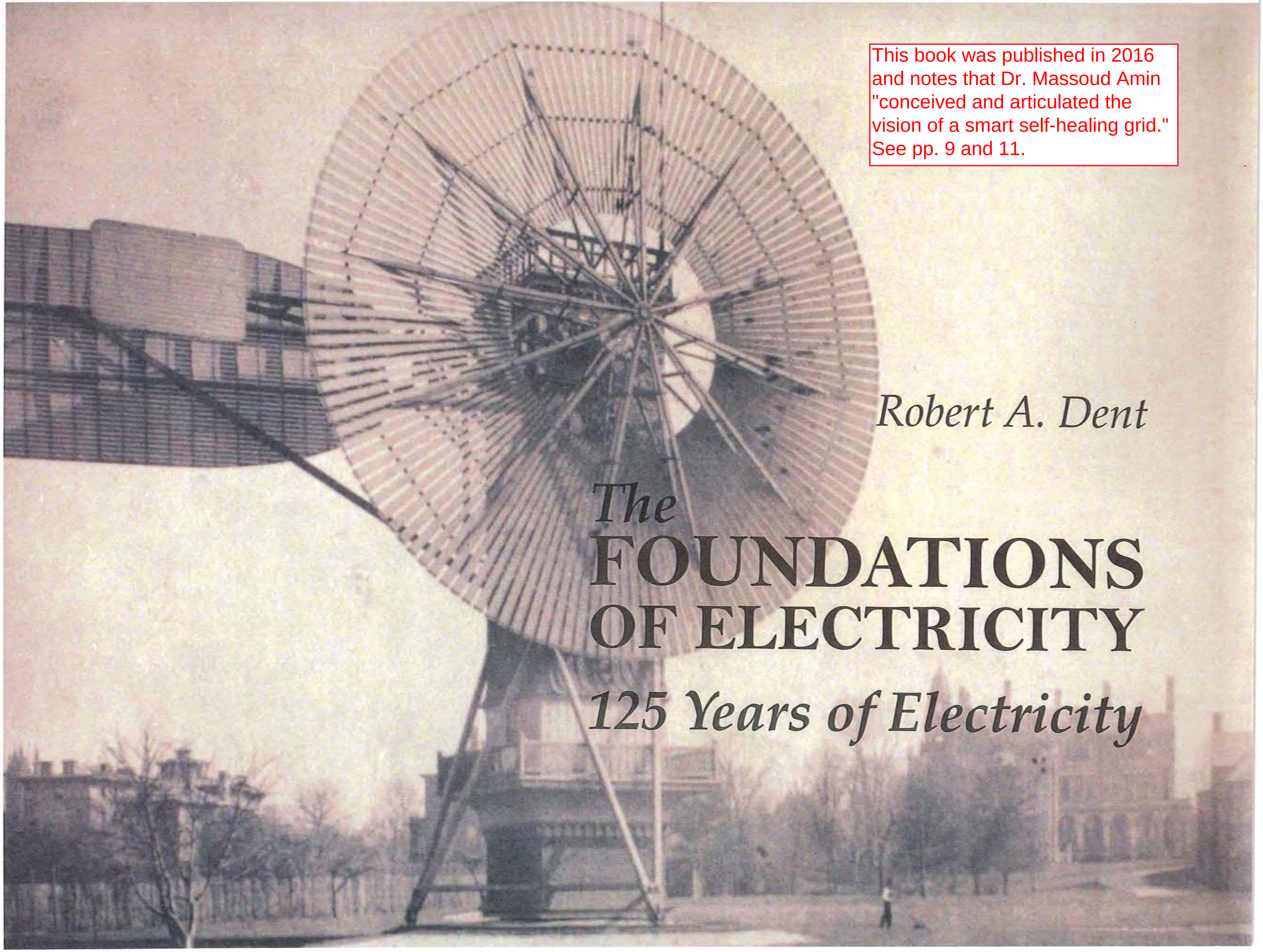
This book was published in 2016 and notes that Dr. Massoud Amin "conceived and articulated the vision of a smart self-healing grid." See pp. 9 and 11.



Robert A. Dent

The FOUNDATIONS OF ELECTRICITY

125 Years of Electricity

Foreword - IEEE PES President

Damir Novosel, Ph.D.

IEEE Power & Energy Society

President

IEEE

Advancing Technology for Humanity

The electric power grid is considered a marvel of engineering and one of the most critical infrastructures in the development of the human culture. Everything from information technology, to banking, transportation and water treatment, is dependent upon the power grid.

Modern society has reached a point where virtually every economic and social function depends on a secure and reliable grid operation. Our industry has been experiencing significant changes caused by new technology trends, environmental drivers and weather patterns, changing public needs, and regulatory requirements.

In the coming decades, the electric power and energy industry will be vastly different than it is today. As we contemplate what the grid of the future will look like and how it will meet the demands of society, it is imperative that we reflect upon the past 125 years of modern energy development and recognize that the initiatives we undertake today will affect the way we live in the future.

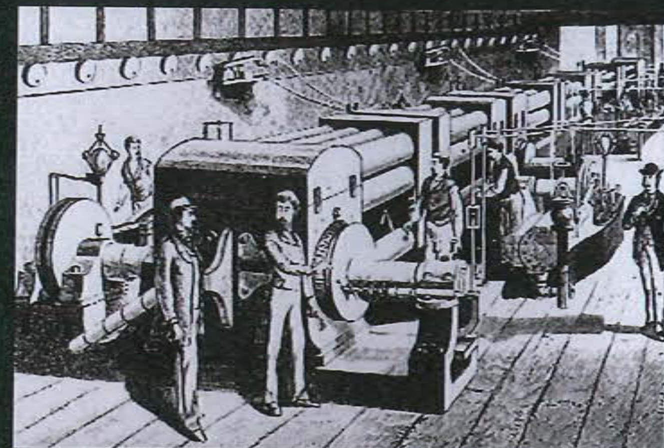
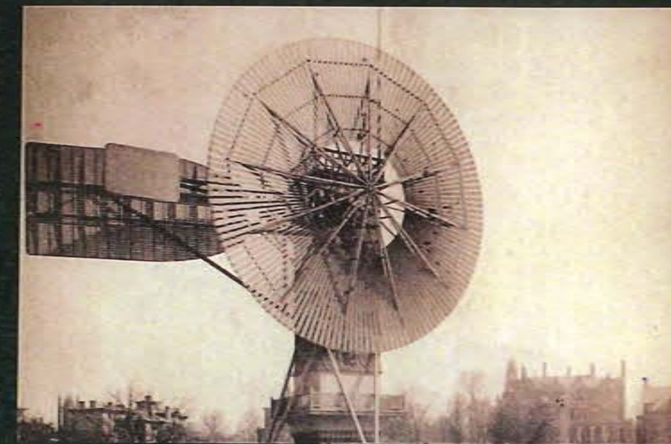
As this publication shows, the first electrical systems started as distributed systems with electric power plants delivering power to a local load. Within a few decades, the transmission system was created and spread to every corner of the globe, with many new applications. The grid continued to interconnect over the years, while focusing on generating power from central generating stations in order to achieve cost-effectiveness, reliability and safety, and most recently to serve open markets. It is interesting to note that the first wind generator produced electricity in 1887 in Scotland, the first electric car was on the road in the US in 1891, and a third of the cars on the road were electrical by 1904. While these trends did not continue at that time, the proliferation of wind generation and electrical vehicles has dramatically increased in the last few decades.

Major technological innovations in the areas such as renewable energy resources, storage, electric vehicles, automation, measurement devices, protection and control, materials, DC technology and robotics resulted in a paradigm shift of how we use electricity. Those innovations have enabled the development of new "smarter" electrical systems, using diverse energy resources, with both central and distributed generation schemes. These achievements have combined to enable fundamental changes in how we use and store electric energy to serve the growing needs of society.

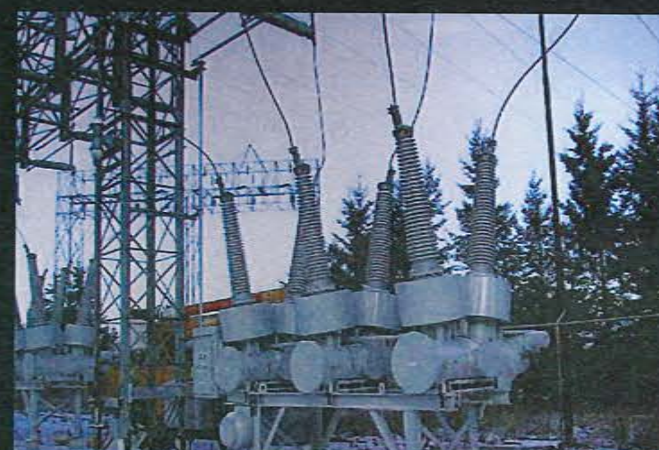
It is predicted that electrical resources, such solar, wind and other renewables, will continue to be the best untapped clean energy sources required to meet increased societal and environmental needs. The electrical power and energy sector will continue evolving as consumer expectations and options will change, technology breakthroughs will happen, and energy sources and their usage will be transformed. Electricity demand is expected to grow even with improvements in energy efficiency.

Globally, electrical energy will replace other forms of energy (e.g. using gasoline for transportation). This book provides valuable information on 125 years of electricity development and how it has formed the most critical infrastructure in the world. It helps us chart the course for the future as electricity will be main source of energy for years to come.

Damir Novosel

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Robert A. Dent

Editor-in-Chief

Robert A. Dent is presently the chair of the IEEE Power & Energy Society History Committee. As a PES volunteer, he has served the Society as its president, vice president, and head of the publications department. As an IEEE volunteer, he has been the director, Division VII and vice president, technical activities. He received the IEEE Millennium Medal in 2000 and PES Meritorious Service Award in 2001.

Mr. Dent is retired. Previously, he has held technical and/or managerial positions at The United Illuminating Co. (an investor-owned electric utility headquartered in New Haven, CT USA), Gibbs & Hill, Inc. (an engineering/design/construction company in New York, NY USA), New York Power Authority (a publicly-owned electric utility in New York State USA), and IEEE. At IEEE, he was the PES Executive Director from 2002 to 2007.

Robert Dent received his undergraduate degree from Stevens Institute of Technology. He has completed graduate degrees in Computer Science from Pratt Institute, and Electrical Engineering, and Management from Polytechnic Institute of New York (now, part of New York University). In 1987, he received the Dow Jones Wall Street Journal Student Achievement Award.

Preface

This book illustrates the significant developments of electricity over a 125-year period. These advancements are built on the discoveries of many giants of electricity, their theories, and the resultant products. The contributions to electricity have occurred by engineers around the world. The outcome of these developments is to make our lives more comfortable by reducing or eliminating drudgery, and for some, it has given them the opportunity to live better lives otherwise experienced only by the wealthy over the last one-hundred years.

This book also demonstrates that electricity has become an intrinsic part of most peoples' lives. The United States Academy of Engineering reviewed the 20th century's greatest engineering achievements. They listed the top 20 most significant achievements that shaped the century and changed the world. They rated electrification at the number 1 position. This finding reinforces the importance that electricity has had on our lives.

It is unfortunate that some people think of the electric power industry as staid and unimaginative. This is far from the truth for those of us who have worked and those who are still working in the industry. The impact of the grid on reliability; FACTS, HVDC, and adjustable-speed drives all using power electronics; high-voltage transmission lines using AC and DC and smart grid are just a few of the recent advancements to provide a more efficient and reliable electricity to consumers.

Robert A. Dent

Editor-in-Chief

Power Technology Timeline

- 1882 – Pearl Street DC Generating Plant.
- 1882 – Vulcan Street DC Hydroelectric Plant.
- 1882 – First Central Station in South Carolina.
- 1887 – First Windmill used to produce electricity built in Scotland.
- 1888 – First American Windmill to produce electricity in the Winter of 1888.
- 1891 – International Electro-Technical Exhibition (Frankfurt, Germany).
- 1893 – World's Columbian Exposition uses AC electricity to power lighting and exhibits.
- 1893 – Mill Creek No. 1 three-phase AC Generating Plant.
- 1895 – First large AC Hydroelectric Power Plant with Step-up Transformers (Adams).
- 1895 – Jaruga Hydroelectric AC Generating Plant in Croatia.
- 1895 – Folsom Powerhouse and associated Transmission Line.
- 1897 – Chivilingo Hydroelectric AC generation in Chile.
- 1890's – Pumped Storage Hydroelectric Plants are built in Switzerland and Italy.
- 1890's – The War of the Currents.
- 1902 – Shawinigan builds a 35-km, 50 kV Transmission Line to supply Montreal, Quebec.
- 1903 – Successful Gas Turbine accomplished (France).
- 1903 – Fisk Generating Station (First all Turbine Plant).
- 1909 – Shoshone Transmission Line.

- 1911 – Discovery of Superconductivity.
- 1921 – Lakeside Power Plant burns pulverized coal only.
- 1922 – CONVEX (Connecticut Valley Electric Exchange) pioneers coordinates utility connections.
- 1929 - Largest DC Generating Plant Privately owned.
- 1930's – HVDC in Sweden and Germany.
- 1936 – Boulder Dam was completed and supplied power to Los Angeles, CA through a 287-kV Transmission Line that spanned 266 mile
- 1953 – First 345-kV Transmission Line.
- 1954 – World's First Nuclear Power Plant generated power in Russia.
- 1964 – The use of Supervisory Control and Data Acquisition (SCADA) systems became widespread as the need for monitoring and control of remotely located equipment becomes more important.
- 1964 – Digital Network Analyzers are replacing Analog Network Analyzers.
- 1965 – First 735-kV Transmission Line (Canada).
- 1966 – Many Northeast electric utilities implement automatic under frequency load shedding schemes.
- 1969 - The first 765-kV transmission line was built connecting Ohio to Kentucky.
- 1970 – The Pacific DC Intertie from Celilo Station, Oregon to Sylmar Station, California started operation transferring 1,440 MW @ 400 kV.
- 1972 – The predominant electromechanical relay is challenged by the solid state relay.
- 1974 - The gas-insulated transmission line (GITL) is invented.
- 1976 – The high-voltage metal-oxide arrester was introduced.
- 1977 – A patent application is filed for an OPGW (Optical ground wire or optical fiber composite overhead ground wire) is submitted.
- 1983 – Introduction of a single-break SF6 circuit breaker for use at 245 kV and 420 kV, 550 kV, and 800 kV with 2, 3, and 4 chambers per pole, respectively. This led to a dominance of SF6 circuit breakers in HV and EHV stations.
- 1986 – The concept of FACTS (Flexible AC Transmission System) was first mentioned in an EPRI Journal.
- September 27, 1991 – A patent application is filed for an optical current transformer.
- 1998 – Massoud Amin conceived and articulated the vision of a "smart self-healing grid."
- 1999 – The first 1,000-kV transmission line with 2 circuits built in Japan.
- May 27, 2010 – A patent application is filed for an optical voltage transformer.

VIII

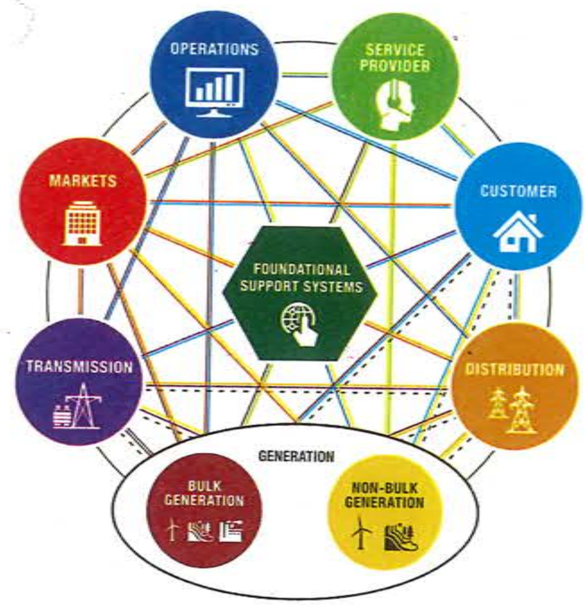
Road Ahead

Smart Grid

In January 1998, Massoud Amin conceived and articulated the vision of a smart self-healing grid where the use of computer, secure communications, sensing and control technologies overlay electric power grids to enhance reliability, improve security, increase resilience and to reduce the cost and emissions. He defined the term "Smart Grid" in the context of the Complex Interactive Networks/Systems Initiative (CIN/SI), which was launched as a joint project of the Electric Power Research Institute (EPRI) and the U.S. Department of Defense (DoD) announced in May 1998. What emerged was a $24 million joint EPRI/DoD Complex Interactive Networks/Systems Initiative (CINSI). This partnership provided funding, during September 1998- September 2002, to six university research consortia, comprised of 240 graduate students and 108 professors in 28 U.S. Universities along with 52 utilities and ISOs and the U.S. DoD, to address security and reliability challenges posed by interconnected and complex critical infrastructures.

The vision was to transform the modernized end-to-end electric power system into a "smart grid" – an integrated, self-healing and electronically controlled secure and resilient power system, necessitating fundamental advances in R&D into dynamical systems that range from advanced micro sensors-controllers to continental-scale coupled infrastructures.

The EPRI/DoD CIN/SI effort laid the foundation for several ongoing initiatives in smart grids and self-healing infrastructures focusing on smart reconfigurable resilient networks. In the case of developing a self-healing power grid, the key components and tools included anticipation of disruptive events, look-ahead simulation capability, fast isolation and sectionalization; and adaptive islanding and self-healing restoration.



IEEE Smart Grid Domains and Sub-Domains

Pictured are the IEEE Smart Grid Domains and Sub-Domains, inspired by the National Institute of Standards and Technology (NIST) Conceptual Model. Each of the eight domains features its own sub-domains, for a total 32 sub-domains.

The idea behind the development of the IEEE Smart Grid Domains and Sub-Domains was to establish a categorization that would allow Smart Grid contributions and activities to be combined for improved communications of stakeholders respectively into specific areas for better understanding of the activities and their correlations, to identify and address gaps in R&D areas through this collaborative effort.

While it is expected the IEEE Smart Grid model to evolve in time, this model provides a foundational approach for organizing existing and emerging Smart Grid-related activities.