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Reviewed by: Lorraine Sadler, David Reyna, Jim Lund, Jill Hruby

**Antineutrino detector provides independent monitoring of nuclear reactors**
By Patti Koning

A new tool under development by Sandia researchers promises to transform the way nuclear reactors are monitored. The antineutrino detector, a joint project by Sandia and Lawrence Livermore National Laboratory (LLNL), has already proven it can perform continuous and independent monitoring of operational status and thermal power of reactors.

Antineutrinos are the antiparticles of neutrinos, fast-moving elementary particles with miniscule mass that pass through ordinary matter undisturbed, and they are produced in nuclear decay. They are difficult to detect, but the sheer number a nuclear reactor emits is so large that a cubic-meter scale detector can record hundreds or even thousands per day.

In simple terms, the antineutrino detector tracks the rate of antineutrinos emanating from a rector and provides direct measurement of the operational status (on/off) of the reactor, measures the reactor thermal power, and places a direct constraint on the fissile inventory of the reactor throughout its lifecycle.

"You can't fake the signal," says Lorraine Sadler (8132), one of the Sandia researchers leading the effort. "The only source that produces a strong antineutrino signal is a nuclear reactor."

David Reyna (8132), Sandia's PI on the project, describes neutrinos as annoying because they rarely interact with ordinary matter and can't be shielded. "But this fact means you can sit outside the reactor itself, where the neutrinos are still flowing unobstructed, so it is a pure monitor of what exactly is happening inside without doing secondary measurements of temperature and back calculating," he adds.

Joining David and Lorraine on the project are Adam Bernstein, the LLNL principle investigator, and his colleagues Nathaniel Bowden, Steven Dazeley and Robert Svoboda along with Professor Todd Palmer and graduate student Alex Misner at Oregon State University. Other Sandia contributors are Jim Brennan (8321), who performed the mechanical design of the detectors and assisted with assembly; John Steele (8227), who played a major role in the design of the electronics readout for the detector system, particularly the FPGA based trigger; Stan Mrowka (8132), who helped implement much of the software for the electronic readout; Kevin Krenz (8132), who designed and fabricated the gadolinium neutron absorbers in the recent plastic detector; and Jason Zaha (8132), who assisted with the design and fabrication of the electronic readout.

The antineutrino detector addresses a critical issue as more countries begin seeking nuclear power—that nuclear reactors and nuclear weapons use very similar fuels. The best-known and most challenging role of the International Atomic Energy Agency (IAEA) is verifying that nuclear States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.

While IAEA nuclear weapons inspectors are "physicists, chemists, and engineers with decades of experience in nuclear weapons research and development, nuclear material safeguards, and intrusive international inspection" according to IAEA Director

General Dr. Mohamed ElBaradei, they still face a daunting task. Today monitoring occurs infrequently, usually every 18 months, and depends on administrative information provided by operators within nuclear facilities.

"The antineutrino detector provides a completely independent way of verifying what is happening inside a nuclear reactor," says Lorraine "This type of monitoring could make nuclear power a viable option to emerging societies."

This spring researchers from Sandia and LLNL wrapped up a field test of the detector at the San Onofre Nuclear Generating Station, located midway between Los Angeles and San Diego. The antineutrino detector was placed in the tendon gallery of the reactor, outside of the containment dome and about 25 meters from the core.

"The test was completely unobtrusive to the power plant, which is very important from the operators' perspective," says Lorraine. "Besides our direct contacts at the plant, other employees were even shocked when we told them we were still there."

Once the detector is in place, the agency doing the monitoring, most likely the IAEA, can acquire data without any intervention or support from the reactor operator. While this test was a complete success, less than half of the reactors worldwide have a tendon gallery design. Work is already underway on detectors that can operate above ground.

"Above ground is a whole different monster," says Lorraine. "Underground you are shielded from cosmic background, but above ground without the earth's shielding, your background noise increases by orders of magnitude."

The researchers currently are working on two separate projects. The first replaces half of the original underground detector, made from a liquid scintillator, with a plastic scintillator. A liquid scintillator poses some safety hazards, so if the same results can be achieved using a plastic scintillator, the technology would be ultimately easier to deploy.

A second set of experiments is focused on above-ground deployment by exploring two avenues: segmenting the existing detector materials to better distinguish external background from signal events, and a new high-sensitivity germanium-based detector technology that would be 1000 times more sensitive to neutrino interactions by looking for a different signature.

"I'm confident we can get the same results above ground, but the technology hasn't been tested yet," says David.

The target application for the antineutrino detector is cooperative monitoring, but there is also a potential for far field monitoring. The current focus, says David, is on making the detector smaller and less invasive with consistent performance.

The antineutrino detector will likely be tested in more reactors soon. David says he is talking to the Columbia Generating Station in Washington State and the Idaho user facility. Internationally, testing could occur in Canada and Brazil.

David and Lorraine say they are pleased with the results so far and excited about the potential of the antineutrino detector. Plus, adds Lorraine, its nice to know that neutrinos have a purpose.

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Photo: The antineutrino detector sits quietly in the tendon gallery at the San Onofre Nuclear Generating Station, waiting for neutrinos to pass by.