A Life's Work Sparked by Invention

"What comes out of darkness is light. What comes out of chaos is new meaning."

Known as the "father of the smart grid," Dr. Massoud Amin, a 1979 Storm King School graduate, grew up in Tabriz and Tehran, Iran. It was here that he first began to understand the impact of electricity on the human condition.

His father was a professor and surgeon, the founding dean of the Tabriz University medical school and chief surgeon at the American Hospital in Tabriz. After World War II, his mother began her studies in Sorbonne, an edifice of the Latin Quarter in Paris, France, and completed her postgraduate study at Cambridge University. She subsequently went on to work for the Iranian Red Cross.

Going from village to village with his parents as they did volunteer work treating patients, Amin recalls seeing families trying to farm "plots of earth so parched they cracked under the searing sun." Most people in these villages only lived to their late 40s, an average life expectancy that was low compared to the surrounding, more developed areas.

In the mid-to-late 1960s, electricity began to reach these villages, and Amin noticed the difference it made in people's lives. Within a year of accessing electricity, life blossomed with lighting and refrigeration, with access to deeper wells and electric pumps providing cleaner water and improved irrigation, and the once-barren farmland became green and fertile. In turn, children grew up healthier and people lived longer; the population began to grow and thrive. Little by little, the villages began to flourish with new businesses, schools, and medical facilities setting roots nearby, driving a more stable and diverse economy.

Even at a young age, Amin remembers recognizing both the engineering and human aspect of electricity, an understanding that sparked his passion for solving infrastructure challenges early on and continues to drive his life's work today.

His research and innovations revolve around the idea that foundationally electricity is one of the most impactful and fragile linchpins of modern society, an awareness that was reinforced in his teens when he traveled to the United States to visit the Storm King School (SKS). During this trip, a 16-year-old Amin also visited Midtown, Manhattan, and witnessed firsthand the New York City blackout on July 13, 1977. A series of lightning strikes wiped out power to the metro area for 25 hours and sent it spinning into chaos.

As recounted in an article written by the *New York Times*, the blackout closed LaGuardia and Kennedy airports and brought traffic to a standstill as 4,000 people were evacuated from the subway system and over 1,000 fires burned throughout the city. Looting and arson ensued, triggering scenes similar to what some witnessed on streets like Brooklyn's Broadway, where "the rumble of iron store gates being forced up and the shattering of glass preceded scenes of couches, televisions, and heaps of clothing being paraded through the streets." Amin was shocked to see looters smash into an electric store just 20 yards away.

The temporary cut from power resulted in 3,800 arrests and over a billion dollars in damage. Some had attributed much of the pent-up angst to economic pressures in addition to fear about a local serial killer known as the "Son of Sam." Amin's early experience with electricity showed him how a society could be built up by innovation, but the blackout helped him understand that the opposite was also true —that when a society relies so heavily on electricity and loses it, the security of modern life is also compromised.

Amin recognized the need to fix a system, and not just any system, but the fundamental infrastructure of modern society — a critical infrastructure that needed to be made smarter, more secure, more resilient, and more efficient.

After graduating from SKS, Amin went on to earn his 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.

Amin was recruited by the Electric Power Research Institute (EPRI) in Palo Alto, California to become the head of mathematics and information science in 1997, where he’d held positions that addressed infrastructure protection and security, grid operations and planning, energy markets, and risk and policy assessment. It is there that he pioneered the research and development (R&D) of the smart grid, which began with researching an automated system that could be applied to aviation, to complex military or civilian transportation/logistics networks, and had little to do with electricity at the time. During a military exercise in May of 1983 over the Negev (a desert region in southern Israel), an F-15 fighter plane collided with an F-4 Phantom. The pilot, Ziv Nedivi, had no idea that during the collision, he had lost about 90% of his right wing, yet he landed safely against all odds. Later, Nedivi said that if he had known how much damage had been done to his plane, he would have ejected from it. It was a miracle he was able to land at all—and at more than twice the speed of nominal landing speed for his aircraft. With the type of damage his plane sustained, he should have lost symmetry and dropped out of the sky.

The ability to land his aircraft within such a small margin for error inspired a question: If humans have the ability to quickly correct themselves in situations like these, is it possible to develop complex, automated systems that can also quickly sense problems and correct themselves?

Both planes were built by McDonnell Douglas (now Boeing Phantom Works), where he was funded by NASA at develop solutions. After three years, a system was developed that could identify if something was wrong within a fraction of a second and compensate for the damage. The technology was tested with hydraulic failure in airplanes. Subsequently, his work on saving complex systems from failure and making them more resilient, secure and agile was applied to squadrons of fighter planes, and during 1992-1997 to the entire logistic networks and battlefields. Starting in January 1998, Amin applied “all had learned” to power and energy networks.

After implementing over 960,000 simulations in the western United States, and over 1.6 million in the eastern part of the North American interconnection, three layers of architecture in the resilient control of the grid emerged. It showed that the smart grid was behaving in the same way a human brain does, with the lower levels moving extremely fast, within a fraction of a second (the lower, oldest part of the brain—the reptilian brain—also moves extremely fast, regulating things we don’t need to think about, such as breathing); the middle levels doing a lot of coordination (like the limbic brain, the part of the brain associated with emotion, coordination, and behavior); and the top levels forecasting strategically, recognizing that what was coming was centralized (similarly to the neocortex, the logical and strategic part of the brain that help us develop language, imagination, and learning abilities).

Using that three-layered architecture for the smart grid, which has real-time monitoring and reaction, and allows the system to constantly modify and tune itself to an optimal state. It also has anticipation, which enables the system to automatically look for problem areas that could trigger larger problems and disturbances. And it has rapid isolation, which allows the system to isolate parts of the network that are going through failure or about to fail from the rest of the system, enabling a more rapid restoration.

As a result of these three functions, the self-healing grid can reduce power outages, minimize their length, detect abnormal signals (whether it's cyberattacks, material failure, human error, or a storm that is beginning to blow), make adaptive reconfigurations to the system, and isolate disturbances to eliminate or at least minimize their impact on the larger system.

In 1998 at EPRI, Amin led the creation and launch the Complex Interactive Networks/Systems Initiative (CIN/SI), a new R&D initiative intended to heighten national security with smart grid technology in response to growing concern that the national infrastructure was increasingly vulnerable. EPRI and the United States Department of Defense collaborated to fund and develop six research groups that comprised 108 professors, over 200 researchers in 28 U.S. universities, and two energy companies. Amin supervised all aspects of the program, including content creation, concept development, program direction and evaluation, funding, and contracting. Amin's research accomplished in the CIN/SI also led the development of over 24 technologies that have since been brought to market in their respective industries.

Ironically, Amin was at a meeting, less than a mile from the Pentagon, discussing disaster risk management with White House, U.S. Department of Defense Officials and other agencies when the terrorist attacks took place on September 11, 2001. In response to 9/11 tragedies**,** he was promoted and directed all security R&D at EPRI for all North American utilities. He advised leadership of public and private sectors, including Secretary of the U.S. DHS, the White House and the National Science Advisor at the OSTP, Director of NSF and NIST, Undersecretaries at the U.S. DoE and DoD, DIA, FBI, and other agencies, while developing and leading innovating effective data-driven applied solutions and deployed strategies against advanced threats.

Six years later, he watched from his office window on the West Bank of the University of Minnesota as the I-35W bridge collapsed into the Mississippi River below — both devastating events re-enforcing his belief that more needs to be done to protect our critical infrastructures and make them more resilient, secure, and robust in face of a broad range of destabilizers. Within less than a year after the August 2007 collapse of the I-35W bridge in Minneapolis, Minnesota, a city of sorts on the south side of the former bridge took shape, complete with a host of heavy-duty equipment pieces, temporary on-site areas for casting and other tasks, and crews constantly at work. The days and months that followed required extraordinary efforts from many, including thirteen of his former students and alumni of the University of Minnesota's Technological Leadership Institute, who were involved in the design and reconstruction of the new I-35W bridge. They incorporated a sensor network into the new I-35W bridge (at less than 0.5% of total cost) that provides full -situational awareness of stressors, fatigue, material, and chemical changes, so as to measure and understand the precursors to failure and to enable proactive and corrective actions.

"As an infrastructure/energy professional and an electrical engineer, I cannot imagine how anyone could believe that in the United States we should learn to 'cope' with bridge collapses and blackouts—and that we don't have the technical know-how, the political will, or the money to bring our infrastructure up to 21st century standards," Amin said at the time. "I do not believe the American people would—or should—settle for a substandard critical infrastructure. Coping, while needed in face of losses, but used primarily as strategy is ultimately defeatist. "

Amin has given five briefings at the White House and ten briefings to congress. He has also spoken at many major national and international forums, including the United States Federal Energy Regulatory Commission on smart grids, security, and leadership in scientific R&D. He has served as a U.S. delegation representative to several world engineering and scientific congresses and has been interviewed and featured in the media with major publications, such as the *New York Times*, *USA Today*, *Forbes*, and the *Wall Street Journal*.

Dr. Amin has also authored and coauthored more than 200 research papers and served on the editorial board of seven academic journals. He has received several awards, including the 2002 President's Award for the Infrastructure Security Initiative, the 2000 and 2002 Chauncey Awards, and six EPRI Performance Recognition Awards between 1999 and 2002 for his leadership.

In his 2012 TEDx talk, titled "Powering Progress: Smart Infrastructure and the Future of Cities," that he gave at the University of Minnesota (where he is currently Director of the Technological Leadership Institute and a Professor of Electrical and Computer Engineering), Amin shared a map of the earth at night showing major cities across the globe lighting up more than other less-developed areas. He attributes the rise of these major cities to having access to a high degree of affordable electrification. He also points out that currently the world has 19 megacities (cities with 10 million people or more); by 2020, there will be more than 30, and by 2050, there will be nearly 60. With increasing population, the need for resources will also increase, and the world's electricity supply will need to triple by 2050 to keep up with demand. In order to meet this growing demand, Amin recognized the need for our existing 450,000 miles of high-voltage power lines to be supplemented with other means, such as wind, solar, geothermal, and biomass energy.

The current electrical system is already under an enormous amount of stress. In the United States, power outages cost the country between 80 to over 187 billion dollars per year. The problem with this scenario is that, nearly 40 years after the blackout in New York City, some of the most advanced societies in the world are still depending the same technology that faltered in the 1977 blackout.

Amin's former organization, EPRI, concluded that, in order to enable more efficient electrical grids, carriers need to add another 9 percent (about 40,500 miles) of power, and the most economical way to do so would be in the form of electricity's most efficient carrier: electrons.

The total cost of a stronger transmission system would be about $82 billion dollars over the next decade. Additionally, to create a smarter end-to-end power delivery system, we must invest between $17 billion and $24 billion over the next 20 years. Investment in a smart grid would nearly pay for itself by reducing stupendous outage costs, a savings of U$49 billion per year, and improving energy efficiency, a savings of $20.4 billion per year. Likewise, through smart grid-enhanced energy efficiency, by 2030 carbon dioxide emissions from the electric sector would be reduced by 58%.

The need to develop a better, more efficient way of using electricity is apparent and has fueled much of Amin's progress developing—and push to implement—his work on the "smart grid," an electrical power system that utilizes digital technology (such as sensors, automation controls, and secure communication networks) to overlay the current electrical grid. The overlaying, secure digital grid would then use real-time communication technologies to monitor any potential issues and heal itself within a fraction of a second to prevent outages and other system upsets by rerouting electricity through other pathways while the physical problem is fixed (downed power lines, disabled power stations, faulty equipment, etc.). Implementing a smart grid over our existing system could help prevent power outages by unforeseen catalysts like severe weather, human error, or even sabotage.

During his time at the Storm King School, Amin found a haven that allowed him to learn and grow in peace throughout a turbulent time in his homeland. In 1978 and 1979, Iran experienced a major revolution that lead to a period of civil unrest, and war - Saddam Hossein's Iraqi invasion of Iran - which lasted for over a decade. Amin recalls that, "the staff and students at SKS, combined with the majesty and peacefulness of the mountain provided a safe place to think, to grow, and to plan [his] future." He also observed this transformational experience help other students cope with a variety of hardships; everything from poverty and the effects of racism and discrimination to the loneliness that resulted from leaving one's family.

Amin found a second family at the school, in addition to an education system that would nourish, encourage, and inspire him in his work.

"These experiences left a very positive and everlasting impression on me. I had terrific, demanding, supportive, and engaging teachers with sharp and precise minds, and great mentors who held high bars for us by challenging us regularly and positively." One of the aspects of SKS he also valued was the willingness of the students and staff to celebrate uniqueness and help each student grow in their own way.

When asked what advice he might have for future and current SKS students, Amin emphasized the importance of commitment, hard work, and leadership, which "begins from within and fundamentally depends on values like courage, decency, honesty, empathy, and care toward ourselves and others." In short, it's a good idea to forget one's insecurities, cultivate a quiet mind, and prepare, as best as possible, for the road ahead. He added that we live in a promising time where scientific discovery, technological progress, and innovation are being challenged and developed in powerful ways. Relying on the power of an idea and asking "why not?" or "what can I do to make a positive difference" can go a long way.

And the most important quality Amin thinks future and current SKS students should embrace? Humility. As George Washington Carter once said, "How far you go in life depends on your being tender with the young, compassionate with the aged, sympathetic with the striving, and tolerant of the weak and the strong. Because someday in life you will have been all of these."

Innovator, strategist, mathematician, academic, 'father of smart grid,' advocate, philanthropist, humanitarian, visionary, leader