SHAPING THE FUTURE

Innovative approaches to upcoming challenges

The Paradox and the Promise of Nanotechnology

Electricity companies are accustomed to the paradox of using very large infrastructure to move very small electrons. Nanotechnologies have the potential to take this paradox to the next level as some of electricity's biggest challenges are addressed with the world's smallest technologies. Nanotechnology manipulates matter at a minute scale. (A nanometer, for example, is one billionth of a meter.)

Nuclear power exemplifies big results (megawatts of electricity) from small (nuclear) processes. In the nuclear arena, two areas of research point to the potential for megascale progress through nanoscale solutions.

Nanocatalysts From Sonoluminescence

EPRI research indicates that nanocatalysts may hold the key for the large-scale production of hydrogen at low temperatures. Currently large-scale hydrogen production is hampered by processes that require temperatures up to 900 degrees centigrade. This limitation could be important in the development of very-high-temperature gas-cooled reactor designs, which will require the capability to produce large amounts of hydrogen.

Supported nickel catalysts with a core/shell structure in a nanoparticle form have met the requirements to produce significant quantities of hydrogen efficiently and at low temperatures. Generating these nanocatalysts may be possible through a process driven by sonoluminescence—the emission of light associated with the "catastrophic collapse" of microbubbles oscillating under ultrasound. Temperatures and pressures achieved by the collapse of micron-size bubbles range up to 50,000 degrees Kelvin and 10,000 atmospheres. Research indicates that multi-bubble sonoluminescence can be used to make nanocatalysts with important new properties.

It's yet another nanoparadox in that the extraordinarily high temperatures and pressures achieved at nanoscale enable a process that can proceed very rapidly at an overall lower temperature, without any toxic products.

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MagMolecules and Liquid Nuclear Wastes

Processing low-level waste effluent streams from nuclear plants has remained a persistent challenge because dissolved radioactive contaminants may be present in only minute quantities, making their removal from large volumes of liquid difficult and expensive. Even if the liquids are evaporated to reduce the volume, radionuclides may represent only a small fraction of the total material that must then be disposed of. Ion exchange systems can remove contaminants more selectively but still produce an unnecessarily large volume of solid waste.

A new approach now being refined in a pilot project promises to greatly reduce radioactive waste volume by using magnetic molecules that target specific radionuclides dissolved in a low-level waste stream. EPRI has received one patent and filed a second application for the MagMolecule Process, which it expects may also be used in other important applications, such as removing heavy metals from industrial effluents and groundwater.

One noteworthy aspect of the process is that it begins with proteins that are produced in the human body. Called ferritins, they are used by the body to store iron in the spleen and liver. The computer industry has used synthetically produced and magnetically stronger "magneto-ferritins" to manufacture data storage disks. EPRI's research has focused on modifying magneto-ferritins to bind selectively to specific contaminants—initially strontium and cesium—that represent important radioactive constituents of low-level waste.

The nano-engineered proteins bind to the targeted contaminants, and with their magnetic core can then be magnetically filtered from the effluent stream. The magnetic filter can be backwashed to collect the solid by-products and then be reused.

Laboratory results indicate that MagMolecule technology has the potential to reduce waste volume by a factor of up to 5,000, compared with conventional ion exchange treatment. Researchers have successfully targeted strontium and cesium with the magneto-ferritins. If the process can be further refined to target other elements and applied at a commercial scale, the result could be significant cost savings for low level waste management in nuclear power plants. Significant potential exists as well for applications in other industries.

Since the laboratory phase of this research was completed in 2007, ongoing research and development has focused on determining what is needed to scale up the process, testing more robust base molecules, and identifying other steps that can lead to commercialization.

Among the results that researchers would like to achieve:

- a selective molecule capable of the complete removal of a target contaminant and no other;
- complete transfer of the absorbed contaminant and magnetic molecule onto the magnetic filter; and
- a robust process, capable of performing in realistic plant conditions with varying pH, temperature, and conductivity.

In practice, the system's effectiveness will be determined by the design and quality of the magnetic molecules and the process application equipment, such as filters. Pilot test work is being carried out at Clemson University.

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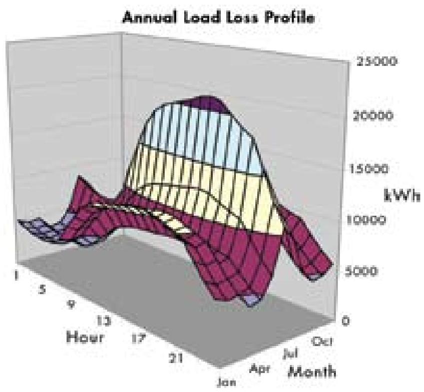
OpenDSS Will Stimulate Smart Grid Development

EPRI's Distribution System Simulator (DSS) has long provided powerful modeling capabilities as a proprietary tool for analyzing utility distribution systems. Now, in an effort to stimulate rapid development of new modeling applications for use in the smart grid, EPRI is releasing the software as an open-source program called OpenDSS. This release will make the software available to researchers, software vendors, utility engineers, and others to support analysis of both system planning and real-time operations in more technologically complex distribution systems.



A smart grid overlays the electricity network with communications and computer control, enabling significant gains in system reliability, capacity, efficiency, and demand response. It also facilitates the delivery of more customer services, including real-time pricing, and the addition of more distributed generation, including intermittent renewable resources. Individual technologies related to smart grids have been available for some time, and demonstrations of the smart grid concept are targeted to receive hundreds of millions of dollars from the federal economic stimulus, but effective integration of the various communications and control elements will require new distribution system analyses. OpenDSS provides for the analyses and structure to incorporate these elements into a system safely and effectively.

Jump-Starting Applications

Making OpenDSS available to system modelers should spur development of new analytical applications, including improvements in fault location, transformer load management, voltage control, energy loss reduction, and integration of distributed resources. As new application modules are incorporated into the program, OpenDSS will gain enhanced capabilities to create load profiles, perform annual system simulations, and handle complex power flow calculations in real time. System operators will be able to use the real-time simulations to reconfigure distribution circuits to optimize performance, while utility planners will use annual load and generation models to forecast future system needs.

"We're seeing the emergence of a new paradigm in managing distribution systems," said Mark McGranaghan, senior technical manager in EPRI's Customer Systems group. "OpenDSS will play a major role in this transformation by modeling the foundations of the smart grid. It can take information from distribution system sensors and a utility's geographic information system, and use this information to provide continually updated models of system conditions that enable operators to optimize performance and reduce losses. Also, it can provide the long-term load and generation forecasts needed for critical decisions about system investment, including effective ways to prepare for adding renewable energy resources. By providing individual utilities, university researchers, and distribution management system vendors an open platform for creating new modeling applications, we can move significantly faster in developing the analytical capabilities needed to create smart grids."

Working With the Software

Because OpenDSS can be used either as a stand-alone program or as a component of an existing utility software platform, users will have flexibility in customizing distribution system analyses to fit their requirements. The program can also be expanded and modified to meet future company needs. It has been designed to operate in the Microsoft Windows environment and supports nearly all steady-state analyses commonly performed on utility distribution systems.

OpenDSS has several built-in solution modes, including power flow as a real-time snapshot of a distribution system, cumulative daily and yearly power flows, harmonics, dynamics, and fault studies. Experienced software developers can further customize OpenDSS by downloading the source code and modifying it as needed, writing software that controls the OpenDSS through the component interface, or developing dynamically linked libraries (DLLs) that plug into the program. OpenDSS is available from the SourceForge.net website.

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