THE MAN BEHIND THE **SELF-HEALING GRID**

In an interview with Dr. S. Massoud Amin, the Professor of Electrical and Computer Engineering at the University of Minnesota, discusses his early career in the development and evolution of the self-healing grid and how he sees the smart grid evolving.

MI: With 20+ years' experience in the smart grid sector and having conceived and articulated the vision of the smart self-healing grid – how has the smart grid of today met/exceeded your expectations compared to your initial design of the potential capabilities of a future smart self-healing grid?

MA: To begin with a brief history, from 1982-1997 I worked on several projects with NASA-Ames, McDonnell Douglas, Boeing and the US Air Force on command/control, predictive analytics, optimisation and stabilisation of aircraft as well as, interdependent logistical and combat systems.

My work in aeronautics involved combining mathematical foundations of nonlinear dynamical complex systems, differential game theory, stochastic optimisation, dynamic risk assessment and artificial intelligence implemented with overlaid networks of sensing, and secure communications and controls.

These foundations formed the basis of the self-healing concept. As my research continued, I moved from studying the survival of individual aircraft to the survival of squadrons and large-scale complex networks, looking at how groups and networks can keep mission effectiveness when critical components, like fueling, go down. I discovered how power systems and interdependent coupled networks for fuel supply, energy and power and communication and energy markets, could be retrofitted or designed to automatically stabilise, optimise and correct themselves.

When I joined the Electric Power Research Institute (EPRI) in 1998, I had already been working on the self-healing concept for several years. However, the vision was articulated through the EPRI research advisory committee.

The original vision of the self-healing grid was a lot more aggressive with the success of research and development programmes for the electric power industry – including the EPRI/DOD Complex Interactive Networks/Systems Initiative (CIN/SI). The goal of the project, which took place between 1998 and 2002, was to retrofit US critical infrastructures and to build integrated networks that were secure, robust and self-healing, by developing and deploying layers of secure sensing, high-confidence communications, and automation networks. The vision was to transform the electric power system into a "smart grid" – an integrated, self-healing and electronically-controlled secure and resilient power system.

If you had asked me 18 years ago how long it would take for smart grid deployments to materialise –using available resources, phasing in real-time information and systems – my initial prediction would have been around 2010.

Additionally,while there have been widespread smart grid efforts globally in Europe, Japan, China, Korea, India and the Americas, progress has mostly occurred in the past six to seven years and is steady, but slower than what is realistically possible.

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While there have been good down payments made in terms of improving security, cost, increased reliability, resiliency, efficiency and sustainability of the electric grid, significant opportunities persist locally and globally.

MI: How has your original vision changed/developed as the smart grid has evolved?

MA: The basic vision of the smart self-healing grid has remained the same – to develop a system that integrates information, sensing, control and communication technologies to allow it to deal with unforeseen events and minimise their adverse impacts. This also involves the development of tools that enable secure, robust and reliable operation of interdependent critical infrastructures with distributed intelligence and self-healing abilities.

The emerging issues in smart grid have also remained fairly constant, subject to local and national priorities. They continue to focus on the integration of distributed energy resources and renewable energy, increasing system reliability, cyber-physical security and resilience, as well to improve efficiency, electrify transportation, and to reduce carbon footprint.

The smart grid is now a global phenomenon with every nation responding to the need for intelligent grids, subject to customers' preferences, social goals or policy mandates. There are commonalities in smart grid pursuits, but most efforts are concentrated at distribution level – this is especially true in the US, where customer empowerment and the corresponding ROI for businesses have been the primary focus.

We are getting closer to the original vision of a smart self-healing grid but we haven't yet gotten to the advanced stages where anticipatory control is employed. This is the point where abnormalities are detected and where these are immediately addressed.

Self-healing involves the holistic management and control at all levels of the grid – device level, communications layer and at the very top, command and control. Eventually, operation of the grid will require very little human intervention apart from general oversight.

MI: Are there any barriers that still remain to smart grid implementation – be they technological, policy/political or need for change in current markets and business models?

MA: While the smart grid industry, locally and globally, has undergone significant evolution in the past five years, much more

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is still to come. Over the next year, and over the next five to ten years and beyond, the industry will continue to face several major challenges and many opportunities that will require action.

We need to address a number of new challenges, such as how to integrate large-scale stochastic (uncertain) renewable generation rules) electric energy storage, distributed generation, plug-in hybrid electric vehicles, and demand response (smart meters). We must also realise methods to deploy and integrate new synchronised measurement technologies, new sensors and new system integrity protection schemes. In addition, we'll need better models (GEN and loads) in many regions across the world.

Every utility has a unique customer base, business model, legacy system and its own interests at stake in providing reliable, affordable power while promoting resiliency in the face of a myriad of vulnerabilities. While the system complexity has increased during the past 20 years and considering how different systems are across the country, we have developed the expertise to manage these differences, to improve quality of life through a highly reliable grid.

MI: How do you see the smart grid evolving over the next few years? What will we be calling the smart grid in five years' time and what will it look like?

MA: Over the next five years, smart microgrids will play a growing role in meeting local demand, enhancing reliability and ensuring local control of electricity. With this in mind, the smart grid community must address:

- Increased focus on cyber-physical security;
- Increased convergence and integration of enhanced power systems and power electronics, with ICT infrastructure and analytics;
- The growing relationship between smart grid and renewable energy resources;
- Issues surrounding renewable initiatives such as the Renewables Portfolio Standards in the US, including how to expand transmission systems and address operational challenges in response to increased regulations;
- New business models for cost recovery;
- Pricing services in relation to the value of reliability, power quality, conservation and innovation;
- Creating positive engagement with end-to-end stakeholder communities;
- Reducing uncertainty around ROI and creating efficient pathways to redesign, retrofit and upgrade the current electrical system to a smart, self-healing one driven by a well-designed market approach.

Some of the global drivers over the next few years will include: optimising energy resources and the efficient use thereof, integration of more distributed energy resources, microgrids, and energy storage and district energy systems.

Other drivers also include electrification of transportation, demand response increasing nature of transnational and interstate utilities.

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MI: What are your top three to five predictions for the global smart grid sector for the next 12-18 months?

MA: Technological:

- Increased convergence and integration of enhanced power systems and power electronics, with ICT infrastructure and analytics
- Smart Grid 2.0 will build upon the foundations already in place (smart meters, AMI/AMR, to increase situational awareness at the local distribution systems, put in more power electronics for automation and controls, and better VAR/voltage support at the distribution level
- Increased focus on cyber-physical security, layered defense, & policies around them.

Policy/Politics:

- The growing relationship between smart grid and renewable energy resources;
- Issues surrounding renewable initiatives such as the Renewables Portfolio Standards in the US, including how to expand transmission systems and address operational challenges in response to increased regulations.

Markets and Business Models:

- New business models for cost recovery;
- Pricing services in relation to the value of reliability, power quality, conservation and innovation;
- Creating positive engagement with end-to-end stakeholder communities;
- Reducing uncertainty around ROI and creating efficient pathways to redesign, retrofit and upgrade the current electrical system to a smart, self-healing one driven by a well-designed market approach.

Dr. S. Massoud Amin

Professor of Electrical and Computer Engineering | University of Minnesota

> ***"Dr. Amin has researched and written about smart self-healing grid concepts and solutions for over two decades"***

Dr. Massoud Amin has researched and written about smart self-healing grid concepts and solutions for over two decades. He has led research, development and deployment of smart grids and the enhancement of critical infrastructures' security during this period and is considered the Father of Smart Grids.

Before joining the University of Minnesota in 2003, he held positions of increasing responsibility at the Electric Power Research Institute (EPRI) in Palo Alto, California.

Nearly 18 years ago, while working at the Electric Power Research Institute (EPRI), Dr. Amin conceived and articulated the vision of a 'smart self-healing grid' where the use of computer, communication, sensing and control technologies operate in parallel with the electric power grid, to enhance reliability, improve security, increase resilience and reduce the cost of energy to consumers. Self-healing refers to a system that uses information, sensing, computational, control and communication technologies to deal with unforeseen events and minimise their impact.

This was a very bold concept and a radical departure from the status quo necessitating fundamental advances in research and development (R&D) activities of various disciplines.

Expressing this vision was only the first steps of the process in achieving the stated goals, as such massive projects require the successful collaboration of many individuals and organisations. Dr. Amin spearheaded the effort to create appropriate government/university/industry partnerships to tackle the problem. What emerged was the largest systems-theoretic R&D initiative during 1998-2001, a US$24 million joint EPRI/DoD initiative in complex interactive networks/systems (CIN/SI). This partnership provided funding to six research consortia consisting of 108 professors, over 200 researchers from 28 US universities, and two energy companies, to address modelling and management of US critical infrastructures. The success of this project has been demonstrated in various ways and includes 420 publications and 24 technologies extracted and implemented in industry.

Throughout the course of the CIN/SI, Dr. Amin formed alliances, led contracting, funding, and management of these government/university/industry consortia for the full range of basic research to products. His responsibilities also included supervision of all aspects of program administration (from concept to marketplace, including content, direction, evaluation, funding, contracting and IP/commercialisation), with numerous stakeholders. He engaged diverse groups (including 94% of the North American utilities, universities, companies, several US Government agencies, the US Congress, the National Academy of Engineering, the National Governors' Association, and the White House), with a clear mission-driven purpose to advance understanding the mathematical underpinnings of these complex and critical systems. Due to his pioneering work in smart self-healing grids, he is considered the "father of the smart grid."

With the accomplishments of the CIN/SI initiative and in response to 9/11, he was promoted and directed all security-related R&D at EPRI for our US utilities, including the Infrastructure Security Initiative and the Enterprise Information Security.

The impact of his leadership reaches beyond the creation of the smart self-healing grid, and is also evident from the following:

- The area of self-healing infrastructure, which Dr. Amin pioneered and works in, was recommended in 2005 by the White House Office of Science and Technology Policy (OSTP) and the U.S. Department of Homeland Security as one of three thrust areas for the National Plan for R&D in support of Critical Infrastructure Protection.
- His foundational work in the above areas has become a leading concept in sixteen on-going programs at EPRI, NSF, DHS, DoE and DoD. These initiatives continue to be widely successful at EPRI, DoE, national labs, and smart grid initiatives in the industry worldwide. Industries involved in developing/managing smart-grid technologies range from telecom/IT, semiconductors and equipment manufacturers to traditional energy suppliers.

Since 2003, he has given four briefings at the White House, ten Congressional briefings, and one testimony at the U.S. FERC on smart grids, security, and leadership in scientific R&D. He has also served as a US delegation representative to several world engineering and scientific congresses. He is regularly interviewed by the media including: New York Times; USA Today; Reuters; CNN; BBC; Washington Post; Forbes; Wall Street Journal; U.S. News; AP; NPR; and PRI. MI

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