Northwest Public Power Association
BULLETIN

January 2014
Volume 68, Number 1

BPA preps the power grid for the "big one"

On the cover: An aerial shot of transmission lines coming in and out of BPA's Raver Substation in Ravensdale, Wash. Photo by BPA Aircraft Patrol Observer Ron Totorica.

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The *Bulletin* is a publication of Northwest Public Power Association, a regional organization of diverse utilities. The membership is made up of utility districts, electric cooperatives, municipalities, and crown corporations in Alaska, British Columbia, California, Idaho, Montana, Nevada, Oregon, and Washington. We are also a trade association for nearly 300 companies, individuals, and organizations affiliated with the electric power industry.

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Bulletin (ISSN 1094-0049)

The *Bulletin* is published monthly by Northwest Public Power Association, 9817 N.E. 54th Street, Ste. 200, Vancouver, WA 98662.

POSTMASTER: Send address changes to: *Bulletin*, 9817 N.E. 54th Street, Ste. 200, Vancouver, WA 98662, (360) 254-0109, fax (360) 254-5731.

by Joel Scruggs

BPA preps the power grid for the "big one"

Experts say it's long overdue and going to be big. This lurking menace is known as a Cascadia subduction zone earthquake — a megaquake with a magnitude of up to 8 or 9 on the Richter scale (with the ground shaking for minutes, not seconds), that's on par with earthquakes that caused tremendous damage in Chile and Japan in 2010 and 2011.

Even though it's been more than 300 years since the last one hit the Northwest, the Bonneville Power Administration (BPA) is heeding the warnings and leading the industry in assessing and mitigating for the potential damage an extreme event would have on the electric power system.

"We've been hardening the Northwest's power system and investing in seismic-related research for more than 20 years," said Leon Kempner, principal structural engineer and seismic program manager at BPA, who leads the agency's seismic-related evaluations, research, standards development, and design mitigations for transmission facilities.

One focus area of BPA's seismic mitigation program has been assessing which areas and components of the system are most vulnerable to significant damage from an earthquake and other natural disasters such as landslides, extreme wind, and ice storms. "We developed a set of engineering tools for performing vulnerability assessments of power system infrastructure during extreme events," Kempner explained. "This has allowed us to prioritize how, where, and when we upgrade or reinforce critical facilities and equipment."

Another component of BPA's multi-faceted seismic mitigation strategy is ensuring its facilities meet current building code for earthquake hazards. With a number of World War II-era and pre-current code buildings, BPA has had to upgrade a number of its key facilities throughout the region. Much of this work includes retrofitting vulnerable equipment; reinforcing support walls with structural braces and stainless steel

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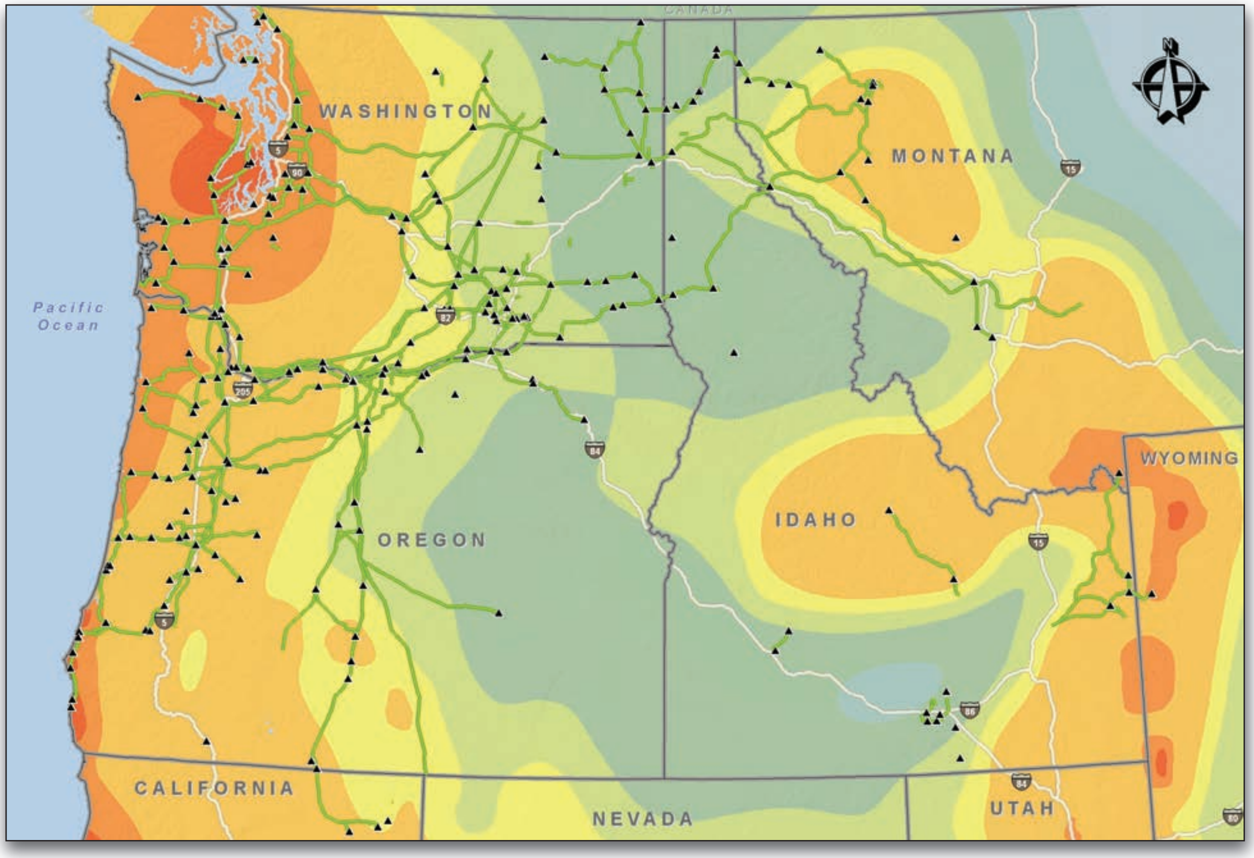

The bright-colored areas indicate seismic hazard zones in BPA's service territory. Photos provided by BPA.

Seismic Program Manager Leon Kempner and Electrical Rigger Foreman II Rick Wiren discuss how to install the base isolators on the 400,000-pound transformer.

studs; and deploying new, Institute of Electrical and Electronics Engineers (IEEE) 693-rated equipment. In recent years, BPA has seismically hardened a control center, eight substation control houses (including hardening nonstructural components such as battery backup systems), a telecommunications building, and other facilities; and updated its seismic design policy for new facilities. BPA has even taken steps to ensure it doesn't lose its inventory of critical system parts in a seismic event. For example, BPA hardened its warehouse that stores its inventory of bushings, which are insulating devices with a center conductor that allow electricity to safely flow into and out of the transformer. In addition, the bushings are stored on special seismically designed racks.

BPA's evaluation of the seismic vulnerability of the transmission system shows that towers are susceptible to large permanent earthquake ground displacements, landslides, and liquefaction (where the soil loses its ability to support structures). Tall river-crossing towers can collapse if their foundations fail. Older substation equipment and rigid bus connections are seismically vulnerable. Power-transformer-mounted surge arresters can fail; bushings can slip or fail; and the radiator can get damaged and leak. So BPA has taken a number of steps to improve resiliency, such as replacing the rigid bus with a flexible bus, bracing, and improving anchoring of circuit breakers.

All of that considered, high-voltage transformers are especially vulnerable in an earthquake, so protecting them is near the top of BPA's seismic mitigation checklist. "They're an essential component to operating the electric system," said Richard Shaheen, BPA's vice president of Engineering and Technical Services. "Without them, the power flow is compromised."

More than action movies and toys, transformers are devices that convert power from one voltage level to another, typically from high to low. Most of BPA's transformers step down electricity from the high voltages needed to move it across vast distances via large transmission lines from where it's generated — such as Bonneville or Libby Dam — to the population centers and industries where it's needed. From there, local electric utilities step it down again to a lower, safer voltage before it flows into homes and businesses.

For decades, BPA installed transformers on concrete pads or pedestals with rails, but these installations weren't anchored to the foundations.

"Unanchored transformers are extremely vulnerable to earthquake ground motions," Kempner said. "Anchoring them reduces recovery time and protects one of the most important components of the power system."

Earlier this year, BPA completed a decades-long project, which involved anchoring approximately 500 transformer, reactor, and station service units in high-risk seismic hazards areas west of the Cascades, from the southern Oregon border to Canada. This year BPA will begin anchoring at-risk transformers east of the Cascades.

As BPA was wrapping up its anchoring project, it also deployed new, state-of-the-art technology designed to protect high-voltage power transformers during an earthquake.

"We have the first base-isolated transformer in North America, and it's one of a few in the world," Kempner proclaimed while leading a tour in November.

Base isolation is a growing method for protecting structures during an earthquake. In recent years, bridges, buildings, storage tanks, and offshore oil platforms have all been engineered with base-isolation technology. As part of a multiyear research project funded by its Technology Innovation Office, BPA partnered with the Multidisciplinary Center for Earthquake Engineering Research (MCEER) at State University of New York at Buffalo to test the performance of base-isolation technology and then install it on an operational unit.

This industry-leading research didn't come without some unique challenges. The standard for testing the seismic performance of equipment is to model it on a shake table. But there's no practical way to shake test a fitted transformer that weighs 400,000 to 500,000 pounds. Not to mention they're incredibly expensive (one can cost more than a million dollars!) and not readily available if one fails and a replacement is needed, which can take up to two years. So researchers designed a mock transformer that modeled the size and weight of a real one.

"We were really impressed with the performance of the base-isolation devices we tested," said BPA Construction Manager Jonathan Ayers.

In September, BPA moved to the deployment phase of the project, where it outfitted a 460-kilovolt transformer at its

Ross Complex in Vancouver, Wash., with four friction pendulum base isolators. The isolators are a little over nine inches tall and consist of two, 24-by-24-inch steel square plates, with one side of each plate featuring a polished concave surface. The two plates are stacked with an articulated slider between the concave surfaces so that during an earthquake the plates and slider move relative to each other and provide isolation between the ground motion and the transformer.

The installation was no small undertaking. Staff from BPA's substation operations; maintenance and engineering; high-voltage laboratory; testing and energization engineering; and a contract construction crew all chipped in at different phases of the process, which involved jacking up the transformer, installing it on a new concrete pad, and then lowering it down on the four isolators, one in each corner.

BPA's river-crossing towers in Longview, Wash. The voltages are 115kv, 230kv, and 500kv, and the tallest one is approximately 460 feet.

"It was a total team effort," said Ayers.

But Kempner's not satisfied with simply being the first in the country to deploy a base-isolated transformer. "Now we're hoping to instrument it so we can see how it performs if and when there's a quake," he said.

Once the device is attached to instruments, BPA can analyze its performance following even modest seismic activity and then model how it's likely to perform in a more potent event. Eventually, BPA could retrofit transformers in high-risk areas with base isolators and make it a standard for transformer units installed at new substations. At less than $100,000 per transformer, base isolators could be a relatively inexpensive upgrade that could make the Northwest's power system less vulnerable to extreme earthquakes and save the region hundreds of millions of dollars in replacement costs.

In October, Kempner spoke about BPA's base isolation project and its other seismic mitigation investments at the Northwest Electric Utility Seismic Group meeting, where representatives from 10 utilities across the region discussed seismic hazards and vulnerabilities, mitigation efforts, and post-disaster response scenarios.

"We all want the power on after the next big earthquake," said Robert Cochran, senior civil engineer at Seattle City Light, who organized and hosted the meeting. "And, if it is, it will most likely be the result of purposeful planning by each utility in the region."

Future meetings between Northwest utilities are planned to help improve the regional response of the power system to earthquake hazards.

BPA's other current seismic research includes investigating the seismic failure mode of draw-type transformer bushings and developing a retrofit option, as well as studying the seismic performance and mitigation options of interconnected equipment at 115-kilovolt, 230-kilovolt, and 500-kilovolt substations. The agency is also participating in the development of industry standards for seismic design of transmission line systems and sponsoring research in earthquake engineering for transmission line systems. Protecting the massive towers that span transmission lines across waterways is another one of BPA's focus areas. Detailed site investigations suggest BPA's four major river-crossings on the Willamette and Columbia rivers are vulnerable to seismic-induced liquefaction, so BPA is developing mitigation options for existing and future river-crossing towers.

Electricity will be critical to the region's recovery if and when a Cascadia subduction zone quake hits. Whether hardening facilities, protecting power system equipment, or researching the latest seismic mitigation tools and technologies, BPA takes its responsibility of shoring up its assets extremely seriously.

"These investments will help us get the lights back on sooner," Kempner added. "Not only that, they'll limit the potential damage to the system, which could save the region hundreds of millions of dollars in avoided replacement costs."

NWPPA

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