RECLAMATION Managing Water in the West

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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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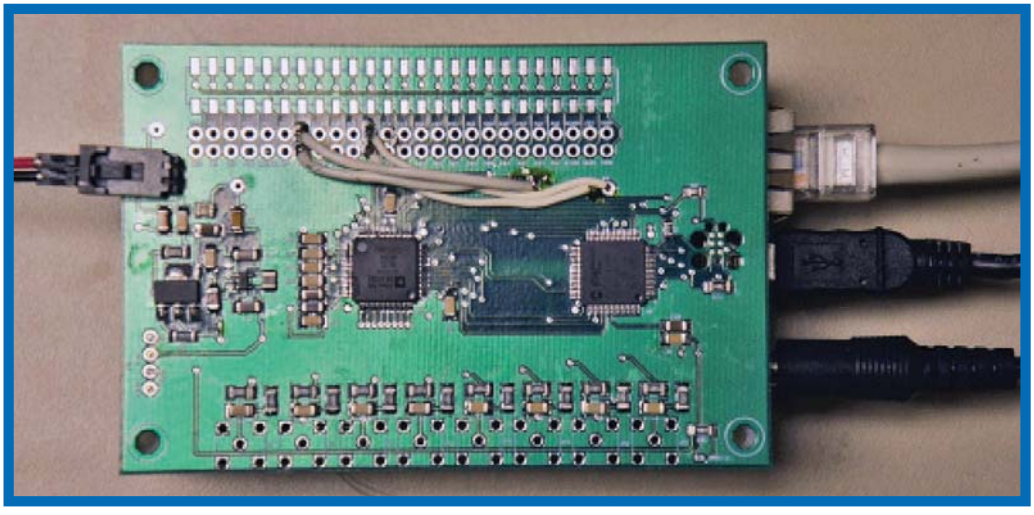

Modular hardware design with Ethernet interface.

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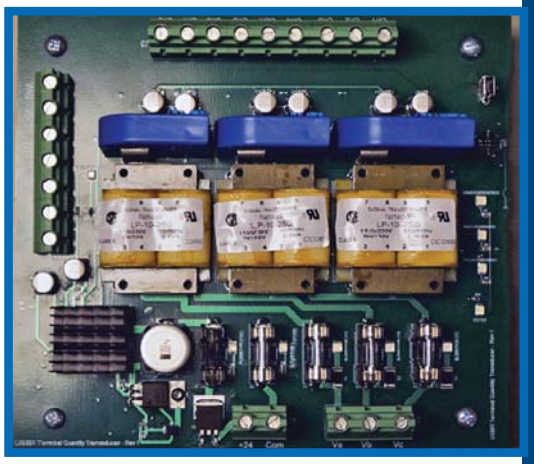
Hardware Tools. Two separate designs were developed for collecting model validation data. The first design was a modular hardware design, which featured separate input and output cards that can be stacked and wired to a main central processing unit (CPU) to gain a nearly limitless number of input and 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.



All-in-one hardware design with calculated voltages.

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."

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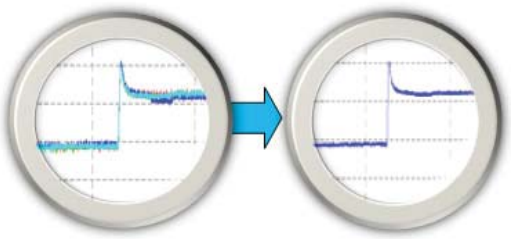
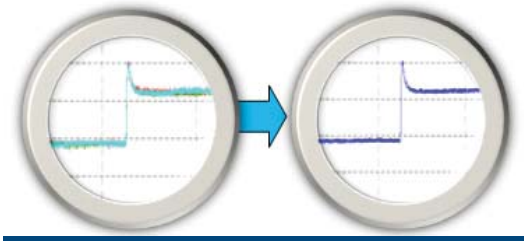


Multiple step responses with system disturbance (all responses analyzed).



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

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