities revealed that the implementation of the project as originally described, while proving the benefits described in the original grant application, would likely intensify sand intake. Increased sand intake would lead to an increase in required shutdowns for maintenance and more rapid depreciation of key equipment which would result in a loss of generation capacity.

A better solution to the problem, one that continued to meet the criteria for the original grant and ARRA standards, was developed. A supporting day trip was planned to visit other facilities located on the Arkansas River to determine how they were coping with the same strong amounts of sand, silt, and debris.

Upon returning from the trip to other Arkansas River facilities it was extremely clear what direction to go in order to most efficiently address the issue of generator capacity and efficiency. Of the plants

visited on the Arkansas River, every one of them was running what is called a rope packing shaft sealing system as opposed to mechanical shaft seals, which the facility was running.

Rope packing is a time proven sealing method that has been around for centuries. It has proved to perform very well in dirty water situations just like that of the Arkansas River.

In April of 2012 a scope change proposal was submitted to the DOE for approval. In August of 2012 the City received word that the change of scope had been approved.

Plans were immediately set in motion to begin the conversion from mechanical seals to a packing box at the facility. Contractors arrived on October 1st, 2012 and the project team began unwatering the unit for disassembly. The seal conversion was completed on February 29th, 2013 with start-up of the unit. Further testing and adjusting was done throughout the first two weeks of March.

Introduction

Rope packing, also known as a packing gland, packing box, or stuffing box, are all used to prevent leakage of fluid (in this case water) between turning parts of a machine. It seals around a rotating shaft, against the river water, where the shaft exits the draft tube and enters into the speed increaser and generator, which are in the dry inside the hydro plant. It is the most common method for preventing water from entering the generator pit inside the plant while still allowing the propeller shaft to turn. The actual “seal” is provided when the tightly wound, square cross-sectioned rope that is impregnated with Teflon (PTFE) is compressed in place.

Prior to the rope packing the facility was using a mechanical shaft sealing system. The mechanical seals are a 10 piece system along with multiple other moving parts. When the plant was first built the seals were made using a composite material, one major ingredient being asbestos. With asbestos in the make-up the seals tended to perform fairly well in the dirty water environment at the facility. The mechanical seals were typically replaced every 12-18 months. Once asbestos was determined to be a health and an environmental hazard and subsequently removed as a shaft seal material component, the seal performance began deteriorating.

For over a decade, many other composites were tried and none performed as well as the asbestos seals. After a few years with multiple outages due to seal failure, engineers at the facility began researching ways to improve the system. It was determined that rope packing was the most efficient way to address the sealing issue. It was also determined that with fewer moving parts in the system outages not directly related to the seals could also be reduced.

With the implementation of the packing box and removal of the mechanical shaft sealing system, maintenance cost, outage time and number of outages per year have been reduced. Previous outage time was 7-14 days every four months and currently outage time is approximately 24 hours once a year to adjust the packing. The replacement of the packing will only be necessary every 3-5 years at 24 hours of outage per replacement.

Even though a hydro is already an efficient way to produce electricity, facility engineers are always looking for ways to increase the generator output and efficiency. The better the facilities perform and maintain, the more competitive the price of hydro power will be in relation to other forms of power generation on the market.

Rope packing was the best way to address an ongoing seal issue and also improve the efficiency of the plant overall. The ten piece seals and approximately 30 other moving parts that made up the mechanical seal system made up the largest component of annual maintenance costs. The packing box reduced that number to approximately 6 parts and became a minimal annual cost.

Along with reduced maintenance time, the amount of spare parts required to be kept in inventory was also decreased. This freed up more physical space inside the plant and capital in the budget. There is no longer a need to have an inventory of large, expensive items which total around over \$250,000, now it is only necessary to stock approximately 6 items at less than \$100,000.

Background

The original intent of this project was to improve the generator capacity and efficiency of the hydro facility. Multiple avenues of improvement were discussed and the engineering and design for the IMD project even began before the seal system project was selected.

Visits to existing plants played the largest role in deciding how to address the issue of efficiency within the facility. A visit to existing facilities motivated the deviation from the original plan in favor of a better solution to multiple recurring problems at the facility.

After meeting with a team of engineers that were familiar with the facility and the hydro world in general, a plan to tackle the efficiency issue was developed. The facility engineers were encouraged to visit plants located on the Arkansas River and see how they were addressing this issue. Once back from that trip, the facility engineers were completely convinced the rope packing system was the right choice and began the design and engineering process.

All of the members of the Hydro Consulting and Maintenance team had worked in hydro plants with mechanical seal systems, the current type of seals at the facility, and rope packing systems. They knew exactly what the project would entail. Many of them had just come from projects where rope packing systems were in use before beginning this job.

Results and Discussion

Once the IMD project was re-evaluated it was made clear that the best option for the facility to meet ARRA standards was to move on to an internal upgrade as opposed to an external machine. A major issue with the mechanical seal system was the dirty water environment provided by the Arkansas River. Upon visits to facilities with IMDs installed, it appeared that the IMD would further stir up the sand and silt at the bottom of the river, creating even more excessive wear on the mechanical seals due to the suspended sand.

From the site visits to facilities with IMDs, it was determined that when implemented successfully, the proposed intake maintenance device is not located in the flow or main channel of a river as it would have been required in the Murray Hydro facility.

Also, to reduce suspended sand from being pulled into the intake or stirred by use of the IMD, plants included a reservoir, which the facility cannot have, due to federal restrictions on the navigation channel for the Arkansas River.

Another major factor in the decision to move away from the IMD project was that none of the plants researched dealt with the quantity of debris regularly flowing into the Murray Hydro facility. Operators were concerned that an IMD as designed would be unsafe to work under normal generating and operating conditions at the facility. Existing operators of the sites visited, noted that while they were often able to operate the IMD while the plant was generating, the parameters for such were very narrow and debris outside that narrow band could and would frequently require plant shutdown and manual removal of debris.

It was determined that the Murray Hydro facility would likely see an increase in maintenance that required shutdown of the plant due to debris removal and an increase in suspended sand that is a characteristic of IMDs as was proposed. The increase in suspended sand is due to the bucket design which must scoop underneath debris for removal and stirs sand back into the current to flow through the facility. The increase in suspended sand could also increase maintenance costs and outage time for many other elements of the entire unit.

After re-evaluation of the IMD project, the cost of the mechanical seals versus a rope packing system, including maintenance, cost of project, and the cost of downtime during outage was analyzed by facility engineers and the maintenance supervisor.

Of the outages over ten years, it was determined that 32% of total maintenance was seal related. An average of 29% per year was attributed to seal maintenance. That is approximately 9,255 hours in 10 years, an average of 925.5 hours per year spent doing maintenance on seal related issues. In a regular 7-14 day outage to replace seals that cost \$30,000 - \$50,000 per set and an additional \$20,000 per day per unit lost if there was no generation, seal outages became very expensive.

When given a price of \$1,000,000 for the packing box project and the guarantee of a 24 hour or less outage each year to inspect, the packing project proved to be a smart economic decision. When it came

to parts and materials, a spool of Teflon impregnated rope packing can be purchased for approximately \$5,000. That spool will last around 15 years.

Accomplishments

One major accomplishment since commissioning is the unit has run successfully with only minor outages that lasted a few hours a piece. Outages so small are something that has been nearly unheard of in the last decade at the facility. Previously outages have lasted 7-14 days and the most recent outages since start-up only lasted a few hours. The reduced down time and fewer wearing parts also greatly reduce the cost of performing seal maintenance at the facility.

Last month, April 2013, was the first full month of generation since project completion and testing. Almost one third of the electricity needed to meet the demands of the city was generated solely by the hydro facility, far above average for the month of April. March also reported above average generation, even though it was only a partial month.

Thus far, the rope packing project has far exceeded expectations. The generator capacity and efficiency have both been greatly improved. At least a year of adjusting and fine tuning was expected, but the unit has so far proven to be running in top shape from commission. The packing has successfully maintained a constant seal within the unit.

Another great benefit of the ARRA project at the facility is the improved air quality in central Arkansas. The wood grinder has removed any need for burning waste from the facility intake that previously existed. The purchase of the wood grinder has also already provided many people with free mulch for landscaping.

Average kWh production for March: 12,828,982 kWh

March 2013: 13,602,000 kWh

Figure 1. March Hydro generation

Average kWh production for April: 13,801,641 kWh
April 2013: 19,968,117 kWh

Figure 2. Murray Hydro Production April

Figure 3. System Load v. Murray Hydro Generation for April 2013

Figure 4. Total System Usage for April 2005-2013

Conclusions

It was determined that the IMD would not be the most advantageous way for the City to improve efficiency at their hydro facility for many reasons. Murray Hydro facility is located in the main channel of the Arkansas River, which is used most commonly for navigation purposes. Because of the primary usage of the Arkansas River and the location of the hydro facility, there is no capability of pooling water for a reservoir. Without the ability to pool water, debris is constantly flowing directly into the intake of the facility with no way to guide or flush away from the facility. From the hydro facilities visited that currently have an IMD installed, none of them were located in the main channel of the river, each of them had pooling capacity in a reservoir, allowing for more guided flow of debris.

It was also determined that with the scooping motion provided by the IMD, more sand and silt would be stirred up from the floor of the river and caused to pass through each unit. The Arkansas River is already an extremely dirty river and there was no desire to further disturb the water passing through the unit. With more sand and silt flowing through the unit, it was determined that other parts would begin to deteriorate and the operators and maintenance crew at the facility would begin to see more serious and more frequent outages for these certain parts of the facility not meant to wear so rapidly or have such high amounts of suspended sand flowing through them.

Another major concern for the operators at the facility was safety. There was serious concern with operating the IMD while the facility was generating. From plants visited with IMDs currently installed it was learned that the operating conditions for the IMD during generating hours were so narrow that it became nearly unjustifiable to operate the IMD. With the amount and size of debris received at the facility, especially during times of generation, it was determined that there would rarely be a situation when the operators could continue generating while removing any debris with the IMD. Much of the debris collection witnessed at other facilities using IMDs, was much smaller in physical size and volume, but still caused the facility to shut down in order to continue removing debris.

The current methods of removing debris from the intake facility also proved to be less costly over time than the engineering, design, and installation of an IMD. The best way determined to improve the debris removal was the method of disposal. The purchase of the wood grinder made it possible to cease burning the organic debris and decreasing air quality. The organic debris is now ground into mulch that is available to the public for no cost.

The decision to change to a rope packing seal system became much easier after the evaluation of facilities with an IMD installed. There was an ongoing issue at the facility to reduce the already present suspended sand effects on the unit and no desire to install a machine that could increase those suspended sand effects.

Other facilities on the Arkansas River were also visited during the re-evaluation process to determine what they were doing to cope with the sand and silt in the river. Each of them had a rope packing seal system, none were using any type of mechanical seal. This discovery further strengthened the study for a rope packing system at the facility.

A rope packing system is a proven method for sealing a hydro facility, most commonly used in dirty water environments such as the Arkansas River.

From the success that has been shown so early on in the implementation of the rope packing system plans have been made to begin engineering and design for the other unit located at the facility. Rope packing has been around for so many years, and has proven itself time and time again. Throughout the hydro industry it seems to be the most trusted source of turbine shaft sealing.