RECLAMATION Managing Water in the West

Summer 2014
Research and Development Office
Newsletter 2014-04

The Knowledge Stream

Hydropower and Renewable Energy Issue

Research and Development Office Renewable Energy Research Coordinator

Erin Foraker joined the Research and Development Office (Research Office) in October 2012 as the Renewable Energy Research Coordinator. In this position, Erin directs the Research Office's renewable energy research program, which focuses on improving maintenance practices of hydropower systems, improving reliability and efficiency for hydropower generation, improving safety, and researching opportunities for other renewable energy generation within Reclamation.

Erin holds a Bachelors of Science in Mechanical Engineering from the University of Memphis and a Masters in Business Administration from the University of Denver, with over 20 years of power industry experience.

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Erin Foraker, Renewable Energy Research Coordinator, served as principal editor for this issue.

In this issue. . .

Generating electricity from falling water dates back to 1879 when the first hydroelectric plant was built at Niagara Falls. Reclamation's first hydropower facility began generating electricity in 1909 at the Theodore Roosevelt Dam in Arizona. Today, Reclamation's fleet of 53 powerplants generate over 40 million megawatt hours of renewable energy yearly, enough to power 3.5 million homes.

As the Nation seeks to reduce its generation of greenhouse gases, Reclamation's renewable hydroelectric power becomes even more valuable. But getting the most power out of our aging powerplants, while maintaining the operational flexibility needed to provide environmental water releases, and also help to accommodate increased amounts of wind and solar generation in the power grid, is not easy. As part of the national power grid, Reclamation's plants supply ancillary services, energy, and capacity to help keep the overall system balanced.

This issue of *The Knowledge Stream* highlights research aimed at helping Reclamation meet the Nation's changing energy needs by improving the safety, efficiency, and capacity of our hydroelectric plants. These projects range from detecting cavitation on our turbine runners, to reducing noise at Reclamation's facilities, to understanding how our facilities are impacted as more wind and solar generation is brought into the power grid.

We also examine ways to augment Reclamation's hydropower fleet, for example, by testing hydrokinetic turbines in Reclamation canals and studying the potential benefits from adding pump storage capacity to our system. All this and more, inside!

Curt Brown, Chief of Research

A new turbine runner being installed at the Judge Francis Carr Powerplant in California, part of the Central Valley Project, with two 85 megawatt generators, prior to the unexpected cavitation damage (see Research Update on page 32). Note worker in bottom left for scale.

About *The Knowledge Stream. . .*

The Knowledge Stream is the Bureau of Reclamation's Research and Development Office's quarterly newsletter bringing you news and information on Reclamation research and science: projects, events, innovation, results, publications, and more.

Help Us Write *The Knowledge Stream*: Send Us Your Content and Ideas

We welcome and encourage content from our readers. Please send your Recent and Upcoming Events, Innovation Around Reclamation, or any other content ideas to: research@usbr.gov.

Sign up to receive *The Knowledge Stream. . .*

There are two ways to subscribe:

1. Follow the link below to our "Sign Up" form: http://goo.gl/e4MlEu

2. Text "ResearchUSBR" to 22828

Regional Science and Technology Coordinators Contact Information

Whether you are a regional researcher, Reclamation partner or customer, or just have an idea for a project that can help your region, the Regional Science and Technology Coordinators can help you with your research ideas, proposals and projects.

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Great Plains (GP)	Collins Balcombe	cbalcombe@usbr.gov	512-899-4162

Print Options and Instructions

This document is designed to be read either electronically via PDF or printed in color or black and white. Please forward it to your colleagues and friends.

You have three options for printing parts or all of this document:

1. Print individual Research Updates on one sheet of paper, double-sided.

2. Print the whole document double-sided, corner stapled on 8.5- x 11-inch paper.

3. For magazine-style, instruct your print professional to print the whole document double-sided, head-to-head, saddle-stitched on 11- x 17-inch paper.

Your suggestions for improvements are always welcome. Please email them to jakervik@usbr.gov.

Thanks,

Jake Akervik, Communication and Information Systems Coordinator,
Research and Development Office

Contents

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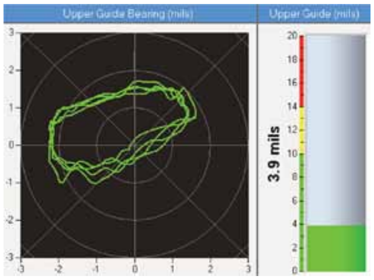

Keeping Track of the Generator's Condition 28

"This open-source software code works with a wide variety of data acquisition equipment including off-the-shelf data acquisition systems, specialized monitoring systems, and other computer systems. Hydrogenerator condition monitoring saves time and money, while improving the reliability of hydropower."

Nathan Myers, Manager, Hydropower Diagnostics and SCADA Group
Reclamation's Technical Service Center

www.usbr.gov/research/docs/updates/2014-12-monitor.pdf

Catching Problems Early: Predicting Shear Pin Failures With Acoustic Emission Sensing and Analysis 30

"The ability to predict some shear pin failures would be advantageous. Replacement of shear pins would no longer be a "hurry-up-and-react" situation resulting in forced outages. Instead, shear pins could be replaced during planned outages. While this process may not predict all failures, even finding one or two could save millions of dollars in damaged equipment."

Russell Anderson, Reliability Program Analyst
Reclamation's Power Resources Office

www.usbr.gov/research/docs/updates/2014-13-shear.pdf

Detecting Cavitation to Protect and Maintain Hydraulic Turbines 32

"Besides predicting and reducing the damaging effects of cavitation, this research could reduce the hazards employees are exposed to during cavitation repairs. Cavitation is very damaging and requires extensive corrective maintenance to repair. Any steps that can be taken to reduce cavitation would be beneficial."

Russell Anderson, Reliability Program Analyst
Reclamation's Power Resources Office

www.usbr.gov/research/docs/updates/2014-14-cavitation.pdf

How Much Does it Cost to Start/Stop a Hydrogenerator? 36

"Reclamation is being called upon more frequently to start and stop units to support grid reliability, but the tools and methods available to understand the costs of these start/stops have been lacking. The development of this cost model will provide great value to Reclamation by delivering more reliable start/stop costs through a more user-friendly process."

Mike Pulskamp, Renewable Energy Program Manager
Reclamation's Power Resources Office

www.usbr.gov/research/docs/updates/2014-15-start-stop.pdf

Hydrokinetic Demonstration Results to Date and Path Forward 38

"A well-developed numerical model will be a useful tool for both private developers and water system owners to help determine if and where a hydrokinetic device could be deployed without impacting existing water delivery operation, before any installations are made."

Josh Mortensen, Hydraulic Engineer
Reclamation's Technical Service Center

www.usbr.gov/research/docs/updates/2014-16-hydrokinetic.pdf

Upcoming Events

The list of events below is intended for informational purposes only and does not necessarily constitute an endorsement by Reclamation. These events may be of interest to the science, research, and related communities and are not necessarily hosted by Reclamation. Find our most recent list of events at:

www.usbr.gov/research/events.

National Hydropower Association (NHA)—NHA Southwest Regional Meeting

September 8 - 10, 2014 | Golden, Colorado

NHA presents the NHA Southwest Regional Meeting. Based on new incentives and increased interest in renewable energy, the United States hydropower industry is primed for growth. Numerous opportunities are available to expand the region's hydropower base, while at the same time providing responsible environmental stewardship of the region's rivers. Additional meeting information:

www.hydro.org/news-and-media/events/details/nha-southwest-regional-meeting/

NHA—Hydropower Finance Summit

October 2, 2014 | New York, New York

This exclusive 1-day event brings together key leaders in the hydropower and financial sectors. Sessions examine project opportunities, financing options, and growth forecasts for the Nation's largest renewable energy resource. Additional summit information:

www.hydro.org/news-and-media/events/details/hydropower-finance-summit/

NHA—Hydraulic Power Committee Fall Retreat

October 6 - 8, 2014 | Holyoke, Massachusetts

This 3-day meeting will focus on hydro operations, dam safety and security, and best practice sharing. The retreat is open to all NHA member companies and invited guests, including owners and operators of hydro projects and service and equipment providers. Additional retreat information:

www.hydro.org/news-and-media/events/details/nha-hydraulic-power-committee-fall-meeting-3/

Midwest Hydro Users Group—Fall Regional Meeting

November 12 - 13, 2014 | Wausau, Wisconsin

The Midwest Hydro Users Group will be holding their annual fall regional meeting, an owners-only meeting, and a full membership meeting. Additional meeting information:

www.midwesthug.org/activities.html

Renewable Energy World Conference & Expo North America 2014 Conference

December 9 - 11, 2014 | Orlando, Florida

With an unwavering history, the Renewable Energy World Conference & Expo North America is returning for its ninth year and will provide the perfect venue to gather and exchange information about the latest in technology, opportunities, and funding in today's changing world. The conference and expo will also, once again, be co-located with Power Generation Week, providing networking opportunities with more than 20,000 professionals and key decisionmakers.

The Renewable Energy World Conference & Expo North America is recognized as the leading platform for information exchange, networking opportunities, and new business development covering all sectors in renewable energy and hot topics such as large-scale

— continued

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renewables, distributed generation, utility integration, renewables and the global market, and innovative energy partnerships. Additional conference and exhibition information: www.renewableenergyworld-events.com/index.html

The Northwest Hydroelectric Association (NWHA)—Workshops, Tour, Annual Conference, and Seminar

NWHA provides a regional voice for the hydropower industry, representing the needs of its membership since 1981. NWHA is dedicated to the promotion of the region's waterpower as a clean efficient energy, while protecting the fisheries and environmental quality that characterize the Northwest Region.

The NWHA technical workshops and seminars offer the engineers, electricians, mechanics, operators, and technicians servicing the hydroelectric industry a forum to discuss and learn about the arts and issues of their work, which is fundamental to the Northwest Region quality of life.

2014 Small Hydro Workshop
September 4 - 5, 2014 | Sisters, Oregon
See www.nwhydro.org/events_committees/low_impact_hydro_workshop.htm

2014 Fall Workshop & Tour
October 29 - 30, 2014 | Spokane, Washington
See www.nwhydro.org/events_committees/regional_meeting.htm

2015 Annual Conference
February 17 - 19, 2015 | Portland, Oregon
See www.nwhydro.org/events_committees/AnnnualConference.htm

2015 Technical & Operations Seminar—Machines, Maintenance, and Management: Keeping Hydro Facilities Up and Running
May 7 - 8, 2015 | Hood River, Oregon

See www.nwhydro.org/events_committees/tech_operations_conference.htm

Additional NWHA information: www.nwhydro.org/default.htm

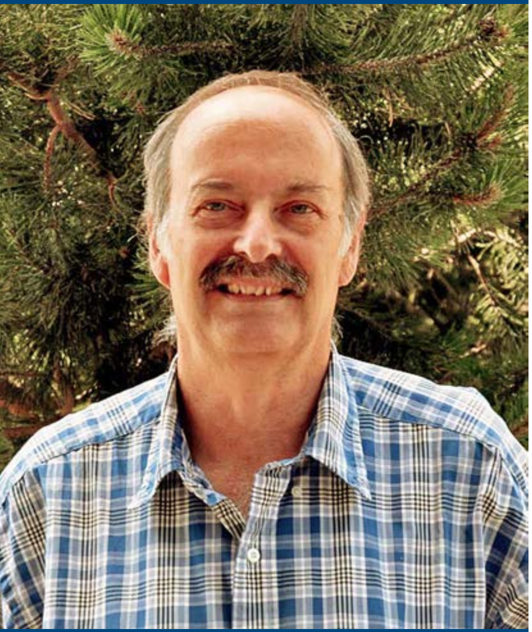
The Association of State Dam Safety Officials (ASDSO)—Dam Safety 2014 Conference

September 21 - 25, 2014 | San Diego, California

ASDSO's annual conference is one of the leading conferences in the United States (U.S.) dedicated to dam safety engineering and technology transfer. The conference and field trips continue to be the annual event to showcase dam safety in the U.S., with over 1,050 industry professionals expected to attend.

This year's field trip is to the University of California-San Diego (UCSD) Large Outdoor Shake Table Facility. UCSD's large outdoor shake table is the largest facility of its kind in terms of footprint and payload capacity of any in the world.
Additional conference information:
www.damsafety.org/conferences/?p=8faca187-a4b0-406d-b9d6-f71c8ba9d192

Featured Faces



John Germann

www.usbr.gov/research/projects/researcher.cfm?id=1969

John Germann, Mechanical Engineer, B.S.

John Germann is a mechanical engineer in the Mechanical Equipment Group in Reclamation's Technical Service Center. He has 33 years of experience with Reclamation as a mechanical engineer performing operation, maintenance, and rehabilitation of hydromachinery.

John grew up in rural eastern Wyoming and spent his youth working on local ranches. He graduated from the University of Wyoming in 1978 with a Bachelors of Science in Agricultural Engineering. After college, John worked in Kansas City, Missouri, for Farmland Industries, where he designed fertilizer plants. In 1980, he again moved west and worked briefly as a mechanical engineer for a consulting engineering firm in Cheyenne, Wyoming.

John started work for Reclamation in 1981 as a mechanical engineer in the Eastern Colorado Area Office (ECAO) in Loveland, Colorado. For 21 years, he provided engineering assistance and services to the power and pumping plants' maintenance sections. During that time, John served for 1 year as ECAO's Acting Chief of Engineering and 1 year as the Great Plains Region's mechanical engineer in the now nonexistent Lower Missouri Regional Office.

Currently, John provides mechanical engineering services to Reclamation facilities, focusing on providing improved maintenance and repair practices. These tasks include unit turbine/generator alignment, machine dynamic behavior (vibration) testing and analysis, balancing, governor adjustments, unit commissioning, and general mechanical engineering consultation. John develops, writes, and updates Reclamation mechanical technical maintenance standards, procedures, and practices documents. In addition, he frequently participates as a team lead and reviewer in power operation and maintenance facility reviews of power and pumping plants.

John Germann field testing at Judge Frances Carr Powerplant, California.

John has conducted numerous research projects as part of Reclamation's Science and Technology Program. At the present time, he has two active research projects: 1) "Detecting Cavitation to Protect and Maintain Hydraulic Turbines" (see Research Update on page 32), which focuses on exploring cavitation detection techniques in powerplant turbines and developing effective monitors to assist powerplant operators so that they can avoid operating generators in cavitation zones; and 2) "Predicting Shear Pin Failures With Acoustic Emission Sensing and Analysis" (see Research Update on page 30), which has the goal of developing a better shear pin failure detector for use in hydroelectric turbines. John hopes both projects will result in significant cost benefits to the power hydrogeneration provider.

John has been married to his lovely wife, Jacqueline, for 20 years. They live near Fort Collins, Colorado, where John spends weekends working on the property. Both John and his wife have a passion for canines. They have numerous dogs, as well as rescue dogs, which enjoy romping on the 20 acres where they live. Jacqueline is a psychotherapist and uses several of the dogs as therapy dogs within her work. Both John and Jacqueline are active in the English Setter Club of Greater Denver. Over the years, they have raised several champion English Setters.

Jim DeHaan, Senior Electrical Engineer, B.S., M.S., P.E.

Jim DeHaan is a senior electrical engineer for the Hydropower Diagnostics and SCADA Group in Reclamation's Technical Service Center. He has 23 years of experience in the electric power field. His present responsibilities include research and field testing in the areas of large rotating machine testing and diagnostics, power apparatus testing and diagnostics, hydroplant condition monitoring, electric power safety, and specialized power system instrumentation development. Jim has a Bachelors of Science in Electrical Engineering from Dordt College, as well as a Masters of Science in Electric Power from Iowa State University. He is a Registered Professional Engineer and a senior member of the Institute of Electrical and Electronic Engineers (IEEE).

In 1991, after obtaining his master's degree, Jim began working for Reclamation in the Electric Power Branch, where he has remained for the last 23 years. During his career at Reclamation, Jim has authored or co-authored over 30 technical papers for external publication and well over 100 field trip technical reports. In addition, he co-authored two Facilities Instructions, Standards, and Techniques (FIST) manuals: FIST 3-8, *Operation, Maintenance, and Field Test Procedures for Protective Relays and Associated Circuits* and FIST 5-1, *Personal Protective Grounding for Electric Power Facilities and Power Lines*. Jim also co-authored Design Standards No. 12, *Synchronous Generator, Motor and Generator/Motor Field Tests*, Chapter 1, "Plant Testing." He holds two patents: 1) High Current Measurement System Incorporating an Air-Core Transducer, and 2) Flexible Printed Circuit Magnetic Flex Probe.

During the first part of his career, Jim assisted and led research related to the application of Personal Protective Grounds (PPGs). PPGs are used to ground deenergized equipment and circuits after a clearance is in place to ensure that the equipment remains grounded during hands-on work. The research measured the actual voltages that a worker could be exposed to across a PPG during an accidental reenergization.

For these field tests, PPGs were placed on actual powerplant equipment, and this equipment was then energized. Power system fault current flowed through the grounds, and voltages were measured at the location where worker contact to the bus was probable during maintenance work. According to the tests, exposure voltages were two to three times higher than would be predicted by calculating the voltage drop just across the PPG. The additional voltage resulted from the geometry of the PPG related to the position of the worker. Mathematical methods to calculate this voltage were then developed. This information, along with the new method to calculate worker exposure voltages, has recently been incorporated in IEEE Standard 1246, *IEEE Guide for Temporary Protective Grounding Systems Used in Substations*.

Jim DeHaan configuring machine condition monitoring at Grand Coulee Powerplant, Washington.

Currently, Jim is leading a research effort to develop and implement a hydrogenerator condition monitoring system to monitor turbine generator vibration and perform other beneficial uses. The system is currently installed on more than a dozen generators at various Reclamation powerplants, with more sites scheduled in the future.

More information on PPGs, IEEE Standard 1246, and hydrogenerator condition monitoring can be found on pages 16, 28, and 42.

Jim DeHaan

www.usbr.gov/research/projects/researcher.cfm?id=13

—continued (from page 1)

"Erin Foraker, Renewable Energy Research Coordinator"

Prior to joining Reclamation in June 1999, she worked at the Tennessee Valley Authority in the Hydro Modernization Program and Fossil Power Engineering at the Allen Fossil Plant.

Prior to joining the Research Office, Erin worked in both Reclamation's Hydroelectrical Research and Technical Services Group and the Power Resources Office.

She has also served as chairperson and as a representative on several power industry committees.

Hydropower 101 and Research

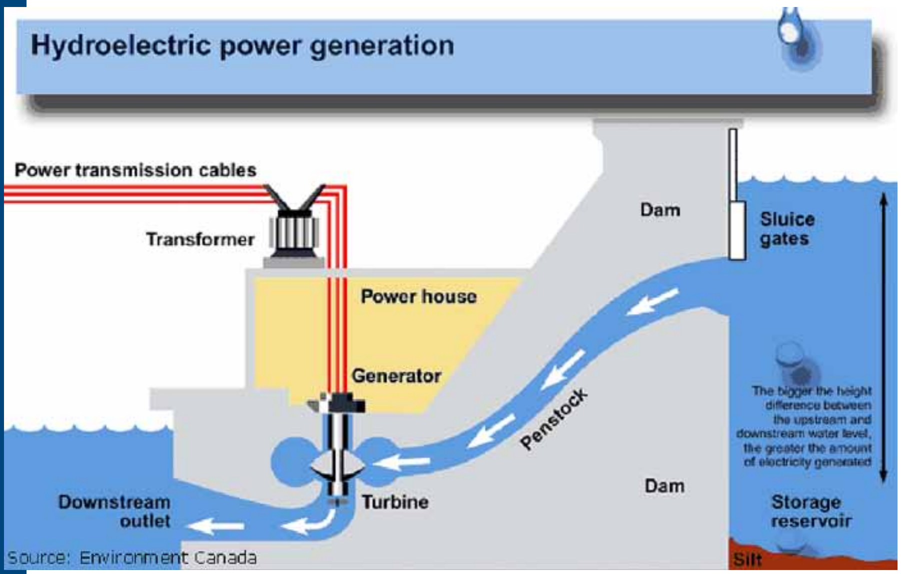
“Hydroelectricity is a renewable, non-polluting energy. It does not cause any greenhouse gas emissions or produce any toxic waste. It currently represents almost 20 percent of global electrical capacity and has development potential of three times its current level. While the investment required and the human and environmental impact weigh heavily on large dam-building projects, the future seems promising for small hydro.”

Planete-energies.com
An initiative by Total

www.planete-energies.com/en/planete-energies-en-100000.html

Hydropower 101

As the primary research and development arm of Reclamation, the Science and Technology Program evaluates potential technical advances in renewable generation as well as opportunities for improved safety, efficiency, capacity, and energy savings. Reclamation works with an array of external partners, including the National Renewable Energy Laboratory (NREL), U.S. Department of Energy National Laboratories, Electric Power Research Institute, Center for Energy Advancement and Technological Innovation, academia, and other research-based organizations.



Source: Environment Canada (www.ec.gc.ca/eau-water/) through the U.S. Geological Survey’s Water Science School website at: http://water.usgs.gov/edu/.

How Hydropower Works

Hydropower, also called hydroelectric power, is produced by the force (or gravity) of falling water, usually stored in a reservoir behind the dam. The dam creates a “head” or height from which water flows. A pipe (penstock) carries the water from the reservoir to the turbine. The fast-moving water pushes the turbine blades, something like a pinwheel in the wind. The water’s force on the blades turns the rotor, the moving part of the electric generator. The coils of wire on the rotor sweep past the generator’s stationary coil (stator), producing electricity, and then the water continues to flow downstream to meet other needs.

View of power lines running from the Grand Coulee Powerplant, Washington.

The electricity produced is then delivered to where it is needed—our homes, schools, offices, and so on. Dams are often in remote locations, so power must be transmitted to its users via vast networks of transmission lines and facilities. All the electricity made at a powerplant comes first through transformers, which raise the voltage so it can travel long distances through powerlines. Transformers on poles (or buried underground, in some neighborhoods) further reduce the electric power to the right voltage for appliances and use in the home.

Other Resources of Renewable Energy

Non-hydroelectric renewable energy resources include wind, solar, and geothermal. Wind and solar resources are a clean, carbon emission-free source of renewable energy, but they are also intermittent. Reclamation's primary objective is to deliver water and power within existing project authorities, contracts, and other the water management constraints associated with its projects. With this water, Reclamation generates power and strives to optimize this power to deliver low-cost, reliable energy to its power customers.

The Role of Research

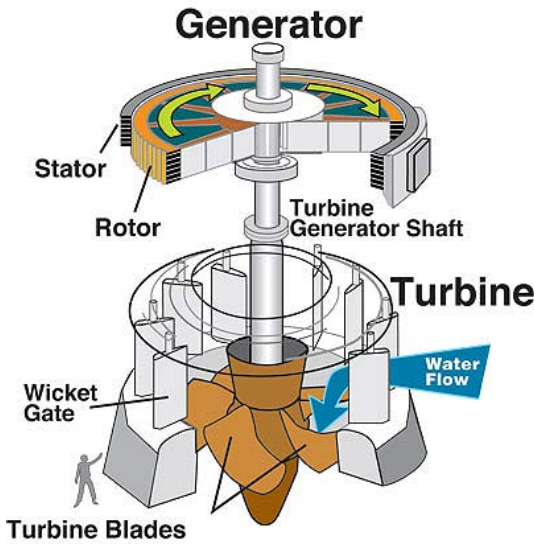
Researching new technologies and adapting industry technologies to Reclamation's unique facilities is vital for providing hydropower that can integrate into an increasingly complex power grid and meet future demands within a changing system. Reclamation's research projects:

- **Help powerplants last longer.** Machine condition monitoring can help powerplant operators understand the best operating ranges, monitor equipment, lengthen service life, and better predict failures. This contributes to more effective maintenance—which, in turn, means less downtime and fewer outages. See the "Powerplant Performance and Reliability" section starting on page 22 in this issue.

- **Optimize operations.** Even a tiny increase in operational efficiency can save millions of dollars. Determining how to operate each generator in each powerplant to respond to the power needs can help Reclamation deliver the most energy for the least cost. Moreover, integrating solar and wind energy into the power grid impacts the way hydropower plants are operated, so Reclamation has been investigating the impacts that increased starts/stops and other changes to operations associated with these resources have on our hydropower units. See the "Powerplant Performance and Reliability" and "Renewable Energy" sections starting on pages 22 and 34, respectively, in this issue.

- **Improve safety.** Safety is a paramount concern, and Reclamation is continually seeking ways to make operations safer. Reclamation is identifying the primary noise hazards and investigating ways to mitigate these to protect the hearing of its workers. The Hydropower Diagnostics and SCADA Group in Reclamation's Technical Service Center is investigating ways to improve arc flash detection and interruption on certain systems in Reclamation powerplants, as well as transferring the technology that has been developed into industry standards. See the "Safety" section starting on page 16 in this issue.

- **Find new opportunities for renewable energy.** Reclamation works with other Federal and non-Federal agencies and organizations to support and streamline renewable generation development. For example, Reclamation is working with NREL to identify opportunities for solar and wind energy on Reclamation lands. Reclamation is also working with private industry to test and improve hydrokinetic turbine technologies and the impacts these technologies may have on Reclamation's canal systems and infrastructures, while maintaining its water and power deliveries. See the "Renewable Energy" section starting on page 34 in this issue.



Source: U.S. Geological Survey's Water Science School website at:

http://water.usgs.gov/edu/.

More Information

For more information on hydropower/hydroelectric power basics or how hydropower/hydroelectric power works see:

http://energy.gov/eere/water/hydropower-basics

or

http://water.usgs.gov/edu/wuhy.html

Watch the "Energy 101: Hydropower/Hydroelectric Power" video (also referenced on page 44 in this issue) at:

http://energy.gov/eere/water/hydropower-basics

or

www.youtube.com/watch?feature=player_embedded&v=tpigNNTQix8

Policy Direction

As technology and demands for power and water use evolved over the last 100 plus years, Reclamation has adapted to these changes to take advantage of new technologies to help meet the Nation's water and energy needs. Today, Reclamation owns and operates 53 hydroelectric plants with over 14,600 megawatts of installed capacity and ranks as the second largest producer of hydroelectric power in the U.S. by generating over 40 billion kilowatt hours of energy each year.

Reclamation's Sustainable Energy Strategy

Reclamation contributes to the Administration's priorities on renewable energy in many ways, including generating more renewable energy, reducing Reclamation's energy use, and supporting the integration of wind and solar technologies into the United States (U.S.) electric grid. These activities are administered through several Reclamation programs throughout Reclamation.

In 2013, Reclamation published a *Sustainable Energy Strategy*, a policy document that details Reclamation's commitment to:

- Increase sustainable renewable energy production and development
- Promote and implement activities that reduce energy consumption

This strategy offers a framework for Reclamation to respond efficiently to its customers' needs and to strategically plan for the future of renewable power development and production in the Western U.S.

Operating Environment

Reclamation's role in renewable development, including hydropower production, must balance multiple—and sometimes even conflicting—objectives. For example, Reclamation must consider several factors, including: individual project authorities; Federal, state, and local laws; permitted land uses; environmental constraints; and other contractual obligations related to flood control and water and power management. Reclamation can build on its history of generating renewable hydropower from projects with multiple operational and legal obligations, and this expertise can provide a foundation for supporting further renewable development that includes both hydropower and non-hydroelectric renewable energy.

Renewable energy has been expanding rapidly over the last decade, and this growth is largely being driven by state-mandated Renewable Portfolio Standards and concerns over climate change. Reclamation can play a significant role in encouraging and supporting ongoing renewable development. For example, Reclamation can promote developing new renewable energy on Reclamation lands and facilities. However, increases in renewable resources can also create unique challenges for electric grid and powerplant operations.

Wind and solar resources are a clean, emission-free source of renewable energy, but they are also intermittent. The Federal hydropower system can help provide balancing reserves to stabilize the electric grid, but Reclamation's primary objective is to deliver water within the water management constraints of each watershed.

Robert V. Trout Hydropower Plant, developed in a partnership with the Northern Colorado Water Conservancy District, at the Reclamation Carter Lake outlet.

Mission and Objectives

Reclamation's Power Resources Office coordinated the development of the *Sustainable Energy Strategic Plan* and worked with various Reclamation offices, including the Research and Development Office (Research Office), Policy and Administration Office, and the regions. This strategy serves as a roadmap where activities occur throughout Reclamation, draws attention to past accomplishments, introduces a long-term strategy for Reclamation's future activities, and identifies the Sustainable Energy Mission:

Building on a century of agency experience in providing renewable, clean, reliable, and affordable hydropower, Reclamation seeks to facilitate the development, production, and integration of renewable energy in an environmentally and economically sound manner in the interests of its water and power customers and the American public alike.

An additional 1.5 million megawatt-hours of renewable energy could be generated through hydropower at existing Reclamation sites.

To do this, Reclamation will:

- Make sound business decisions
- Collaborate with power marketing agencies, other Federal agencies, customers, Indian Tribes, state entities, and other stakeholders

Six long-term strategic objectives were developed to further Reclamation's Sustainable Energy Mission. These objectives are to:

1. Increase renewable generation from Reclamation projects.
2. Facilitate non-Federal development of renewable energy projects.
3. Increase energy savings and conservation at Reclamation projects.
4. Support integration of variable non-dispatchable renewable resources into the U.S. electrical grid.
5. Increase benefits of renewable energy through technological innovation.
6. Improve management efficiencies related to the implementation of renewable energy and energy savings projects.

Several supporting activities have been identified for each strategic objective. Many of these activities are supported by multiple offices within Reclamation. The Research Office does support many of these activities with its directed Renewable Energy Research Program.

More Information

More information on the *Sustainable Energy Strategy* can be found at:

www.usbr.gov/power/Reclamation%20Sustainable%20Energy%20Strategy%20.pdf

"Through collaboration and partnerships with other Federal agencies, the hydropower industry, the research community, and numerous stakeholders, these [MOU] agencies have been able to succeed in the majority of their efforts."

Memorandum of Understanding for Hydropower, Two-Year Progress Report, April 2012

Memorandum of Understanding for Hydropower

Reclamation has a long and successful history of generating renewable, clean, reliable, and affordable hydropower. As the power operating environment has evolved over the past century, Reclamation has adapted, leveraging new technologies and partnerships to meet the Nation's water and energy needs.

To promote reliable, affordable, and environmentally sustainable hydropower, the U.S. Department of the Interior (through Reclamation), the U.S. Department of Energy (DOE) (through the Office of Energy Efficiency and Renewable Energy), and the Department of Army (through the U.S. Army Corps of Engineers) entered into a *Memorandum of Understanding for Hydropowe*r (MOU), signed on March 24, 2010.

The MOU provides for a long-term, collaborative working relationship, prioritizing similar goals and aligning ongoing and future renewable energy development efforts between the three agencies. The MOU agencies identified 13 high-level goals to address issues ranging from enhancing sustainable hydropower development and improving environmental performance to assessing the effects of climate change on hydropower operations. The high-level goals are supported by 17 action items, which include activities related to hydropower resource and integrated basin-scale opportunity assessments, renewable energy integration and energy storage, and improving the regulatory process.

In April 2012, the MOU agencies published a *Memorandum of Understanding for Hydropower, Two-Year Progress Report* (Two-Year Progress Report), which detailed progress made on action items and identifies opportunities for future activities. Some of the two-year accomplishments are :

Jo-Ellen Darcy, Assistant Secretary of the Army for Civil Works; Steven Chu, Secretary of Energy; and Ken Salazar, Secretary of the Interior signing the MOU on March 24, 2010.

- Hydropower resource assessments, identifying 370 megawatts of potential hydropower at existing Reclamation dams and conduits
- A climate change assessment, evaluating the effects and risks associated with climate change on water supplies available for Federal hydropower generation
- A basin-scale opportunity assessment, identifying opportunities to increase hydropower and environmental performance in the Deschutes Basin
- The Advanced Hydropower Technology Development funding opportunity announcement, offering financial assistance to non-Federal projects that develop and demonstrate innovate hydropower technologies
- The Two-Year Progress Report also identifies future MOU activities, including opportunities to address aging infrastructure concerns and to develop new generation through research and demonstration of advanced technologies

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The MOU agencies have continued these actions, and are drafting a *Phase II Action Plan* that identifies MOU priorities and action items for the next 2 years. In addition to reaffirming MOU agency commitments to sustainable hydropower, the *Phase II Action Plan* provides updates on ongoing action items and introduces new action items. New action items build off of the accomplishments thus far and include, among others:

- Quantifying ancillary services available from hydropower assets
- Quantifying reliability and cost impacts of operational changes and technology deployments for hydropower assets
- Developing best practices guidance manuals for hydrokinetic canal testing

In general, phase II priorities address the major issues facing both Federal hydropower and the broader hydropower industry. Phase II priorities include:

- Analyzing hydropower systems
- Developing technology and testing performance
- Addressing environmental issues
- Sharing information

The *Phase II Action Plan* is expected to be published by the end of fiscal year 2014.

More information

MOU:
www.usbr.gov/power/SignedHydropowerMOU.pdf

Two-Year Progress Report:
www.usbr.gov/power/hydropower-mou/HydropowerMOU.pdf

More information on the MOU and Two-Year Progress Report can be found on Reclamation's Power Resources Office website at: www.usbr.gov/power/.

Additional information on the MOU can be found on the Federal Memorandum of Understanding for Hydropower website at: http://en.openei.org/wiki/Federal_Memorandum_of_Understanding_for_Hydropower

Turbinator hydroturbine, a new low-head modular hydropower technology, to be installed by Earth by Design at the 45 Mile Site on the North Unit Main Canal in Bend, Oregon. The 45 Mile Site project is funded through the Advanced Hydropower Technology Development Funding Opportunity Announcement (FOA). The FOA (jointly funded by Reclamation and DOE through the MOU) provided funding (nearly $17 million) in 2011 to demonstrate new hydropower technologies.

In total, 16 projects received FOA funding, three on Reclamation's infrastructure. The three projects are being developed by Earth by Design, Percheron Power, and Natel Energy. Earth by Design will demonstrate a new low-head modular hydropower technology on North Unit Main Canal, 45 Mile Site; Percheron Power will install the Nation's first Archimedes Hydrodynamic Screw hydropower system on the South Canal, Drop 2; and Natel Energy will deploy and test a scaled-up version of the modular Schneider Linear hydroEngine on the North Unit Main Canal, Monroe Drop.

RECLAMATION Managing Water in the West

Summer 2014
Research and Development Office
Bulletin 2014-07

The Knowledge Stream
Research Update

Safe and Grounded

Ensuring deenergized equipment is adequately grounded while maintenance work is being performed

Bottom Line

The placement of temporary grounds with respect to the location of the electrical work being performed can greatly influence how effective grounding is at protecting workers from being shocked or killed during an accidental energization. This research examines various factors that influence grounding effectiveness and provides equations to calculate safer grounding placement.

Better, Faster, Cheaper

Providing more accurate methods to calculate the effectiveness of safety ground cables in limiting worker exposure voltage during an accidental energization is critical to safely protecting workers.

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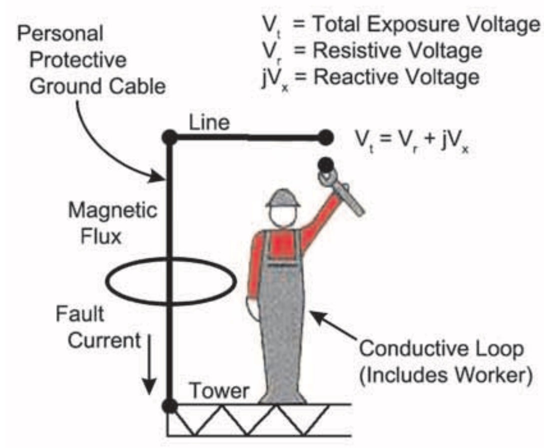
Problem

Worker safety is paramount in hydropower and other utility work, particularly as work often times requires direct contact with deenergized high-voltage equipment and transmission lines. High-voltage equipment and transmission lines need to be deenergized, placed on a clearance, and safely grounded with temporary personal protective ground (PPG) cables prior to performing maintenance. But determining what constitutes a safe level of grounding and how ground cables should be configured is a difficult question.

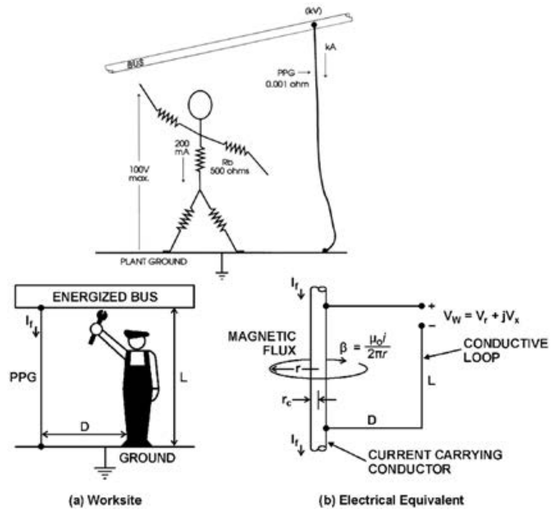
Grounding deenergized high-voltage equipment and power lines during maintenance or construction activities is critical for worker safety. This is usually done by applying PPGs according to the utility's procedure to create a safe work zone. However, in practice, many of these procedures tend to underestimate the maximum voltage a worker would be exposed to during an accidental energization of the equipment.

Solution and Results

The Hydropower Diagnostics and SCADA Group in Reclamation's Technical Service Center (TSC) has been testing different grounding methods used in the electric industry. The research looked at measuring the actual voltages that a worker could be exposed to across a PPG during an accidental energization. The field tests involved installing PPGs on deenergized powerplant equipment or transmission lines. The PPGs were then intentionally energized and the resultant currents in the PPGs, and the resultant exposure voltages at locations where worker contact with energized equipment was probable, were monitored.



Inductive ground loop principle.



Reclamation's grounding principles.

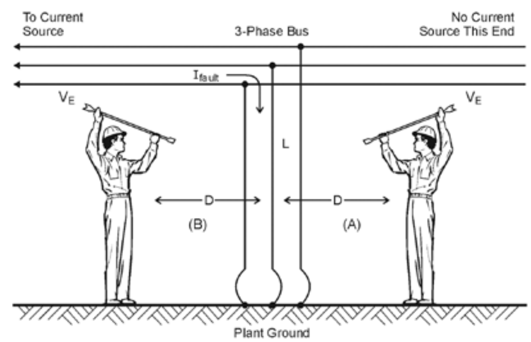


Illustration of worker relative to protective grounds.

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The field testing found that the exposure voltages were 2 to 3 times higher than what would be predicted by calculating the voltage drop just across the PPG. The additional voltage was the result of the geometry of the PPG in relationship to the position of the worker.

Historically, the PPG cable resistance was placed in parallel with the worker's body to calculate worker exposure touch voltage and the resultant current through the body if the grounded worksite was accidently energized. The PPG cable resistive voltage drop resulting from the power system fault current was the key factor in determining worker touch voltage.

However, the field testing demonstrated that the PPG cable reactive voltage drop often is a significant component of the worker touch voltage. Reactive voltage is developed due to the magnetic induction around the PPG that is produced by the flow of current in the PPG. This magnetic induction inherently produces a reactive voltage drop at the worksite due to the loop that is formed between the PPG cables and a worker. Therefore, the PPG cable resistance and reactance should both be considered for realistic worker exposure touch voltage evaluation.

Following these field test data, the recorded information was analyzed and the effect of the reactive voltage drop was then incorporated into Reclamation's Facility Instructions, Standards, and Techniques (FIST) manuals. FIST 5-1, *Personal Protective Grounding for Electric Power Facilities and Power Lines,* provides PPG procedures that enable Reclamation workers to perform their duties within a safe working environment.

To further expand on the field test data and to better predict expected worker exposure voltages, mathematical methods to calculate the worker exposure voltages were developed that include both the resistance and reactive components. Six temporary protective grounding scenarios were modeled to illustrate the effect that magnetic induction has on worker exposure voltage when a worksite is accidentally energized. The Hydropower Diagnostics and SCADA Group also participated with the Institute of Electrical and Electronic Engineers (IEEE) Standards Association to incorporate these findings into IEEE standards. The latest edition of IEEE Standard 1246, *IEEE Guide for Temporary Protective Grounding Systems Used in Substations* incorporates Reclamation's research findings.

Workers working on high power transformer lines.

"The primary purpose of personal protective grounding is to provide adequate protection against electric shock causing death or injury to personnel while working on deenergized lines or equipment. This is accomplished by limiting exposure voltages at the worksite to a safe value if the line or equipment is accidentally energized."

Phil Atwater
Electrical Engineer, retired
Reclamation employee

Collaborators

Reclamation:

- **Hoover Powerplant**
- **Grand Coulee Powerplant**

Western Area Power Administration

Future Plans

Continue to inform the power industry through guides such as IEEE Standard 1246 and through publishing additional papers on these new mathematical models to predict worker exposure voltages.

More information

www.usbr.gov/research/projects/detail.cfm?id=5446

RECLAMATION Managing Water in the West

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Bulletin 2014-08

The Knowledge Stream

Research Update

Making Reclamation Powerplants a Quieter Place

Reducing noise in Reclamation's powerplants by implementing advanced engineering controls

"This Voodoo noise control stuff really works!"

Bob Hotze
Green Springs Powerplant Foreman, Reclamation's Pacific Northwest Region

Bottom Line

Long-term exposure to high noise levels can cause noise-induced hearing loss, worker fatigue, and other problems, thus increasing safety risks. Reducing noise levels through the use of engineering controls significantly mitigates those risk factors.

Better, Faster, Cheaper

Reducing noise levels in powerplants will result in a significantly reduced incidence of noise-induced hearing loss in Reclamation workers, thus avoiding degradation of their quality of life as well as reducing workers' compensation claims.

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Problem

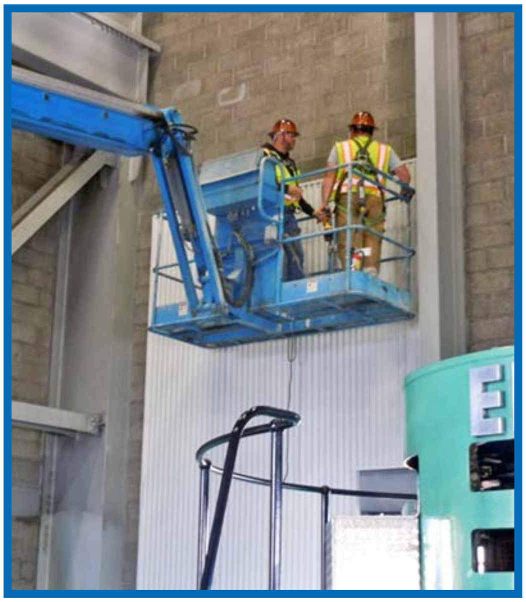
Noise is often overlooked as a hazard at powerplants—and everywhere else—because there are no obvious indicators of acute or chronic exposure. Yet repeated exposure to loud noises can cause hearing loss or other noise-related problems, thus significantly affecting a worker's quality of life. Exposure to high noise levels over the course of a workday can also result in worker fatigue and decreased performance and increase the risk of safety incidents.

Solution

This Reclamation Science and Technology Program research project researched and developed a pilot program in three Pacific Northwest (PN) Region powerplants. Reclamation has partnered with the Office of Naval Research (ONR) and their contractor Noise Control Engineering, LLC (NCE) of Billerica, Massachusetts, on this research project. NCE has been involved with ONR for a number of years, working on a major program to reduce hearing loss and other damages for troops on warships.

Application and Results

Reclamation put the noise-induced hearing loss program's technology to use in the following Reclamation powerplants by determining noise levels with advanced measurement techniques and designing appropriate, cost-effective engineering controls: Green Springs Powerplant in southern Oregon, Roza Hydro Electric Powerplant in the Yakima Valley in eastern Washington, and Chandler Hydro Electric Powerplant, southeast of Prosser, Washington.



Panel installation at the Roza Hydro Electric Powerplant.

Green Springs Powerplant was the first powerplant to complete the installation, with dramatic results. Before this installation, noise levels in the penstock area during powerplant operation were 90.3 A-weighted decibels (dB[A])—about a train whistle at 500 feet. Sound absorption treatment was installed in the turbine pit, high transmission loss panels were hung in the pit opening, and sound absorption panels were mounted on the wall in the penstock area. This reduced levels in the penstock area by 16 dB and in the control room by 10 dB (and, as decibel levels are logarithmic, this basically cut the noise level in half). These engineering controls in the Green Springs Powerplant significantly reduced overall noise levels in the powerplant. Now, except for the turbine pit, all levels in the powerplant area are below 85 dBA—about a telephone dial tone level. For the turbine pit, appropriate hearing protection should be worn.

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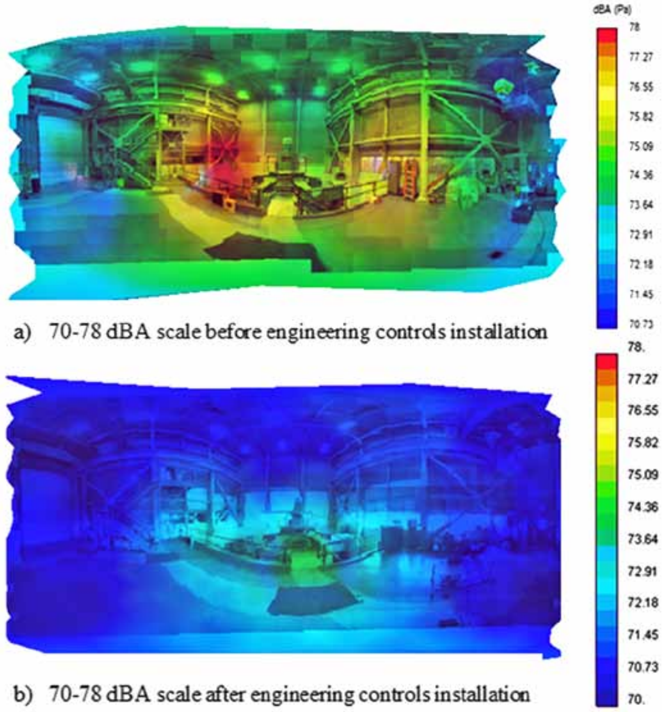
The table below shows noise levels in Green Springs Powerplant before and after controls.

Location	Noise levels before controls were installed (dBA)	Noise levels after controls were installed (dBA)
Turbine pit	101.4 (a jack hammer at 32 feet)	98.7 (a circular handsaw at 3 feet)
Penstock area	90.3 (an angle grinder outside at 3 feet)	74.5 (a passing car at 25 feet)
Control room	80.6 (very loud traffic noise at 25 feet)	70.6 (close to a main road by day)
Cooling water levels	86.6 (2-stroke chainsaw at 2 feet)	78.4 (un-silenced wood shredder at 2 feet)

Each powerplant is a little different, and thus it is important to tailor the type of controls to the type of noise sources. At the Roza Hydro Electric Powerplant, two large cooling fans that blew air directly through openings in one of the walls were found to be a major source of high noise levels. This was verified through the use of an advanced measurement technology called an acoustic array, which takes a three-dimensional picture of a room and then overlays the sound sources on top of the picture to verify the source of the noise. To reduce the noise from these cooling fans, silencers were designed and installed. The figure below shows the acoustic array results before and after the installation. Note the acoustic “hot spot” in the top figure that disappears after the installation. Sound absorption panels and a special spray-on material on the cooling ducts were also installed, which reduces the vibration of the ducts and keeps energy from this vibration from radiating as noise into the powerplant. Noise levels were reduced by 5 to 7 dB, and now all areas on this level fall below the 85 dBA target.



a) 70-78 dBA scale before engineering controls installation

b) 70-78 dBA scale after engineering controls installation

Installing controls at the Chandler Hydro Electric Powerplant also reduced noise levels by 3 to 5 dBA, to get below the target 85 dB(A). Because much of the noise was due to a direct path of energy from generator cooling slots, in addition to damping material on the ducts and absorption panels on the walls, it was necessary to install sound absorption barriers that block this direct path.

Future Plans

Because of the success of this pilot program, a number of other plants are being targeted for installation of these noise reduction engineering controls. Measurements have already been taken at seven other Reclamation powerplants and appropriate engineering controls, where necessary, are being considered for installation. This new research helps Reclamation take the steps necessary to assure that noise does not harm its workers.

Collaborators

Reclamation:

- **Safety and Health Office**
- **PN Region, Yakima Field Office**
- **Green Springs Powerplant**
- **Roza Hydro Electric Powerplant**
- **Chandler Hydro Electric Powerplant**

Office of Naval Research:

- **Noise Control Engineering, LLC**

More information

www.usbr.gov/research/projects/detail.cfm?id=6433

Previous Research Update at:

www.usbr.gov/research/docs/updates/2012-28-noise-exposure-powerplants.pdf

Thomas (Tom) Glover is a Power Systems Supervisor for the Yakima Field Office in Reclamation’s Pacific Northwest Region. Prior to working for Reclamation, Tom oversaw maintenance and rehabilitation projects at the U.S. Army Corps of Engineers’ hydropower facilities. Since Tom has been at Reclamation, he has overseen Roza, Chandler, and Green Springs Powerplants projects. Tom was instrumental in the testing of these engineering noise control technologies.

RECLAMATION Managing Water in the West

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The Knowledge Stream
Research Update

Testing and Verifying Rope Access Anchors

Making sure concrete anchor bolts perform safely for rope access technicians

Bottom Line

This research tested concrete anchor bolts and identified and verified "best practices" for their use in the field.

Better, Faster, Cheaper

Providing general guidelines to aid the experienced rope access technician to more effectively build safe anchor systems. Investigating safe anchor systems improves Reclamation's ability to conduct safe rope access work on its aging infrastructure.

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Problem

Workers use rope access to access structures, geologic features, or other inaccessible locations that cannot be accessed by "normal" means. These rope access technicians pin their lives on these ropes as the primary means of support, positioning, and safety protection to ascend, descend, and traverse a location while suspended in a specially designed harness.

Concrete anchor bolt while holding the OSHA weight limit (5,000-lb static load).

Ropes are anchored to a surface and must support the worker, weight of the rope, and anything attached to the rope. The Occupational Safety & Health Administration (OSHA) mandates that life safety anchors must be capable of supporting a 5,000-pound (lb) static load (OSHA CFR 1926.502).

Reclamation personnel frequently use a variety of anchor types, and often use anchor bolts installed in concrete or rock. Using these anchors safely relies on the experience and judgment of a rope access technician for proper assembly and installation. Concrete anchor bolts have been studied extensively, but still they are one of the most mysterious forms of anchoring and, therefore, contain a certain amount of risk. The strength and condition of the concrete at Reclamation's aging structures are unknown. Moreover, there are no general guidelines to preparing and using these anchors, so verifying that the anchor bolts are installed correctly can also be difficult.

Epoxy anchor bolt failure by pulling out of its hole until the concrete shear cone ruptures.

Solution and Results

This Reclamation Science and Technology Program research project investigated the various anchors Reclamation's Rope Access Team use. To mitigate the risk of uncertainty in the substrate and to verify the installation of the anchor, proof load tests were conducted to evaluate an anchor bolt before it is put into use. Criteria were also developed for the acceptable use of anchor bolts.

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Two categories of concrete anchor bolts were tested: adhesive-type anchors and mechanical-type anchors. Each type of system has distinct advantages and disadvantages and was expected to be susceptible to different installation errors. Furthermore, both types of systems are commonly used at Reclamation and, therefore, merited testing. To simulate potentially common installation mistakes that might be expected during field installations, various installation defects were tested. To simulate relatively weak and stronger concrete, two concrete mix designs were used. Results showed that:

- Pull testing ½-inch Powers, Hilti Kwik, and Redhead bolts to 5,000 lbs had little or no effect on the performance of the bolts. Therefore, proof load testing to relatively low loads of 1,100 lbs (approximately 5 kilonewtons) as recommended by Reclamation rope access guidelines seems unlikely to weaken the anchors.

- Many of the anchor configurations tested were not strong enough to meet the 5,000-lb static load requirement specified by OSHA and the Society of Professional Rope Access Technicians (SPRAT) guidelines. When using these configurations, anchors should always be used in load-sharing pairs that achieve the minimum requirement of 5,000 lbs. Great care should be taken with load-sharing anchor bolts with less than a 5,000-lb strength. Due to the angle of pull on load-sharing bolts, two 4,000-lb anchor bolts may add up to be less than a 5,000-lb anchorage.

- Even if an anchor meets the 5,000-lb requirement, the failure mechanism may provide an added measure of safety if it fails gradually by pulling out of its hole instead of failing catastrophically (i.e., bolt fracture).

The final report provides details on anchor configurations and specific recommendations for using concrete anchor bolts for rope access at Reclamation's facilities. These findings will be incorporated into the *Reclamation Rope Access Guidelines Manual* (soon to be renamed "Bureau of Reclamation Rope Access Safe Practices").

Future Plans

Reclamation's Rope Access Team continues to work on testing safety equipment to help improve safety standards. Further testing needs include:

- Testing concrete anchor bolts for other defects and to produce additional data points for determination of statistical significance, or to evaluate other types of anchor bolts as they enter the market.

- Researching existing structural supports (such as I-beams) to obtain specific examples of various configurations currently employed within Reclamation's Rope Access Team.

- Testing more configurations of vehicle anchors and developing Lock-Out, Tag-Out procedures to ensure the vehicle is properly protected against any kind of tampering. Test procedures should also be created to dynamically test vehicles as anchors using drop tests based on the preliminary static testing of vehicles as anchors.

"This research into life safety anchors helps Reclamation continue to develop safe practices and protocols for rope access maintenance and inspection of inaccessible features on Reclamation structures."

Shaun Reed
Mechanical Engineer, Reclamation's Technical Service Center

More information

www.usbr.gov/research/projects/detail.cfm?id=6390

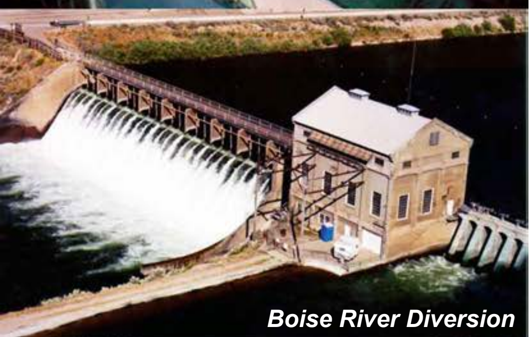
Anchor testing configuration. A hydraulically actuated ram is connected through a clevis rod and quick linked to the anchor. Threaded rods provide height and level adjustment.

Powerplant Performance and Reliability


Black Canyon


Palisades


Minidoka


Boise River Diversion


Anderson Ranch

Getting the Most Out of Reclamation Hydropower Plants

A common rule of thumb is to operate each similar unit in a powerplant equally. This meets generation and flow requirements. However, this does not provide the absolute best methods for ensuring that each drop of water creates as much power as possible and that powerplants operate efficiently in the bewildering array of factors (peak power needs, waterflow requirements, operation and maintenance schedules, etc.). Sophisticated algorithms can take all of these factors into account without sacrificing unit reliability and find the best way to operate. Getting the most power, or optimization, can save millions of dollars—even a 1 percent increase in efficiency among Reclamation's non-optimized powerplants can save $3.57 million per year.

Reclamation has been researching power optimization since the early 2000s. The T2, Waterview2000, and Acres optimization systems have been compared, as well as Reclamation's own optimization system. Waterview2000 has been demonstrated at Grand Coulee Powerplant (providing an extra 421,700 megawatt hours [MWh] of power annually) and Reclamation's system at Yellowtail Powerplant (a smaller plant providing an extra 8,700 MWh of power annually). This research allowed Reclamation to gain valuable experience with optimization systems and provided the experience and knowledge to move forward with the current efforts of its Power Resources Office. A Reclamation Science and Technology Program research project is developing new and modern algorithms to answer questions such as the "economic dispatch problem" (how to get the highest water-to-power efficiency in a plant without turning a unit on or off) and the "unit commitment problem" (determining the most efficient generation solution for a plant that includes unit status changes) (see www.usbr.gov/research/projects/detail.cfm?id=3906). Although this is not quite ready for "prime time," these algorithms provide a promising future for efficient optimization.

In the meantime, Reclamation's Power Resources Office is working on a decision support system to help plant operators know how to optimize generation at a glance. This system consists of a powerplant optimization algorithm and a user interface to provide input and to get operational recommendations. The system connects to a supervisory control and data acquisition (SCADA) system to obtain real-time plant information. The optimization system is modular, so if better algorithms are ready for use, they can be "swapped out" easily. Reclamation's Technical Service Center adapted an optimization algorithm from the U.S. Army Corps of Engineers; however, this algorithm is not modular, thus it was embedded in the user interface and SCADA systems. So to better meet the needs of Reclamation, it was made into a modular, stand-alone algorithm.

The hope is to have these optimization systems at every powerplant in Reclamation. The first installation was in August 2013, at the Black Canyon Control Center, which serves five powerplants in Idaho: Black Canyon, Palisades, Minidoka, Boise River Diversion, and Anderson Ranch. In 2014, installation is planned for the

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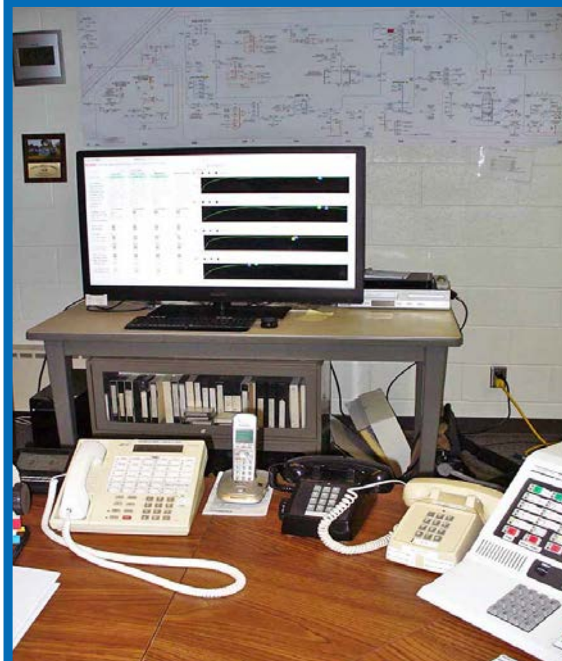
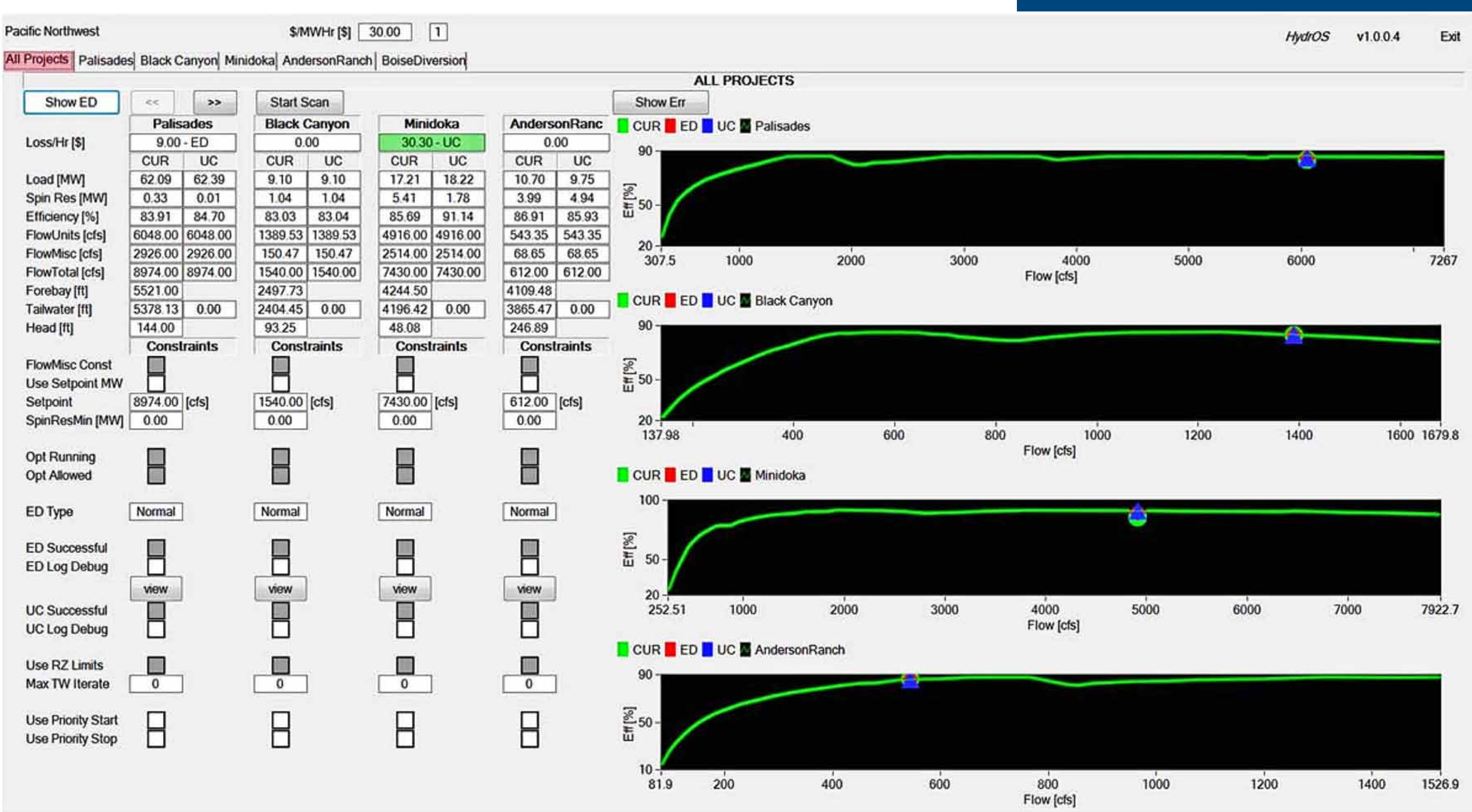
Glen Canyon Control Center and Elephant Butte Powerplant. As a control center can run up to 18 powerplants, Reclamation will be even closer to the goal of improving efficiency by at least 1 percent for all its powerplants.

Using this system, powerplant operators (and SCADA systems) can provide information about the amount of flows, power demands, maintenance, and other parameters. The interface then provides a guideline for which units to operate at what capacity to achieve the most effective operations. This is akin to a Global Positioning System (GPS) system for a car—the system provides a roadmap, which operators then consider as they grapple with other factors. Having this system will allow Reclamation's powerplants to function at their very best—saving money, providing more water for other uses, and garnering many benefits for Reclamation.



A view of the optimization system from the operator's desk.



Optimization screen demonstrating that it is possible to keep the same cubic feet per second (cfs) flow through Palisades, but generation can be increased from 62.09 to 62.39 megawatts (MW). At Minidoka, the cfs flow can be kept the same, but generation can be increased from 17.21 to 18.22 MW.

RECLAMATION Managing Water in the West

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The Knowledge Stream

Research Update

Validating and Improving Models for Power Systems

Using online “disturbance” data to help improve the accuracy of Reclamation’s power system models

Bottom Line

This research provided several new methods for testing and validating computer models of powerplant generator controllers to develop more accurate methods of simulating generator systems.

Better, Faster, Cheaper

Meeting WECC and NERC requirements for modeling generator systems is vital in keeping Reclamation powerplants operating reliably. The more accurate Reclamation’s power system simulations are, the better they are able to help predict potential power system instability issues and avoid outages. Moreover, this research developed improved ways to use online data, saving staff time, travel expenses, and generation outages—and getting more accurate data over a longer timeframe.

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Problem

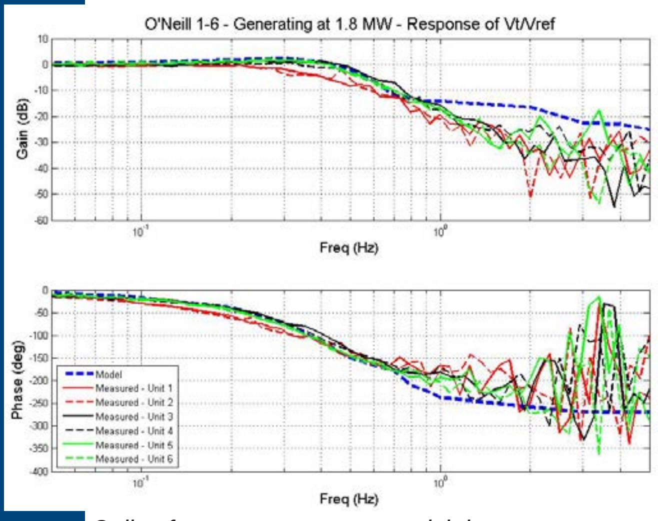
Power system operators and planners regularly perform dynamic simulations using computer models. After the power system blackouts of 1996, studies by the Western Electricity Coordinating Council (WECC) showed that many generation plant models were inaccurate and could not predict the type of system instability that led to the blackouts. To correct this inaccuracy, WECC began requiring generator owners to regularly validate the computer models representing their plants.

Validating models involves a series of staged tests and/or naturally occurring events with adequate recorded measurements of the response of the installed equipment, followed by computer simulations of the measured tests events, and then adjustments to the model until the simulation produces similar results. This has improved simulation accuracy of major dynamic events and, currently, North American Electric Reliability Corporation (NERC) standards are being drafted to require all plants in North America to regularly validate plant computer models.

However, there are no standard procedures for obtaining data, performing validations, or determining the quality of the resulting model. Consequently, model quality varies widely. Moreover, there is no listing of which tests or natural events are most important and which yield less value for the invested effort in test, measurement, and validation. To increase power system reliability, more research is needed to develop the standards that would result in best practices, economic solutions, or significantly improved models.

Solution and Results

To gain more insight into the best way to improve simulation accuracy, this Reclamation Science and Technology Program research project examined four test parameters:



Online frequency response model data versus measured data.

1. **Frequency Response Measurements.** Code was developed for the computer to simulate the online frequency response test. This provides a more complete picture of generator control systems interacting with the power system. (Previously, frequency response data in the simulation program were only available when the generator unit was offline.) This new code is used in a software package that simulates large power interconnections, so the frequency response tests of a single unit connected to the power system can be simulated under the same conditions as the actual staged tests.

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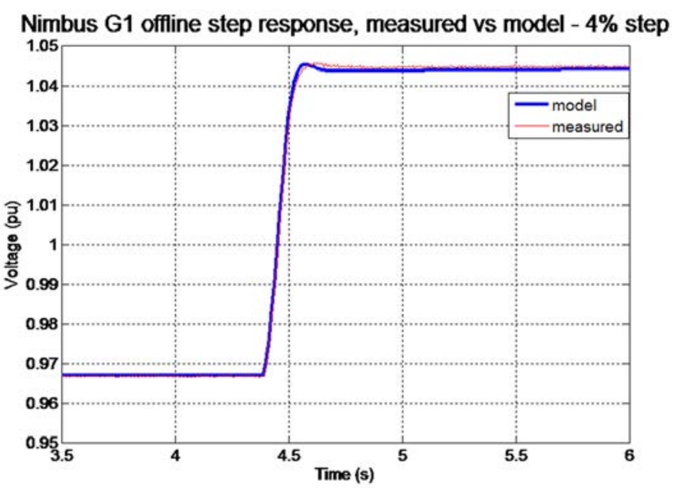
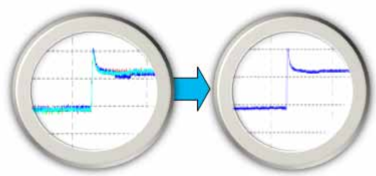
2. **Online Disturbance Data.** Typically, test engineers must go to the facility, run a series of tests on each piece of equipment, record the data, and bring it back to the office for processing. However, if the powerplant has online "disturbance" monitoring systems that record critical data (power, voltage, current, frequency, etc.), snapshots of power system events can be used to compare an event to the simulation of the same event to confirm (or improve) existing models. A new process was developed using disturbance data from online monitors at Yellowtail Powerplant, Montana, to confirm model simulations. Unfortunately, this newly developed process could not be fully tested as the recorded signals from the online monitors were inaccurate (incorrect scaling or offsets) and too slow (sampling rate was too low). The online monitoring system at the powerplant has been improved by replacing transducers and increasing the sampling rate. Once additional disturbance data are captured, this process can be fully tested.

3. **Exciter Step Response.** For WECC model validation, step response tests are typically performed by inserting a 1 percent (%) change in voltage into the exciter input and measuring the excitation system response. At Nimbus Powerplant, California, additional research tests of 2, 3, and 4% magnitudes were conducted to determine if simulated model step responses match measured data just as well for larger responses as they do for the standard 1% response. When larger step responses were performed, the exciter hit upper or lower limits and stimulated internal processing non-linearities. By performing additional larger step responses, these limit values and processing non-linearities can be proven in the test results and then used in the models.

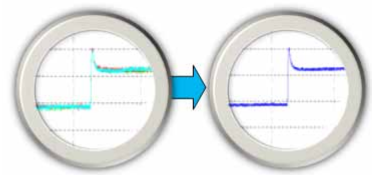


A terminal voltage response, 4% step response, measured test data versus calculated model data.

4. **Time Domain Averaging Technique.** The time domain averaging technique uses multiple step responses to create a single "clean" step response. The technique has successfully removed random noise and power system disturbance signals, while also providing users with the tools to determine step responses that contain outlying data properties (to be removed by the user) for a more accurate representation of the actual step response. One key feature of this algorithm is that it does not affect the phase response or overall shape of the response—it merely removes random and power system disturbance-based noise signals. This technique can be further refined by using standard deviations and/or other data point comparison techniques to remove outlying data points from the time domain averaging algorithms automatically.



Multiple step responses with system disturbance (all responses analyzed).



Multiple step responses with system disturbance (selected responses analyzed).

"This research is helping Reclamation become more efficient in obtaining higher quality data and validating models to save a significant amount of money and resources."

James Zeiger
Manager, Power System Analysis and Control Group, Reclamation's Technical Service Center

Future Plans

Reclamation has installed new transducers at the Yellowtail Powerplant to address the scaling and bandwidth issues and will plan to re-validate the disturbance data to the computer models once a significant power system disturbance is recorded. This re-validation will prove that Reclamation's power system models can be validated using this method, as long as a detailed model development was already performed by collecting data for each individual piece of equipment at the powerplant.

Test engineer performing model validation testing.

Results of this research will be presented at the WECC modeling workshops in 2014, and beyond, to make the industry aware of Reclamation's valuable findings.

More information

www.usbr.gov/research/projects/detail.cfm?id=1482

RECLAMATION Managing Water in the West

Summer 2014
Research and Development Office
Bulletin 2014-11

The Knowledge Stream
Research Update

Signal to Noise: Analyzing Generator Performance and Reliability

Adapting signal processing techniques to analyze generator and controller structures, operating parameters, and performance.

Bottom Line

This research project developed new hardware and software tools based on common digital signal processing techniques. The hardware and software tools are being used to collect more accurate model validation data from generators and controllers (e.g., voltage regulators, power system stabilizers, and speed governors) used in Reclamation powerplants. With more accurate data, Reclamation can do a better job verifying powerplant performance, providing early warnings for potential power system stability problems, and preventing power system outages and blackouts.

Better, Faster, Cheaper

Meeting WECC and NERC requirements for modeling generator systems is vital in keeping Reclamation's powerplants operating reliably. The more accurate Reclamation's power system simulations are, the better they are able to help predict potential power system instability issues and avoid power system outages. Moreover, this research developed improved ways to collect and analyze field data, which results in models that better represent actual response and performance of equipment installed at Reclamation's powerplants.

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Problem

As hydropower system interactions become more complex with the growth of the power grid, more reliable information about a powerplant's performance and condition is needed. Getting information about the structure, operating parameters, and performance of generators and controllers (voltage regulators, power system stabilizers, speed governors) is becoming even more critical as hydrogenerator control systems must be ever more reliable.

Further, organizations such as the Western Electricity Coordinating Council (WECC) and North American Electric Reliability Corporation (NERC) require monitoring information as input to model the Nation's power grid. The model needs to accurately represent the actual installed equipment so that regional power system stability studies can be more meaningful. It is important to collect "clean" test data without the random signal "noise" and disturbances from the power grid. Otherwise, the model could be influenced by the negative effects of "noise" which could, in turn, result in skewed models that do not represent the equipment accurately.

Currently, to get this information, test engineers must travel to the generation site with specialized test equipment, insert test signals, record test data, and interpret results. This is high risk, time consuming, labor intensive, and costly. Most of the costs involved are a direct result of temporarily taking the generators out of service for an average of a couple of days per generator, which could easily result in lost generation costs totaling thousands of dollars.

Solution and Application

To increase the quality and accuracy of the field data collected for model validations, Reclamation researched the following hardware and software tools:

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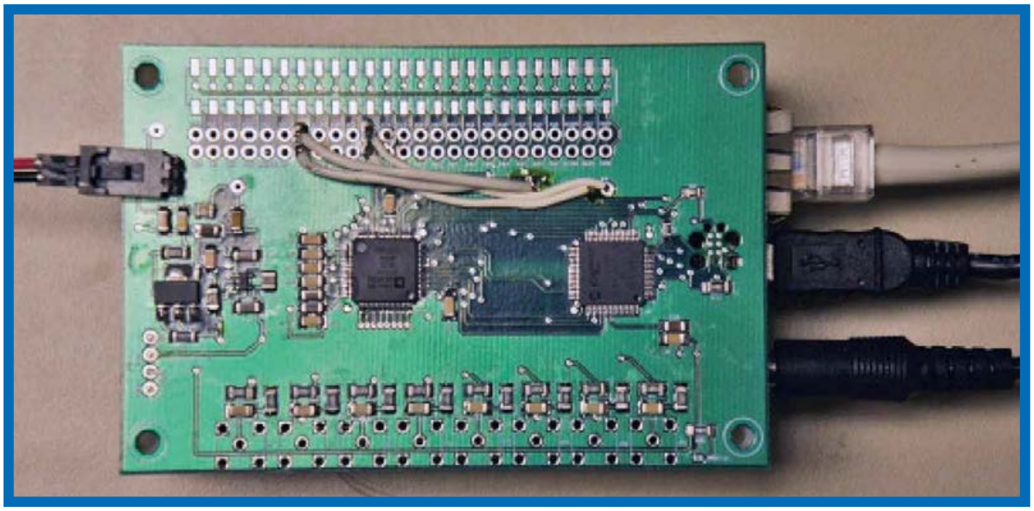

Modular hardware design with Ethernet interface.

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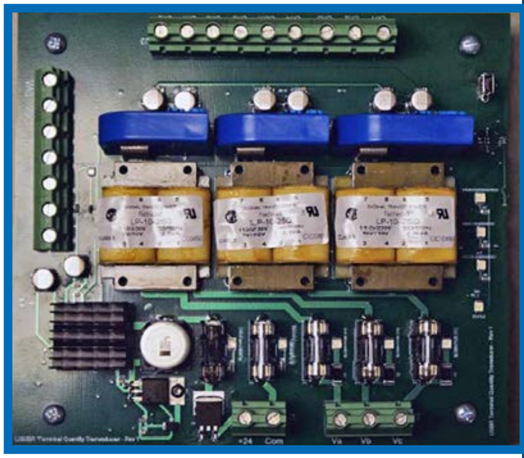


All-in-one hardware design with calculated voltages.

Hardware Tools. Two separate designs were developed for collecting model validation data. The first design was a modular hardware design, which featured separate input and output cards that can be stacked and wired to a main central processing unit (CPU) to gain a nearly limitless number of input and output channels. The main advantage to this modular design is that the CPU digitizes all of the analog input readings and sends the values across to a personal computer that can store the real-time data without the need for a separate data acquisition module.

The second design was a three-phase, all-in-one board, which featured input circuitry for handling large signals. However, this design lacks the capability to expand the number of input and output channels and has no Ethernet connection to a personal laptop. Instead of an Ethernet connection, each analog output channel provides a direct current (DC) voltage output in the range of ±10 volts that is proportional to the corresponding input signal. This board is designed for use with a commercial, off-the-shelf-type data acquisition system.

The developed hardware uses chips that have only been available for a few years and are capable of performing faster calculations, leaving room for more data to be processed. This encouraged the efforts to improve signal processing techniques and derive better algorithms to get precise data. The equipment can even be quickly modified to provide viewing and recording of dynamic signals for any application, not just generator testing alone.

Software Tools. While looking through step responses, Reclamation noticed that some were "noisy" at the same time that others were "clean." It was decided to experiment with a time domain averaging technique that uses multiple step responses to create a single "clean" step response. The technique has successfully removed random noise and power system disturbance signals, while also providing users with the tools to determine step responses that contain outlying data properties (to be removed by the user) to provide a more accurate representation of the actual response. One key feature of this algorithm is that it does not affect the phase response or overall shape of the response, it merely removes random and power system disturbance-based noise signals. This technique can be further refined by using standard deviations and/or other data point comparison techniques to remove outlying data points from the time domain averaging algorithms automatically.

Future Plans

The Power Systems Analysis and Control Group in Reclamation's Technical Service Center now uses these digital signal processing techniques to perform tests for Reclamation powerplants. The next step is to continue designing, testing, and fine tuning the hardware solutions developed for this research project to continue pushing the limits of collecting data that are more accurate and better represent the actual equipment from which the data are being measured. Case studies are being done to present to WECC for the industry to adapt, so that collection of better data can be used for performing model validation studies.

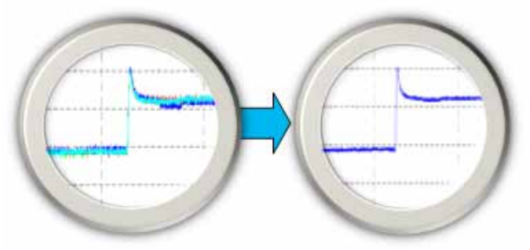
More information

www.usbr.gov/research/projects/detail.cfm?id=9962

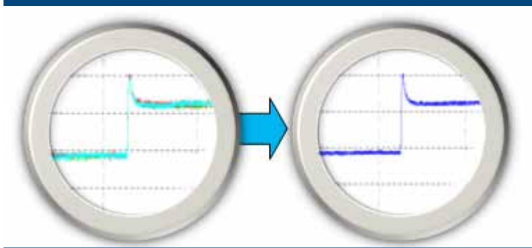
Clair, K. and J. Stenberg. 2012. *Signal Processing Techniques for Determining Powerplant Characteristics.*

"This research is helping to provide Reclamation with cutting edge tools used for generator control system testing and generator plant model generation/validation."

Kyle W. Clair
Electrical Engineer, Reclamation's Technical Service Center



Multiple step responses with system disturbance (all responses analyzed).



Multiple step responses with system disturbance (selected responses analyzed).

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RECLAMATION Managing Water in the West

Summer 2014
Research and Development Office
Bulletin 2014-12

The Knowledge Stream
Research Update

Keeping Track of the Generator's Condition

Industry's first open source hydrogenerator condition monitoring software package

Bottom Line

This research developed a machine condition monitoring package for hydropower plants with a broad range of applications that can be used to monitor a wide variety of plant equipment. It uses free, open-source software code and can be expanded to communicate with existing or future data acquisition hardware.

Better, Faster, Cheaper

Without machine condition monitoring, it is very difficult to determine when preventive maintenance is needed. This system is an online, real-time detection system that can ascertain when repairs are needed without bringing the generator offline. The system enhances plant operator's ability to prevent unplanned outages and detect impending problems that, if left unresolved could lead to a catastrophic failure resulting in millions of dollars in repairs and outage costs, lives lost, and/or power system blackouts.

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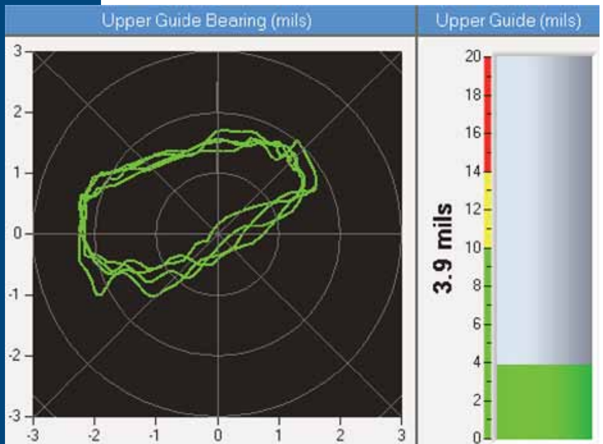
Problem

Operation and maintenance costs are a hydropower plant's largest expense. Maintenance is typically scheduled on a periodic basis that may result in some plant components being undermaintained (increased risk of failure), while other components being overmaintained (increased cost). For example, the generator rotating components must remain properly aligned and balanced, and the generator bearing clearance must be properly maintained. If there is an issue with any of these components, the generator will become unbalanced (imagine an imbalanced washing machine the size of a large room shaking). Without a monitoring system, experts must travel to the unit and set up a temporary monitoring system to check these components.

Improper operation of a generator can also lead to generator component failure and increase costs. For example, operating a generator in a rough zone for an extended period of time can decrease the life of generator components and, in some cases, could potentially lead to a catastrophic failure of the generator. A generator rough zone occurs only at specific operating points that change depending on the elevation of the lake. When a unit is in a rough zone, the water turbulence just below the generator turbine pushes the turbine sideways, which increases generator vibration, and the turbulence smacks into the draft tube wall, which shakes the plant and causes a loud booming sound. At remote automatic operating plants, no one is around to hear the problems or feel the shaking, and the situation could continue until the generator is damaged. In addition, the magnitude of the sound or vibration is subjective, thus without monitoring there is no definite way to determine the magnitude of the problem. The worst case scenario occurred at Sayano-Shushenskaya Power Station in 2009, when a unit was operated in a rough zone for an extended period of time, which contributed to a catastrophic generator failure resulting in the partial destruction of the plant and the deaths of 75 workers.

Following the Sayano-Shushenskaya Power Station event, all of Reclamation powerplants must now install a generator vibration monitoring system. *Power Equipment Bulletin No. 42* states that "all facilities shall install vibration monitoring on all units. The system must consist of proximity probes at each guide bearing elevation, with output data transmitted to a system that is capable of alarming on peak-to-peak vibration levels."



Partial screenshot of an orbital plot to determine a generator's vibration.

While industry has proprietary monitoring systems that can be installed to meet this requirement, these systems are often costly and require specialized upgrades. Moreover, industry may stop supporting certain hardware and/or software, requiring the expense of an entirely new system when repairs to the monitoring system are required.

Solution

Reclamation's Power Resources Office and key Reclamation facilities collaborated on this Reclamation Science and Technology Program

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research project to develop a system that can meet these monitoring needs. Reclamation's machine condition monitoring system can:

- Record almost any signal (e.g., bearing runout, megawatts, megavars, terminal voltage and current, field voltage and current, frequency, pressures, gate limit and position, speed, forebay and tailbay elevation, flows, temperatures, breaker status)
- Measure and display generator vibration (orbit plots) and provide alarms to plant operators, if extensive vibration is detected
- Allow the user to detect rough zone operation and provide alarms to plant operators, if extended rough zone operation is detected
- Allow the user to diagnose and troubleshoot abnormal events
- Capture electrical and mechanical quantities and signals that can indicate potential problems that may otherwise go undetected
- Provide different alarm thresholds to reduce false alarms during startups, shutdowns, or any other defined operating condition
- Gather and store data over a long period of time for understanding a generator's condition more acurately, evaluate trends in operation, and provide meaningful data for improved operation of the hydroelectric facilities
- Alert remote operators to potential problems, allowing the most effective and safe operations
- Adapt to new and future needs, provide an open-source software code that allows the software to be modified to work with a large variety of data acquisition hardware, and can expand to meet the unique requirements of all hydropower plants

Jim DeHaan of Reclamation's TSC installing and configuring the machine condition monitoring system at Grand Coulee Powerplant, Washington.

The system helps diagnose pre-failure conditions to prevent catastrophic failures. It allows the user to predict when to perform maintenance on various components on the generator. The software can alarm to let the operators know when the generator is in an abnormal condition, and prevent any unnecessary wear and tear on the machine. Thus, machine condition monitoring reduces operation and maintenance costs, increases plant availability, and preserves Reclamation's infrastructure by providing current and relevant information on the present condition of plant equipment.

Application and Results

This project has already shown that it can meet the needs at Reclamation's powerplant facilities. The near-term goal is to cover about half of Reclamation generators. The initial version of this system is presently installed on over a dozen generators at various Reclamation powerplants. Several more sites have either scheduled, or are considering, adding this system. Field personnel from the initial installations have provided valuable feedback to improve the system. Several improvements have also been identified that will make the system easier to use and improve computer security. These improvements are being implemented in a second version of the software, already in development.

Future Plans

A new version of this software should be available to install by the end of calendar year 2014. Reclamation's Technical Service Center (TSC) plans on supporting the machine condition monitoring package in the future. TSC is continually expanding this software to eventually supersede the functionality of machine condition monitoring packages currently available on the market.

"This open-source software code works with a wide variety of data acquisition equipment including off-the-shelf data acquisition systems, specialized monitoring systems, and other computer systems. Hydrogenerator condition monitoring saves time and money, while improving the reliability of hydropower."

Nathan Myers
Manager, Hydropower Diagnostics and SCADA Group, Reclamation's Technical Service Center

Collaborators

Reclamation:

- **Power Resources Office**
- **Elephant Butte, Fontenelle, Fremont Canyon, Grand Coulee, Judge Francis Carr, Mount Elbert, Palisades, Yellowtail, and Lower and Upper Molina Powerplants**

Army Corps of Engineers:

- **Truman Powerplant**

More information

www.usbr.gov/research/projects/detail.cfm?id=2879

RECLAMATION *Managing Water in the West*

Summer 2014
Research and Development Office
Bulletin 2014-13

The Knowledge Stream

Research Update

Catching Problems Early: Predicting Shear Pin Failures With Acoustic Emission Sensing and Analysis

Monitoring turbine linkage shear pins and detecting shear pin failures at Reclamation's powerplants

Bottom Line

Under certain conditions, the failure of a turbine wicket gate shear pin can cause substantial damage to the turbine of a hydroelectric generator. This research explores using acoustic emission and other types of sensors attached to shear pins to detect the start and propagation of a crack before the shear pin breaks so that the unit can be shut down to prevent further damage.

Better, Faster, Cheaper

It is crucial that Reclamation keeps its powerplants running. By detecting shear pin failures in time, operation and maintenance costs can be reduced, powerplant availability can be increased, and Reclamation's infrastructure can be preserved. This also provides current and relevant information on the real-time condition of powerplant equipment, reducing the downtime needed for maintenance. This preventative maintenance can generate significantly more hydropower and avoid more costly failures of a turbine component.

Principal Investigator

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Problem

In the past, when hydroelectric units were manually controlled, it was common to staff plants with a plant operator(s) 24 hours a day, 7 days a week. A major element of the plant operator's job was to monitor the unit—to listen for abnormal sounds and to take action to shut the unit down if a shear pin failed. Today, it is more common to remotely control plants or units. Most Reclamation plants are not staffed on weekends and some smaller, remote located plants only see occasional maintenance staff visits during the workweek. This puts the power generation units at a high risk, as no one is around when a serious problem develops.

Finding problems early then becomes key to avoiding serious failures. Most hydroelectric turbines have around 20 wicket gates, each with a shear pin, that control the waterflow into the turbine. Shear pins are designed to shear or break if there is a mechanical overload on the wicket gate and are sacrificial parts that prevent more expensive parts from being damaged.

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Hydroelectric turbine at Flatiron Powerplant. Photograph courtesy of John Germann.

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Yet, without a way to detect when a shear pin fails, the turbine will continue to run and risk even more damage. A wicket gate with a broken shear pin disrupts the waterflow and can cause the unit to severely vibrate. On occasion, the gate will violently slam closed causing adjacent wicket gate shear pins to break, creating a cascading effect of failures. Hydraulic imbalance created by the uncontrolled gates can move the rotating runner into destructive contact with the guide bearings and stationary wear rings. A number of hydroelectric units within the industry have suffered severe damage from not detecting a shear pin break early enough to shut the unit down in time.

Solution and Application

Using acoustic emission sensors is a promising method for detecting shear pin failure early. Acoustic emission techniques have a proven history for detecting cracks. When external forces or internal pressures cause discontinuities within a material, it emits stress waves at the onset and during crack growth. In a shear pin, the pin is stressed by an applied load. Acoustic emission sensors can detect this early release of energy and provide warning signs prior to the sudden failure of a material, in this case, the shear pin.

There is increased evidence that fatigue may also contribute to frequent shear pin failure with older shear pins. This Reclamation Science and Technology Program research project examined ways to effectively detect fatigue crack propagation prior to failure. Reclamation looked at detecting shear pin failure by continuously monitoring acoustic emissions through the crack process—from the early start of microcracks in the stressed pin through ultimate failure. The ultimate goal of the research is to design a detector that is non-intrusive to the pin, easily adaptable to any kind of shear pin, robust, reusable, cost effective, and maintenance free.

Understanding the fundamentals of shear pin cracking and fatigue-related issues of metal shear pin failures will lead to better methods to protect hydroelectric turbines from catastrophic failure and reduce maintenance requirements. Laboratory results so far have led to a better understanding of how shear pins fail and of the material science used for shear pins. These results have shown that acoustic emissions may be a useful method to detect shear pin failure.

Future Plans

Reclamation plans on further laboratory work and then testing results in the field. If a successful shear pin protective device can be designed and constructed, it will be available and deployed to Reclamation powerplants as another tool in the overall machine condition monitoring package. Findings will be shared through technical papers with Reclamation and the hydropower community.

More information

www.usbr.gov/research/projects/detail.cfm?id=7567

"The ability to predict some shear pin failures would be advantageous. Replacing shear pins would no longer be a "hurry-up-and-react" situation resulting in forced outages. Instead, shear pins could be replaced during planned outages. While this process may not predict all failures, even finding one or two could save millions of dollars in damaged equipment."

Russell Anderson
Reliability Program Analyst, Reclamation's Power Resources Office

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Collaborators

Reclamation:

- **Northern California Area Office**
- **Eastern Colorado Area Office, Elephant Butte Powerplant**

RECLAMATION Managing Water in the West

Summer 2014
Research and Development Office
Bulletin 2014-14

The Knowledge Stream
Research Update

Detecting Cavitation to Protect and Maintain Hydraulic Turbines

Detecting, monitoring, and preventing cavitation damage at Reclamation's powerplants

Bottom Line

This research develops effective cavitation detection and monitor techniques to accurately predict erosive cavitation and thus substantially reduce hydro turbine maintenance costs.

Better, Faster, Cheaper

Turbine cavitation damage is usually the most costly maintenance item on a hydroelectric turbine, and there is no effective method to detect ongoing erosive cavitation on an operating turbine. This research provides a better understanding of cavitation to identify ranges where damaging cavitation occurs so that the turbine can be operated to avoid those ranges.

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Collaborators

Reclamation's Northern California Area Office

Problem

It is crucial to our Nation's power system that Reclamation's powerplants keep running. Moreover, changing reservoir levels due to droughts or floods can require powerplants to operate at water conditions that they were not designed for, which can cause damage.

Vapor bubbles form when exposed to an area of subatmospheric conditions. When these tiny bubbles of vapor are subjected to pressure in a liquid, they can implode onto a surface (such as a turbine runner blade) causing damage called "cavitation." Cavitation commonly occurs in a wide variety of equipment (e.g., marine propellers, hydrofoils, nozzles, and injectors). When damaging cavitation occurs in the turbine, unexpected shutdowns and unplanned maintenance is required for repairs. The Judge Francis Carr Powerplant (J.F. Carr) in California has two units, both with recent cavitation issues that have cost an estimated $5 million in lost generation and repairs, not including long-term costs related to lost operational ranges, future repairs, and future lost generation. This unexpected repair work should be minimized to maximize hydroelectric production. Although hundreds of papers have been written on the subject, minimal research has focused on preventing cavitation damage occurring within an actual operating hydropower turbine.

Cavitation damage to a turbine runner blade of J.F. Carr Unit 2 in February 2013. Photograph courtesy of John Germann.

Various types of cavitation can occur, which require different detection, prevention, and mitigation measures. Cavitation commonly occurs in hydroelectric turbines around guide vanes, wicket gates, the turbine runner, and in the draft tube. Cavitation damages to the machinery components are compounded with other associated problems, including losses of efficiency and output, lengthy repair outages, and severe vibrations.

Cavitation in hydraulic turbines is primarily influenced by hydraulic design and operating conditions. Detecting cavitation in an operating hydroelectric turbine is difficult, as this is a complex phenomenon that is difficult to assess. Direct access to

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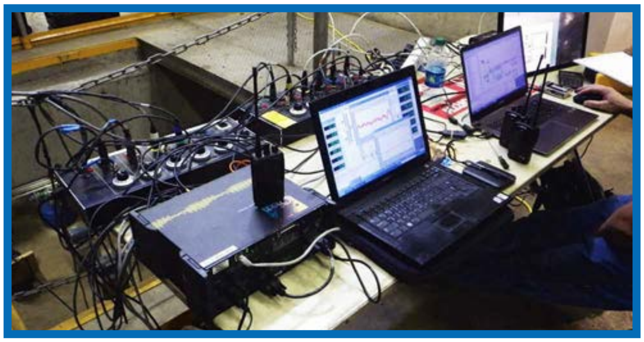
assess cavitation occurring within the water passage of the turbine when the unit is running is impossible, and thus it is hard to determine if the cavitation is damaging the unit—until it is too late. Reclamation initially began researching cavitation detection in hydro turbines in 2004, purchasing and testing several commercially available cavitation monitors. These monitors used a very simplistic approach and did not perform well, as they could not distinguish damaging (erosive) cavitation from non-erosive cavitation within the fluid stream. Thus, Reclamation and the hydropower industry need a machine condition monitoring tool to detect cavitation problems while the turbine is operating.

Solution and Application

This Reclamation Science and Technology Program research project is developing better techniques and instrumentation that will be used as a machine condition monitoring tool. One goal is to build an online cavitation monitor to identify, alarm, and record cavitation activity over long-term operations. This allows better prediction of cavitation behavior over varying unit operations and reservoir elevation. A prototype system was tested in 2011 at the Fremont Canyon Powerplant in Wyoming.

A shaft mounted cavitation detector was developed to better detect damaging cavitation. This new package uses a shaft-mounted accelerometer and acoustic emission sensor, and then a wireless transmitter to send high frequency signals from the turbine shaft. Online tests showed this wireless system operation to be reliable. As well as accelerometers, acoustic emission sensors are used to assess cavitation impact signals and track cavitation activity, as very high frequency noises unique to cavitation can often be identified.

Jim DeHaan of Reclamation's TSC installing a cavitation monitor at the J.F. Carr Powerplant.



Monitoring for cavitation.

Current cavitation research is focused on the existing runners at the J.F. Carr Powerplant in northern California. These units are an excellent research platform for these studies because they exhibit severe erosive cavitation. This powerplant has two hydro turbines with new turbine runners that are exhibiting extremely aggressive cavitation. In 2013, Reclamation's Technical Service Center (TSC) and Northern California Area Office (NCAO) partnered to conduct machine condition monitoring and cavitation detection research at J.F. Carr Powerplant. These tests were to determine if it is possible to detect and measure cavitation-induced vibration and acoustic signals created by cavitation that is causing severe erosion on the leading edges of the turbine blades.

The tests identified the operating ranges where peak cavitation is occurring on the turbine runners. Online cavitation monitors are being developed that will monitor and map conditions over long-term operations. Current cavitation damage is being repaired and the new monitors are being installed.

"Besides predicting and reducing the damaging effects of cavitation, this research could reduce the hazards employees are exposed to during cavitation repairs. Cavitation is very damaging and requires extensive corrective maintenance to repair. Any steps that can be taken to reduce cavitation would be beneficial."

Russell Anderson
Reliability Program Analyst, Reclamation's Power Resources Office

Future Plans

Reclamation's TSC and NCAO will work together over the long term to determine cavitation trends and further identify operational ranges to avoid cavitation, and hopes to continue to improve on cavitation detection and analysis and to refine past techniques. These new monitors could potentially be adapted to monitor and avoid cavitation in a wide variety of cavitation-prone hydro turbines. Findings will be shared through technical papers with Reclamation and the hydropower community.

More information

www.usbr.gov/research/projects/detail.cfm?id=2386

www.usbr.gov/research/projects/detail.cfm?id=9933

The Phoenix Area Office in Arizona, in cooperation with staff from NREL, performed an analysis of the capabilities of using renewable energy to transmit water the long distance from the Colorado River to the central Arizona communities of Phoenix and Tucson. In this analysis, Reclamation worked closely with NREL staff using the "Solar Energy Suitability Analysis" Reclamation produced to locate and screen the potential renewable energy sites on Reclamation properties.

The two categories considered were utility-scale and facility-scale installations. NREL used the information provided from the Solar Energy Suitability Analysis and gave specific information on both of these categories of renewable generation. It was determined that it may be feasible to add solar generation at the Hassayampa, Arizona, commercial site to operate the existing pumping system. It was also determined that solar photovoltaic could be installed at the Phoenix Area office to augment grid connected power. NREL provided specific benefits for each installation and the potential challenges Reclamation should expect.

National Renewable Energy Laboratory Partnership

Reclamation has partnered with the National Renewable Energy Laboratory (NREL) to investigate the feasibility of primarily solar and wind (also called non-hydroelectric renewable energy) development at Reclamation's lands and facilities. Renewables can be used to meet a wide array of Reclamation needs and objectives, both on a facility scale—where renewable energy is used to supply some or all of the power demand for a Reclamation building or structure—and on a utility scale—where renewable generation is massed in a complex large enough to produce significant amounts of electricity for the power grid. Reclamation's hydropower fleet is its major source for renewable energy generation, so it is recognized that non-hydroelectric renewable energy is controversial and, therefore, its development must be directly related to Reclamation's mission and customer needs.

Developing and integrating wind, sun, and geothermal energy can help Reclamation meet Federal objectives. Possibilities include:

- Building onsite renewable energy generation to meet small or large Reclamation power loads, such as for office buildings, pumping plants, or water treatment plants, especially when old power contracts expire and costs increase
- Reducing power transmission and distribution losses and costs by making energy exchanges between Reclamation's power marketing agencies and other utilities
- Improving reliability by co-locating solar energy to provide backup power in the event of electric grid emergencies and widespread power outages
- Mitigating price shocks to customer groups
- Meeting goals associated with the *Guiding Principles for High Performing and Sustainable Buildings* where energy consumption from renewable energy is one of the guiding principle requirements and installing non-hydroelectric renewable energy will further a building's progress towards compliance

Development must consider a range of factors including administration goals, available budget, local renewable resources, permitted land uses and environmental constraints, existing loads and market prices, and viable business models for either Federal or private development. NREL has worked with Reclamation to:

- Use Geographic Information System (GIS) to identify Reclamation-owned land (by county), which are potentially suitable for utility-scale concentrating solar power, photovoltaic, and wind power development. The counties with the greatest potential for power development with Reclamation lands were identified and ranked from highest to lowest. Further analysis is necessary at each individual site to identify the specific capacity potential based on Reclamation's lands and facilities.
- Assess the facilities at the Phoenix Area Office in Arizona. The facility can host up to 200 kilowatts (kW) of photovoltaic power. Salt River Project incentives are available for systems up to 30 kW in size. The payback for a Federal Government-owned system (up to 30 kW) is estimated to be 27 years. A power purchase agreement with a private developer may have better cost benefits.

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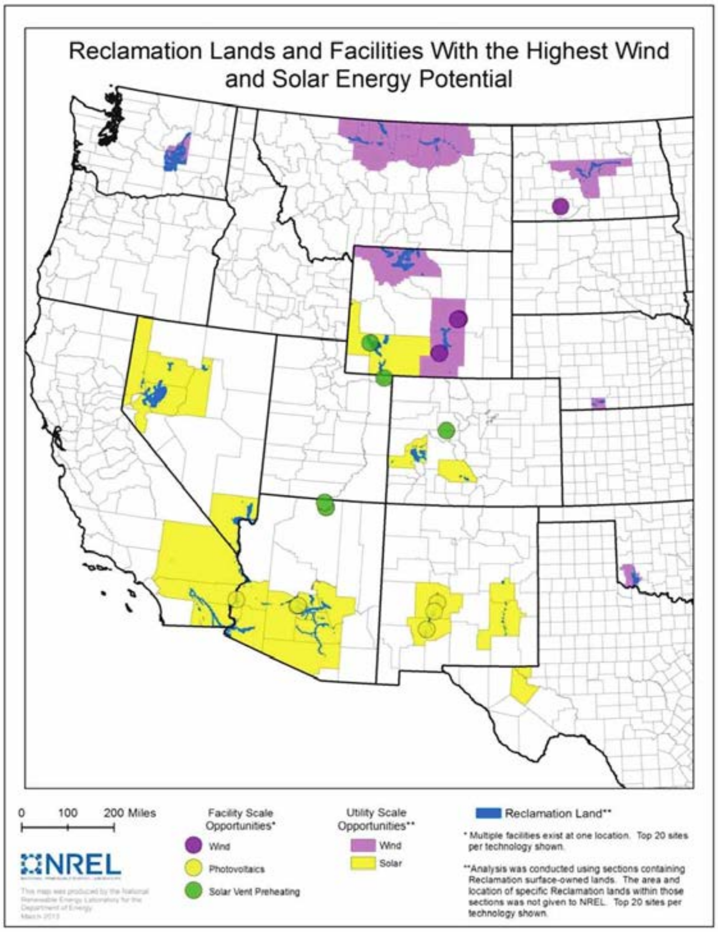
- Assess the economic feasibility analysis of installing photovoltaic (PV) at the Willows Office and Lake Berryessa Recreation Resources Branch facility (Lake Berryessa facility) in California. The Willows Office already has a small PV installation that generates approximately 12,000 kilowatt hours (kWh) per year. Reclamation identified other areas that could accommodate 265 kW (93 kW is sufficient to make the office net zero). Payback is estimated to be 15 years for a third party-owned system. The Lake Berryessa facility has three ground-mounted photovoltaic power opportunities totaling 133 kW. Estimated payback is 15 years for a third party-owned system and 22 years for a Federal Government-owned system. However, operational constraints may preclude actions now.

- Conduct site assessments of potential sites for utility-scale concentrating solar power and photovoltaic facilities along the Central Arizona Project and the Yuma Area Office in Arizona.

- Evaluate the suitability for wind energy development in the North Platte cluster in Montana and west of Casper, Wyoming, to identify parcels most suitable for wind energy development. In Montana, one parcel (Chouteau County cluster) can support over 300 megawatts (MW) of wind energy development; two parcels (Glacier County and Philips County clusters) can support approximately 100 MW each; and five additional parcels that can potentially support modest wind energy development (50 to 100 MW). In general, Reclamation-owned parcels do not appear to offer compelling advantages over nearby non-Reclamation-owned land. In most cases, Reclamation-owned parcels will need to be aggregated with adjacent non-Reclamation-owned land to support a large wind farm.

- Provide training to over 60 Reclamation employees on non-hydroelectric renewable energy at Reclamation. This 3-day training session included participation from the Bureau of Land Management, National Park Service, U.S. Fish and Wildlife Service, and Nevada State agencies. Topics ranged from technical information on solar and wind technologies to environmental concerns, NEPA compliance, and case studies for facility- and utility-scale development at Reclamation.



"The working relationship with NREL was terrific and I recommend using their services in the future for other renewable energy endeavors."

Mitch Haws
Water Resource Planner,
Reclamation's Lower Colorado Region

More information

www.usbr.gov/research/docs/updates/2012-24-renewable-energy.pdf

Top 10 counties and top 20 facilities (by technology) for potential renewable energy deployment (see *Renewable Energy Assessment of Bureau of Reclamation Land and Facilities Using Geographic Information Systems* at: www.nrel.gov/docs/fy13osti/57124.pdf).

Utility-scale solar and wind data can be viewed as part of the BORGIS Tessel web mapping application (http://dogis/Tessel8).

Please note that Tessel is a Reclamation-specific web application and is not available to the public.

RECLAMATION *Managing Water in the West*

Summer 2014
Research and Development Office
Bulletin 2014-15

The Knowledge Stream

Research Update

How Much Does it Cost to Start/Stop a Hydrogenerator?

Determining start/stop costs for hydropower generators to support integrating renewable power into the grid

Bottom Line

Integrating renewable energy into the power system requires existing energy sources to provide additional services to ensure the reliability of the power system. These additional services, such as increased starts/stops, have both direct and indirect costs directly correlated to capital costs, maintenance, and operation. This project strives to determine realistic costs realized by hydro utilities when incorporating renewables into their energy portfolio.

Better, Faster, Cheaper

Being able to assign costs for each time a hydropower generator is started/stopped allows planners to determine the most cost efficient and effective way of operating powerplants and integrating wind and solar energy into the power grid. Understanding the associated costs allows the utilities to have an improved understanding of costing for the services they provide over the life of equipment to support renewables.

Principal Investigator

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Problem

Having power available anytime you want to plug in a device is a tough balancing act, juggling energy demands with power production—on a minute-to-minute basis. Traditional powerplants using coal need a long time to ramp up to produce energy and cannot change output quickly. Wind and solar energy production rely on natural cycles, so their availability may not match demands. Hydro generation has unique characteristics that make it attractive as a source of variable power. Hydro can be started, stopped, and load-changed more easily and economically than steam generation. In fact, many hydrogenerators are operated in just this way—as a variable supplement to base-loaded powerplants.

Thus, hydropower generators can be held in a reserve mode, ready to deploy to meet demands in a more flexible manner, but these operations also must consider many factors such as water operations, water availability, and generator maintenance.

Starting and stopping generators help to balance power availability and assist in integrating wind and solar energy into the power system. However, just like driving your car in stop-and-go traffic, which causes more wear and tear on your engine, more frequent starts/stops can increase the cost of operation and maintenance. When a generator is called upon to start from dead-stop (not spinning) to become available for service, there are impacts on staff, equipment, and water supply. These impacts have real effects on operation and maintenance practices and overall plant costs. As more starts/stops are required, these costs increase and should be accounted for. It may be appropriate for the increased costs to be incorporated into power rates charged to customers.

The question is: how much of an increase is there, and how are these costs determined? Powerplant operations are complex, spanning a wide range of factors. Because each plant is unique, no single start/stop cost factor can be applied to all plants. The fossil fuel generation industry has done extensive research into costing unit cycling, but very little reliable information exists in the hydroelectric industry about start/stop costs. The available studies approach the costing task in different ways and, currently, there is no industry standard for which cost factors should be included or how to derive the cost of each factor.

Thus, a start/stop cost model is needed that addresses all potential cost factors and that provides a reasonable framework for calculating start/stop costs at a powerplant—to use at Reclamation powerplants and, possibly, to be adapted industry-wide.

John W. Keys III Pump-Generating Plant, Grand Coulee Dam, Columbia Basin Project, Washington.

Solution

As part of this Reclamation Science and Technology Program research project, a model was developed that includes cost factors of increased maintenance, accelerated equipment degradation, lost generation opportunity, lost water, and reduced efficiency. This model was then used to calculate start/stop costs for a pilot plant, resulting in a cost of approximately $274 to $411 per start/stop, depending on assumptions used. These figures should be used with caution, representing only one generating unit at one plant. However, these numbers are consistent in magnitude with other industry studies that use different assumptions and methods.

The control room at Flatiron Powerplant, Colorado-Big Thompson Project, Colorado.

This research includes a sensitivity analysis that identifies which cost factors are most important to overall start/stop costs, thus providing direction for future emphasis in refining costs. The model and methods developed in this research can be applied at other Reclamation powerplants. Experience at other plants will improve the model and broaden the base of data analyzed, better ensuring a reasonable start/stop cost.

Application and Results

For the pilot plant test study, the Flaming Gorge Powerplant on the Green River in northeastern Utah, and part of the Colorado River Storage Project in the Upper Colorado Region, was selected. Start/stops have significantly increased at the powerplant in the last several years. This test study found that some cost factors are more significant than others and that the relative importance of factors may depend on the site.

Right Powerhouse, Grand Coulee Dam, Columbia Basin Project, Washington.

Future Plans

The results of the hydro model data project provide a good starting point in working with other hydropower producers, power marketing administrations, and renewable energy integration model builders in creating more accurate models. The results of this study can be used to direct future research and as a template for start/stop cost analysis at other Reclamation plants. Full-fledged data collection for improving integration models (planning and/or real-time dispatching) will require significant improvement in Reclamation's data collection and reporting systems. This improvement can be coordinated with another initiative to establish standard operations reporting data throughout the hydropower industry.

"Reclamation is being called upon more frequently to start and stop units to support grid reliability, but the tools and methods available to understand the costs of these start/stops have been lacking. The development of this cost model will provide great value to Reclamation by delivering more reliable start/stop costs through a more user-friendly process."

Mike Pulskamp
Renewable Energy Program Manager, Reclamation's Power Resources Office

Collaborators

- Reclamation's Power Resources Office and Flaming Gorge Powerplant
- National Renewable Energy Laboratory
- Centre for Energy Advancement through Technological Innovation (CEATI)-Hydraulic Plant Life Interest Group
- Bonneville Power Administration

More information

www.usbr.gov/research/projects/detail.cfm?id=6144

RECLAMATION *Managing Water in the West*

Summer 2014
Research and Development Office
Bulletin 2014-16

The Knowledge Stream

Research Update

Hydrokinetic Demonstration Results to Date and Path Forward

Can hydrokinetic projects work in canals while still maintaining efficient water and power deliveries?

Bottom Line

Develop and calibrate a model (HEC-RAS) to determine if a HK project could work in a particular canal while maintaining efficient water and power deliveries. This tool will use canal geometry and operating information to predict impacts on water delivery systems and associated powerplants from HK turbines.

Better, Faster, Cheaper

This model will be a useful tool for both private developers and water system owners to help determine if and where an HK device could be deployed without impacting existing water or power operations, before any installations are made.

Principal Investigator

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Problem

Unlike traditional hydropower or low-head hydropower, hydrokinetic (HK) devices do not require a reservoir or head drop to operate. HK devices use flowing water to turn the turbine rotor and produce energy. In general, Reclamation's canals were designed so that water flows slowly and efficiently to deliver water with the least amount of wasted energy possible. Thus, adding a new component such as an HK device could impact canal hydraulics. Moreover, powerplants or other existing hydraulic structures and facilities in the system could be affected, lowering their efficiency. Therefore, these HK devices should only be installed in systems and at strategic locations where they can operate without causing negative impacts to existing canal operations. Careful consideration should be given to determine if and where this could be possible.

Since 2011, Reclamation has received requests from private HK developers to install their technology in Reclamation canal systems for demonstration testing. This is a relatively new field and, while many new technologies are being developed, their impact on the performance of the overall system is still largely unexplored.

Solution and Application

As the impacts of this technology on existing systems are unknown, Reclamation partnered with a private developer to install an HK device and to determine the hydraulic effects of these devices on existing water delivery and hydropower operations.

— continued

The HK device is attached to a spanning structure that is secured to both sides of the Roza Canal on concrete foundations. The spans prevent contact with the existing canal structure to preserve the physical integrity of the canal lining, as well as ongoing operations. Visitors to the site (left to right): Jane Shaw, Canadian Consulate Seattle; Shannon Halliday, IES; Sid Ottem, Reclamation; Brett Hawse, IES; Ken Miller, IES; Phil Georgariou, BAE Systems; Ali Grovue, IES; Jim Hawse, IES; Shane Grovue, IES; and Congressman Doc Hastings.

— continued

In August 2013, Instream Energy Systems Corporation (IES) deployed their newly designed 25 kilowatt (kW) BAE Systems rotor and generation system in the Roza Main Canal near Yakima, Washington, about 5 miles upstream from the existing Roza Powerplant.

This Reclamation Science and Technology Program research project will use the data from this installation to develop a computer modeling tool to predict the devices' impacts on canal systems. Water surface elevations and canal velocities were measured, which if changed, could alter the canal operations (e.g., raising the canal's water levels or impeding the waterflow). Physical data from this installation is currently being used to calibrate the numerical model under a range of canal and HK turbine operating conditions. By using this model, private developers and water system owners can evaluate if an HK device could be deployed without impacting existing water delivery operations.

To ascertain the effects of the HK device on existing hydropower operations, a performance test on the downstream Roza Powerplant was also conducted. As the device did not impact hydropower performance at the Roza Powerplant, it was determined that there was no need for further testing for existing hydropower impacts at the powerplant. However, as each hydropower plant has varying circumstances and factors that need site-specific consideration, further analysis will be needed for each potential site to determine the hydraulic impacts to any existing hydropower operations.

Future Plans

It is anticipated that testing at the Roza Canal will continue through 2015, with various configurations of turbine scenarios. Field results will help calibrate the numerical model to better predict impacts within the range of conditions that have been tested. For example, Reclamation or an irrigation district could provide canal geometry and operational information and the model could then predict what impacts would occur, determine whether HK devices are appropriate and, if so, then identify potential places for effective HK use.

Reclamation recognizes the valuable opportunity to provide field testing and help further understand the operational criteria and limitations of HK devices. As with other renewable energy technologies, the market and economics will help define the niche that these devices can play in the future of the electrical power grid.

More information

www.usbr.gov/research/projects/detail.cfm?id=7973

http://instreamenergy.com/projects/yakima-washington/

"A well-developed numerical model will be a useful tool for both private developers and water system owners to help determine if and where a hydrokinetic device could be deployed without impacting existing water delivery operation, before any installations are made."

Josh Mortensen
Hydraulic Engineer, Reclamation's Technical Service Center

Tagline and Rio Grande Acoustic Doppler Current Profiler (ADCP) at a section upstream from the HK turbine. Canal velocities were measured at the same cross-sections as water surface elevations with and without the HK device operating for comparison.

Collaborators

- **Reclamation's Power Resources Office**
- **Instream Energy Systems Corporation**
- **Sandia National Laboratories**

Hydro Award Recipients

Hydro Research Foundation Announces New Research Awards Program Recipients

The Hydro Research Foundation (Foundation) was established in 1994 and became an independent 501(c)(3) non-profit corporation in 1996. The Foundation has two principal objectives: 1) to facilitate research and 2) to promote educational opportunities related to hydropower.

On May 30, 2014, the Foundation announced 12 new research students joining its Research Awards Program, a Fellowship program.

The Fellowship program was established to award research opportunities to graduate-level students researching topics of interest to the hydropower industry through a 2-year, $1 million grant from the U.S. Department of Energy's Wind and Water Power Program.

A selection committee that represents utilities, academia, industry, and researchers selected the 2014 class of research students. Forty-five applicants from 26 universities applied and 12 were selected to conduct research related to conventional or pumped storage hydropower. The research students selected began their work with the Foundation as early as June 2014.

More than 25 students working with the Foundation attended the HydroVision International Conference in Nashville, Tennessee, in July 2014. The new research students introduced their topics of study and 25 final findings were presented by previous classes of Fellows.

The Foundation will be working with the hydropower industry to secure internships, partnerships, mentors, and career opportunities for each of these research students.

Contact: Brenna Vaughn, Program Director | Hydro Research Foundation, 303- 324-1736, brenna@hydrofoundation.org

PennWell Hydro Group Announces Inaugural Class of Women With HydroVision Award Recipients

On July 1, 2014, the PennWell Hydro Group (HydroWorld) announced the inaugural class of recipients of the Women with Hydro*Vision* Award.

This award program is designed to honor the most influential women in the hydropower industry. As the industry itself is rather diverse, the market/award was divided into 10 separate categories. The 2014 winners are listed below by category:

- Communications; Public Relations; Industry Support—Deborah Linke, Executive Director and President
- Dam Safety—Peggy Harding, Chief Dam Safety Engineer
- Engineering Consulting and Plant Services/Maintenance—Lorraine Krout, Chief Executive Officer
- Environmental Protection and Mitigation—Celeste N. Fay, Senior Project Engineer
- Equipment Supply—Jeanne Hilsinger, President and Executive Chairman
- Marine and Hydrokinetic Energy—Susan Skemp, Executive Director
- New Development—Kristina Johnson, Chief Executive Officer
- Policies and Regulations—Linda Church Ciocci, Executive Director
- Power Plant Portfolio Management/Operations and Maintenance—Janet M. Audunson, P.E., Esq., Senior Counsel
- Research and Technology—Maryse Francois-Xausa, Senior Vice President

These 10 women were all nominated by their peers and were selected for this honor based on the tremendous influence and impact they have had on the larger hydropower industry.

The awards were given at the Women with Hydro*Vision* luncheon at the HydroVision International Conference in Nashville, Tennessee, in July 2014.

More Information

Information about the Hydro Research Foundation can be found at: www.hydrofoundation.org/index.html

More information about the Hydro Research Foundation's 2014 Research Awards Program recipients and their topics of study can be found at: www.hydrofoundation.org/awardNews.html

Information about the PenWell Corporation can be found at: www.pennwell.com/index.html

Information about the PenWell Hydro Group (HydroWorld) can be found at: www.hydroworld.com/index.html

More information about the 2014 winners can be found at: www.hydroworld.com/articles/2014/06/inaugural-class-of-women-with-hydro-vision-award-recipients-announced.html

Hydro Research Foundation

PennWell

HydroWorld.com
The Hydro Industry's Proven Authority
Powered by Hydro Review and HRW-Hydro Review Worldwide

Recent Hydropower/Renewable Energy Research Products

The following publications were either sponsored or produced by Reclamation's Research and Development and Power Resources Offices.

Bechtel, Ted. September 2009. *Science and Technology Literature Survey of Wind Power Integration With Hydroelectric Energy.* Bureau of Reclamation Science and Technology Program, Project ID 9608 (completed June 2014). Available at: www.usbr.gov/research/projects/detail.cfm?id=9608

Bureau of Reclamation. April 2012. *Technology Review: Stator Winding Insulation Life Expectancy and Start/Stop Related Aging.* CEATI Report No. T102700-0369. Hydraulic Plant Life Interest Group (HPLIG). Report for Centre for Energy Advancement through Technological Innovation (CEATI) International, Inc., Montreal, Quebec, Canada.

Bureau of Reclamation. June 2013. *The Bureau of Reclamation's Sustainable Energy Strategy, Fiscal Year 2013-2017*. Available at: www.usbr.gov/power/Reclamation%20Sustainable%20Energy%20Strategy%20.pdf.

Bureau of Reclamation. February 2014. *Information on Invasive Mussels for Reclamation*. Power Equipment Bulletin No. 53. Power Facilities Advisory.

Bureau of Reclamation, Power Resources Office. July 2013. *Pumped Storage Evaluation Special Study: Yellowtail, Seminoe, and Trinity Sites*. Final Phase 2 Report.

Bureau of Reclamation, Power Resources Office. August 2014 Expected Release. *Pumped Storage Screening Study II*.

Claire, Kyle and Jeff Stenberg. October 2012. *Signal Processing Techniques for Determining Powerplant Characteristics.* Bureau of Reclamation Science and Technology Program, Project ID 9962.

HDR Engineering, Inc. May 2014. *Assessment of the Potential for In-Stream Hydrokinetic Technologies in North America*. CEATI Report No. T122700-0539. Strategic Options for Sustainable Power Generation Interest Group (SOIG). Report for Centre for Energy Advancement through Technological Innovation (CEATI) International, Inc., Montreal, Quebec, Canada.

Sandia National Laboratories, Water Power Technologies. Quarterly Release. *Canal Based Hydrokinetic Testing: Summary of Activities*. Water Power Milestone Report. Prepared for the Wind and Water Power Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington D.C.

Jim DeHaan installing specialized monitoring equipment inside a generator.

Hydroplant condition monitoring setup.

Hydrogenerator Condition Monitoring

Jim DeHaan is a senior electrical engineer for the Hydropower Diagnostics and SCADA Group in Reclamation's Technical Service Center. Jim is presently leading a research effort to develop and implement a hydrogenerator condition monitoring system. The system software was developed "in-house" and is designed to work with a wide variety of off the-shelf data acquisition hardware. The software measures, analyzes, and stores sensor data from the generator that are used to help predict the "health" of the unit. Having more information available to plant operators enhances their understanding of generator conditions and reduces operation and maintenance costs—the largest expense for a hydropower plant.

One of the system's main uses thus far is to monitor turbine generator vibration. High vibration can lead to generator damage and, potentially, to catastrophic failure. The monitoring system helps detect and diagnose high vibration conditions and can alert plant personnel to a potential problem.

The monitoring system is currently installed on over a dozen generators at various Reclamation powerplants, and several more sites are either scheduled for installation or under consideration. The short term goal is to equip nearly half of Reclamation generators with this hydrogenerator condition monitoring system.

Contact: James (Jim) DeHaan | Reclamation's Technical Service Center
303-445-2305, jdehaan@usbr.gov

Federal Highway Administration Adopts Reclamation Hydraulic Model

The Federal Highway Administration has officially adopted Reclamation's Sedimentation and River Hydraulics–Two-Dimensional Model (SRH-2D) hydraulic and sediment transport model to simulate the river hydraulics past bridge crossings. This model was developed by Dr. Yong Lai of the Sedimentation and River Hydraulics Group in Reclamation's Technical Service Center (TSC) and has been used extensively by TSC, several area offices, consultants, and others internationally.

The hydraulic model simulates water depth and velocity along and across the river channel and floodplains for a given streamflow hydrograph. The model is also capable of simulating the erosion and deposition of sediment over time. These results are important for protecting infrastructure and property and for restoring habitat to keep Reclamation projects functioning.

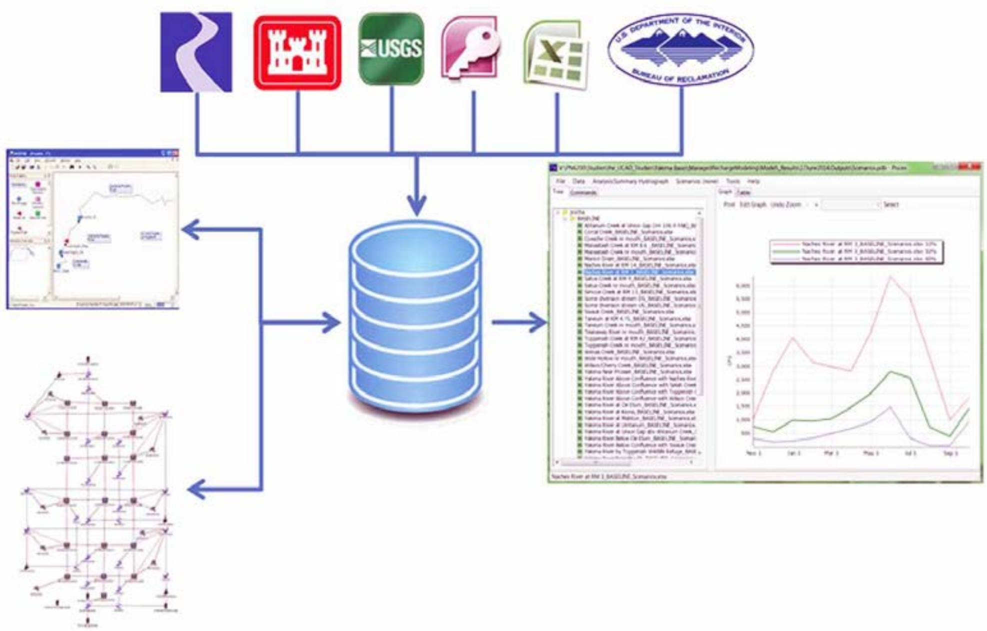
Contact: Yong Lai | Reclamation's Technical Service Center
303-445-2560, ylai@usbr.gov or

Timothy (Tim) Randle | Reclamation's Technical Service Center
303-445-2557, trandle@usbr.gov

Pisces

Large datasets often show data for long periods of time at fine temporal resolutions. These large datasets can be unwieldy and hard to manipulate to determine trends and identify patterns. The Pisces tool is a powerful data management and analysis toolset that can handle large time-series datasets typically associated with hydrologic and meteorological observations and model outputs. Pisces has several built-in functions that make summarizing and analyzing large datasets easier. Pisces' open source nature, its hierarchical library organization, and the ability to program plug-ins in the C# programming language ensure a good level of flexibility in enabling Pisces to interact with multiple data repositories and modeling platforms.

Pisces is able to interface with U.S. Geological Survey, U.S. Army Corps of Engineers, Oregon Water Resources Department, and Idaho Department of Water Resources data repositories and web services to download hydrologic data. It is also able to import RiverWare DMI, MODSIM, and Microsoft Excel and Access model outputs. Pisces can be easily customized via the use of plug-ins to import any kind of time-series data, to perform virtually unlimited calculations and analyses on time-series datasets, and to interface with various modeling platforms. The Pisces source code is available on GitHub at https://github.com/usbr/Pisces and an executable installer is available at www.usbr.gov/pn/hydromet/pisces/.



Pisces Time-Series Database connects to many time-series sources.

Example Custom Programs That Leverage Pisces Libraries

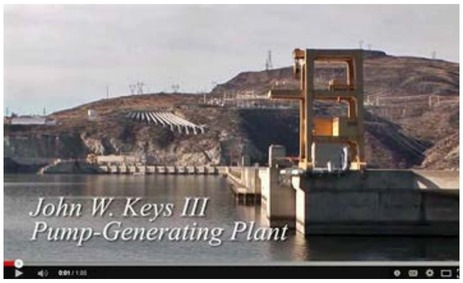
RiverWare DMI	This program provides a custom data interface between Pisces and RiverWare DMI.
Pisces to MODSIM	This program loads the MODSIM model with time-series data managed by Pisces.
Rogue Biological Option Minimum Flow Checker	This custom Pisces database and program analyzes the Rogue River Basin to determine if minimum flow requirements are met depending on time of year, river gage, ramping rates, and upstream and downstream diversions.
U.S. Geological Survey Oregon Water Resources Department Idaho National Labs Idaho Power Company Natural Resources Conservation Service's Snotel	Custom programs for each of these data types leverage the different Pisces libraries to import data into the Pacific Northwest Region's Hydromet System.

Contact: Karl Tarbet | Reclamation's Pacific Northwest Region
208-378-5272, ktarbet@usbr.gov

Multimedia Around Reclamation

How It Works: John W. Keys III Pump-Generating Plant

The pump-generating plant at Grand Coulee Dam was completed in 1973. It contains 12 pumps that lift water from the Columbia River up the hillside to a canal that flows into Banks Lake, which provides irrigation water to over 670,000 acres in the Columbia Basin Project. Six of the pumps can be reversed to generate hydroelectricity when demand exists.



Published on August 7, 2014. See:
www.youtube.com/watch?v=kuLpIUeAqHs&feature=youtu.be

Hydroelectric Dam Model

Working Model of a Hydroelectric Dam—This is the scale working model of a Hydroelectric Dam built for Reclamation. It was built to illustrate four concepts of a hydro dam: 1) the spillway, 2) the bypass, 3) the riverflow, and 4) electric generation.

Published on June 3, 2014. See:
www.youtube.com/watch?v=ufB3U6GxnUQ&feature=youtu.be

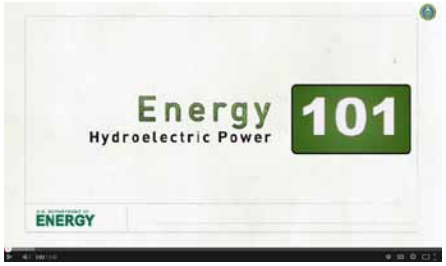
Grand Coulee Dam: A Man-Made Marvel

The *Grand Coulee Dam: A Man-Made Marvel*, produced by Reclamation's Pacific Northwest Region Public Affairs Office, is now showing to enthusiastic audiences at the dam's Visitor Center. This film, newest in the lineup, is loaded with historic construction footage, photographs, and newsreels from Reclamation's legendary hydropower workhorse.

Published on May 13, 2014. See:
Trailer: www.youtube.com/watch?v=_Z3LAj4RxHg
Full Movie: www.youtube.com/watch?v=BU4qw9zYX9Y

Energy 101: Hydropower

Learn how hydropower captures the kinetic energy of flowing water and turns it into electricity for our homes and businesses.



Published on April 19, 2013. See:
www.youtube.com/watch?v=tpigNNTQix8

Q&A With Acting Commissioner Lowell Pimley – Climate Change and Drought

Acting Commissioner Lowell Pimley provides the second in a series of podcasts. In this question and answer session he discusses climate change and drought.

Published on July 8, 2014. See:
www.youtube.com/watch?v=t0u6BdsNoV4&list=PL97E2B161CFD30D5B&index=2

"About a year ago, Great Plains' Public Affairs folks were brainstorming how to better 'tell our story.' That effort led to development of a [hydroelectric dam] model we can use for outreach events. We have already identified several events where we can use the model to spread the word about who we are and what we do.

"Buck Feist is our primary person for this. From concept through design and development, he cajoled, coordinated, collaborated, and delivered the product. Perhaps our partners in the U.S. Corps of Engineers or one of the power marketing agencies may want one for their outreach?"

Michael (Mike) Ryan
Regional Director,
Reclamation's Great Plains Region

"Buck [Feist] and the crew did a nice job running through the various design and build stages of putting the model together. I think it will serve us nicely at a good number of public outreach events in the coming years."

Tyler Johnson
Supervisory Public Affairs Specialist, Reclamation's Great Plains Region

DesertLCC [Desert Landscape Conservation Cooperative]

Reclamation and the U.S. Fish and Wildlife Service have partnered to develop the *DesertLCC* webinar video series. The Desert LCC is a binational, self-directed, non-regulatory regional partnership formed and directed by resource management entities as well as interested public and private entities in the Mojave, Sonoran, and Chihuahuan Desert regions of the Southwestern United States and Northern Mexico. Through collaborative partnerships, the Desert LCC seeks to provide scientific and technical support, coordination, and communication to resource managers and the broader Desert LCC community to address climate change and other landscape-scale ecosystem stressors.

For further information about Desert LCC please visit www.usbr.gov/dlcc/.

Latest webinar series video published on June 19, 2014. See:
www.youtube.com/user/DesertLCC/feed

Reclamation Climate Change Research Series

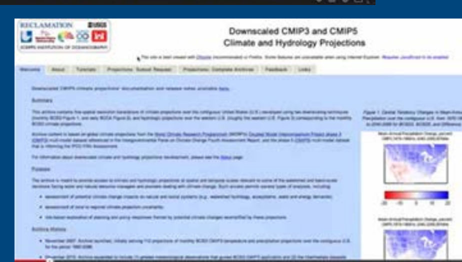
This video series summarizes collaborative research addressing climate change and variability impacts, estimating flood and drought hazards, and improving streamflow prediction. This information was presented in January 2014 at the Second Annual Progress Meeting on Reclamation Climate and Hydrology Research. To learn more about climate change and variability research please visit www.usbr.gov/research/climate.

Latest series video published on May 29, 2014. See:
www.youtube.com/playlist?list=PLvHsnLEo5Rt4MZjJ1sYrmEXvQm7TVcMYv

Introducing the Downscaled Climate and Hydrology Projections

These two videos serve as an introduction to the *Downscaled Climate and Hydrology Projections* website. Several Federal and non-Federal agencies partnered and collaborated on this website, which provides access to downscaled climate and hydrology projections for the contiguous United States and parts of Canada and Mexico, derived from contemporary global climate models.

In the first video, Dr. Subhrendu Gangopadhyay, hydrologic engineer at Reclamation's Technical Service Center, introduces the website and provides an overview of the MetEd lesson, *Preparing Hydro-Climate Inputs for Climate Change in Water Resources Planning*. This lesson provides necessary background information needed to use the projections site effectively to retrieve climate and hydrology projections data for impacts analysis. In the second video, Dr. Gangopadhyay steps through the process of retrieving projections data using the website.



This resource, produced in cooperation between Reclamation and the COMET® Program, is hosted on COMET's YouTube Channel.

Published on January 29, 2014. See:
Videos: www.youtube.com/playlist?list=PLsyDl_aqUTdERdXxM0guc1ZHWj1Eqzknk
Website: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/
MetED Lesson: www.meted.ucar.edu/training_module.php?id=959

Recent Events

This list of events is intended for informational purposes only and does not necessarily constitute an endorsement by Reclamation. These events may be of interest to the science, research, and related communities and are not necessarily hosted by Reclamation.

Find our most recent list of events at: www.usbr.gov/research/events.

HydroVision International Conference and Exhibition

July 22 - 25, 2014 | Nashville, Tennessee

The HydroVision International Conference and Exhibition, the year's largest gathering of influential hydro decisionmakers, featured more than 70 sessions and over 450 speakers covering a wide range of topics important to the further development of hydropower.

The HydroVision International Conference and Exhibition is the leading annual hydro event with more than 3,000 attendees and over 300 exhibitors, which offered attendees countless opportunities to network, share best practices, meet with product and service providers, and more.

Radial gate on East Low Canal.

The opening keynote was from Lieutenant General Thomas P. Bostick, the Commanding General of the U.S. Army Corps of Engineers (Corps), on plans and investments for modernizing the Corps' fleet of aging hydropower and civil infrastructure facilities. Attendees also heard from the World Bank as "sustainable hydropower is part of the solution for tackling the development challenges encompassed in its mission to end extreme poverty within a generation and boost shared prosperity."

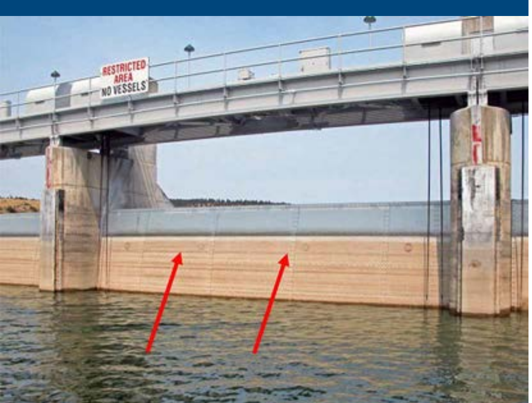
Additional conference and exhibition information:

http://s36.a2zinc.net/clients/pennwell/hvi2014/Public/Content.aspx?ID=43509

Corrosion Mitigation of Gates—Webinar Training

July 24, 2014 | Denver, Colorado

Reclamation has hundreds of gates on structures such as dams, canals, and pumping plants. Due to the high cost and frequency of recoating, Reclamation is increasingly considering retrofitting gates to include cathodic protection as part of the corrosion mitigation system. Jessica Torrey in Reclamation's Technical Service Center presented information on design, installation, maintenance, and testing of corrosion mitigation for gates. Additionally, Jessica presented an introduction to the Mobile Information Collection Application (MICA). This is an app for tablets, which was developed by the U.S. Corps of Engineers and has been tailored for field data collection of cathodic protection systems. The field test and integration of this app into Reclamation is being funded through Reclamation's Science and Technology Program (www.usbr.gov/research/projects/detail.cfm?id=6816). This Reclamation-hosted webinar training consisted of a 40-minute presentation followed by 20 minutes of questions, answers, and comments.



Radial gate with impressed current cathodic protection at Angostura Dam. Low profile disc anodes can be seen mounted to the skin plate.

Contact and additional webinar training information:
Jessica Torrey, 303-445-2376, jtorrey@usbr.gov
Daryl Little, 303-445-2384, dlittle@usbr.gov

https://www4.gotomeeting.com/register/886793375

Safety Evaluation of Existing Dams International Technical Seminar and Study Tour

June 10 - 19, 2014 | Denver, Colorado

Reclamation officials provided the training for this seminar. The first portion of this seminar took place in Denver, Colorado, and consisted primarily of classroom presentations and discussions. A tour of the Reclamation Research Laboratories was also featured. Lectures, case histories, and structured discussions covering all aspects of a dam safety examination program were led by Reclamation engineers and geologists with extensive experience and knowledge in the areas of design, construction, operation, maintenance, and dam safety. The training outlined the hydrologic, seismic, geotechnical, electrical, mechanical, and structural considerations of dam safety as well as operation, maintenance, surveillance, and emergency preparedness. Presentations, case histories, and a walk-through abbreviated examination was used to present the multidiscipline approach to an effective dam safety program. The second portion of this seminar consisted of site visits and took participants to the States of Nevada and Oregon. Participants also enjoyed a "free" day in Las Vegas, Nevada.

Contact and additional seminar and study tour information:
Leanna Principe, 303-445-2127, lprincipe@usbr.gov
Angela Medina, 303-445-2139, amedina@usbr.gov
www.usbr.gov/international/seed_2014seminar.html

Hoover Dam in Arizona/Nevada.

Data Stewardship - Best Practices—Information Technology Workshop

June 10, 2014 | Denver, Colorado

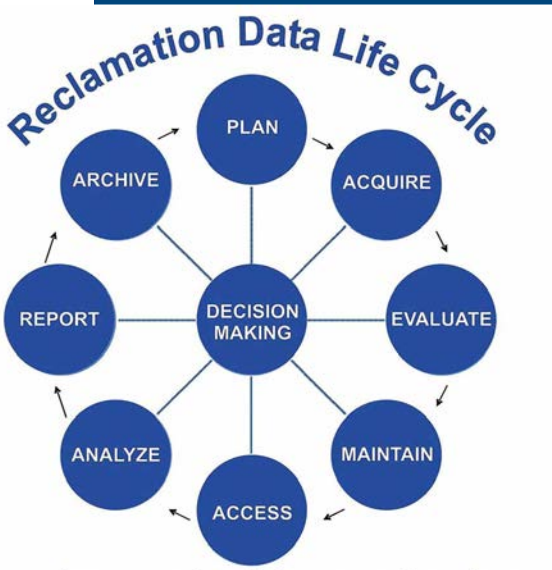
Reclamation hosted U.S. Geological Survey (USGS) representative, Vivian (Viv) Hutchison, who described what data stewardship is, why it is important, and how it should be undertaken. Viv also illustrated best practices and the USGS experience. Douglas Clark in Reclamation's Technical Service Center presented, and participation via webinar was also available.

Viv Hutchison

Contact and additional workshop information:
Douglas R. Clark, 303-445-2271,
drclark@usbr.gov

Curt Brown, 303-445-2098,
cbrown@usbr.gov

https://www4.gotomeeting.com/register/540119503



"If your data source is well documented, you know how and where to look for your information and the results you return will be what you expect. In addition, accurate data are legally and scientifically defensible. Such data may aid the agency by reducing litigations and appeals."

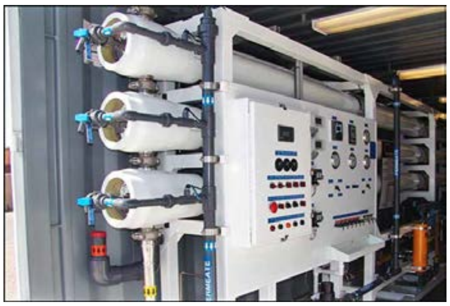
Recent Research Products

To get the information generated by research quickly into the hands of end users and the broader public, our researchers and partners publish their results in peer-reviewed journals, technical memoranda, research reports, and other venues.

Contact the authors/principal investigators for information about these documents or research projects. Use the Science and Technology Program research project ID number to access contact information or the documents themselves at:

www.usbr.gov/research/projects/search.cfm.

Rock Ramp Design Guidelines
By David Mooney, Chris Holmquist-Johnson, and Susan Broderick
Project ID 7621



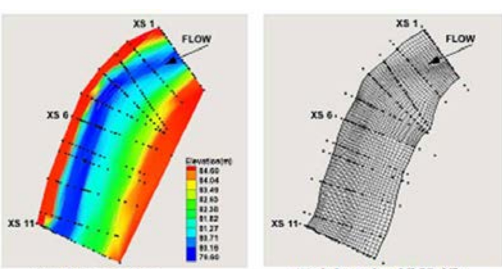
Optimizing Seawater Reverse Osmosis for Affordable Desalination
By John MacHarg
Project ID 9081

Water Resistant Concrete
By Kevin Kelly
Project ID 919

Equilbrium Scour Downstream of Three-Dimensional Grade-Control Structures
By Steven Abt, Michael Scurlock, and Christopher Thornton
Project ID 7621

On a Two-Dimensional Temperature Model: Development and Verification
By Yong Lai and David Mooney
Project ID 7872

Physical Hydraulic Modeling of Canal Breaches
By Tony Wahl
Project ID 8442



(a) Topography (b) Mesh for SRH-2D

Coupling a Two-Dimensional Model With a Deterministic Bank Stability Model
By Blair Greimann, Robert Thomas, Yong Lai, and Andrew Simon
Project ID 6606

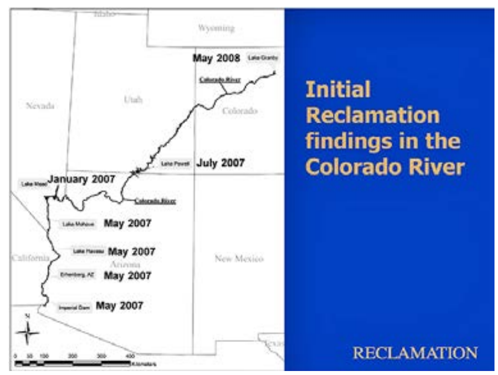
Membrane Pretreatment With Ion Exchange for Natural Organic Matter (NOM) Removal
By Steve Dundorf
Project ID 536

Brackish Water Treatment for Native American and Small Communities in the Pacific Northwest Region
By Steve Dundorf
Project ID 1282

Scour Analysis Upstream of the San Acacia Diversion Dam on the Rio Grande
By Yong Lai and Jon Aubuchon
Project ID 6606

Flow Calibration of Submerged Sluice Gates
By Tony Wahl
Project ID 2597

American Recovery and Reinvestment Act Toxin Data
By Chris Holdren
Project IDs 1221 and 2358



Factors Affecting the Spread of Dreissenid Mussels in Western Reservoirs
By Chris Holdren
Project ID 1221

An Analysis of Phosphorus Perchlorate Inputs to Lake Mead
By Chris Holdren
Project ID 1221

Factors Affecting the Spread of Dreissenid Mussels in Western Reservoirs
By Chris Holdren
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Project ID 92

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By Blair Greimann
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The Influence of Rebates on the Purchase of and Willingness to Pay for Water Conservation Devices
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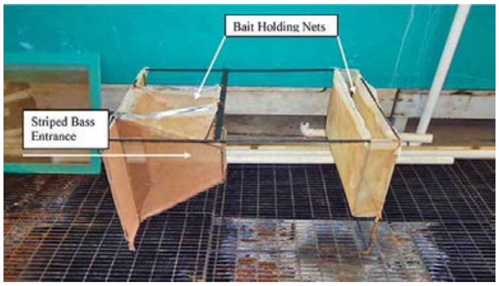

Fish Predator Reduction Using Fish Traps With Bait Attraction
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By Sherri Pucherelli
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By Kevin Kelly
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The Value of Water: Scoping a Research of Analysis
By Darlene Tuel
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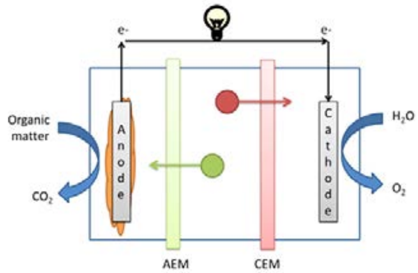
The Influence of Conservation Pricing and Other Non-Price Factors on Residential Water Demand
By Steven Piper
Project ID 414



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Effects of Electrofishing Removal on the Channel Catfish, Ictalurus Punctatus, Population in the San Juan River, New Mexico
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By Douglas Clark
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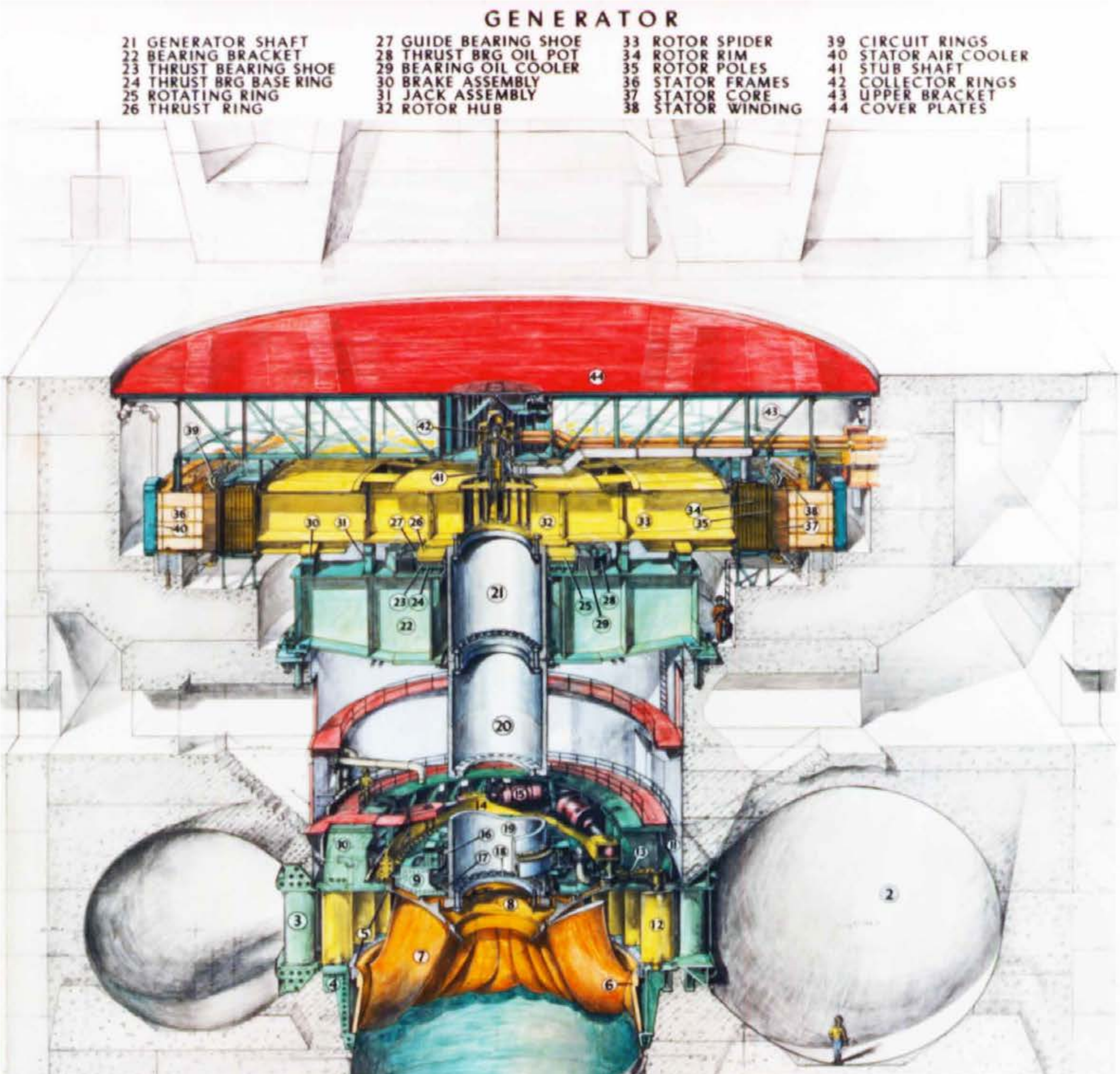

Photograph and detailed drawing of Turbine–Generator. Note the size ratio of the worker in the lower right side of the drawing just above the photograph.