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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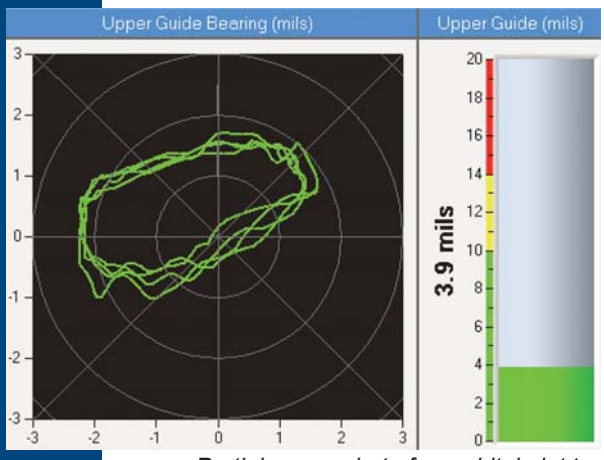
Problem

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