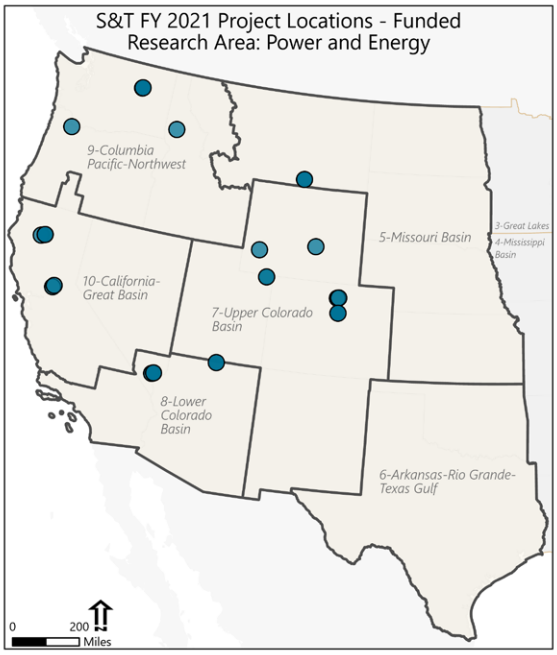
BUREAU OF RECLAMATION

Research Updates
R&D Office
Power and Energy

U.S. Department of the Interior

January 2021

Executive Summary



The Power and Energy (PE) Research Area of the Science and Technology Program (S&T) examines research in the following categories: Hydro Powerplants, Energy Efficiency, Pumping Plants, and Non-Hydropower Renewable. In FY21, S&T funded 21 PE Projects approximately totaling $1.7M: 4 were new totaling $0.31M and 17 were continuing totaling $1.4M. Benefit Cost Ratio calculations (BCR) are estimated for two PE projects each year to demonstrate the value of this research. A BCR of 25.9 was calculated for the Feasibility of Utilizing Optical Instrument Transformers primarily due to dissuading a wholesale adoption of this technology to replace Instrument Transformers in powerplants and switchyards. A BCR of 9.7 was calculated for Power System Safety: Electromagnetic Rotor Turner, Arc-Flash Reduction, Passive Voltage Indication, and Generator Fire Suppression. This project examined several safety related ideas to determine which were feasible to implement. The economic benefits are realized through reliability improvements, avoided damage to equipment which reduces operation and maintenance (O&M) costs, and the significant efficiency gains and prevention of personnel injuries due to the development of an electromagnetic rotor turner. As demonstrated, PE research is extremely valuable to Reclamation, both by development of new O&M methods and techniques, as well as by learning about technologies that should not be adopted by Reclamation's O&M Program.

Science and Technology Program: Research Areas

Reclamation's Research and Development Office (R&D) manages the Science and Technology Program (S&T) and is focused on providing innovative solutions for Reclamation water and power facility managers and its western customers and stakeholders, primarily through research projects led by Reclamation employees.

The S&T Program has five research areas (listed below) directly related to Reclamation's mission. For more information, visit: https://www.usbr. gov/research/st/needs_priorities/index. html)

Power and Energy
Hydro Powerplants, Energy Efficiency, Pumping Plants, and Non-Hydropower Renewable

Water Infrastructure
Dams, Canals, Pipelines, and Miscellaneous Water Infrastructure

Environmental Issues in Water Delivery and Management
Water Delivery Reliability, Invasive Species, Water Quality, Sediment Management, and River Habitat Restoration

Water Operations
Water Supply and Streamflow Forecasting, Water Operations Models and Decision Support Systems, Open Data, and Climate Change and Variability

Developing Water Supplies
Advanced Water Treatment, Groundwater Supplies, Agricultural and Municipal Water Supplies, and System Water Losses

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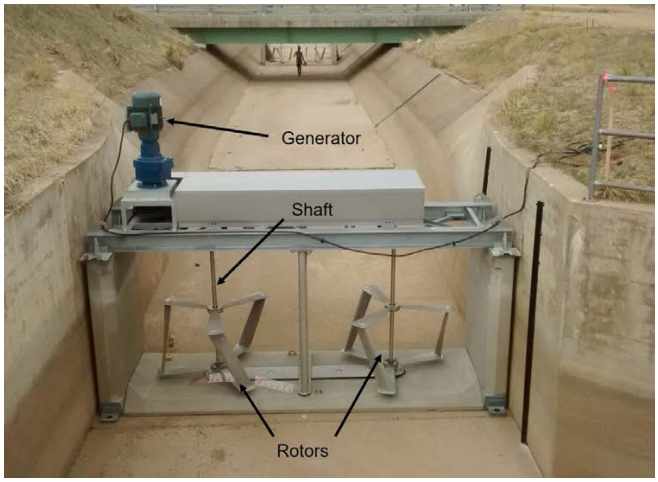
Power and Energy

FY20 Completed Projects

1707: Hydraulic Impacts from Hydrokinetic Installations - Josh Mortensen

Hydrokinetic (HK) power technologies advantageously utilize the existing infrastructure and flow conditions of canal systems but impacts to daily operations and canal safety must be considered. Depending on canal discharge, geometry, and slope, as well as the number and spacing of the HK units, water levels can exceed freeboard restrictions and become a safety concern. This work provided guidance to assess energy loss of the canal flow versus power output from the HK unit, impacts to water levels, and the potential to limit the canal discharge for safe operations if the HK units are spaced too closely.

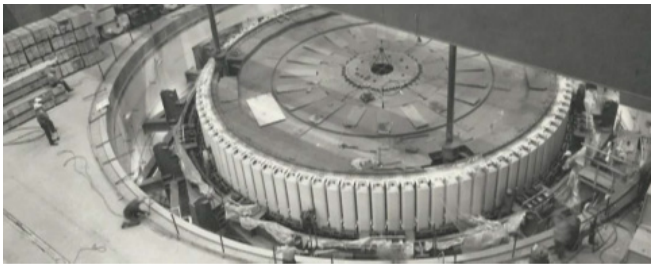
Hydrokinetic unit in operation with temporary upstream transitions made of tarps.



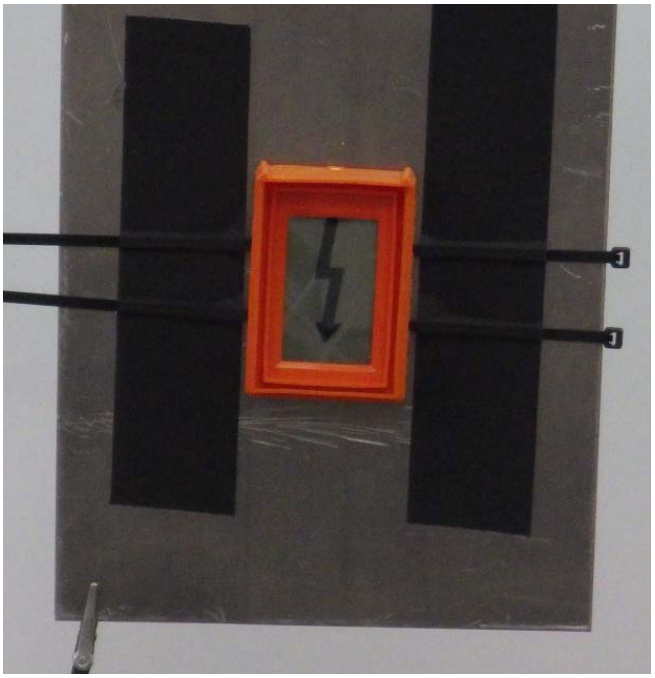
Dual rotor hydrokinetic unit installed in a dewatered canal, looking upstream.

1800: Power System Safety - Jim DeHaan

New technologies and changing safety standards necessitate the need to continue to advance personnel safety within Reclamation powerplants. This research effort focused on improving personnel safety by addressing four current safety concerns encountered at Reclamation facilities: DC and AC arc-flash reduction, improved worker safety while turner rotors, prevention of mis-operation of energized equipment, and evaluating the need for alternative generator fire suppression systems. In addition to safety improvement, the reliability of Reclamation powerplants will improve by reducing or eliminating potential damage to equipment which in turn results in reduced operation and maintenance costs.



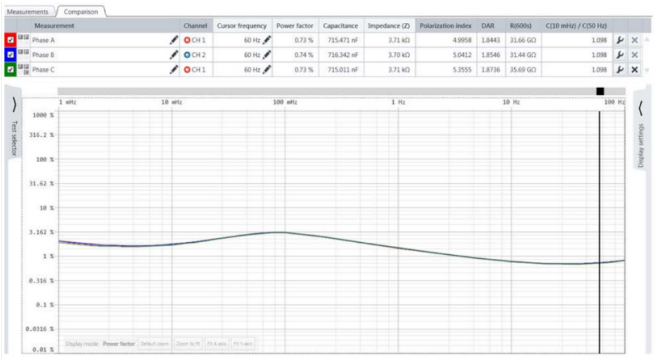
Rotor lifting operation at Grand Coulee's Third Powerhouse, which is a high-risk endeavor for both personnel safety and maintenance induced failures.



Test setup for a large area conductor. The lightning bolt appears on the display when high voltages are detected.

1862: Dielectric Frequency Response of Generator Stator Windings - Benjamin Few

Test methods and results for generator stator winding diagnostics are either vague or extremely sensitive resulting in inaccurate assessments or confusing results. Dielectric Frequency Response (DFR) testing performs tests over a range of frequencies, provides test data points from several traditional test methods, and results in a more complete picture of the results. Applying DFR to solid insulation, as found in generator windings, is an emerging area. Stator winding tests showed DFR did not correlate well with, and is not a suitable replacement for, traditional test methods.



Dielectric frequency response test results from the Hungry Horse G3 stator. Tests are safely run through the desired frequency range without required interaction from the test operator.

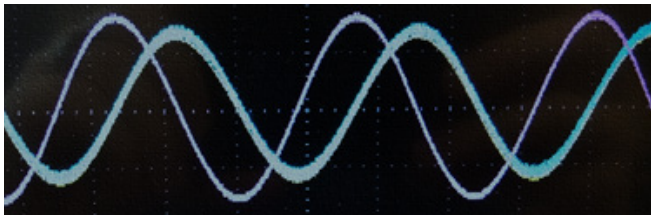
1880: Determining Hydro Generation Start/Stop and Cycling Costs - Jim DeHaan

Hydro generation costs associated with the integration of renewable energies such as wind and solar is not well understood, but there is justification to provide budgetary compensation to hydropower facilities for providing these services. Frequent start/stops and unit cycling of hydropower facilities to support renewables comes with a cost; this research aimed to identify and quantify them. Through collaboration with other hydropower partners via CEATI, a final report entitled "Establishing a Standard Methodology to Evaluate Start/Stop and Cycling Costs and Impacts," and an accompanying Excel spread sheet that implements the methodology was developed.

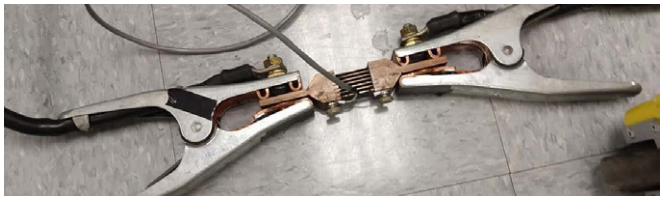
1880: Hydroelectric plant operator making adjustments at the facility switchboard.

19219: Feasibility of Utilizing Optical Instrument Transformers in Reclamation Power Facilities - Ryan Hogg

Instrument transformers (ITs) are an integral component of the electric grid that transform the primary current and voltage waveforms on the power grid to levels usable by controllers, meters, and relays. Conventional ITs (iron and copper) have a variety of drawbacks including possible misrepresentation of primary values and safety concerns. Optical instrument transformers (OITs) can provide improved representation of the primary values and reduce safety concerns. OITs provide this increased performance at the cost of complexity. In general, this complexity outweighs the benefits of OITs. The continued use of conventional ITs for the vast majority of new and replacement ITs is rational and justified. Market available OITs are niche devices that will only be justifiable in highly specialized applications.



Screenshot of instrument transformer oscilloscope data with two sine waves approximately 90 degrees out of phase.

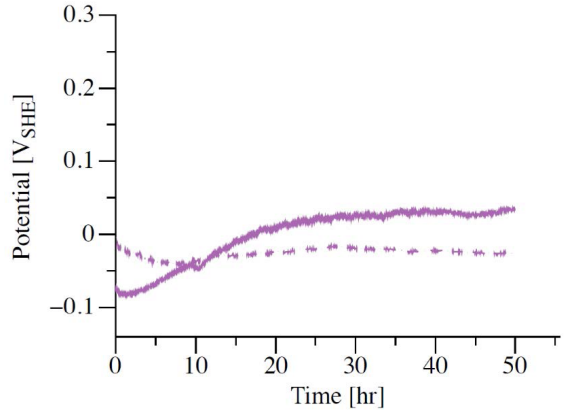


500 A to 50 mV shunt in primary circuit, part of the optical current transformer test set up.

20035: Optimizing feasibility of using Additive Manufacturing to print 3D metal parts - Stephanie Prochaska

This work sought to determine the effect of various post-processing techniques on the corrosion response of additively manufactured 316L stainless steel by evaluating the open circuit potential (OCP) and microstructure of as-printed and heat treated additively manufactured disk specimens. OCP showed that heat treatment made the specimens more susceptible to corrosion. The unhomogenized grain structure of the as-printed specimen did not provide any quick paths for electrons to reach the substrate and also had a higher resistance to corrosive attack; the smaller-grained heat-treated specimen had a higher density of grain boundaries for easier electron transport and thus had more negative potentials.

Micrograph showing the small-grained microstructure of a chemically sensitized specimen produced via additive manufacturing a magnification of 12.6X.

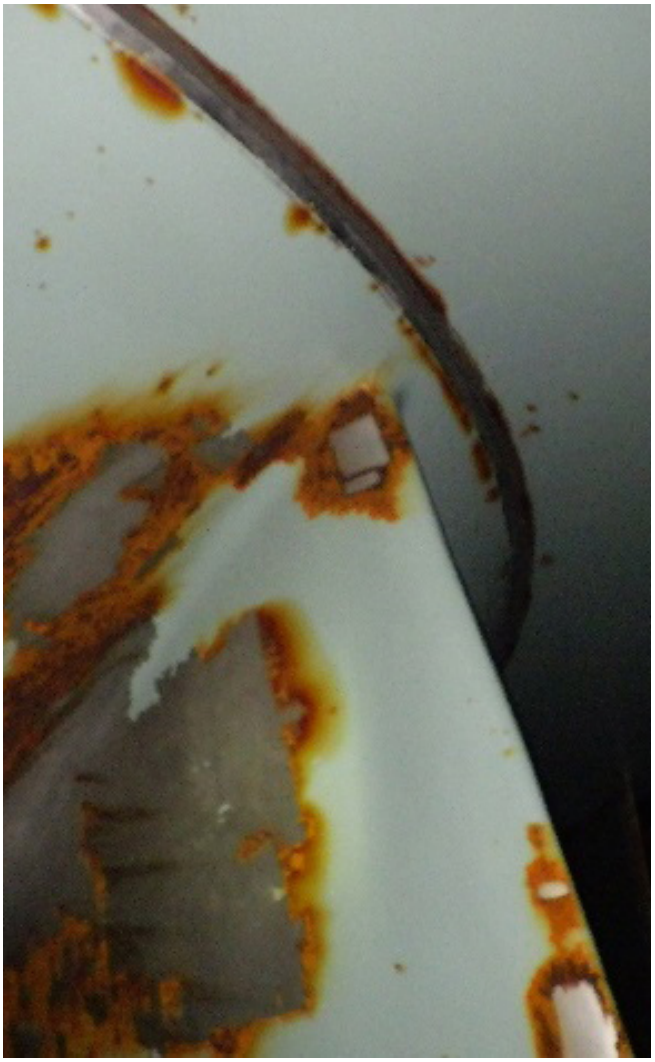


Potential vs. time plot showing the open circuit potential of the polished and unpolished heat treated specimen after 50 hours.

FY21 New Research Projects

21104: Optimizing Hydraulic Turbine Operation and Maintenance Through Reducing Cavitation - John Germann

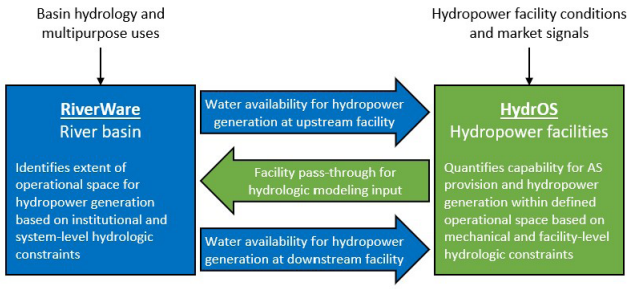
This project continued the development and testing of better cavitation detection and monitoring techniques, better inspection and quantification of erosive cavitation damage, improved sensor selection and placement location and signal interpretation for use in the detection and characterization of cavitation and different cavitation types in hydraulic turbines.



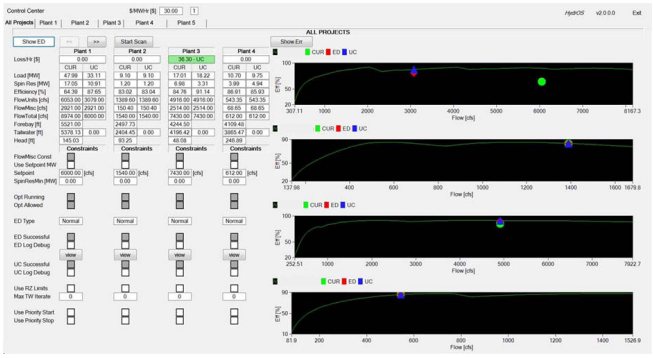
Screenshot of instrument transformer oscilloscope data with two sine waves approximately 90 degrees out of phase.

21087: Quantifying the Flexibility and Economic Potential of Reclamation's Hydropower Assets - Melissa Estep

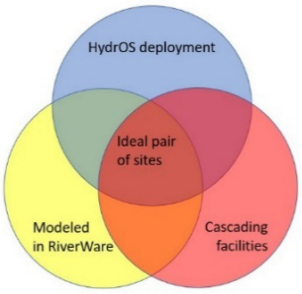
The proposed research leverages HydrOS and RiverWare to improve system-level hydropower outcomes. Specifically, the research will couple the modeling tools to: (1) identify the maximal operational space for hydropower production for individual facilities (RiverWare); (2) quantify the capability for ancillary services provision and optimal hydropower generation within the defined operational space (HydrOS); (3) evaluate multiple site-specific ancillary services and generation solutions across cascading facilities to deliver system-level optimization (RiverWare).



A diagram describing the conceptual model linkage between HydrOS and RiverWare.



A screenshot of the HydrOS "Control Center" screen.



A Venn Diagram displaying the primary criteria for pilot site selection.

21027: Online Monitoring of Protection Systems: Pilot Project - Stephen Agee

This project will develop and install online protection system monitoring on two generators, a generator step-up (GSU) transformer and the 125VDC battery system as a prototype system at Glen Canyon Power Plant. The controller would be programmed to continuously interrogate the connected relays, meters and battery monitor to insure near continuous monitoring of the protection system. If deteriorated performance is detected, the Glen Canyon Control Center would receive an alarm.

New Online Monitoring Glen Canyon Unit 1 and Unit 2, the test units for the pilot system.

Transformer Differential Relay, the relay will be connected to the pilot system.

21006: Development and Refinement of Rotor Turning Device for Safer and More Efficient Maintenance and Diagnostic Tasks - Jacob Lapenna

This project will further develop and refine a rotor turning device designed to improve safety and efficiency while turning generator rotors at Reclamation's hydropower facilities. Many diagnostic tests require a rotor to be turned slowly including slow roll airgap and future technology such as visual inspections and rotor mounted corona mapping. In addition to diagnostic tests, other tasks such as bearing alignment, rotor balance, and machine alignment require precise turning of the rotor within its bore. Further development and testing of this device will occur to bring this technology to the field for more wide-spread implementation.

Electromagnetic rotor turner prototype consisting of two modified commercial power supplies and a lab-built current reversing module and handheld control box.

Technology Transfer Projects

Denver Water Cooperative Research and Development Agreement (CRADA), April 2017 - April 2020:

A joint final report was completed and is being vetted for publication pending agreement from all parties.

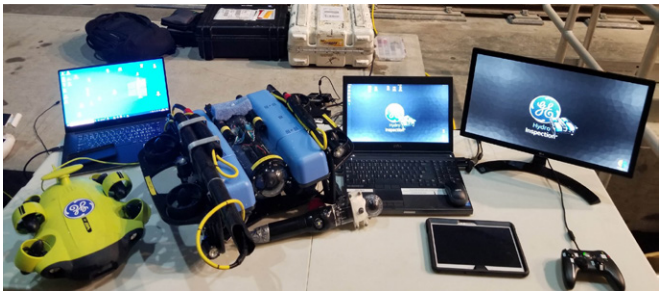
Original General Electric (GE) CRADA, April 2017 - September 2018:

This CRADA was extended through September 2021 due to delay of outages on Unit G-24 at Grand Coulee Powerplant. Grand Coulee, R&D, TSC and GE are determining when the final inspection will take place to close this agreement. This project is funded through projects 8121 and 21104. The scope of work included cavitation testing and monitoring, air injection for rough zone mitigation, and residual stress measurement. A joint report will be developed once the final work is completed.

GE CRADA, September 2020 - September 2025:

This CRADA was developed as a follow-on to the original. The scope includes continued cavitation monitoring and further inspections which will include Faro Laser Measurement and robotic inspection without dewatering.

FARO LLP Scanning Cavitation Damage.



Robots for future inspections.

FY21 New and Continuing Research Projects

ID	Final Year	Title	Lead	FY21 Funding Amount
300	2021	Performance Testing Multiple Units of Similar Hydraulic Design	Shanna Durham	$112,491
8121	2021	Cavitation Detection Techniques for Optimizing Hydraulic Turbine Operation and Maintenance	John Germann	$61,116
8141	2021	Noise induced hearing loss (NIHL)	Lisa Duncan	$70,276
19078	2021	Rotor Installed Corona Mapping of Stator Windings within Large Diameter Hydro Generators	Jacob Lapenna	$33,960
19085	2021	Additive Manufacturing Investigation and Demonstration for Hydropower Applications	David Tordanato	$150,000
19146	2021	Demonstration and Use of Advanced 3D Measuring Techniques using Portable Laser and Arm Technology	Jordan Lemer	$113,634
19223	2022	Reduction of Damaging Stator Core and Winding Vibrations in Large-Diameter Salient-Pole Synchronous Machines	Eric Eastment	$97,120
19251	2021	Effects of Water Absorption on Epoxy-Mica Based Stator Winding Insulation Systems	Eric Eastment	$35,000
20009	2022	Power System Instrumentation	Patrick Council	$110,000
20012	2022	Machine Condition Monitoring (MCM)	Jim DeHaan	$108,000
20013	2021	Fuel Cell Evaluation	Jim DeHaan	$22,798
20014	2022	Rotor-Mounted Scanner	Jim DeHaan	$80,000
20036	2022	Evaluating Kevlar Rope for Use in Gate Hoist and Crane Applications for Improved Service Life	Zach Cepak	$57,989
20048	2021	Utilizing the Winter-Kennedy method for Hydropower Flow Measurement	Josh Mortensen	$128,056
20076	2021	Using Strain-Sensing Technology to Increase Safety and Reliability of Inaccessible Critical Connections in Hydropower Equipment	John Germann	$32,368
20100	2022	Evaluation of Alternative Fire Suppression Methods for Generators For Improved Safety, Effectiveness and Reliability	Randall Egan	$42,500
20203	2022	New Reclamation-wide Maintenance Management Toolset	Jim DeHaan	$182,808
21104	2023	Optimizing Hydraulic Turbine Operation and Maintenance Through Reducing Cavitation	John Germann	$96,960
21087	2022	Quantifying the Flexibility and Economic Potential of Reclamation's Hydropower Assets	Melissa Estep	$57,250
21027	2023	Online Monitoring of Protection Systems: Pilot Project	Stephen Agee	$81,000
21006	2023	Development and Refinement of Rotor Turning Device for Safer and More Efficient Maintenance and Diagnostic Tasks	Jacob Lapenna	$77,500