More Power to the National Grid

By Rachel Faugno

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Clogged arteries can dramatically decrease blood flow and eventually stop the heart; so, too, can the "arteries" that transmit and distribute electricity become clogged and stressed, leading to catastrophic failures. WPI students are seeking ways to extend the life of the existing grid while keeping the delivery of electricity flowing.

The Great Blackout of 2003— the largest in North American history—began on August 14 and affected the northeastern United States and eastern Canada. It shut down more than 100 power plants, including 22 nuclear reactors, knocked out power to 50 million people over a 9,300-square-mile area ranging from New England to Michigan, and cost an estimated $6 billion in related financial losses. The culprit: old and antiquated technology.

At a speaking event the following day in a national park in California—a state that had experienced numerous brownouts and blackouts in 2001—President Bush told reporters that he viewed the power failure "as a wake-up call... the grid needs to be modernized, the delivery systems need to be modernized.... This particular incident has made it abundantly clear to the American people that we've got an antiquated system, and now we've got to figure out what went wrong and how to address it."

To be sure, there are no easy solutions. The demand for electricity continues to climb at roughly 2 to 3 percent annually, fueled largely by an increase in the installation of computer equipment and the power necessary to keep it cool. Addressing the problem will involve considerable cost and a high risk of failure unless ways can be found to augment power companies' ability to handle increasing loads. That is exactly what a group of WPI students working with the National Grid USA Service Company in Northborough, Mass., is hoping to do.

Dollars and sense

Jack Coyne '05 (ECE), Anu Myne '06 (ECE), and Munaf Aamir '07 (SD/MIS) began exploring new technologies for augmenting electric supplies last fall under the direction of professors Khalid Saeed (SSPS) and Alex Emanuel (ECE). The team is developing computer models that forecast the costs and benefits of retrofitting National Grid USA's distribution network with storage and distributed generation devices.

"We hope to develop a tool to play out different investment scenarios," says Coyne. "Demand will exceed capacity before long, and the company is facing decisions about when to upgrade equipment." Adds Aamir, "If we can extend the life of a few transformers by three or four years, we've enabled the company to defer millions of dollars of expenses and possibly take advantage of future technological advances. At the same time, it's important that the delivery of electricity remains adequate and reliable." Demand and delivery are foremost in the students' work. National Grid USA, the holding company for National Grid Transco's U.S. business, is one of the 10 largest utilities (by number of customers) in the country. It has the largest combined electricity transmission and distribution network in the New England and New York region, with more than 3.2 million customers in nearly 900 cities, towns, and villages.

“Electricity is provided to consumers in three stages,” says John Bzura, principal engineer at National Grid USA. “First, generators at large power plants produce electricity—at around 10,000 volts—from turbines powered by fossil fuels, nuclear fuel, or water (hydroelectric plants). Massive transformers raise the voltage to transmission levels of 115,000 to 765,000 volts. Companies such as National Grid purchase the electricity and transmit it across high-voltage transmission lines to substations [there are over 500 in Massachusetts], where the voltage is typically reduced to 13,800 volts. From there the electricity goes to distribution utilities, which carry power from the substations to customers and reduce the voltage to 120 to 240 volts for homes and higher voltages for larger customers. The WPI project targets the distribution of electricity from the substation.”

A major challenge for suppliers of electricity, says Saeed, is to meet the demand at peak times. “Electricity pricing follows a progressive structure,” he explains. “Getting supply at peak demand levels costs more. Peak demand also strains the distribution system. We are investigating ways to purchase electricity during low-demand times and store it for use when the demand peaks.” This concept, called peak shaving, would require the installation of batteries or other storage devices at substations.

Banking electricity

The team is also exploring the installation of distributed small-scale power generation devices placed near major consumers or at the substation. “This option is becoming feasible with emerging technologies that include solar photovoltaic (PV) systems, microturbines, wind turbines, and fuel cells,” says Saeed. “These devices could be connected at the substation to deliver energy during peak loading.”

Despite the potential advantages of utilizing storage and distributed generation devices, both options present challenges. The devices are expensive to install and operate, especially in comparison to large-scale generation. The linkup technology is not yet fully developed. Charging and reloading batteries can create unexpected dynamics. Generators tend to be noisy. And the costs and benefits of the various retrofitting options are not clearly understood; their environmental impact is also unknown.

“An important challenge is that the retrofitting modifications will also affect the ways in which the electric utilities protect the distribution lines against abnormal conditions, such as lightning and short circuits,” says Emanuel. “We will need to deal with this problem in the future phases of the project.”

Because of so many variables, in both economic and engineering issues, “we are employing a system dynamics model that simulates both the load dynamics and the economic implications for the retrofitting options selected,” Saeed says. “This model will propose ways to achieve low-load fluctuation, reduce the cost of power, extend the life of transformer equipment, and defer capital costs.”

Although the students have yet to finalize their report, Bzura is pleased with the results. “If their proposals appear to be cost-effective,” he says, “we will certainly examine them closely for possible implementation.”

Myne adds that if the model they’re developing is as useful as they hope it will be, “the implications of its wide-scale adoption could be huge in terms of saving money and reducing the chances of wide-scale blackouts.”