Modelos e mudanças de paradigma no passado, presente e futuro dos sistemas energéticos de redes inteligentes

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Outline

- Philosophical Considerations - Vision of the Electric Grid
- New Models and Paradigm Shifts
- Grid Modernization – Paradigm Shifts
- Where does the Paradigm Shift Occur?
- The Unfolding of Paradigm Shifts
- Smart-Grid Technologies Development
- Past, Present and Future - Paradigm Shifts
- The Vision of the Future

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Philosophical Considerations

Overview of Dimensions, Their Quality or Core, and an Elaboration for a Smart Grid.

Dimensions	Quality or core aspects	Application to smart grid
Arithmetic	Discreet quantity, number	Measureable quantities like voltage, current, and power.
Spatial	Extent, unbroken extent	Spatial arrangement of transmission and distribution lines.
Kinematic	Movement, continuous movement	Rotating machines, energy flow.
Physical	Energy, interaction	Properties of conducting and isolating materials.
Biotic	Life, organic, vegetative, vital	Influence of energy generation and transport on life and vice versa.
Psychic	Feeling, sensitive, sensorial	Feelings of safety and control of humans in a smart environment.
Analytical	Logic, rational, analytical distinction, conscious distinction	Distinction between different types of grids: micro, smart, super and so on.
Formative	Controlled forming, power of freedom, power, domination	Control of power generation, distribution and consumption. Smart meters and the (dis-) empowerment of residential customers.
Lingual	Denotation, meaning, symbolic meaning	The meaning that customers attach to the term "smart grid".
Social	Intercourse, coherence, communion, interconnectedness	Influence of micro grids and smart grids on the behavior of and interaction between users.
Economic	Control of rare goods, stewardship, fertility, productivity	Price differentiation depending on momentary supply and demand. Return on investment of smart grids.
Esthetic	Harmony, beauty, allusion, full diversity of shades	Esthetics of buildings and systems. Beauty of V2G connection points. Design of smart meters and intelligent systems for households.
Juridical	Retribution, justice, law	Liability for a failing smart grid. Ownership of micro, smart and super grids. Privacy protection.
Moral	Love, care, fidelity, willingness to serve	Contribution of smart grids to a sustainable future. Safety of energy generation and transport .
Trust/Faith	Transcendental certainty, reliability, faith, credibility	Trust of consumers in micro and smart grids. Utopian trust in technological progress.

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A Philosophical Vision of the Electric Grid

- An Electric Energy Grid is a complex system that demonstrates great “unity” and “diversity”.
- It presents indissoluble interrelations among aspects and irreducible functionalities.
- It also shows “extensive expanse” and dynamic “motion”. The “power flow” reveals that it can be “live” or “dead. “Sensitivity” is necessary to avoid fatalities.
- Each crucial element of the grid must undergo significant and repeated “analytical examination and scrutiny” in order to achieve the highest levels of integration along with safety concerns, something that is typically given “formative actualization” via standards and engineering recommendations.
- Another crucial element is “signs and signals“ that electrical engineers employ to communicate to each other and with the grid at large.

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A Philosophical Vision of the Electric Grid

- There can be no room for error in the "meaning" that is given to the interrelationship of these signs so that the result will be a "unified harmony" of operation and interrelationships.
- Similarly, electrical grids perform an obvious significant "socially integrative" function as well as an "economic" purpose and can do so optimally only when it meets all the state's "legal" norms as well as the "ethical" norms of integrity and honesty that a given political order provides for the general welfare of their people in such a case.
- Finally, all grid planners must be committed to building a grid that the people can "trust" because they are "confident" regarding the "reliability."

New Models and Paradigm Shifts

In science and philosophy, a paradigm is a distinct / exclusive set of concepts or thought patterns, including theories, research methods, postulates, and standards for what constitute legitimate contributions to a field.

The world is a field in which change, and permanence contend. Change is rebellion. But behind this unending conflict arises the deeper truth—that change is but the mode in which permanence expresses itself.

Paradigm shifts occur in different ways over time: suddenly, progressively, and repeatedly (technology that come and go).

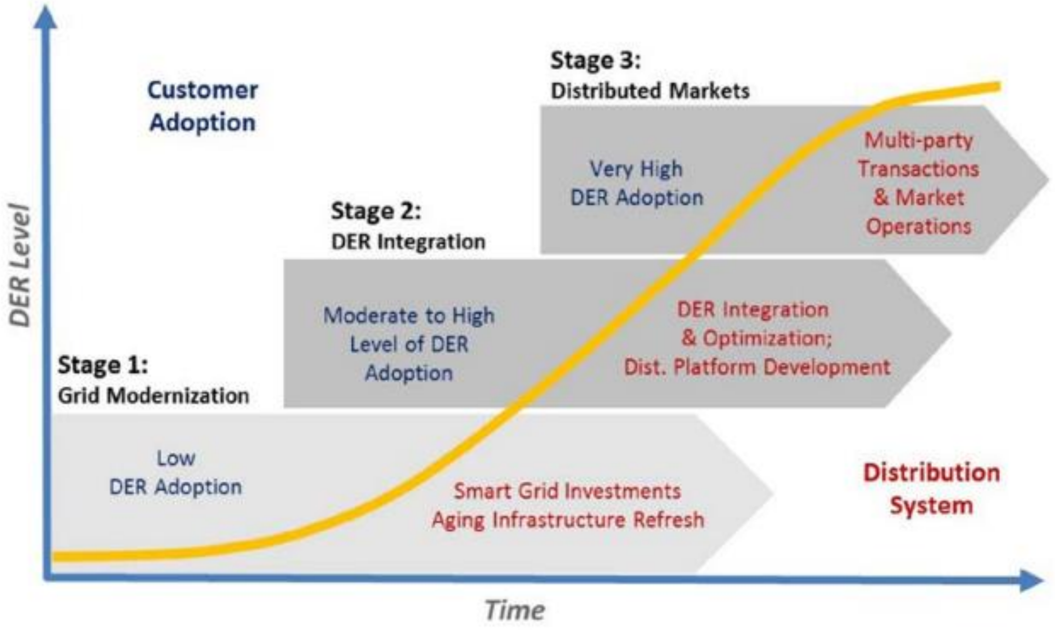
Occurs normally in stages: Modernization, Integration, Adoption

And dynamically: Trigger, Peak of Inflated Expectations, Trough of Disillusionment, Slope of Enlightenment and them Stable Utilization

New terminology does not always imply and paradigm shift

Grid Modernization – Paradigm Shift

Stages

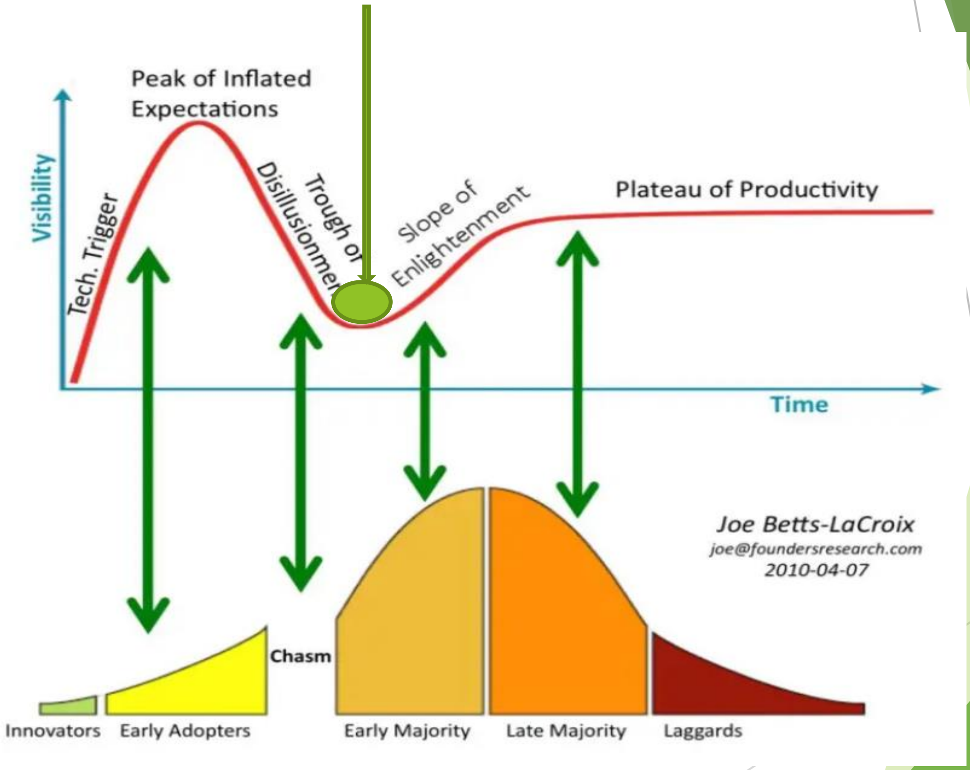


Grid Modernization – Paradigm Shift

Stages

Where does the Paradigm Shift Occur?

Dynamics



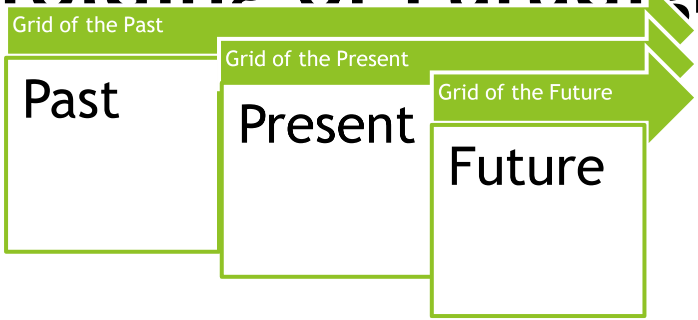
Phoenix Paradigm

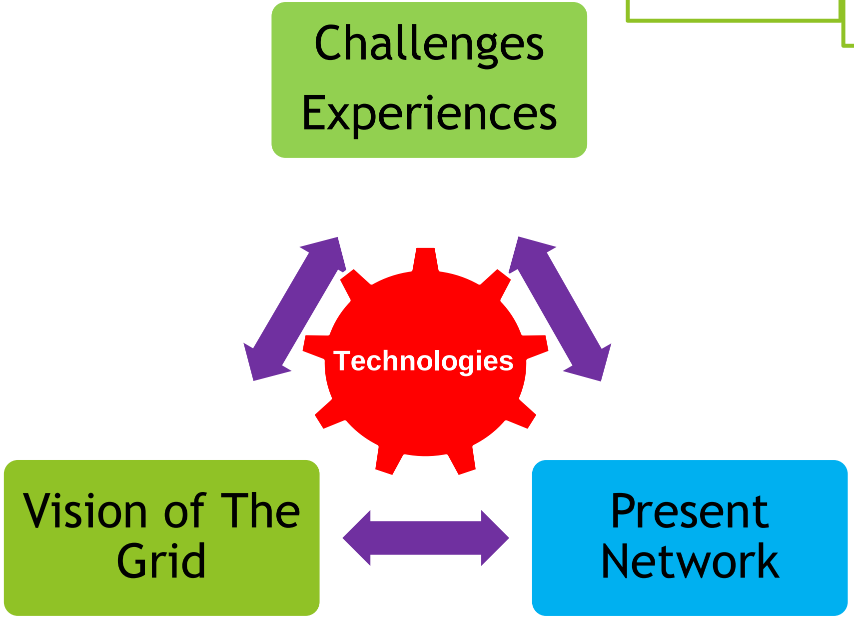
Paradigm Shifts Occur

When system transformations require interconnected changes to technologies, social practices, business models, regulations, and societal norms, and an intentional process design to fundamentally alter the components and structures that cause the system to behave differently, a paradigm shift is underway

New terminology does not always mean a paradigm shift occurred.The great difficulty is to present a very complex paradigm shift that happens suddenly. If we do justice to the complexity, the time the reader takes to understand will destroy the feeling of unexpectedness. If we get in the unexpectedness, we shall not be able to get in the complexity. It is like spectral analysis: when we get the frequency, we lose the time information. Paradigm shifts suffer from this language phenomena.

The Unfolding of Paradigm Shifts



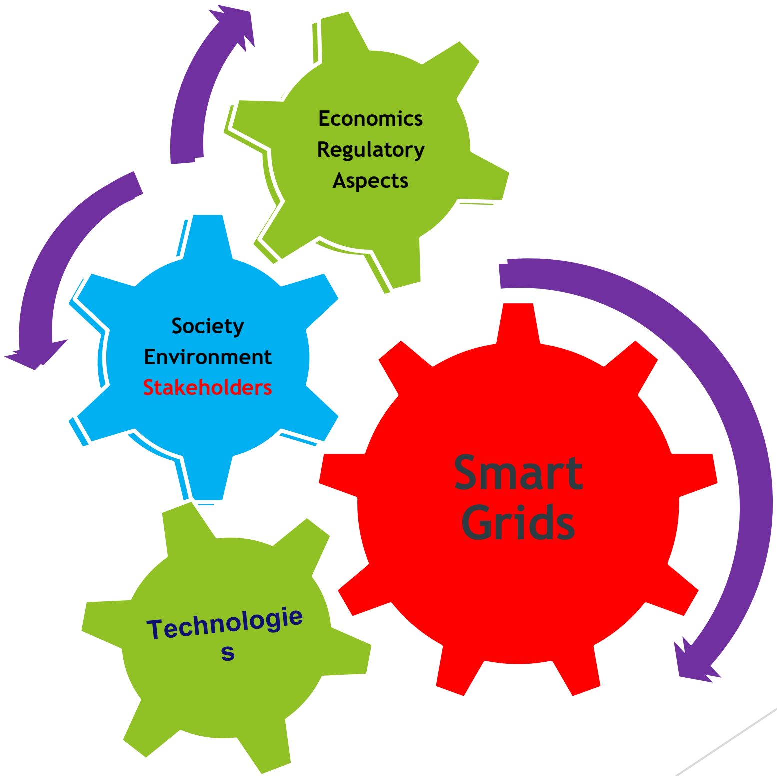


We all have learned in other fields of study how transitory the 'assured results of modern technology' can be.

We also need to be aware of chronological snobbery

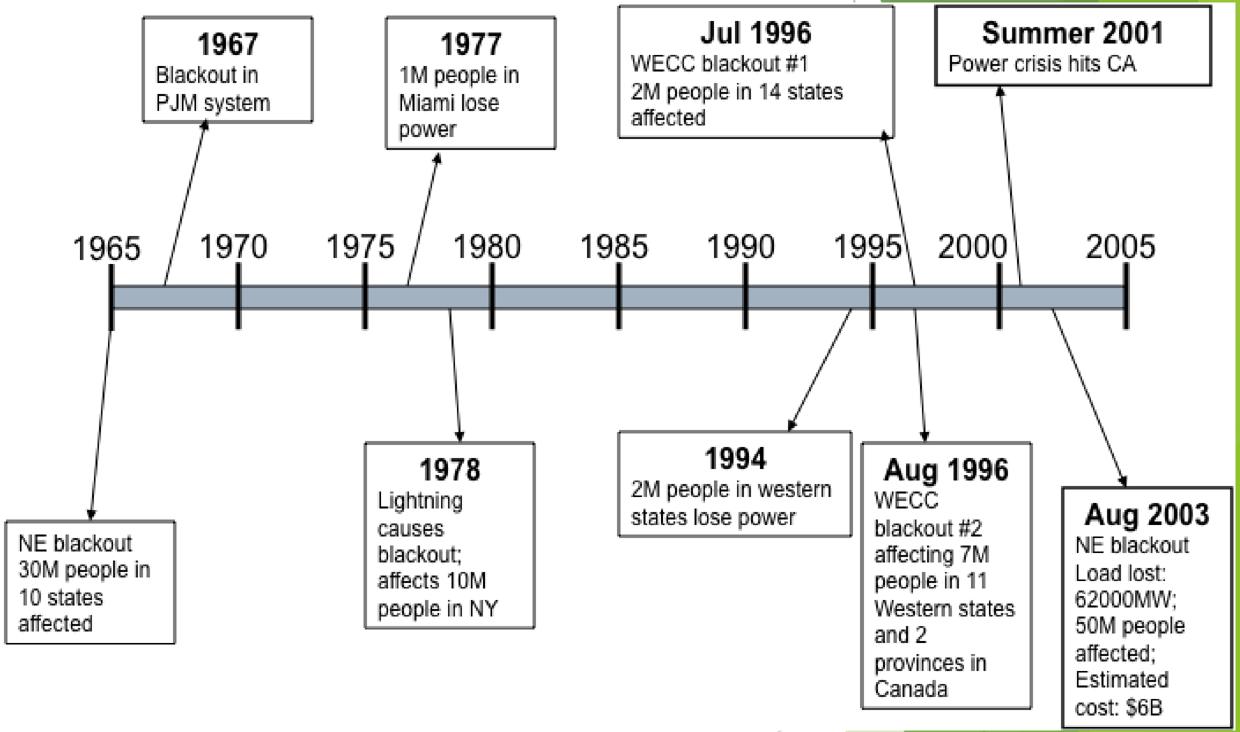
The Unfolding of Smart Grids

In designing complex technological systems the phases “analysis” and “creative design” are not successive steps but are strongly interwoven.



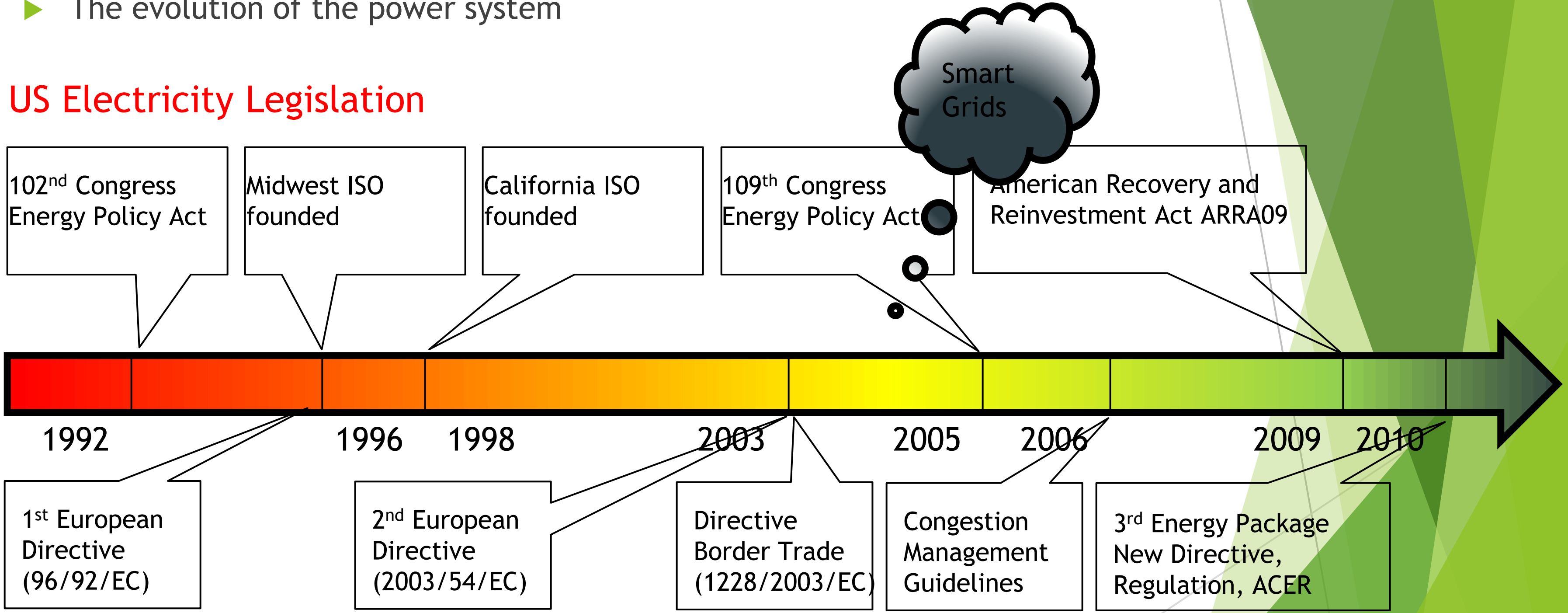
Smart-Grid Development

Timeline of some events related to the electricity grid with several legislative mandates which provided various opportunities for the modernization of the electric grid in US



Smart-Grid Development

- The evolution of the power system



European Electricity Legislation

Transmission, Distribution, Microgrids, Virtual PP, and Aggregators Smart Grid

1985 I was part of a team commissioning a 220cap-140ind MVAr SVC for Transmission Application.
1992 I went to EPRI on a fixed term appointment to assist Dr. Hingorani on modeling and simulating a particular design of a TCSC.
1995 I was responsible for design of a 30MVA Power Electronics Interface for a SMES device. Paradigm Shifts

Control Attributes	FACTS Controller
Voltage Control	STATCOM, SVC, UPFC, IPFC
VAR Compensation	STATCOM, SVC, UPFC
Damping Oscillations	STATCOM, SVC, SSSC, TCSC, UPFC, IPFC
Transient and Dynamic Stability	STATCOM, SVC, SSSC, TCSC, UPFC, IPFC
Voltage Stability	STATCOM, SVC, SSSC, TCSC, UPFC, IPFC
Current Control	SSSC, TCSC
Fault Current Limiting	TCSC, UPFC
Reactive Power Control	UPFC, IPFC
Active Power Control	UPFC

Past and Present Paradigm Shifts

Area	From	To	Driving Force	When First Proposed Applied
Transmission	Synchronous Condensers	Static Var Compensators	Power Electronics SCRs	1970s – 80s – 90s SVC Fortaleza Transmission Application in South America 1986
	Traditional AC Traditional DC	FACTS Devices	Power Electronics	1990s 1970s-1980s
		Statcom TCSC UPFC		

Past and Present

Area	From	To	Driving Force	When First Proposed Applied
Generation	Centralized	Distributed	Reduced costs of DER and local control/energy density	2000s
	Synchronous	Inverter Based	Power Electronics	2010s
Distribution Sub-transmission	No Generation	Customer Generation	Technology Advances	2010s
	Unidirectional Flow	Bidirectional Flow		

In 20 years, a small demonstration project – became a 50MW wind farm - - - Paradigm Shift

Past and Present

Area	From	To	Driving Force	When First Proposed Applied
Controls	PID	AI – Fuzzy-Neural	Technique Developments	2000s
	Individual Independent	Distributed Systemic		
System Performance	Voltage Quality	Power Quality	Better Integration with Economics	1990s

--	Voltage dip	Voltage swell	Harmonics	Supraharmonics	Slow voltage variations	Fast voltage variations	Flicker	Transients	Voltage unbalance	Frequency variations	Overvoltage	Primary emission	Secondary emission
Voltage dip	--		●	●					●			●	●
Voltage swell		--	●	●					●			●	●
Harmonics			--	●			●		●	●	●	●	●
Supraharmonics			●	--			●		●	●	●	●	●
Slow voltage variations					--								
Fast voltage variations						--							
Flicker			●	●			--	●		●	●	●	●
Transients			●	●			●	--					
Voltage unbalance			●	●					--	●			
Frequency variations			●	●						--			
Overvoltage			●	●					●		--		
Primary emission			●	●								--	●
Secondary emission			●	●								●	--

The Current Revolution in PQ is the Convergence of:

- Integration of AC and DC
- Advanced Energy Systems Management
- New Distributed Generation
- New Power Electronics Technologies
- Advanced Signal Processing and Analysis
- Advanced Monitoring
- Interlacement of PQ Parameters
- Higher Computer Power - Graphical Environment
- Advanced / Intelligent Communications
- Controls Systems
- Economics

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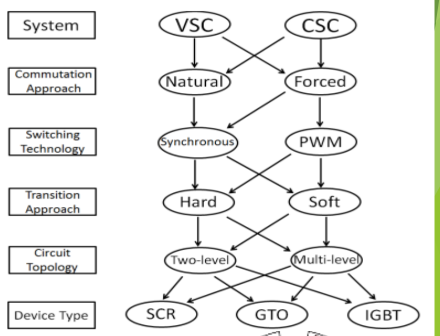
Past and Present

Area	From	To	Driving Force	When First Proposed Applied
Energy Storage	Hydro and Fossil Fuel	Diverse Forms	Renewable energy	2000s
	SMES, Flywheels, etc.			70s, 80s, 90s ..
Power Electronics	SCRs (1957)	GTO (60s), IGBTs (1983)	Semiconductor Developments	1990s
	Current Source Converters	Voltage Source Converters	Power Electronics	2000s

Application Area	ESS Service
Bulk Energy	Electric Energy Time Shift (Arbitrage) Electric Supply Capacity
Transmission Infrastructure	Transmission Upgrade Deferral Transmission Congestion Relief
Distribution Infrastructure	Distribution Upgrade Deferral Voltage Support
Customer Energy Management	Power Quality Power Reliability Retail Electric Energy Time Shift Demand Charge Management
Ancillary	Regulation Spinning, Non-Spinning and Supplemental Reserves Voltage Support Black Start

Diode (pn Junction)
Silicon Controlled Rectifier (SCR)
Gate Turn-Off Thyristor (GTO) GE
MOS Turn-Off Thyristor (MTO) SPCO
Emitter Turn-Off Thyristor (ETO) Virginia Tech
Integrated Gate-Commutated Thyristor (IGCT) Mitsubishi, ABB
MOS-Controlled Thyristor (MCT) Victor Temple
Insulated Gate Bipolar Transistor (IGBT)

Request for Proposal for a 30MVA VSC resulted in these 9 proposals



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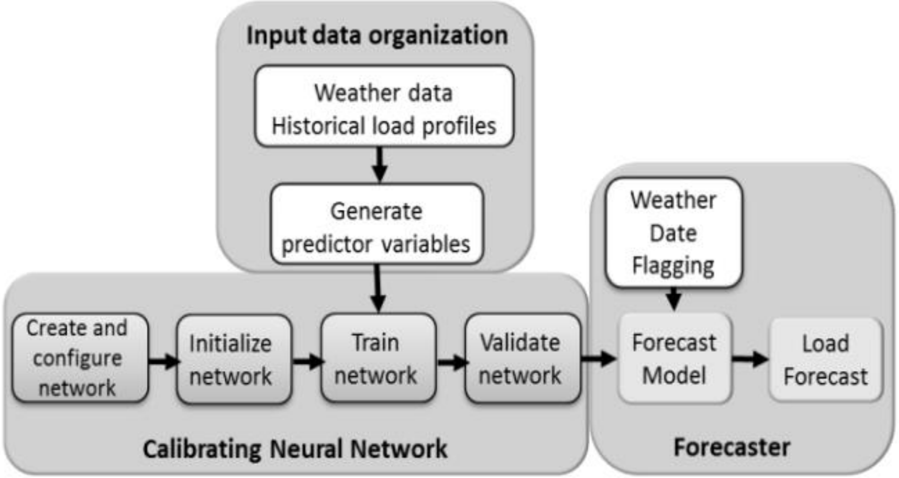
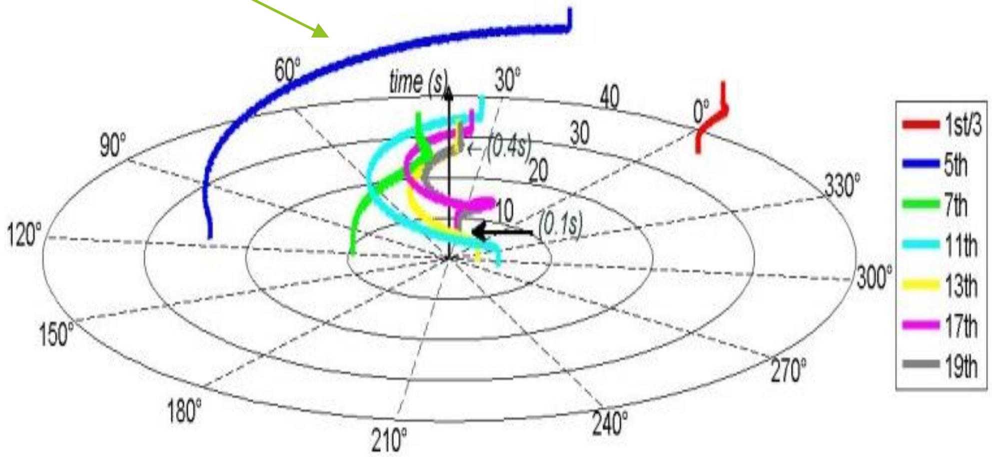
Past and Present

				When First Proposed
Protection	Electromechanical	Digital	Technology Advances	2000s
Load Forecasting	Traditional	AI	Internet of things	2010s
Signal Processing	Spectral Analysis	Time-Varying Analysis	Computational Developments	90s-20s

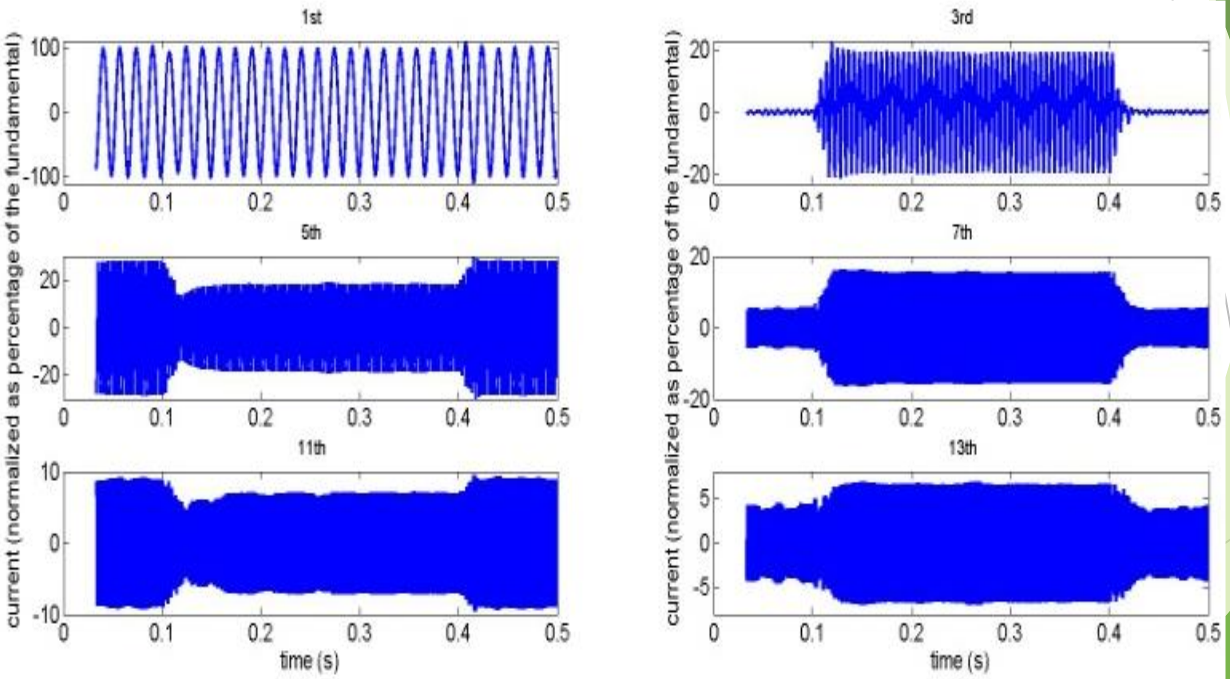




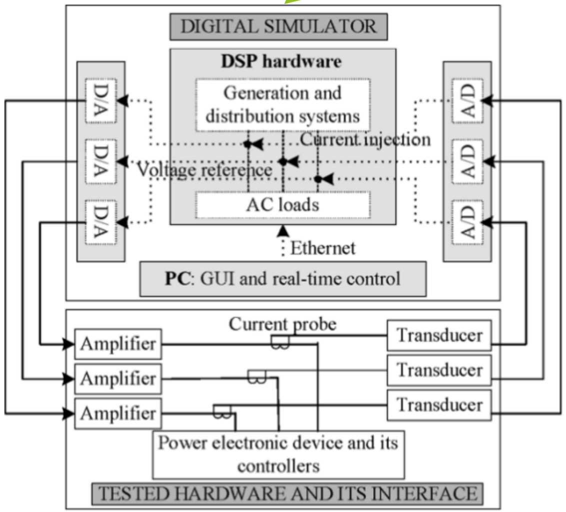
Time-Varying Harmonics Analysis

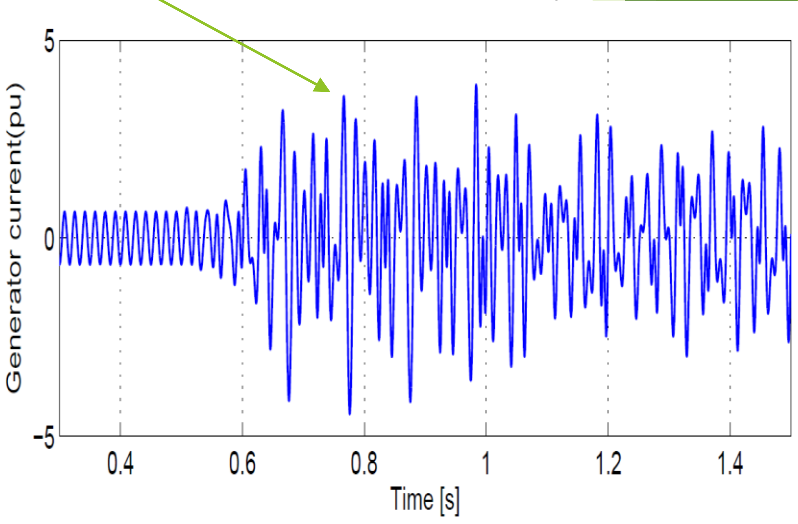
Interlacement of Voltage and Harmonics

A New Paradigm



System Modeling and Sim.	Traditional M&S	Real-Time Digital Simulation with Hardware-in-the-Loop	Computational Developments	2000s
	EMTP Type Computation	Multi-Physical Domain Simscape	Computational Developments	2000s





Past and Present

Communications	Dedicated Channels	Internet of Things (Internet of Energy)	Internet	2010s
Data Analysis	Statistical / Probabilistic	Big Data Analytics	Computational Developments	2010s
Structure of the Sector	State Owned	Private (US is municipal, cooperative, federal and investor owned)	Policy Changes	1990s
	Regulated	Deregulated	Policy Changes	1990s

Past and Present

Topology of the Grid	T&D	Microgrids with long distance transmission to support energy deficienties.	Technology Advances	2000s
Social Economic Approach	Energy as Business	Energy as Life-Sustaining	Technology Advances	2010
	Energy Access	Energy Democracy		
Finances	Traditional	Blockchain	Consumer participation into energy market	For future. Not yet. Blockchain will be a future tool to allow energy trade among prosumers
Storage **SMES Technology**	Fastest response to instabilities and oscillations			70s – 80s, 90s, ….2000 ..

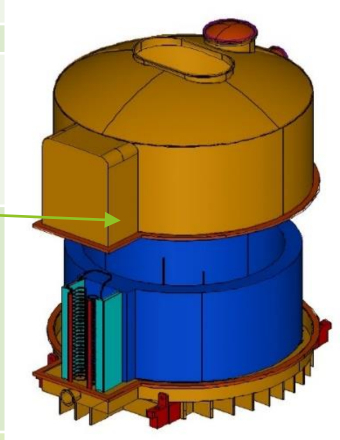
System Ratings
Power – 96 MW
Energy – 100 MJ (28kwh)
Power Exchange - +/- 50 MW
@ 0.2-3 Hz 15s
Voltage – 24 kV
Current – 4 kA

Future

				When it will take place
System Planning	Traditional Design	Systems Engineering and Engineering System	Distributed energy resources. Climate change affects sources of energy	2030s
	Ignore cyber design	Cyber design part of system design	Cyber threat	Late 2020s
	1 event in 10 years capacity resource target	Energy resource targets, not capacity	Integration of energy constrained resources	Late 2020s
System Modeling	Electrical, Mechanical ..	Multi-System (e.g. communications, natural gas)	Simulation requirements to develop new design basis for system reliability	2030s
Big Data Analysis	Computer Storage limitations and simple sensor technology	Unlimited (?) Computer Storage and advanced sensor technology	Faster control of systems, and ease in spotting trends/asset management	Late 2020s

Future

System Topology	AC Distribution	DC distribution	Local Generation and energy efficiency	Late 202s
Transmission	DC Point to Point	DC Multi-Terminal	Need to transfer energy to energy deficient areas	2030s
		Long distance transmission to bring energy from where it is excess to areas that are deficit.	Need to transfer energy to energy deficient areas	
Residential Customer	AC	DC	Local generation and energy efficiency	Late 2020s
	Mechanical Switches	All Digital – Apps Controlled	User Friendly interface	2020s
	Minimal generation	Active generation source	Breakthrough technology development	2030s
Energy Storage	Batteries SMES	SMES, long-term storage to support local deficits of wind and solar, or excess wind.	Intermittency and variability of Renewable energy sources and environmental sustainability	2030s 2030s
Energy Democracy Eliminating Energy Poverty	Uneven and undemocratic energy availability and affordability	Energy available to everyone that wants it, at a price that is affordable.	Social change and societal pressures. Advances in technology to enable reliable delivery at all times	2030s



Vision for the Future

Integrating

Smarter Grids - Smarter Cities -

- Holistic Micro-Grid Applications
- Residential Customer, Generation
- Active Voltage Support
- Distributed Storage
- Fault Detection, Isolation and Restoration
- Electric Vehicles Charging/Discharging Points
- Substation and Feeder Monitoring
- Renewable Distributed Generation Support

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Understanding the Changes In the Shifts in the Electric Industry

We can no longer dismiss the change of the electric grid model as a simple progress from error to truth. No model is a catalogue of ultimate realities, and none is a mere fantasy.... Each new model and paradigm shift will be a serious attempt to get in all the phenomena known at a given period, and each succeeds in getting in a great many.

But also, will reflect the prevalent psychology of an age almost as much as it reflects the state of that age's technological knowledge....

It is not impossible that our traditional model of the grid will die a violent death, ruthlessly smashed by an unprovoked assault of new Smart Grid facts - - - But I think it is more likely to change when, and because, far-reaching changes in the mental temper of our descendant's demand that it should.

The new Smart Grid will not be set up without evidence, but the evidence will turn up when (and if) the inner need for it becomes sufficiently great.

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Vision for the Future

Integrating:

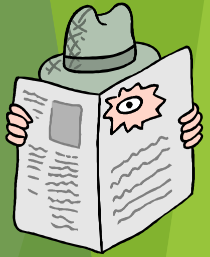
Engineering - Multi-Disciplinary
Engineering Design Philosophy
Engineering Ethics

Smart Grid + Smart Cities >>>> Smart Living

Vision for the Future

And do not worry
Just keep doing your best!

Reflections and Conclusions



The grid is evolving as a response to societal demands - - - challenges and opportunities

Technologies, and standards are available - - - and still needed - - -

Cooperation of stakeholders is essential - - -

Many paradigm shifts will occur in a dynamic and ever-changing environment.

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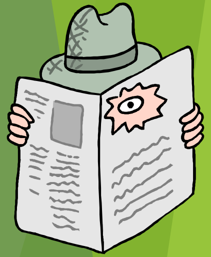
Reflections and Conclusions



Neither personal prejudices nor vested interests can permanently keep in favor a model of the grid which cannot be technically and economically justifiable.

The grid of the future, call it: Smart, Smarter, Intelligent, Flexible, Modern, Integrated, Clean, Affordable, Edge, Virtual, etc. will triumph over the traditional one (if it does) not because the current model is desperate, but only if it proves to be a better one.

When the Smart Grid model is abandoned in the future (I will not be around), the same principle will be in operation. The post-smart-grid-edge model will depend on the technical developments as well as on the human psychology and preferences.

Questions?

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