Government Technology Magazine Q&A with Prof. Massoud Amin[1]

1.Tell me a little about yourself.
I was born in Iran in 1961 and lived in the cities of Tabriz and Tehran. In August 1978, when I was 17 years old, I moved to the United States.

My parents were healthcare professionals: my father was a surgeon and my mother worked for the Iranian Red Cross. As a young boy, I often accompanied my parents to local villages where they treated patients and I saw first-hand how families scratched out subsistence livings on parched plots of farmland and I understood that people in the villages had short life expectancies. But electricity began reaching these villages in the mid- to late-1960s and suddenly communities had irrigation systems for farming along with new schools, businesses and medical facilities. People began to lead better and healthier lives.

I realized at a young age that electricity is fundamental to modern society. This passion was reinforced when I was 16 and happened to be visiting New York City when lightning triggered a 24-hour blackout in the city. I saw that advanced societies critically depend on reliable electricity to support their economies and quality of life. I've been committed since then to helping improve electric power systems because this infrastructure has so much positive influence on the human condition, our economy and security.

I received my bachelor's and master's degrees in electrical and computer engineering from the University of Massachusetts–Amherst, and my master's and doctoral degrees in systems science and mathematics from Washington University in St. Louis. Over the years my work has enabled me to work on research and development projects for a wide range of systems, including power grids, helicopters and airplanes, aviation and ground traffic control, and Department of Defense logistic networks, among other things.

While the projects have been diverse there are certain fundamental problems and underpinning dynamics that exist in all of these systems. These are the types of problems I have attempted to address: how to improve performance monitoring; where to judiciously place sensors; which variables to measure and the value of the information the measurements provide; how to develop robust controllers and better automation to improve performance; and how to evaluate security, economic and other related impacts of new systems or augmentations. As my R&D activities have evolved, my work has also moved from the micro to the macro, from smaller systems to larger and larger ones. But I have never abandoned my childhood belief that electricity is the linchpin--the most fundamental critical infrastructure--of modern society.

2. What is IEEE in a nutshell?
IEEE refers to itself as "the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity," and I believe those words characterize IEEE really well.

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[1] The first part of this interview (http://www.govtech.com/technology/Massoud-Amin-Smart-Grid.html) is published in the September 2012 issue of the Government Technology Magazine www.govtech.com

IEEE is short for the Institute of Electrical and Electronics Engineers. The organization has about 400,000 members in fields as diverse as aerospace, biomedical engineering, computing, consumer electronics, electric power, and telecommunications. It is well known for its professional and educational activities, its peer-reviewed and general interest technology publications, the conferences it hosts around the world, and its standards development organization.

3. How do you define the smart grid?

The smart grid is a next-generation electrical power system that uses digital technologies, such as computers, secure communications networks, sensors and controls, in parallel with electric power grid operations, to enhance the grid's reliability and overall capabilities. The smart grid extends all the way from the source of fuel for the electric power production to the many devices that use electricity, such as a household refrigerator, a piece of manufacturing equipment or a city park's lighting fixtures.

In particular, the secure digital technologies added to the grid and the architecture used to integrate these technologies into the infrastructure make it possible for the system to be electronically controlled and dynamically configured. This gives the grid unprecedented flexibility and functionality and self-healing capability. It can react to and minimize the impact of unforeseen events, such as power outages, so that services are more robust and always available.

The smart grid also has very important features that help the planet deal with energy and environmental challenges and reduce carbon emissions. To give a few examples, a stronger and smarter grid, combined with massive storage devices, can substantially increase the integration of wind and solar energy resources into the generation mix. It can support a wide-scale system for charging electric vehicles. Utilities can use its technologies to charge variable rates based on real-time fluctuations in supply and demand, and consumers can directly configure their services to minimize electricity costs.

4. What's the IEEE's role in smart grid?

IEEE is involved in virtually every aspect of Smart Grid. Its engineers in academia, government and private industry are helping guide its evolution and standardize its technologies and they are deeply engaged in designing, testing and deploying smart grid projects around the world.

IEEE members have published around 2,500 papers on smart grid topics in more than 40 IEEE journals. I'd like to mention, in particular, the *IEEE Smart Grid Newsletter*, a monthly newsletter that I'm involved with. It provides up-to-date news about smart grid, results of field tests, as well as forward-looking commentary on important issues. It is published on the IEEE Smart Grid Web Portal (http://smartgrid.ieee.org/), which the IEEE hosts as a comprehensive information gateway to smart grid resources and expertise.

5. What's the history behind the smart grid?

A groundbreaking research program was conducted jointly by the Electric Power Research Institute (EPRI) and the U.S. Department of Defense (DoD) from 1998 to 2001. The goal of this program, which I created and directed while at EPRI, was to develop ways for power grids to adapt automatically to deal with unforeseen events, like power failures, to minimize the adverse impacts these events can have. The project provided the mathematical foundations and simulations for a “smart and self-healing grid” and established its feasibility. Hundreds of professors and graduate students from 28 U.S. universities participated, along with 52 utilities and grid operators.

This initiative caught the attention of *Wired* magazine in July 2001. An article published in that issue appropriately characterized the smart self-healing grid this way: ``Every node in the power network of the future will be awake, responsive, adaptive, price-smart, eco-sensitive, real-time, flexible, humming -- and interconnected with everything else."

Since then, experts from around the world have continued to work assiduously on a wide range of initiatives to advance and refine the smart grid concept. In the United States, participants include experts from the DoD, EPRI, DoE, the Federal Energy Regulatory Commission, IEEE, the National Institute of Standards and Technology, dozens of universities and hundreds of companies in private industry.

Governments and regions now recognize smart grid’s importance. Recent policies introduced in the U.S., China, India, the United Kingdom and the European Union have formalized specific goals for national and regional smart grid deployments. These policies are helping attract a high level of interest in smart grids.

6. How has the smart grid evolved in the last 5 years?

The national and regional policies are beginning to provide the public support needed to deploy smart grids, though we are still at a nascent stage in this evolution. I’ll focus my remarks on what’s going on in the United States.

In 2007, the U.S. Congress passed the Energy Independence and Security Act (EISA). The Act established policy to modernize the U.S. electricity system to meet future growth in demand and increase the use of digital information and controls to improve reliability, security and efficiency of the grid.

In 2009, the American Recovery and Reinvestment Act (ARRA) authorized $3.4 billion in federal funding to hasten the transition to a smart grid. The Act established the Smart Grid Investment Grant (SGIG) program, which was authorized by the EISA and managed by the Department of Energy, to offer and oversee the funding. The SGIG was structured as a public and private partnership, with the federal government matching investments from the private sector on a 1:1 basis. Over the last three years, this partnership between the ARRA and private industry has funded $7.8 billion in projects for upgrading the grid.

The program was launched in early 2010 and, as of March 2012, about two-thirds of the federal funds have been expended for around 100 projects. Every state in the country has conducted projects. Smart meters, now being distributed to households and businesses, should meet their deployment targets in 2013-2014. Funding is also helping deploy customer systems, such as load-control devices, in-home monitors, and programmable thermostats. Funded infrastructure projects should be complete by 2015. The projects include deploying critical sensors that are used to enable real-time monitoring and control of high-voltage grids.

7. How do you envision it being in the next 10 years?

Various scenarios that have been suggested for a smart grid vary, and they vary wildly. But a common understanding has emerged that, in the coming years, electricity will play a much greater role in the global society than at present.

I believe it is entirely possible that nations, regions and cities that best implement new strategies and infrastructure could reshuffle the world pecking order. It's very possible that emerging markets could leapfrog other nations in smart grid markets and deployment. For example, while the U.S. has invested about $7.8 billion in smart grid technologies, China has invested $7.3 billion and will spend $96 billion on smart grid technology by 2020, when its energy needs are expected to double. Many changes in China will focus on residential households: the country is expected to account for 18.2% of global smart grid appliance spending by 2015. South Korea has also formalized its ambitions. It plans to implement smart grids nationwide by 2030 and, in preparation for this, has begun implementing a fully integrated grid for a 6,000-home pilot program that involves wind farms, transmission lines, energy storage systems, and plug-in vehicles. The total budget is close to $200 million, with $68.5 million in public funds.

Global drivers for smart grid development and deployments are multifaceted and there are no cookie cutter solutions. The drivers are often created by local, regional and/or national priorities, and drivers for advanced economies can differ from those of developing ones. Motivations are also influenced by a variety of factors in the larger, macro system, such as standards, technologies and policies. How decision-makers perceive and manage risks under uncertain conditions is another factor. For example, it is impossible to anticipate the following: if and when an oil peak will come, since new discoveries occur repeatedly; the extent to which shale gas will prove viable; if and when power plant carbon capture and storage techniques are commercialized; the policies individual nations will adopt for nuclear power; and how climate action across the globe will evolve. Social changes are also a significant part of this macro system that can impact a country's or region's smart grid motivations.

The strategic goals are clear, however. To ensure that we can reliably and securely meet our growing energy needs, we must use energy resources more efficiently. To do this we must set and achieve some very strategic goals. We must transform transportation by expanding home-grown fuel sources and we must electrify transportation. We must reduce emissions by greening the electric power supply. We must build a stronger and smarter electrical energy infrastructure that is self-healing and can rapidly restore services to eliminate systemic failures. And we must enhance the security and cybersecurity of critical power and energy infrastructure. We must also expand the associated market sectors and business opportunities in these areas.

8. Will the creation/expansion of a smart grid call for an increase in a STEM workforce?

We need an increase in the entire STEM workforce to deal with smart grid and many other important technologies that are shaping business and society today. The World Economic Forum, for example, has ranked the United States 51st in the quality of science and math education it provides. And according to the Organization for Economic Cooperation and Development (OECD) Program for International Student Assessment (PISA), the U.S. ranks 35th in math and 29th in science worldwide. In developed nations, the U.S. ranks 25th in math and 17th in science among college students majoring in science and engineering. This woeful situation will not tactically or strategically serve our nation’s future.

I do believe these are very promising times, however, because there is increased recognition of the strategic need for new core technologies and capabilities that can enhance our quality of life. But we must make a conscious choice to fund technology development and training and put mechanisms in place to train technology leaders in these new areas.

In the past, America has invested judiciously and strategically to develop technology leadership, with huge payoffs. In the 1960s, our goal was to reach the moon and the talents and resources that came together to make that succeed, and its benefits such as national pride and the inspiration of a generation of young students to study science and technology are indisputable. The smart grid is such a goal, but it definitely will require investing in research and development and the human capital needed to build, manage, maintain and upgrade these systems.

9. If so, you’re in the education field, do you think the nation is prepared? If not, what must be done to make the U.S. prepared as well as remain globally competitive?

"The empires of the future," said Winston Churchill, "are the empires of the mind." Echoing this in his 1981 book, *Investing in people: The Economics of Population Quality*, economist and Nobel Laureate Theodore Schultz argued that the wealth of nations is not limited by land or minerals, it comes predominantly from "the acquired abilities of people, their education, experience, skills and health."

What are we doing about this? I don't mean to overstate the roles of science and technology, but nations that invest in those fields of human capital do better economically than those nations that do not.

We must invest in education, and technology education, if we intend to build a twenty-first century economy that is supported by high-quality infrastructure. According to Robert Solow, a Nobel laureate in economics from the Massachusetts Institute of Technology, more than 60% of the U.S. economy is driven by technology. The abilities of our workers to perform and innovate in technology fields directly impact our national security, job creation, and our companies’ leadership and competitiveness in global markets.

Universities, government and industry can partner to provide training and build strategic capacities in technology. I can illustrate, from my own personal experience, how this can be done. At the Technological Leadership Institute, which I direct at the University of Minnesota, we train full-time business professionals to become technology leaders for their companies. TLI alumni are affiliated with more than 400 companies in Minnesota and beyond and the program is having a direct, positive economic impact on the state’s economy.

These types of partnerships and coalitions in science and technology will become more and more important as the world opens through globalization and competitiveness puts greater pressure on businesses to advance their knowledge and expertise to develop technology innovations. Business leaders, too, must pursue knowledge and learning with a passion, because understanding the always-changing business environment demands this.

We must also continue to invest in research. Today, U.S. spending in R&D accounts for about 2.3 to 2.5% of the gross domestic product (GDP). U.S. scientists and engineers working in R&D make up about 75 out of every 10,000 people employed in the country. For comparison, the proportions are about 80 researchers for every 10,000 employees in Japan, 50 out of 10,000 employees in the U.K, 30:10,000 in Italy and less than a handful per 10,000 in most developing countries.

Companies that invest in R&D can position themselves to advance and launch technological innovations. They don't have to do this alone. Increasingly, leadership in science and technology developments will emerge from an "open research model" that emphasizes collaborations among coalitions of companies, universities, national labs, and government agencies. This open model is practical and efficient for companies because it allows them to extend the use of their research assets.

I must point out, however, that we are significantly and unfortunately disadvantaged by a lack of research and development in the U.S. electric power system. If you evaluate R&D spending as a percentage of a business sector's revenue, the electric power sector is second-from-last of all industries in the U.S. We need public/private partnerships to support targeted research funding that will help motivate companies to invest in modernizing their systems.

And we must invest in smart grids to ensure our ability to compete in increasingly competitive global markets. Most of the infrastructure used in the U.S. electric power system was deployed in the 1960s and 1970s and the system is overloaded. In the last 10 years, the number of power outages per year in the country has increased from 152 to 248. Depending on what part of the United States you live in, the grid averages 90 to 214 minutes of interrupted service, or blackouts, per customer per year. The outage data excludes interruptions caused by extraordinary events such as fires or extreme weather. Japan, by contrast, averages only 4 minutes of interrupted service each year. And the costs add up. The total number of outages and power quality disruptions cost the nation an average $100 billion per year, ranging from $80-188 billion. And the outages inconvenience everybody because they shut down businesses, schools and the services we use in our daily life.

10. What does it mean to have a sustainable smart grid? How can we have one?

Smart grids have the potential to substantially reduce energy consumption and CO2 emissions. In fact CO2 emissions alone could be reduced by 58 percent in 2030, compared to 2005 emissions.

Microgrids that localities build to serve campuses, communities and cities will contribute to smart grid's sustainable benefits. Microgrids are wonderful examples of the "think globally, act locally" principle. They draw their energy from locally available, preferably renewable resources. They use smart grid technologies to continually monitor customer demand and they offer innovative pricing and other programs to manage the load and encourage customers to conserve energy. The microgrid ships any excess capacity it has back into the grid.

Microgrids can be almost entirely self-sustaining. In fact, they can produce as much energy as they consume and generate "zero net" carbon emissions. We've shown this at the University of Minnesota. We're building a microgrid at the UM Morris campus that uses biomass from nearby farms, as well as solar and wind resources. It will soon be energy-self-sufficient. It has been zero-net-carbon since 2008.

Certainly, the power grid backbone also needs to become increasingly efficient and smart grids are designed to do this by efficiently integrating renewable resources that reduce society's need for fossil-based resources, among other approaches. The upgraded backbone, combined with microgrids, will help us meet our goals for an efficient and eco-friendly electric power system.

11. Why is it important to have national smart grid standards and is an international body needed to govern standards?

Technology standards are needed so that products can interoperate with one another and so businesses can distribute their products to multiple countries or regions. The economies of scale standardization creates can drive down costs, which benefits everyone. And because more vendors might participate in a market, customers have more product choices. Also, when a technology is standardized, customers can have more confidence that their products will function as expected.

The IEEE Standards Association has more than 100 smart grid standards developed or in development, and these will support a wide range of technologies and services that will be used throughout a smart grid system. Many other regional and international standards development organizations are also creating smart grid standards. IEEE and other leading groups are working together on smart grid standards because they recognize that collaboration is necessary to make sure smart grid succeeds.

This type of collaboration actually represents a new paradigm in standards development today. Collaboration is seen as a practical means of solving problems that are common to all participating groups and stakeholders regardless of the formal status of a particular standard within an industry or country.

12. What's the simplest thing about the smart grid? What's the most complex thing about it?

The simplest thing about smart grid is consumers' general expectations for their electric services. Basically, consumers expect that when they turn on an appliance or product that uses electricity, it will work without any disruptions of service, it will be safe and secure and affordable.

What's complicated is achieving the infrastructure needed to deliver on those expectations. We have established the general architecture needed for smart grids and have begun putting the initial technologies, like smart meters, in place. But it will take 5 to 10 and possibly as many as 20 years, depending on the level of effort, to deploy the technologies to create complete, end-to-end smart grids. And we need to come up with some truly breakthrough engineering achievements to solve some of our toughest smart grid challenges. This all ties back to my previous comments about the need for public and private partnerships and financing to support smart grid research and deployments and training.

13. In that vein, there are always pros and cons of a solution. What are those as related to the smart grid?

The smart grid will create a more stable and efficient electric power system. It will significantly reduce the number of power outages experienced in the United States and if an outage does occur the smart grid will minimize its impact to such a degree that most consumers will not know that it happened. Outages such the one affecting New York City in 1997 would be avoided.

I’ve mentioned that smart grids will introduce energy efficiencies to better support the increasing demands for electricity while reducing environmental impacts. And consumers will have opportunities to use in-home energy-management tools, programmable appliances and other applications that improve their quality of life.

Unfortunately, around 68 percent of consumers have no idea what a smart grid is and their understanding is needed to help gain acceptance for the technology. We need leadership in the private and public sectors to educate consumers, as well as incentives and other mechanisms to bring smart grid into reality.

14. How is the smart grid community addressing interoperability and security as it pertains to the smart grid? What role, if any, is the IEEE playing there?

The IEEE Standards Association (IEEE-SA) has published an architectural framework for the smart grid, called IEEE 2030, which defines the interconnection and interoperability standards for the power, IT and communications technologies that will be used in smart grids.

IEEE-SA is working actively on standardization with the NIST Smart Grid Interoperability Panel, which includes IEEE-SA standards in its catalog of smart grid standards. IEEE-SA also collaborates with many standards organizations that represent specific industries, countries or regions to help make sure that products that operate on smart grids are complementary and compatible with one another.

Security, which includes privacy and cybersecurity, is fundamentally necessary for reliable grid operations and for customer acceptance of smart grids, and many in IEEE and the smart grid community are developing technologies and standards addressing this issue. What’s most important, however, is that security is incorporated into the architectures and designs at the outset, not as an afterthought. For the microgrids I’m involved with, we employ security technologies for each equipment component we use and for each customer application we develop and we do this in a way that cannot be reverse engineered. We use an architecture that cannot be taken down. If any part of the system is compromised, the system reconfigures to protect itself, localize and fend off the attacks.

15. Why is it important for states and localities to build a smart grid infrastructure?

I’ve mentioned the overloaded grid conditions we have today. Yet the situation is certain to get much worse, especially with the increasingly digital society. Twitter alone puts a demand of 2,500 MWh per week on the grid that didn’t exist before. Because of increasing demand, experts believe that the world’s electricity supply will need to triple by 2050. This aligns with the vision I described above in question 7.

Localities should build microgrids because these facilities can meet community energy demands in an eco-friendly way that also provides cost advantages to consumers and families. I also believe that local commitments to microgrids will help the country overall by showcasing their capabilities and just proving that it can be done. Cities, communities, and universities are great candidates for microgrids because their microgrid projects can be manageable in size and the local participants are passionate about the opportunity and want their programs to succeed.

Local entities can use their microgrids as well to develop and test innovations for consumers, such as smart homes, and the results of these programs can be used in developing other smart grid projects around the country.

16. It's not just important to have a smart grid. What other factors will contribute to truly having a smart grid?

Smart grids provide energy security because they help a country reduce its dependence on foreign energy supplies. They also protect a country's economic interests and the environment. To build a truly smart grid, we need a better backbone for the grid and we must also build intelligence into the system end-to-end.

The desired system will require a high-voltage power grid that can serve as its backbone and also efficiently integrate renewable resources into the grid. It will likely cost about $82 billion, or $8 billion per year for 10 years, to achieve the upgrades needed for the high-voltage system serving the U.S.

Making the grid smarter, which will be achieved by replacing traditional analog components with digital ones and incorporating the computing, IT, sensors and other equipment, will have a separate price tag. This will cost about $338 billion to $476 billion over the next 20 years, or about $17 billion to $24 billion annually.

It seems exorbitant, but the investment will pay for itself. These technologies are expected to reduce outage costs by about $49 billion per year and save about $20.4 billion per year from improved energy efficiencies. The technologies will also produce the intangible benefits of increased security, reductions in CO_2 emissions, and related environmental improvements.

17. What implications does broadband have on the grid?

Utilities will use a variety of wired and wireless, broadband and narrowband communications technologies for their smart grids. Communications networks will carry information to and from the many sensors, control technologies, and metering devices that will be used in a smart grid, including devices used in homes and businesses.

A utility will use broadband connections to engage with customers for smart grid services. Customers will use network-connected applications on in-home energy monitors, home computers and smartphones to interact with demand-response or energy management programs.

Utilities will likely use a combination of broadband communications technologies, including their own infrastructure for broadband over the power line communications. They will also use a variety of fiber optic, wireline and wireless technologies for broadband communications.

18. What is a self-healing infrastructure?

A self-healing grid uses digital components and real-time communications technologies installed throughout a grid to monitor the grid's electrical characteristics at all times and constantly tune itself so that it operates at an optimum state. It has the intelligence to constantly look for potential problems caused by storms, catastrophes, human error or even sabotage. It will react to real or potential abnormalities within a fraction of a second, just as a military fighter jet reconfigures itself to stay aloft after it is damaged. The self-healing grid isolates problems immediately as they occur, before they snowball into major blackouts, and reorganizes the grid and reroutes energy transmissions so that services continue for all customers while the problem is physically repaired by line crews.

Upgrading the grid infrastructure for self-healing capabilities requires replacing traditional analog technologies with digital components, software processors and power electronics technologies. These must be installed throughout a system so that it can be digitally controlled, which is the key ingredient to a grid that is self-monitoring and self-healing.

19. Does the smart grid need to have a self-healing infrastructure?

It needs a self-healing infrastructure to ensure that power grid can continue to operate reliably for businesses and consumers who depend on it. A smart grid that is overlaid with the various sensors, communications, automation and control features that allow it to deal with unforeseen events and minimize their impacts will be resilient and secure.

As I mentioned previously, the annual business losses in the U.S. from electrical failures average about $100 billion. Much of this is from short power interruptions. On any day in the U.S., about a half million people are without power for two or more hours.

Not only can a self-healing grid avoid or minimize blackouts and associated costs, it can minimize the impacts of deliberate attempts by terrorists or others to sabotage the power grid. Its ability to seamlessly maintain services under all of these types of conditions makes our country more secure. And overall, it improves the quality of electricity services for end users.

20. What are you currently reading?

I'm reading *Make It In America: The Case for Re-Inventing the Economy*, by Andrew Liveris, chairman and CEO of The Dow Chemical Company. The book argues that America needs a healthy manufacturing sector and that it must revitalize the sector to improve the country's economy.

This book resonates with me on many levels. I've worked in several innovation-enabled sectors and I've been engaged in projects that range from local to global in scale. I really believe that the best of America is yet to come. Many of the new "greatest generation" will be the veterans of the Armed Forces who will be tackling our most important technology goals. These future technology experts and innovators will find real ways to do things we now consider impossible. They'll make it possible to reduce the costs of electricity by 20-30%, for example, or substantially improve automotive batteries so vehicles can travel 200-250 miles on a single charge. They'll find ways to improve solar panels to reduce the cost per watt by 50%.

However, timing is critical. Many of us work at a pace governed by Moore's Law, which explains that the technical performance capabilities of silicon chips will essentially double every 24 months. Because of the pace of change, we have to make wise strategic choices when selecting and developing new technologies.

We must provide this leadership now. Here at home and throughout the world we have basic needs for job creation, economic growth and stability. Meeting these needs requires a systematic effort to reduce any uncertainties we have and to focus our efforts to meet our most strategic targets.

21. Who inspires you?

I am inspired every day by the many, many people in different walks of life whose humility, commitment to excellence and wisdom, courageous and unselfish acts all combine to advance progress and improve lives.

This message has been eloquently put into words by George Washington Carver: “How far you go in life depends on you 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.”

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