Building and Testing Smart Systems in an All-New Clean-Slate Microgrid

Written by S. Massoud Amin

While opinions may differ about whether there is a single "right size" for smart grid demonstration projects, most will agree that a village is too small and countries too large to produce meaningful results. University campuses and communities represent an appealing intermediate scale, with enough diversity to put claimed benefits and costs to the test, as well as the intellectual resources to devise innovative approaches. An ambitious program at the University of Minnesota is showing how this can be done.

Seeing an opportunity to assess how smart grid features can be incorporated into an existing grid, with an eye on accommodating more renewable generation and allowing for time-of-day electricity pricing, our team at the University of Minnesota has been redesigning the power system serving its Morris Campus. The project, led by facility managers, a vice chancellor, engineering professors, staff and graduate students, was described in the December issue of this newsletter. A second University of Minnesota community—this one in the making—is the residential development project UMore Park: It is providing the opportunity to build a smart microgrid from scratch, so that an optimal architecture with a judicious mix of technologies can be incorporated at the outset and economies of scale can be exploited.

Ultimately the technologies explored and validated at the Morris Campus and UMore Park may be adopted system-wide at the University of Minnesota, which would probably make it the nation's first institution of higher education to serve as a major smart grid testbed.

One objective is to make the university zero-net-energy and zero net-carbon—a community that produces as much energy as it consumes. To accomplish that, the university's facility managers will need the ability to reconfigure energy systems to accommodate new construction and building renovations, put affordable smart grid equipment and upgrades to the best possible use, optimize in real time the operation of all energy-consuming devices, and seize opportunities for on-site power generation and storage.

Plans also include phasing in electrified transportation and vehicles with reactive power support to minimize reliance on gasoline-powered cars and buses.

The vision, if fully realized, is of a community in which electricity is generated in part by windmills and solar arrays, surplus energy is stored not only in dedicated storage facilities but also in car batteries, and two-way communications at all nodes in the system automatically direct energy to where it's most needed and see that it's used as efficiently as possible when it gets there. Ultimately, this vision may be most fully realized at UMore Park.

The 5,000 acres of land in which the UMore Park residential community is being developed came into the hands of the university rather by happenstance in 1947-48. During World War II, the U.S. government started to build a factory at the site to manufacture the smokeless gunpowder that served as the propellant in most ordnance, only to complete it just after the war ended. No longer needing the site, the Federal government deeded the property to the university.

Located about 25 miles southeast of the university's main Twin Cities campus, UMore Park will host a residential community for up to 20,000-30,000 people, to be developed over 30 years. Income generated by the project will help guarantee long-term support for research, education and public service activities at the university, while at the same time contributing to economic development of the region and demonstrating sustainable energy technologies. After adopting a master plan for the project in December 2008, the university created a limited liability company to manage it and an endowment fund to channel income to suitable university programs. Construction of the first homes is tentatively set to begin next year.

Energy aspects of UMore Park were a high priority from the outset, and our team quickly reached some strategic decisions. One major decision was that the whole community will rely on a district energy configuration with combined heat and power, that is to say, generating systems in which waste heat is converted to steam and used to heat buildings. Another was that homes and commercial buildings will be designed and built to be "smart grid ready": They will be equipped with smart meters and in-home energy-management tools; programmable major appliances; inverters to change incoming DC current from photovoltaics arrays to grid-compatible AC; electric vehicle charging stations; and backup battery storage.

At estimated additional installation price tag of $10,670 to $27,190 per home, the estimated cost of all that equipment is not

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trivial, coming to about 4 percent of the total cost of each home. But the estimated benefits both to individual families and to the community as a whole are prodigious.

Another major strategic goal is to enable real-time demand management and response—to make it possible for customers to modify consumption in reaction to hourly changes in electricity prices and availability. To that end, we see inexpensive but advanced two-way secure wireless communications as essential. Dynamic modeling of energy flows, their optimization and control equally depend on the availability of trustworthy data streams from sensors and monitors distributed throughout the electricity delivery system, for example on power lines and local distribution transformers. Drawing on those inputs and the even more ubiquitous data transmitted securely and wirelessly from substations, operations engineers will be able to spot potential problems and make adjustments before problems arise.

As these systems are put in place, they will provide the opportunity to investigate the whole range of issues that arise in connection with the smart grid, from hybrid vehicle integration and electricity market design to system automation and security. If the smart grid is to fulfill its promise, it needs to be not just more efficient but also more robust than our current power systems (which are by no means dumb), both self-healing and highly resistant to attack.

Thus, we have developed and assessed a novel cyber-physical security attack detection-framework that is distributed, agent-based, automated, self-configuring and self-tuning, scalable, and "lightweight" with respect to computational and communications resources being required. Cyber-agents include traffic analyzers, content analyzers, physical-system signals analyzers—such as an agent inspecting voltage, current, rates of change, frequency signals of power lines—and user-behavior analyzers.

We also are currently investigating the potential savings for groups of distribution customers that are served by backup energy storage systems during a time of outage, using a sophisticated cost model recently developed at **Lawrence Berkeley Laboratory**. Enabled by remote load controllers, intelligent load shedding can be implemented on the legacy distribution systems or in microgrids to prioritize emergency power service to critical or high cost-of-outage loads.

Taken as a whole, the University of Minnesota smart grid program will provide opportunities to develop, test and demonstrate innovative distribution technologies at all scales: smart room, smart home, smart microgrid, and smart macrogrid. That is, if successful in all its dimensions, what we have dubbed our smart grid sandbox could be the model for regional distribution systems that are interactive, self-correcting and self-defending.

That is, once the smart grid concept has been stress-assessed from micro to macro, stakeholders will be able to see the way forward toward implementing it nationwide.

Tags: **micro-grid**, **demonstration**, **carbon neutral**, **energy planning**, **project**

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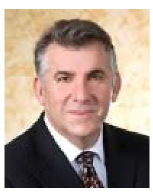

Massoud Amin, a senior member of IEEE, chairman of the IEEE smart grid newsletter, and a fellow of ASME, holds the Honeywell/H.W. Sweatt Chair in Technological Leadership at the University of Minnesota. He directs the university's Technological Leadership Institute (TLI), is a University Distinguished Teaching Professor and professor of electrical and computer engineering. He received the B.S. degree with honors and the M.S. degree in electrical and computer engineering from the University of Massachusetts-Amherst, and the M.S. degree and the D.Sc. degree in systems science and mathematics from Washington University in St. Louis, Missouri. Before joining the university in 2003, he held positions of increasing responsibility at the Electric Power Research Institute (EPRI) in Palo Alto. After 9/11, he directed EPRI's Infrastructure Security R&D and served as area manager for Security, Grid Operations/Planning, and Energy Markets . Prior to that, he served as manager of mathematics and information sciences, where he led the development of more than 24 technologies that transferred to industry, and pioneered R&D in "self-healing" infrastructures and smart grids.

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