The magazine of the University of Minnesota Alumni Association

MINNESOTA

JANUARY • FEBRUARY 2005 $2.95

Professor Massoud Amin knows the human side of electricity

Power to the People

In Search of Happiness • 1918 Flu Epidemic on Campus • When Human Nature Meets Mother Nature

Power to the People

University professor Massoud Amin has seen firsthand how electricity changes lives and has dedicated years to making the "most complex machine in the world"—the North American electrical grid—more reliable and less vulnerable. **By Elizabeth O'Sullivan**

As a young boy growing up in Tehran in the 1960s, Massoud Amin often visited the arid villages outside the city of Fath-Abaad while his father, a doctor, saw patients there. The young Amin witnessed families scratching out a subsistence living, farming plots of earth so parched they cracked under the searing sun. Then electricity reached these small villages.

With new wells, pumps, and irrigation, barren soil bloomed into green cropland. Life stabilized, the population grew, and better schools and medical facilities followed. More babies survived and grew into children, and more of those children received a better education. A tractor parts factory and other businesses came to the area, providing a more stable and diverse economy.

Amin, now a University of Minnesota professor in electrical and computer engineering and a leading expert on power distribution systems, was deeply affected by seeing people lead longer, less arduous lives because they had electricity. "I could see the engineering aspect of it and the human aspect of it. So the passion started very early on," Amin says. "It's the linchpin: electricity."

But that pin, upon which the stability and security of modern life depends, is too often taken for granted. Motivated in part by a gentle concern for people, Amin has dedicated years to making electrical power systems more reliable. He understands the weaknesses of the web-like North American network of interconnected power plants and transmission lines—its vulnerability to terrorist attack and the increasing demands society is placing upon it. Shortly after leaving Iran at 16 to attend a boarding school near New York City, he experienced the chaotic blackout of July 1977. There were fires, looting, and 3,775 arrests, but also many stories of neighbors helping one another. "I saw a system that needed to be saved," Amin says of the power grid, "and that system dealt with the human condition."

Amin stayed in the United States, receiving bachelor's and master's degrees in electrical and computer engineering from the University of Massachusetts–Amherst and master's and doctoral degrees in systems science and mathematics from Washington University in St. Louis. In the 15 years since, his work has led him to diverse projects, including aviation and ground traffic control, but he has never abandoned his childhood belief that electricity is the linchpin.

Says Amin: "Electricity infrastructure constitutes the fundamental infrastructure of modern society."

Photograph by Mark Luinenburg

Before September 11, 2001, "electrical security" generally meant that the power supply would not "wobble," causing lights to flicker and computer chips to shut down with even a split-second power interruption. Although those wobbles cost industry billions of dollars annually in productivity and product losses, since September 11, electrical security has also come to mean keeping the system safe from terrorists.

On September 11, Amin was just a few miles from the Pentagon, in a meeting to discuss preventing failures to the nation's electrical infrastructure. Amin was then working for the Electric Power Research Institute (EPRI), a California-based think tank. All of a sudden, a number of pagers went off and their wearers—White House representatives—hurried from the room. They returned briefly to report the news of the attack.

"As soon as we knew that this was an attack on our nation, I felt that electricity could be potentially a high value target for terrorists because it underpins our quality of life and economy," Amin says. "A successful terrorist attempt to disrupt electricity supply and delivery could have devastating effects on our national security, our economy, and the lives of every citizen."

During the 1990s, demand for electricity in the United States increased about 35 percent, while the grid's ability to transmit the power increased only 18 percent. During this decade, the percentage gap is expected to be even greater.

Amin says that "within two seconds" he envisioned three likely ways the power grid could be vulnerable: direct physical attack on the system, climbing transmission towers to launch chemical or biological weapons, or destroying the system from within by manipulating computers or other regulators to send huge surges pulsating through the system, knocking out critical controls and potentially creating widespread, crippling outages.

By the following Sunday, just five days later, Amin had brought together 30 experts from the federal government, leading laboratories, utilities, and private industry. The group looked carefully at the vulnerabilities of the power system and worked to minimize them. "We didn't limit [the discussion] to dogs, guards, cameras, and guns," Amin explains, since no amount of those could completely protect such a vast and decentralized system. "We went to what difference science and technology can make."

In an exercise called "red teaming," they asked outside experts to examine the system for potential ways to disrupt it. When those experts found holes in security, researchers worked to close them. Amin's team created specialized parts to protect weaknesses, made the communication system of the electrical utilities more secure, and made the infrastructure's computer networks harder to penetrate. (Amin notes that documented computer hacking attempts on regional power networks grew from 2,100 in 1997 to more than 80,000 in 2002.)

Amin was a good person to have leading that charge, according to his former boss, EPRI vice president Clark Gellings. "He wants to do cutting-edge stuff that would make a big difference," Gellings says. "He likes to take on significant challenges."

His former professor and colleague Ervin Rodin, of Washington University, says Amin "goes from accomplishment to accomplishment. He just wants to do more and more. He works countless hours, thinks of problems all the time, and the only other thing he has time for is to be nice to people, and he does that." Amin's whole motivation is to help people, Rodin says, and "to do the best he can do, and it's considerable."

"The North American power network may realistically be considered to be the largest and most complex machine in the world," Amin says. "Its transmission lines connect all the electric generation and distribution on the continent." The National Academy of Engineering has labeled it as the supreme engineering achievement of the 20th century.

Electricity spread rapidly across the United States for about 80 years beginning in 1882. That year, Thomas Edison created the first large electrical system using a central power plant, lighting up several blocks of lower Manhattan. Within a decade, many large cities in the United States and Western Europe had electrical systems. With technological advances, power became less expensive and more reliable early in the 20th century. But bringing electricity to rural areas, which were more expensive to serve, had to wait for the Depression-era Rural Electrification Authority (REA). Electricity then spread rapidly to rural parts of the United States.

Today, thousands of power plants generate electricity in the United States. Expanding steam (as in most coal, gas, or nuclear plants), falling water, wind turbines, or other forces rotate magnets past a coil of wire, producing an electrical flow. Electricity pours from plants into an interconnected network of web-like regional grids that channel and regulate the flow. Transmission lines—202,000 miles of them in the United States—distribute the electricity. Substations pump the current up for transmission, then a series of transformers step it down for household or business use. Sophisticated controls strive to keep voltage precisely balanced throughout the system despite constant shifts in demand.

Controlling the entire system from a central location would be impractical, in part because that one location would be extremely vulnerable to attack. Regional grids also help protect the system as a whole, making it easier to localize disturbances so the rest of the system can function normally. They're also more efficient, as little power is lost over long-distance transmissions.

But connections between regional grids are vital. Demand typically peaks in very hot or cold conditions and during the business day when computers and machines are operating. Unlike water or natural gas, however, extra electricity cannot be effectively stored for later use. With a system that is interconnected, excess power generated in Minnesota can, during times of high demand elsewhere, be sent to virtually any electric outlet in North America. "Reliable electric service is critically dependent on the whole grid's ability to respond to changed conditions instantaneously," Amin explains.

But the system's interconnectedness also leaves it open to domino-like failures. Electricity rushing to areas of greatest need can potentially overwhelm power lines or transformers. If those shut down, electricity is instantly rerouted. But if not properly controlled, either by automatic systems or operators, it can begin surging in waves around a grid, knocking out other lines and transformers. If not halted in time, these power surges can spread beyond their regional grids into others, and others beyond that.

On August 14, 2003, a few unrelated power line failures in Ohio cascaded into the largest blackout in North American history, leaving some 50 million people without power in the northeastern United States and parts of Canada. The blackout cost businesses between $6 billion and $10 billion. These catastrophic failures can also affect heating and cooling of homes, food storage, and, if they go on, sanitation and other utilities.

Despite the economic and safety implications of maintaining a stable and reliable electrical system, Amin argues that investments in the grid are not keeping pace. While most critical parts of the system have backups and emergency controls, during the 1990s, demand for electricity in the United States increased about 35 percent, while the grid's ability to transmit the power increased only 18 percent. During this decade, the percentage gap is expected to be even greater. "We are not keeping up the infrastructure," Amin says. "This is the least investment in infrastructure in over a quarter of a century, especially on the transmission side." There are also fewer "shock absorbers" being put into place to buffer fluctuations and halt outages before they begin, he says. Between 1996 and 2000, outages affected 15 percent more consumers than they did between 1991 and 1995.

Amin is looking at the effects of extending electricity to some of the 2.2 billion people—almost one-third of the world's population—with no access to electricity. Reliable power can help build the quality of life that people in those places desire, Amin says.

Although he sees a system struggling to keep up, Amin believes that hard work, new technology, and investment will allow our electrical grid to rise to the occasion. While at EPRI, Amin led research to develop technology that would make the grid "self-healing" or "smart." This means that the grid would respond with more sophistication during times of crisis. If a domino—a transmission line or an entire regional grid—begins wobbling dangerously, the "smart grid" might automatically resolve the problem before a failure occurs. If that isn't possible, it might protect surrounding lines and regions to prevent massive outages, keeping power supplied to as many people as possible. In the 2003 blackout, there were moments when intervention might have limited the spread of outages, but human operators were overwhelmed with information and choices in the two minutes during which most of the collapse occurred.

In 2003, after the northeast blackouts, Amin delivered a set of recommendations to Congress calling for a public-private partnership to develop and deploy "smart grid" technology. "It's a very rich area for research and development," he says, noting that some smart-grid tools already exist while others are little more than ideas on drawing boards. Amin's recommendations met with support among elected officials, and a White House agency recently recommended self-healing technologies be one of three main areas of research and development for infrastructure protection. But to create a truly self-healing system would cost about $100 billion over several years, something there currently is little political will to tackle. The recommendations, which asked the ominous question of whether society will "master the complexities of the grid before chaos masters us," conclude with a typically optimistic exhortation from Amin: "We will be successful!"

Amin joined the University in March 2003. He holds the H.W. Sweatt Chair in Technological Leadership and is director of the Center for the Development of Technological Leadership (CDTL). A professor at Washington University for a several years before joining EPRI, Amin has had numerous job offers over the years. He came to the University because academia "feels like home," while he still works with industry and government in his dual role. His wife, Elizabeth Amin, has recently been named an assistant professor of chemistry at the U.

As director of CDTL, Massoud Amin oversees a University program dedicated to helping tech-savvy professionals become leaders in their companies and industries. He is working with CDTL's board of directors to refine the center's mission while developing ties to Minnesota companies and responding to their training needs. He leads a staff of four endowed chairs, 11 professional staff, and 45 affiliated faculty from across the University.

In his faculty role, Amin teaches while also conducting cutting-edge research in "global transition dynamics"—simulating how technological advances will affect the world and its cultures. Amin's new research uses mathematics and computer simulation to predict the ramifications of technological change. For example, he is running simulations on how hydrogen fuel cells can reach their potential to improve lives while minimizing unintended social, environmental, political, and other consequences.

He is also looking at the effects of extending electricity to some of the 2.2 billion people—almost one-third of the world's population—with no access to electricity. Reliable power can help build the quality of life that people in those places desire, Amin says, but his modeling will make clear the environmental, social, and economic changes that may occur.

Amin's work is tied to his unshakable belief that reliable electricity changes and enriches lives. Amin's father, who became an elected legislator in the decades before Iran's Islamic Revolution, believed this as well. "He really helped build many of those routes to electrification, and for roads and for bridges to improve the quality of life," Amin says proudly.

Amin has seen the chaos an urban blackout can cause. He recognized immediately that 9/11 changed the very meaning of infrastructure security. But before that, Amin saw poor villages, and the lives of their people, blossom through electricity. "[It's] service to society," he explains of his work, "using science and technology with the goal of improving social conditions." ■

Elizabeth O'Sullivan is a freelance writer living in Minneapolis.