Feature—The Power Industry's New Birds

EPRI Explores the Use of Drones for Power Plant Inspections

By Garrett Hering

When a magnitude-9.0 earthquake rocked Japan on March 11, 2011, a tsunami overwhelmed the seawall at Tokyo Electric Power Company's Fukushima Daiichi nuclear power plant, resulting in equipment failures, multiple reactor meltdowns, and the release of radioactive material. Because of the power outage in the early hours of the disaster, utility and government officials could not assess the damage and how best to respond.

EPRI's Modular Accident Analysis Program software has filled in many blanks about how the accident unfolded, yielding essential lessons for the global nuclear power industry's disaster response guidelines. One key lesson: The industry needs a tool for assessing difficult-to-reach sites and providing real-time data to inform responses without endangering workers.

Such a tool may soon become available to nuclear plant operators. The University of North Carolina at Charlotte (UNCC), with technical assistance from EPRI, is developing a radiation-resistant, remote-controlled drone called the Severe Mobile Accident Investigator, or SAMI.

"With SAMI, we are looking at how to use drones to make the best out of a worst-case scenario," said Stephen Lopez, EPRI project manager.

SAMI is one of several drone applications EPRI is investigating. Others include inspecting power lines, transmission towers, fossil plant boilers, wind turbines, solar photovoltaic panels, hydroelectric dams, and cooling towers. These tasks are time-intensive and potentially dangerous, sometimes requiring human inspectors to climb structures as high as several hundred feet or perform work on suspended scaffolding or in areas with hazardous materials. As a result of safety or cost concerns, some power plant inspections may be deferred, leaving stakeholders without up-to-date information about their assets.

"Deploying drones for certain jobs can promote worker and plant safety, reduce inspection costs, assess and extend the life of components and power plants, and enable nondestructive examination for difficult-to-access areas," said EPRI Program Manager John Lindberg. "Utilities want to take this technology in the field and are seeking federal licenses to do so."

Soaring Industry Interest

All commercial drone operators require permission from the U.S. Federal Aviation Administration (FAA) to fly in American airspace, even if solely for demonstration purposes. Over the past year, the FAA has loosened restrictions on commercial operation of unmanned aircraft systems (its formal term for drones), enabling new opportunities for partnerships between utilities and drone vendors.

Since 2014, vendors and power companies have obtained FAA authorization for low-risk, controlled missions in U.S. airspace through an exemption under Section 333 of the FAA Modernization and Reform Act. With streamlined FAA approval, authorizations have soared in recent months.

As of September 2015, the agency had approved approximately 1,550 applications for Section 333 exemptions. Almost all of these authorizations were issued in 2015, including more than 80 for utilities and drone vendors to inspect power lines, transmission towers, or power plants. Hundreds of additional utility and vendor requests are under review.

Although the number of authorized drone operators is growing, Lindberg cautioned that a steep learning curve remains. “Before drones can become part of a commercial utility fleet, we need more research collaborations and demonstrations to see what they can really do for utilities and what limitations need to be addressed,” he said.

Drones to Inform Nuclear Accident Response

A month after the Fukushima accident, Tokyo Electric Power Company deployed drones to take aerial photographs of the damage. EPRI is now investigating ways to deploy drones much earlier in an accident’s progression to reduce its severity.

A key objective of a nuclear accident response is to gather data on plant conditions while minimizing worker exposure to radiation and other hazards. SAMI serves this purpose, as it is intended for deployment shortly after a beyond-design-basis accident.

“Fukushima spurred our interest in developing a drone to fly inside a nuclear facility following a severe accident, survey the site, and inform a quick response,” said Lopez. “Our goal is a small, lightweight, stable, maneuverable, and resilient drone able to withstand high temperatures and radiation inside a nuclear plant.” Radiation resistance is critical for preventing damage to the device’s electronics.

In the SAMI project, UNCC engineering students conducted most of the prototype design, development, fabrication, and testing, with EPRI providing technical assistance.

The team specified several performance requirements for SAMI: maneuverability inside a nuclear plant’s containment structure; payload for recording data on temperature, radiation, humidity, and air pressure; and real-time data transmission off-site for analysis.

Researchers then designed a prototype of a four-propeller helicopter, or quadcopter, approximately 3 feet in diameter with an 8-pound carrying capacity. In a feasibility study, researchers outlined concepts for flight-control and data-collection systems. These include fiber-optic communications between an off-site operation command center and the quadcopter’s base station in the nuclear plant, as well as wireless communications between the base station and the drone.

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As built, the prototype was equipped with waterproof motors, a high-resolution GoPro® camera,* infrared temperature sensor, and communications. Researchers operated it to validate power, navigation, and communication systems.

EPRI is planning next stages to include designing a blast-proof base station to house multiple drones for longer missions; improving the heat and radiation resistance of the drone's frame, electronics, camera, and sensors; adding a more powerful motor to boost the carrying capacity; constructing a more radiation-resistant prototype; and durability testing.

Inspect Concrete Structures Safely

Also with EPRI's assistance, UNCC engineering students have developed a quadcopter to detect damage in large concrete structures such as cooling towers, containment structures, and hydroelectric dams.

Hydropower dams are among the electric power sector's oldest concrete structures. "The current generation of dams is on average about 50 years old, but many are 60 to 80 years old, and they must be inspected regularly," said Lindberg. In fact, more than 5,000 dams around the country are at least 100 years old, according to the U.S. Army Corps of Engineers. Routine structural evaluations of dams typically require inspectors to rappel from the top or work on scaffolding that must be erected.

Equipped with a high-resolution GoPro® camera, global positioning system, telemetry radio, and lithium ion phosphate battery, this quadcopter is designed to locate, record, and transmit images of concrete damage to a ground station, where an inspector analyzes the results.

Inspectors then upload information collected by the drone to a robotic concrete crawler for a more detailed examination. The robotic crawler, which EPRI has been developing and testing since 2011, carries equipment to measure and map specified areas of the structure, as well as nondestructive evaluation devices that inspect deeper concrete layers.

A second generation of the concrete-inspecting drone added new features such as an improved camera, GPS system, and propeller guards to protect rotors from damage as the drone hovers close to a structure.

"We're planning a third generation with improved features and flight control capabilities, more payload capacity, and a bigger battery," said Lindberg.

Researchers have tested critical equipment in the laboratory. In one test, the camera detected simulated flaws in concrete structures from different distances. The team has also validated the drone's in-flight stability.

"The prototypes have proven quite effective for our research, but full-scale demonstration in the field requires a jump to commercial products," said Lindberg. "Depending on utilities' needs, we may seek an FAA exemption for a demonstration of commercial drones in 2016 or 2017."

Drones for Boiler Inspection

Inspecting power plant boilers is time-intensive and physically demanding. To prepare for the inspection, plant operators must first shut down the boiler to construct scaffolding inside. Inspectors then climb on the scaffolding and crawl around small, dark, and dirty spaces.

With United Dynamics Advanced Technologies, EPRI has investigated the use of drones to make this task easier and more cost-effective. EPRI previously worked with United Dynamics on diagnosing boiler tube failures and heat recovery steam generator (HRSG) inspection manuals. The company's Magnabot—a rectangular-framed quadcopter measuring 18 inches across—recently attracted EPRI's interest because of its ability to fly inside boilers and conduct inspections.

Through site visits to EPRI's utility members, EPRI has evaluated Magnabot's potential value, identifying additional work needed to ensure effective inspections. "During weekend and forced shutdowns, members have successfully flown Magnabot to inspect their boilers without exposing workers to hazardous conditions," said Bill Carson, manager of EPRI's HRSG Dependability program. "The drone has demonstrated the benefit of inspecting difficult- or impossible-to-reach areas." Carson added that discussions with members in EPRI's Boiler Reliability Interest Group revealed how these inspections provided the utilities with valuable information for planning, as well as for compliance reporting for federal Mercury and Air Toxics Standards.

The drone's payload includes high-intensity floodlights, a high-resolution camera for still shots and video, and communications. The accompanying control station enables focus on areas of interest through live camera feeds. Other features requested by EPRI members include landing on and attaching to boiler tube walls—which could conserve power during inspection—and rollers for climbing boiler tube walls for close-up views.

EPRI plans to work with United Dynamics to deploy nondestructive evaluation devices as potential Magnabot payloads in field trials. For instance, ultrasonic testing can help determine thickness of boiler tubes—a key indicator of their remaining life. EPRI will also continue to evaluate drones from other manufacturers to gauge their potential for boiler inspections.

Drones' Future Flight Path

Whether they're used for severe nuclear accident response or to inspect concrete structures and boilers, drones provide wings for existing inspection devices. Because this means adding payload, drones may need more powerful motors and bigger batteries. EPRI is working with vendors to address these and other limitations for specific applications.

In approving dozens of drones for use in the electric power industry this year, the FAA has validated the enhanced safety enabled by these unmanned aircraft systems. Now it is up to researchers, utilities, and vendors to work together on a flight path for the power sector's new birds.

Key EPRI Technical Experts

Stephen Lopez, Bill Carson, John Lindberg