ELECTRIC POWER
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Electrochromic Windows Advance with Federal Grant: A Conversation with Haresh Kamath and Ammi Amarnath

EPRI's Office of Technology Innovation (TI) together with a set of industrial partners recently received a $5 million Advanced Research Project Agency – Energy (ARPA-E) federal grant to advance the technology of electrochromic window coatings. In this brief interview, EPRI TI's Haresh Kamath and Ammi Amarnath describe the opportunities that these coatings present.

What are electrochromic window coatings?

Kamath/Amarnath: Electrochromic window coatings allow you to make building windows opaque or transparent on demand to reduce/increase ambient building temperature. Chemical compounds embedded in the coating reversibly change color when you apply a small electric current to them. This color change remains after the initial current stops but you can reverse it by applying current in the opposite direction.

What are the business benefits of installing these coatings?

Kamath/Amarnath: These coatings have the potential to reduce peak electric loads in many commercial buildings by 20-30%. This means lower energy costs for building owners and operators and a load leveling opportunity for utilities. Most of these savings would come from reduced cooling loads, especially in parts of the country with lots of sunshine. We can get the most potential savings if we can control the degree of transparency in specific windows through the use of

> *"EPRI's Office of Technology Innovation can help make this very valuable product a reality in 5–10 years."*
>
> *– Haresh Kamath*

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a building energy management system that responds to both changing light conditions and electricity price signals.

Electrochromic coatings on windows could help utilities and their customers meet the tougher efficiency standards being developed for new buildings. For example, the California Public Utilities Commission recently adopted the Long-Term Energy Efficiency Strategic Plan. It says that all new residential construction must provide "zero net energy" by 2020, and that new commercial construction must do this by 2030. This means that each building has to offset its annual use of electricity or natural gas from utilities with a combination of energy-efficient building features and distributed generation. Adjustable-transparency windows that the customer can control could play an important role in achieving these goals.

What are the next, most important steps towards deployment?

Kamath/Amarnath: We need to reduce the cost of the window coatings. Today, they cost about \$60-\$100 per square foot, but we need to reduce this cost to \$2-\$5 per square foot for widespread application. We also need the coated films to be available in flexible rolls, so that you can be easily applied to either new or existing windows. We can only do this by developing enhanced thin-film coating technologies and accelerating their introduction in about a five-year process. To help achieve this, EPRI and a set of industry partners have received a \$5 million federal ARPA-E grant to further develop this technology. The focus of the grant is to address technical, business, and market barrier challenges, to transition this technology into a pilot-scale production capability. Successful completion of the ARPA-E project will mature technology readiness levels and manufacturing readiness levels to reduce technology risk and motivate industry led strategic partnerships to commercialize electrochromic window technology. This grant makes a big difference in being able to make these coatings a practical reality.

To find out more about EPRI's work on electrochromic window coatings, contact Kamath at (link to Kamath) 650.855.2268, hkamath@epri.com, or Amarnath at 650.855.1007, aamarnath@epri.com.

Metal Insulating Sensors Provide Early Warning on Equipment Failure

Power and distribution transformers are a critical piece of the world's electric power infrastructure, representing an investment of several hundred billions of dollars. The unexpected failure of any of these components results in equipment replacement costs, of course, but more importantly, causes customer inconvenience and in many cases, leads to significant customer outage costs. The best way to protect the investment in these devices is via equipment condition monitoring techniques – assessing the condition of each transformer periodically before it fails. As insulating oil or paper degrade, they emit characteristic gasses in the transformer. Current online methods of monitoring these gasses are high cost and complex.

EPRI's Office of Technology Innovation (TI) is developing solid-state micro-sensors that detect hydrogen (an indicator of partial discharges) and acetylene (an indicator of arcs) in power and distribution transformers. These metal-insulator-semiconductor (MIS) micro-sensors promise to enable low-cost, fast-response, online dissolved gas monitoring for these transformers.

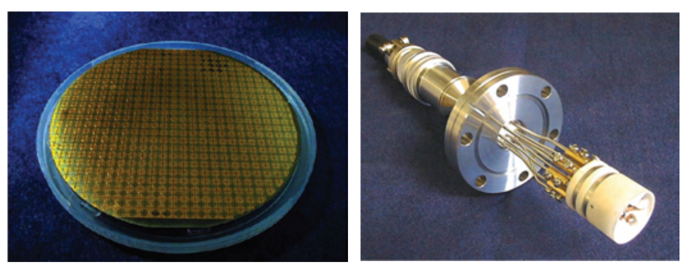


Figure 1. Metal-insulator-semiconductor (MIS) sensors (like the 500 hydrogen sensors shown at left) are being tested in field trials (using assemblies like the one at right) to demonstrate their condition monitoring value in transformers.

For additional information on EPRI's TI Program on advanced sensors, click here [link to Issue Brief sheet].
Technical Contacts: *Project Manager: Dr. Luke van der Zel, 704.595.2232, lvanderz@epri.com*
Strategic Program Manager: *Andrew Phillips, 704.595.2728, aphillip@epri.com.*

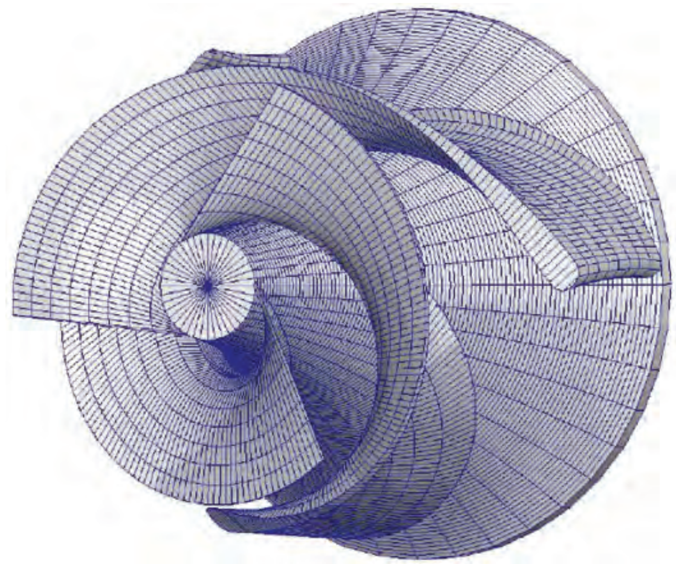
Breakthrough Innovations: Fish-Friendly Turbine for Hydroelectric Generation

For many existing hydropower plants, protection of fish, including eels, from turbine entrainment injury and mortality represents a potentially significant challenge to continued economical operations. Diversion structures and other bypass methods are costly, may reduce output of non-emitting energy, and may not in all cases be effective in supporting species protection goals. A new "fish-friendly" turbine promises to reduce entrainment mortality by more than 95% without decreasing energy production. This exceeds the performance goals set by the U.S. Department of Energy (DOE) and industry stakeholders.

EPRI's Office of Technology Innovation (TI) helped advance the turbine's novel design at a critical stage—after its promise had been identified but before it had demonstrated the power production levels required to position the technology for field testing and commercialization.

Creation of the fish-friendly turbine began in the late 1990s under DOE funding. First, Alden Research Laboratory identified the hydraulic phenomena contributing to entrainment-related mortality. Then, Concepts NREC, a turbomachinery developer, applied this new knowledge to initiate development of a turbine designed to both reduce pressure and speed gradients and eliminate direct-hit incidents. In 2004, EPRI stepped in when the initial DOE funding cycle ended, supporting computational fluid dynamics modeling and flume testing. Tasks included redesigning the scroll case to increase power output, quantifying the effect of leading-edge blade shape on fish mortality and energy production, and optimizing conceptual design of the entire turbine.

The resultant Alden/Concepts NREC turbine features a helical-shaped runner with three long blades, as compared to the 6 to 18 blades found on comparable turbines. Its reduced blade count, thicker leading-edge blade profile, larger flow passage, and other features provide for fish survivability exceeding 95% plus energy conversion efficiency of 90%, comparable to that of existing turbines.



Computational fluid dynamics modeling of the fish-friendly turbine helped optimize blade design and other features to minimize entrainment mortality while maximizing power production.

This breakthrough innovation is expected to provide a cost-effective alternative to diversion structures and other measures for reducing entrainment mortality in small rivers and low-head environments. It may yield savings in the millions to the tens of millions of dollars in retrofit applications at individual hydro plants, and it may prove critical to regulatory approval of both capacity additions at existing projects and new installations. In addition, its deployment may expand the amount of hydropower production eligible for supporting compliance with renewable portfolio standards.

In 2008, EPRI and its industry partners were awarded $1.2 million under a new DOE funding cycle to construct and test a physical model of the fish-friendly turbine and complete the design engineering phase. A full-scale field demonstration is planned to begin in 2012 at Brookfield Renewable Power's School Street Project on the Mohawk River near Albany, New York.

For more information, Technical Contact Doug Dixon 804.642.1025, ddixon@epri.com

What If Torrefaction and Pelletization Could Increase Biomass Cofiring Fractions?

An emerging pretreatment process for raw biological materials could allow existing coal plants to operate reliably and efficiently at biomass cofiring fractions up to 25%. The torrefaction and pelletization process (ToP) could provide an innovative near-term solution for generating baseload power from a renewable resource while substantially reducing greenhouse gas emissions from current coal capacity.

EPRI analysis indicates that torrefied biomass pellets may be pulverized and fired using existing power plant equipment to replace up to about 25% of the coal load. This could reduce carbon emissions from current coal capacity at a cost of less than \$30/ton CO_2, positioning ToP cofiring as a cost-effective near-term alternative to post-combustion carbon capture and storage. ToP cofiring also may provide a low-cost option for meeting RPS requirements.

By reducing handling and transportation costs, the ToP process may expand biomass fuel markets to national and global scales. This would remove a major barrier to stand-alone biomass generation, as the siting and sizing of plants generally depends on the availability of ready supply of fuel within reasonable shipping distance.

At present, plants blending clean, high-quality biomass with coal operate effectively at biogenic fractions of up to 10% by heat input due to the high moisture content and fibrous nature of most types of raw fuel. Current pretreatment methods to reduce moisture and compress fuel into pellets are relatively expensive and cannot be used with some feedstocks.

Torrefaction and pelletization transform raw biomass fuels into charcoal-like pellets with handling, storage, grinding, and combustion properties that could allow reliable and efficient cofiring at biomass fractions of up to 25%.

The (ToP) process begins with a drying and roasting step analogous to that used for coffee beans. Raw biomass is baked at 250° to 300°C in the absence of oxygen to evaporate water and drive off some volatile components. The remaining char is then compressed into pellets. The energy content per unit of mass for pelletized fuel is about 30% higher than that of raw feedstock and comparable to that of coal. High energy density, uniformity, water resistance, and other factors make the pellets much easier to store, transport, and use.

EPRI is designing a pilot-scale ToP testing facility that will allow power producers to supply raw biomass materials for analysis of torrefaction, pelletizing, grinding, and combustion properties. This will facilitate ToP cofiring demonstrations, as well as provide the key process parameters needed to support mass production. Test facility commissioning is anticipated for 2010.

For additional information on EPRI's TI Program on Torrefaction and Pelleting, click here (link to Issue Brief sheet)

Technical contacts: *Luis Cerezo,704.595.2687 or Dave O'Connor, 650.855.8970, doconnor@epri.com*

Strategic Program Manager: *Stan Rosinski 704.595.2621, strosins@epri.com*

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com