RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Research Update

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Bottom Line

This research project examined operating data and developed a finite analysis model to use to determine operating limits for some temporarily repaired hydropower generators.

Better, Faster, Cheaper

More accurately analyzing synchronous machine operating limits can save money and time from unit shutdowns and more effectively operate and maintain generating units.

Principal Investigators

James DeHaan
Electrical Engineer
Hydropower Diagnostics and SCADA Group
Technical Service Center
303-445-2305
jdehaan@usbr.gov

Moshe (Jeff) Redmon
Electrical Engineer
Power System Analysis and Controls Group
Technical Service Center
303-445-2372
mredmon@usbr.gov

Research Office Contact

Erin Foraker
Renewable Energy Research Coordinator
303-445-3635
eforaker@usbr.gov

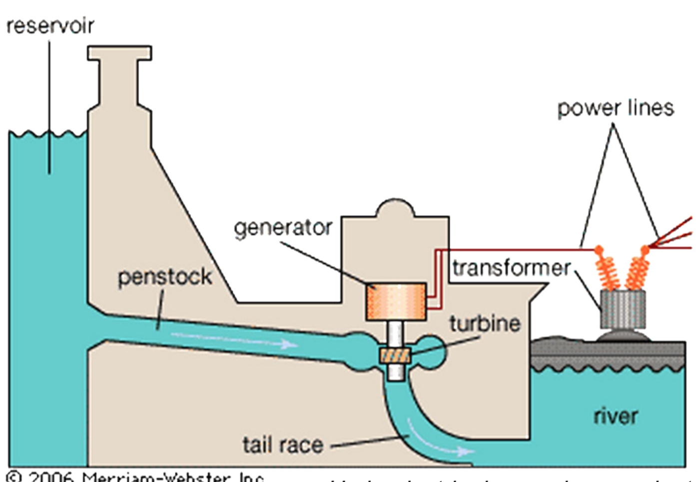
Analyzing Synchronous Machines With Bypassed Coils

Examining the viability of using Finite Element Method-based modeling software to determine operating limits for synchronous machines

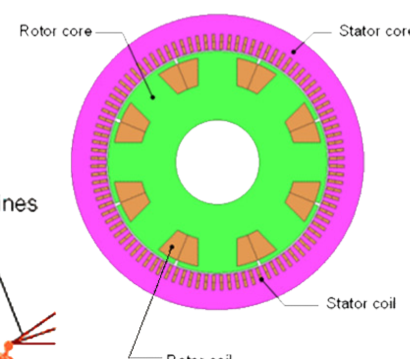
Problem

Nearly all of the power industry utilizes synchronous generators to produce electric power. These units are very reliable; however, the generator windings will eventually fail. Internal faults can be caused by a number of issues ranging from aging or faulty electrical equipment to water leakage in the machine. These internal faults can damage the armature windings, thus rendering the machines inoperable. Generators are then taken out of service for months while a complete winding replacement is scheduled and performed. These large unit outages are often very costly as they supply large amounts of power to the electrical grid and generate substantial revenue for the powerplant.

Temporary repairs to electrically bypass damaged coils can allow the unit to continue operating at reduced loading until the winding is replaced—rather than taking the entire unit out of service. New operating limits for a unit, while the temporary repairs are in place, are traditionally determined using a set of conservative hand calculations outlined by sources, including Electric Power Research Institute Report EL-4983. As the reliability of the power grid grows ever more crucial, Reclamation needs ways to more effectively determine these temporary operating limits so that the unit operates as efficiently as possible while avoiding further damage.



Hydroelectric dam and powerplant.



Synchronous machine components.

Solution

This Reclamation Science and Technology Program research project examined whether sophisticated numerical modeling software (finite element modeling) could more effectively determine these temporary operating limits for synchronous machines with bypassed coils.

Application and Results

This research project examined Unit 2 at the Glen Canyon Powerplant in Arizona, whose armature winding was temporarily repaired by electrically bypassing the circuit with damaged coils. Researchers:

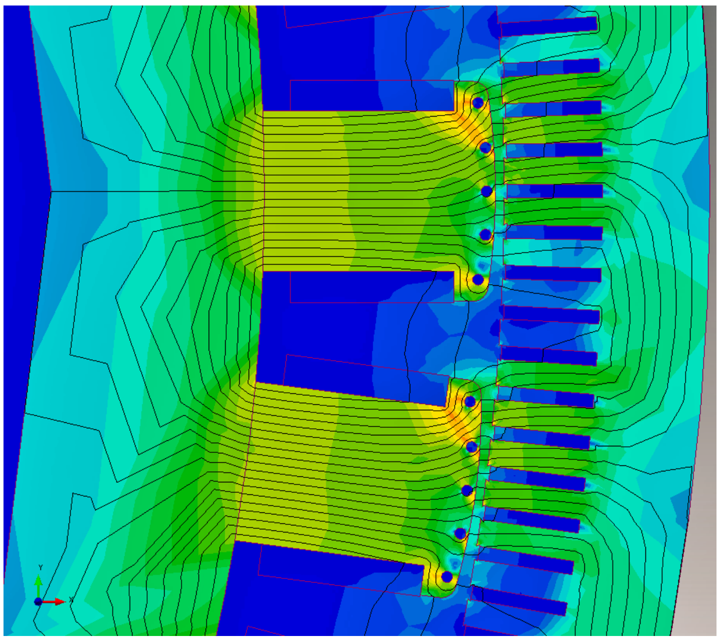
- Measured voltage and current data at the terminals of the unit and on each of the eight parallel circuits on the winding for multiple operating points at leading, lagging, and unity power factors

- Developed a synchronous machine numerical model of the unit (the rotor core, rotor poles, stator core, and machine windings)

- Used the numerical model to simulate the electromagnetic fields seen in the machine at the measured operating points

- Used the results from the numerical model simulation to calculate the corresponding voltages and currents in the windings

- Compared the calculated voltages and currents to the field data to assess the accuracy of the numerical model



Simulated flux lines and magnetic flux densities (color spectrum), Glen Canyon Powerplant Unit 2, Arizona.

Results showed that the numerical model accurately simulated the majority of the data points measured at Unit 2. The largest difference between simulated and measured currents was less than two percent of the machine's rated full load current. This accurate model thus lays the foundation for fine-tuning operating limits during temporary repairs for other generators of this type.

Future Plans

Future work based on the results of this research project is recommended to:

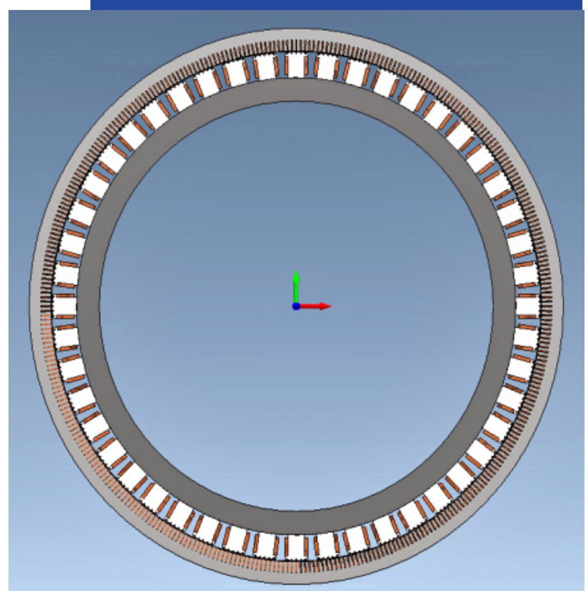
- Further refine the inputs and assumptions used to create the numerical model to potentially improve its accuracy

- Perform additional simulations with the current model to examine single turn faults in rotor or stator coils

- Develop models for other Reclamation generators with different winding and core configurations to perform similar studies

"With these new models, we can more accurately assess effective operating limits for Reclamation's generators."

Jeff Redmon
Electrical Engineer
Reclamation's Technical Service Center



Numerical model of Glen Canyon Powerplant Unit 2, Arizona.

More Information

http://www.usbr.gov/research/projects/detail.cfm?id=3772

Reclamation. 2015. *Analysis of Synchronous Machines With Bypassed Coils Using FEM-Based Modeling Software*. Science and Technology Program, Final Report ST-2015-3772-1.

For printable version see: www.usbr.gov/research/docs/updates/2016-17-synchronous-machines.pdf