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Data-Centric Evolving Power Grid

Tuesday, 27 June 2023 | Technical Engineering Webinar

Presented By

Professor Akhtar Kalam | EIT Academic Board Deputy Chair

About EIT

EIT
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We are dedicated to ensuring that you receive a world-class education and gain skills that you can immediately implement in the workforce.

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EIT is one of the only institutes in the world specializing in Engineering. We deliver professional certificates, diplomas, advanced diplomas, undergraduate and graduate certificates, bachelor’s and master’s degrees, and a Doctor of Engineering.

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Introduction - Presenter

"My vision is to provide exciting higher education science and engineering courses, research, consultancy and collaborate in development work of the industry and communities within Australia and beyond."

Professor Akhtar Kalam JP

BSc, BScEng, MS, PhD, FIET, CEng, FAIE, FIEAust, CPEng, PEV, NER, APEC Engineer, IntPE(Aus), MCIGRE, Life Senior Member of IEEE

Head of External Engagement and Professor at Victoria University
Chair and Deputy Chair of TCA and EIT Academic Board, respectively
Director of Al-Kalam Educational Solutions
Editor-in-Chief of AJEEE

- Distinguished Professor/Adjunct Faculty in Australia, India, Malaysia and Oman
- Published over 610 publications in his area of expertise and written over 29 books in the area
- Supervised 49 postgraduate research students to graduation consisting of 38 PhDs and 11 MEng. Currently, 12 postgraduate research students being supervised (one MEng student)
- Public, University and Motivational Lecturer
- Consultant for the electricity supply industries
- Assisted in change management plans to Universities and higher education sector.

Education

- The University of Bath, Bath, UK, PhD, Electrical Engineering
- The University of Oklahoma, Norman, USA, MS, Electrical Engineering
- Aligarh Muslim University, Aligarh, India, BScEng, Electrical Engineering
- St Xavier's College, Calcutta, India, Applied Science.

Professional Society Activities

- Australian Institute of Energy – Fellow
- Engineers Australia – Fellow
- The Institution of Engineers and Technology, UK – Fellow
- The Institution of Electrical and Electronic Engineers, USA –Life Senior Member.

Agenda

1	Welcome and Introduction
2	Drivers for change of design and operation of electrical power systems
3	Challenges facing designers and operators of net-zero power systems to ensure system resilience
4	Identified challenges and Smart Grid
5	Conclusion and Q&A

Evolving Power & Energy Network

- **Evolving/new market structures/operation**
  - Increasingly liberalised market
  - Increased cross-boarder bulk power transfers to facilitate effectiveness of market mechanisms
- **New generation/storage technologies (mostly PE interfaced and often not visible to system operator, ie, <100 MW typically invisible to SO)**
  - Proliferation of non-conventional renewable generation (large on-shore & off-shore wind farms & PV) and storage at all levels - largely stochastic and intermittent
  - Small scale (widely dispersed) technologies in DN

Evolving Power & Energy Network

- Proliferation of PE based “transmission facilitating” technologies
  - Increased use of HVDC lines of both, LCC and predominantly VSC MMC technology (in meshed networks and as a super grid)
  - Increased presence of static and active shunt and series compensation
  - Increased deployment of FACTS devices in general
- New types and operational patterns of load
  - New types of loads within customer premises (e.g. heat pumps, PE loads, lighting), some with greater controllability
  - Electric vehicles (spatial and temporal uncertainty)





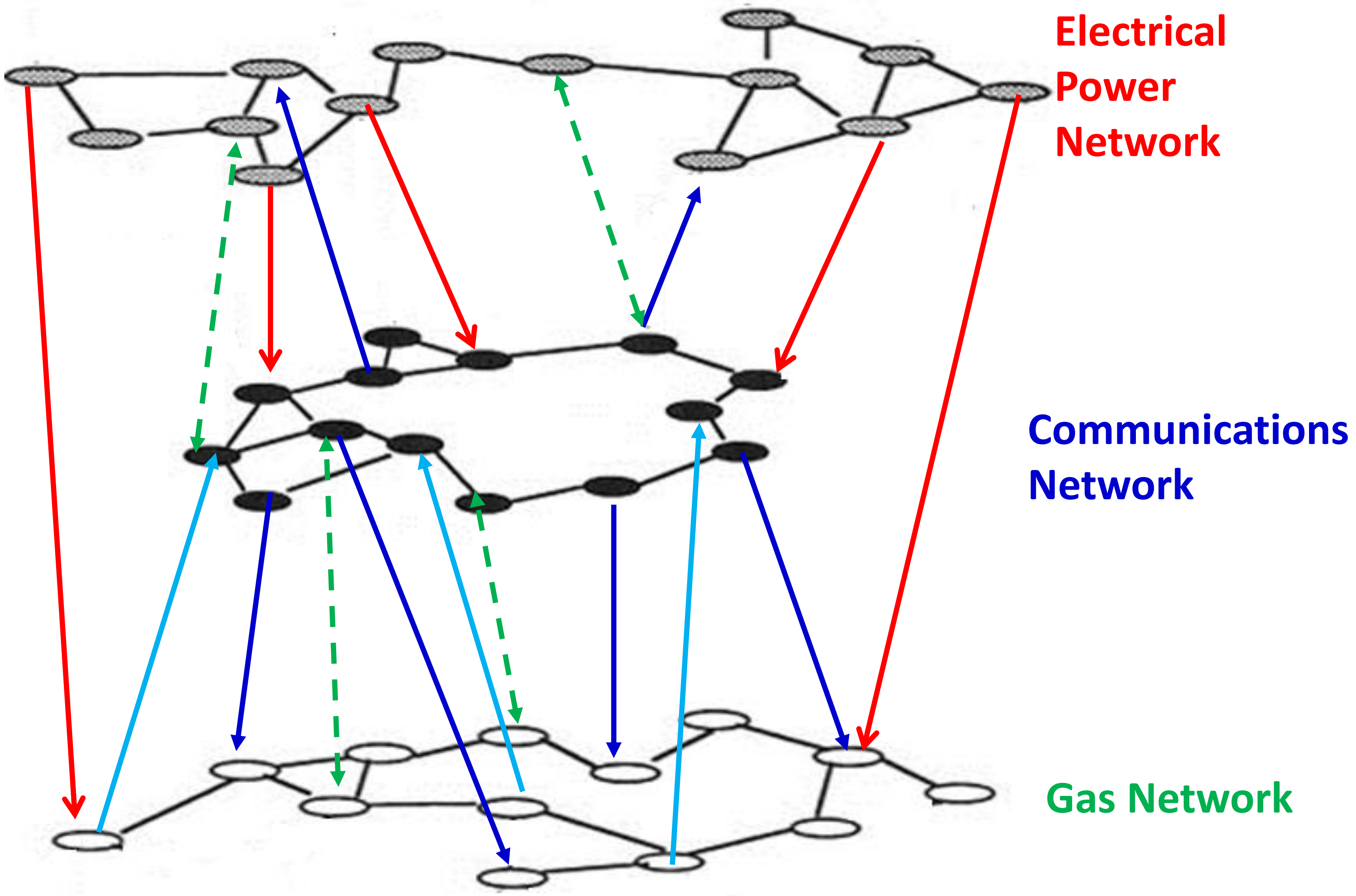




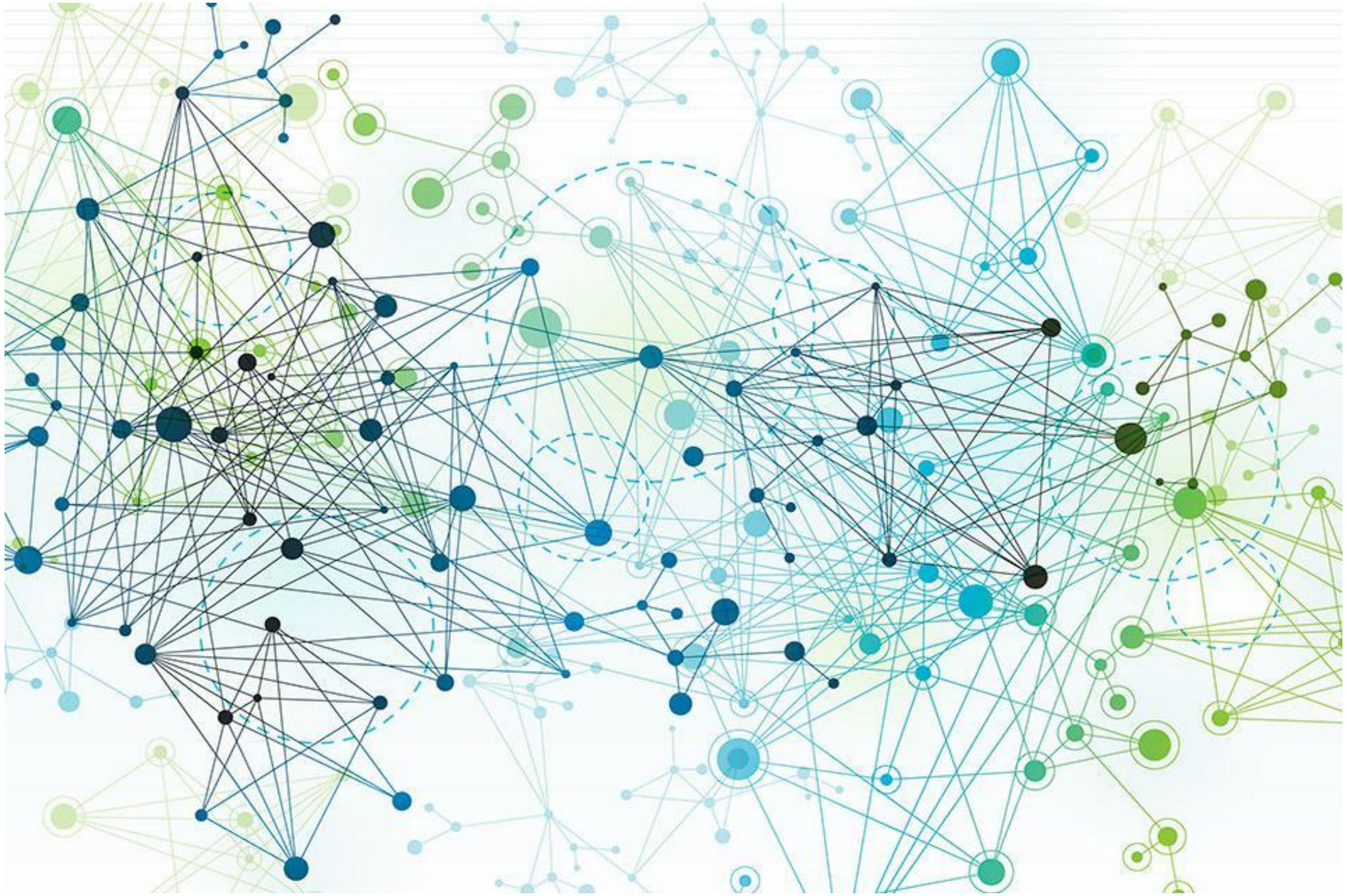
Evolving Power & Energy Network

- Energy & information security of integrated systems require integrated approach
  - Integrated ICT - Information extraction challenges
  - Integrated “intelligent” PE devices enabling bi-directional information flow
  - Different energy carriers
  - Cyber security


Integrated systems - System of systems



Smart* (Building, City, Network…)



Is this
a future model of
“Smart City/Network”?

Natalie Wolchover, “Treading Softly in a Connected World”, Quanta magazine, March 18, 2013, https://www.quantamagazine.org/20130318-treading-softly-in-a-connected-world/

“ID” of Future Power & Energy Networks

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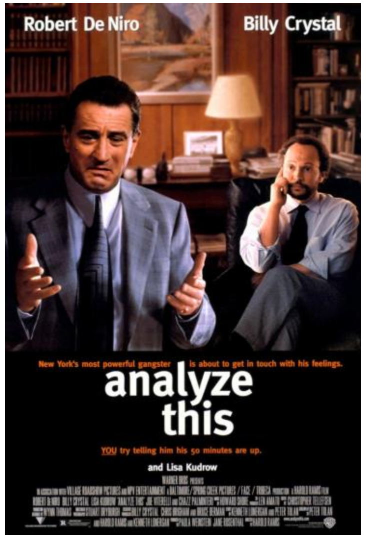
- Evolving/new market structures/operation (**variable** power flows)
- New, largely **uncertain**, generation/storage (PE connected) technologies
- Proliferation of PE based “transmission facilitating” technologies
- New types (many PE based) and operational patterns of **temporally and spatially varying and uncertain** load
- Abundance of **data**
- **Energy & information security** requires integrated approach









Uncertainties & Data!

Possible threats – What can go wrong?

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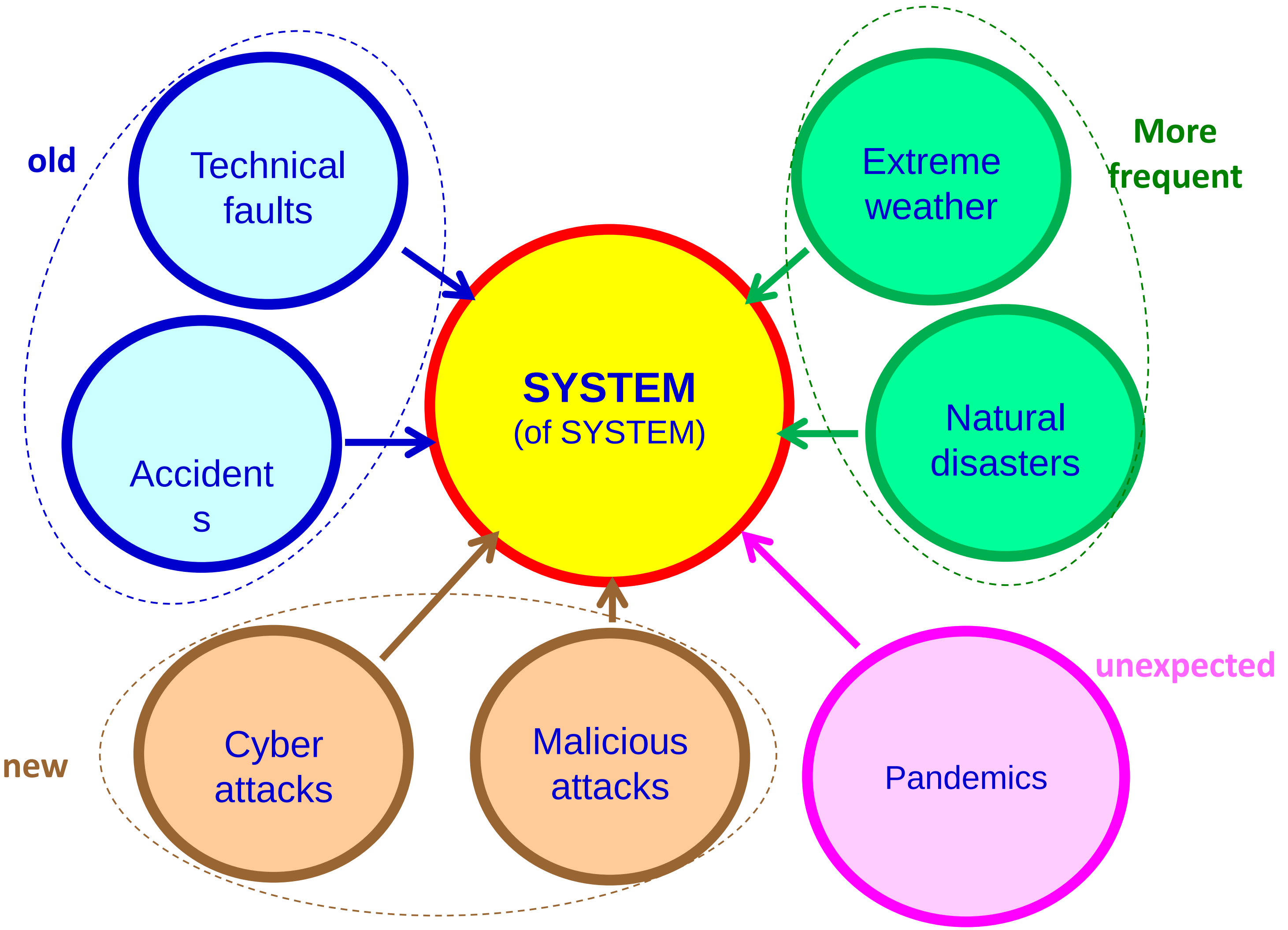
Clearly all these phenomena/events are stochastic, their effects on the system are different, widely spread and potentially disastrous and they have to be appropriately modelled and accounted for in all aspects of system planning, operation and control



Network Resilience

The network needs to be resilient to future risks with particular focus on

- network resilience - “classical” resilience of physical assets
- workforce resilience - available skilled, trained and content workforce
- cyber resilience - data and ICT network resilience

Power System Resilience

The power system resilience is the **ability** of this system to **withstand disasters** (low-frequency high-impact incidents) efficiently while ensuring the **least possible interruption** in the supply of electricity, sustain critical social services, and enabling a quick recovery and restoration to the normal operation state.

Long term monitoring data combined with probabilistic (forecasted) evaluation of metrics

Comprehensive (multi-faceted) and credible evaluation of the impact is necessary

Metrics

- Power/energy “not supplied”
- Duration “of interruption”
- Frequency of “impactful event”
- Probability of “impactful event”

Impact

- Economic
- Social
- Geographic
- Health & Safety

Power System Resilience

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"Power system resilience is the ability to limit the extent, system impact, and duration of degradation in order to sustain critical services following an extraordinary event.

Key enablers for a resilient response include the capacity to anticipate, absorb, rapidly recover from, adapt to, and learn from such an event.

Extraordinary events for the power system may be caused by natural threats, accidents, equipment failures, and deliberate physical or cyber-attacks"

EEE PES Task Force & "Methods for Analysis and Quantification of Power System Resilience": A.M. Stankovic(Chair), K.L. Tomsovic (Co-Chair), F. De Caro (Secretary), M. Braun, J.H. Chow, N. ˇCukalevski, I. Dobson, J. Eto., B. Fink, C. Hachmann, D. Hill, C. Ji, J.A. Kavicky, V. Levi(, C-C. Liu, L. Mili, R. Moreno, M. Panteli, F.D. Petit, G. Sansavini, C. Singh, A.K. Srivastava, K. Strunz, H. Sun, Y. Xu, S. Zhao (Members), IEEE Transactions on Power Systems (Early Access), 10 October 2022 DOI: 10.1109/TPWRS.2022.3212688

Outline of presentation

- Drivers for change of design and operation of electrical power systems
- Challenges facing designers and operators of net-zero power systems to ensure system resilience
- Identified challenges and Smart Grid
- Summary

Challenges - 1

- DATA: Efficient use and reliance on existing and newly acquired data through deployed local measurement devices and two-way communications enabled meters and global monitoring data (WAMS) for state estimation, static and dynamic equivalents and control (including real time control)
  - Efficient data management (signal processing, aggregation, transmission) and ICT network reliability are essential for both static and dynamic observability as well as for operation and control of the system

Data Analitics – Data is not information

Challenges - 2

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- MODELLING: for steady state & dynamic studies
  - Variable, and to extent stochastic, operating conditions influenced by market forces and uncertainty in generation and load
  - Clusters of RES (generation and storage) of the same or different type some of those not visible at transmission level
  - Demand, including new types of energy efficient and PE controlled loads, heat pumps, customer participation and behavioural patterns, EV, etc.
  - Storage technologies for provision of ancillary services
  - Large interconnected networks with mixed generation technologies including highly stochastic renewable generation, FACTS and short/long distance bulk power transfers using HVDC lines
  - Modelling/analysis of efficient and effective integration of different energy carriers into self sufficient energy module/cell
  - Interconnected critical infrastructure systems, “system of systems”

Too many uncertainties to justify conventional deterministic modelling – the probabilistic modelling is necessary

Challenges - 3

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- CONTROL: Design of advanced controllers and control structures – increased network automation
  - Design of supplementary controllers based on WAMS to control and stabilise large system (including real-time) or parts of it (which may vary) with uncertain power transfers and load models and stochastically varying and intermittent PE connected generation, demand and storage – *stochastic/probabilistic control of systems with reduced inertia*
  - Design of new control systems/structure (distributed, cooperative or hierarchical, adaptive, close to real time) for power networks with fully integrated sensing, ICT technologies and protection systems – *risk limiting control*

Risk is an uncertain event or condition that, if it occurs, has an effect on at least one objective, it is the probability of something happening multiplied by the resulting cost or benefit if it does.

Real time risk limiting control

Addressing identified challenges

DATA: Introduce Data analytics for planning, operation and control

- New skills of the workforce are required: re-training, re-skilling and employment of people from non-engineering (e.g., computer science, mathematics, communications, social science, etc.) backgrounds

MODELLING: Strong emphasis will need to be put on developing appropriate, most likely probabilistic models of components, processes and events

- New skills of the workforce are required: re-training, re-skilling and employment of people from non-engineering (e.g., mathematics, social science) backgrounds

CONTROL: New control approaches (stochastic distributed control), greater network automation, deliver real time risk limiting control of the system.

- New skills of the workforce are required: re-training, re-skilling and employment of people from non-engineering (e.g., control systems, mathematics, communications) backgrounds

Outline of presentation

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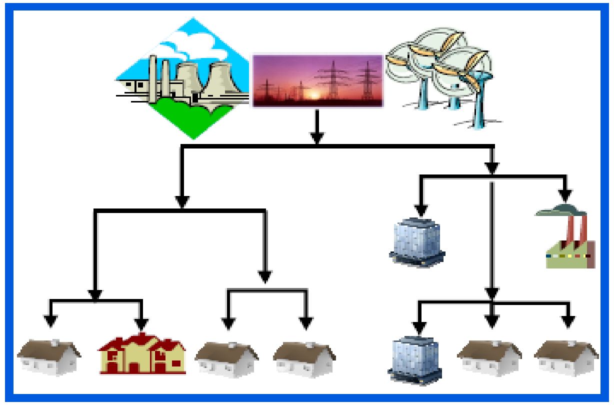
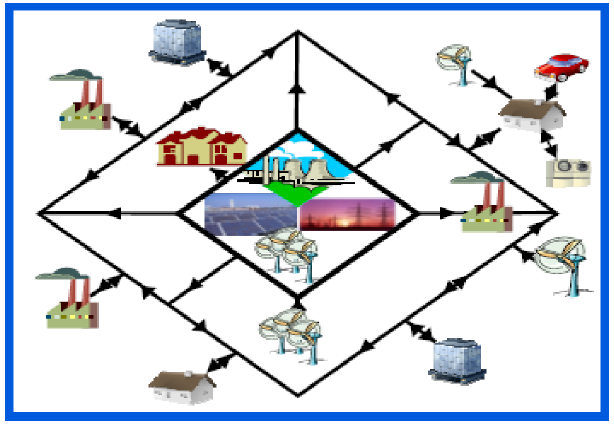
Evolution of grid design
From traditional to future grids

traditional grids



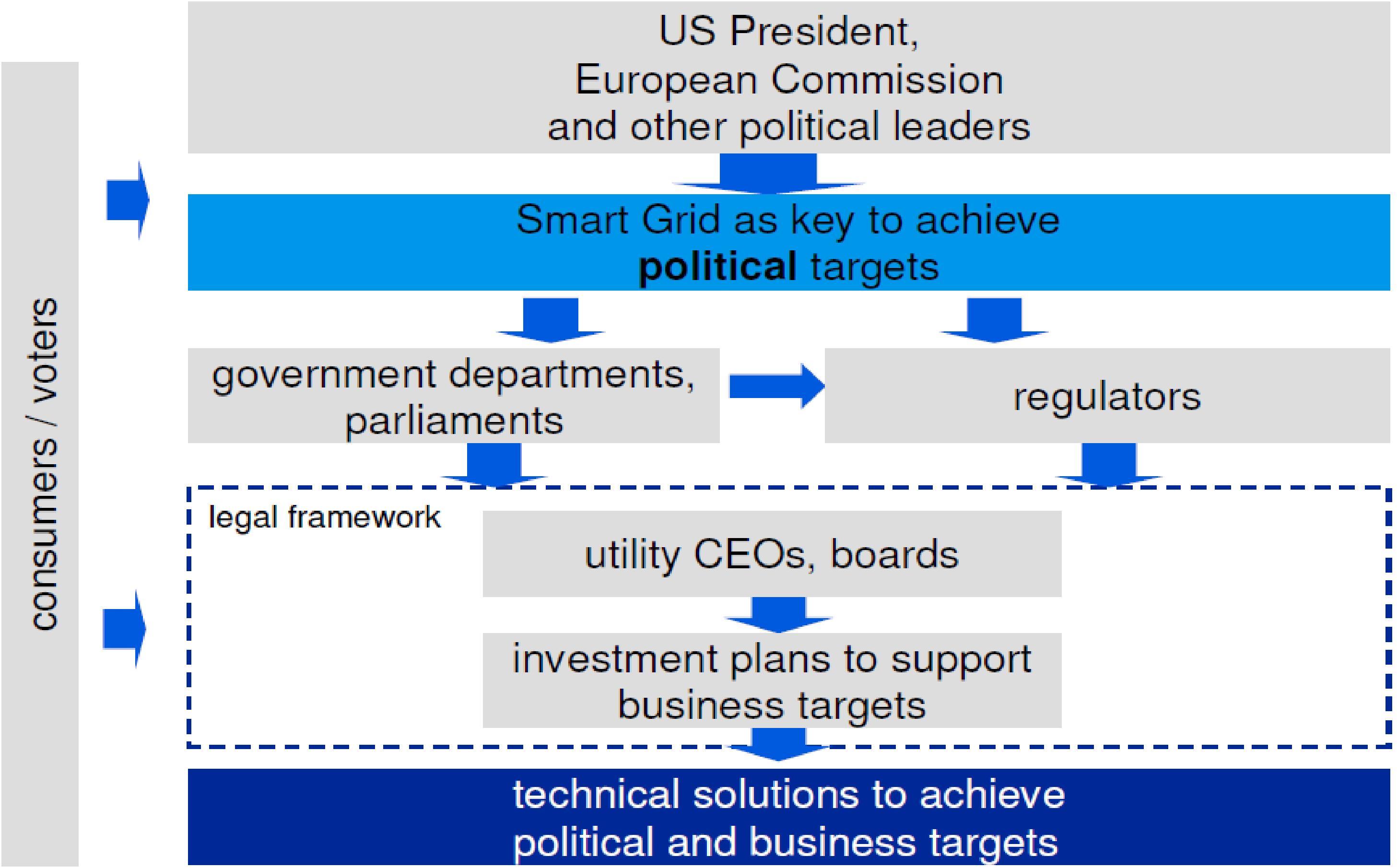
- Centralized power generation
- One-directional power flow
- Generation follows load
- Operation based on historical experience
- Limited grid accessibility for new producers

future grids



- Centralized and distributed power generation
- Intermittent renewable power generation
- Consumers become also producers
- Multi-directional power flow
- Load adapted to production
- Operation based more on real-time data

But Smart Grid is also a political issue
Many players need to be informed consistently



SMART GRID PORTFOLIO

Production

traditional power plants

solar generation

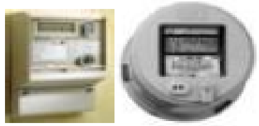
wind farms

distributed generation

Smart Grid

- **Network Manager** for market operation system including real time pricing and control centers including wide area monitoring, outage management, power applications for wind/solar integration,
- **Substation and feeder automation** including IEC 61850
- **Utility communication systems** for power line carrier, optical fibre and wireless communication
- **FACTS** for increased grid stability and grid code compliance of renewable production
- **SVC Light® energy storage** for stationary battery storage
- **HVDC Classic** and **HVDC Light®** for efficient long distance transmission
- **Integration of**
  - **Wind and solar power production**
  - **Electric vehicles** including outlet boxes for charging, demand response and communication
  - **Smart meters** for demand response and improved outage management, network planning, quality monitoring
  - **Industrial energy management systems** for demand response
  - **Smart house devices** for demand response

Consumption



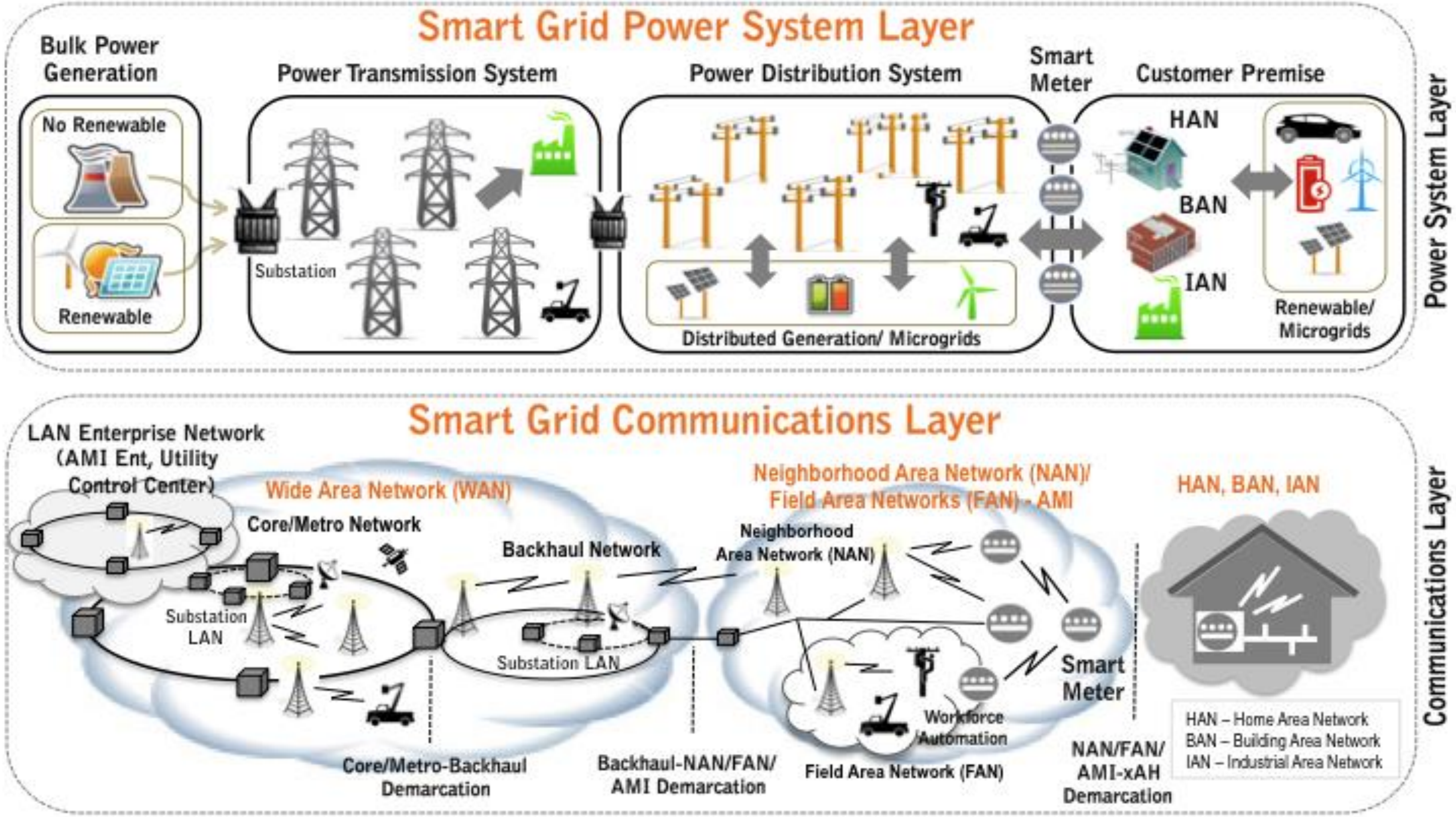
smart meters

smart house

plug-in vehicles

industry

The Smart Grid Overarching Communications Framework



SMART GRID - Hurdles

- Beyond normal challenges faced by new technological entrants, smart grid technologies confront a regulatory system that often discourages their adoption
- A series of changes in regulations governing investor owned utilities overcome disincentives to, and create incentives for, adoption of smart energy technologies
- The need for training in new grid technologies and to replace an aging utility workforce represents an opportunity to address two critical power industry issues at once.

SMART GRID VISION STATEMENT

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- The coming decade will be defined by a rampant growth in new Intelligent Energy technologies, just as computers and communications devices have defined the recent past. Making our energy systems "smart" holds the key to protecting our planet and to fuelling our global economy.
- Innovative approaches to deliver energy-efficient and environmentally-friendly processes and products will be enabled by the application of information systems to production, logistics, product design, transport, consumption and many other aspects of our day-to-day activities.
- Empower the user to actively participate in this process, through a range of interactive intelligent home appliances, allowing them to save energy and assisting them in addressing the inevitable price increases for electricity.

Shaping the Future

"Here's the deal, customer: We'll give you a house, but what we want is your utility bill, your internet access and your telephone service for the rest of your life and your children's lives."

Ted Waitt, CEO
Gateway Computers

The New Reality: Is Your Refrigerator on the Internet?

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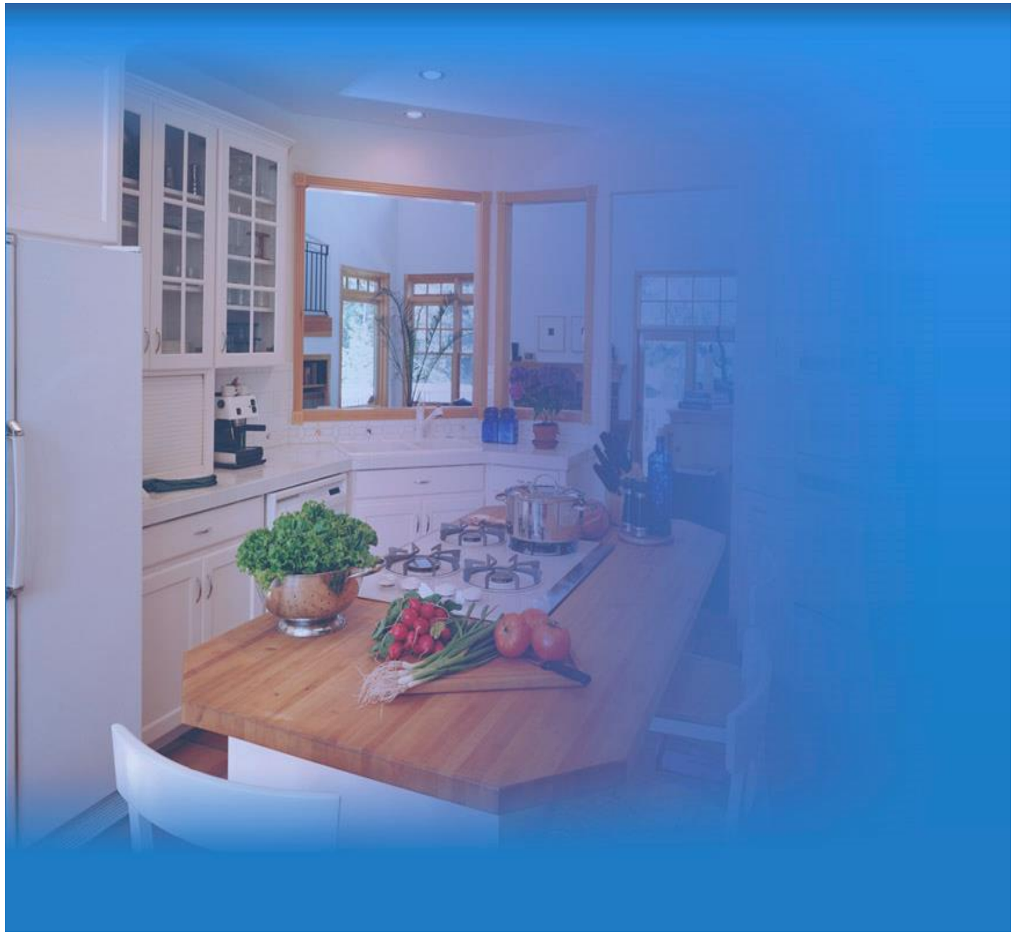

- Power sales by appliance
- Integrate “islands of automation”
- Granular energy management
- Appliance diagnostics
- Consumer behavior
- Co-marketing

The Power to Transform an Industry

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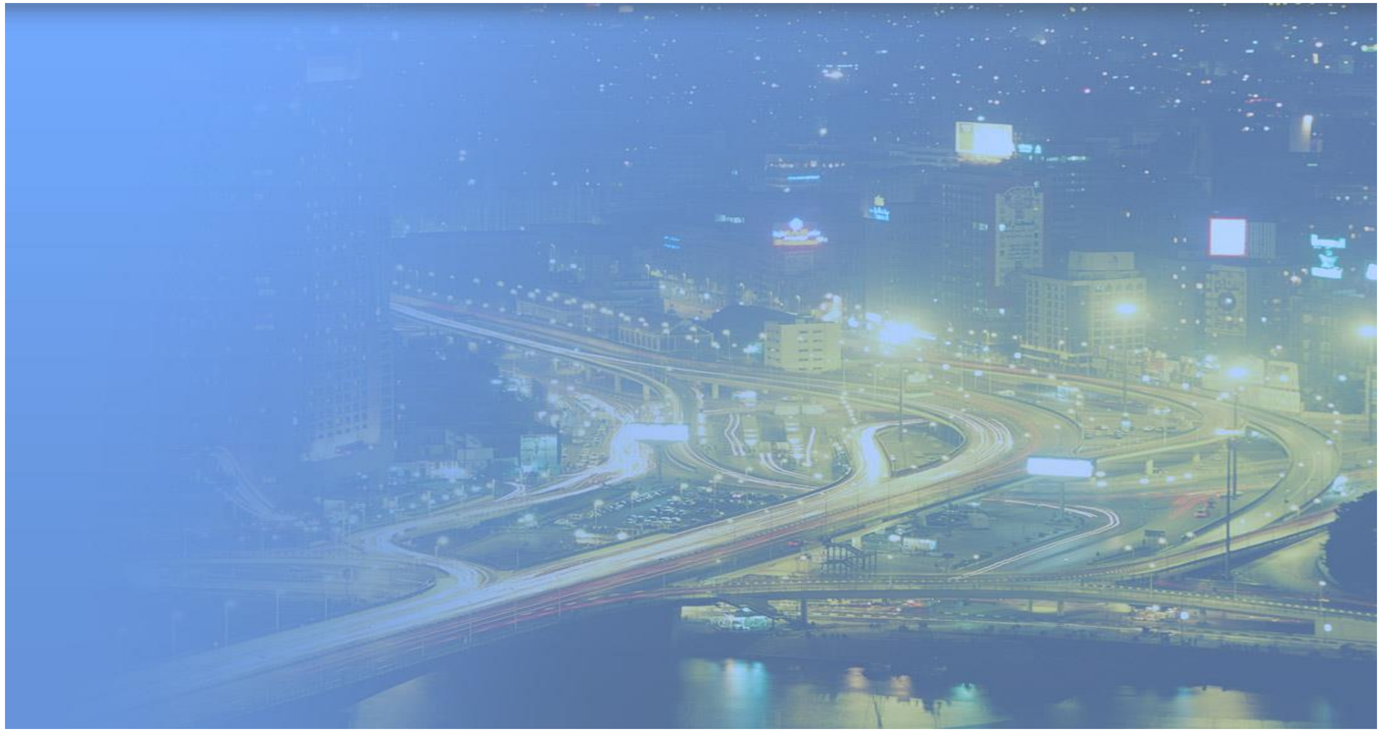
Available Technologies Abound

- Internet
- Distributed Resources
- Energy Management Systems

But the Future will be Driven by Disruptive Integration



- Reliability issues
- Economic volatility
- Available technology
- Business and customer drivers

The Future is Already Here...

What could you be doing?

- Scan and understand markets
- Act, initiate and try new technologies
- Develop new options
- Build alliances, partnerships
- Leverage your advantage
- Prepare for disruptive market forces

Technology is a key to the Vision

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- Close Gaps on Technical Issues
- Develop, Demonstrate Advanced Systems
- Integrate distributed resources
- Close Gaps on Electrical Integration Issues
- Identify Optimal Community Power Solutions
- Resolve Policy and Market Rules

So, Future Power Network needs to be

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S

- Signal processing
- State estimation
- Stochastic generation
- Self*

M

- Monitoring (WAMS)
- Multi energy carriers
- Multivariable optimisation/control
- Mixed generation
- Market enabling

A

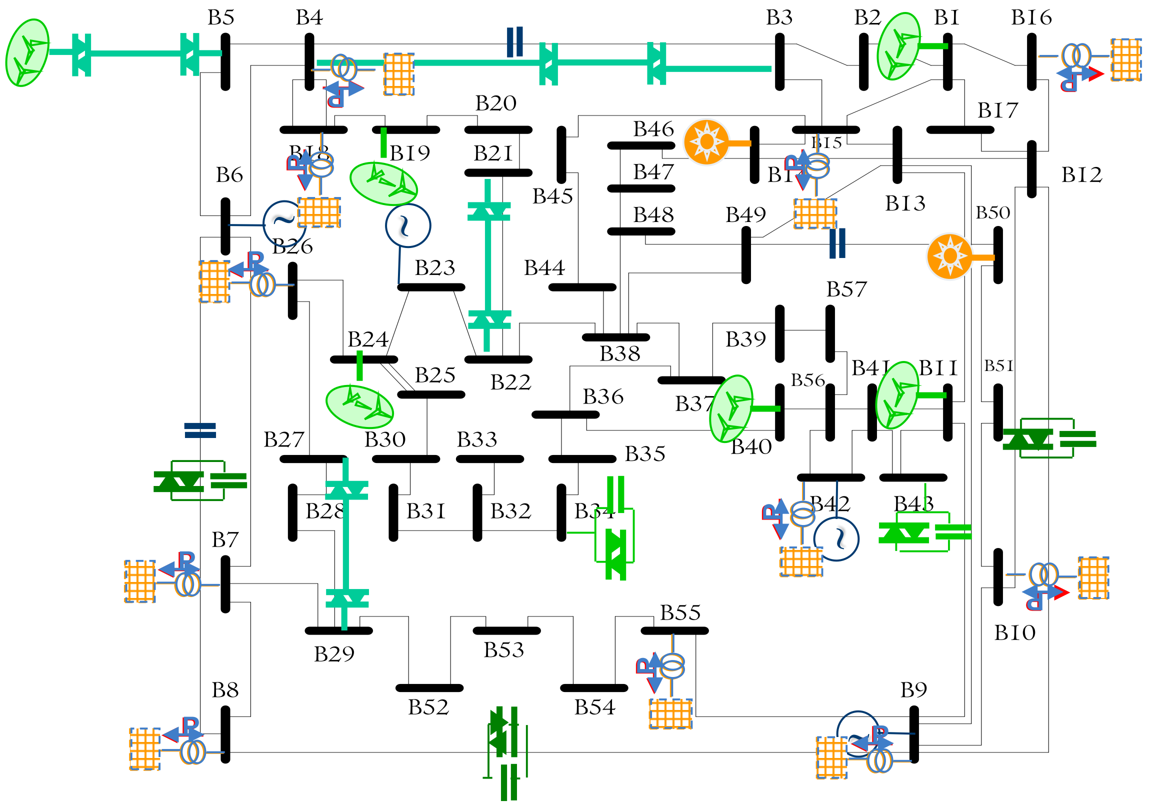
- Adaptive/hierarchical control
- Augmented power transfers FACTS/HVDC)
- Affordable solutions

R

- Robust
- Responsive demand
- Reliable ICT
- RES
- Real time control
- Reduced uncertainty

T(er)

- Trans continental
- Tailored for individuals
- Tolerant to behavioural patterns
- Trade-off analysis



GRID

modelled and operated by relaying on

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non-deterministic and close to real time approaches for (energy) system control and operation including stochastic, probabilistic and computer intelligence based models, data handling and methodologies, and possibilities offered by state-of-the-art WAMS, integrated ICT systems and intelligent PE devices

SUMMARY

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- Smart Grids are prerequisites to reach political targets such as environmental, efficient energy and secure supply.
- Implementation of Smart Grids is an evolution of the existing grids
- Many requirements, like increased efficiency and reliability can be addressed by today's products
  - Outage management based on meter information instead of trouble calls
  - FACTS and HVDC installations
- Some requirements, like full-scale integration of renewables and electrical cars, need new solutions based on pilot installations for test and demonstration:
  - Electrical storage
  - Demand response
  - Charging infrastructure
- Industry standardization required
- The Smart Grids challenges and technologies should attract many young engineers to the power industry

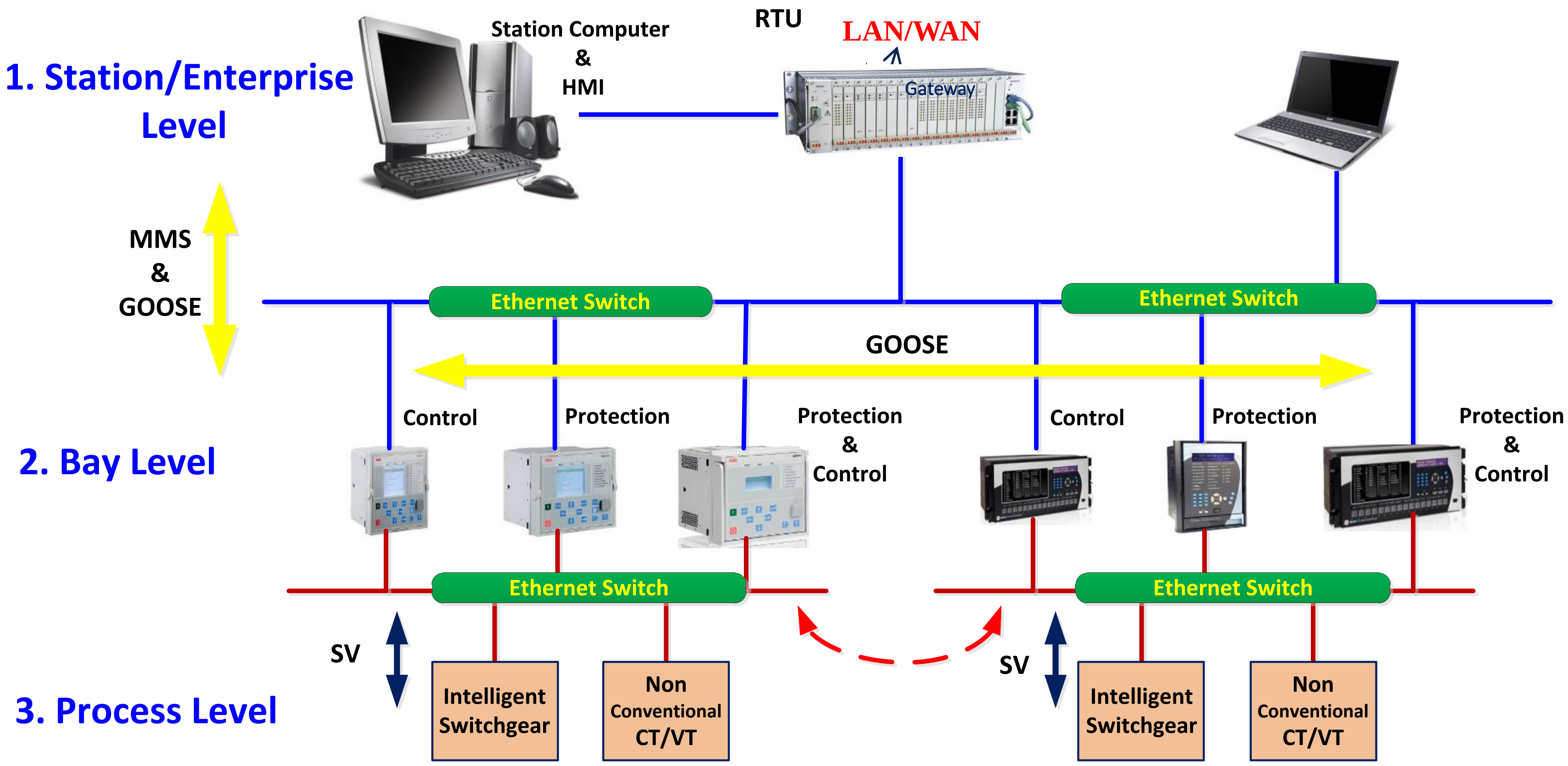
Key areas to watch

Data Analitics

Probabilistic modelling

Real time risk limiting control

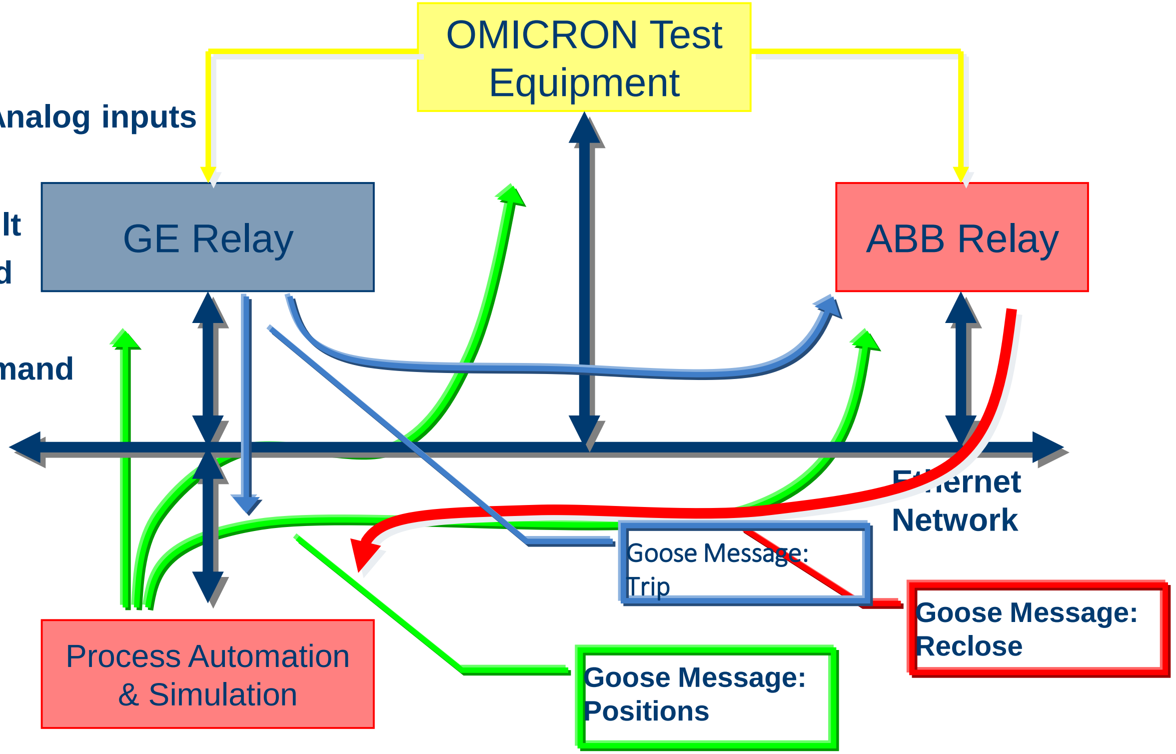
IEC61850-Based Substation



Lab demo: What is VU doing?
Trip and auto-reclosing

The GOOSE demo

1. Simulated fault
2. Trip generated
3. New position
4. Reclose command
5. New position



Network architecture and communication links developed for VUZS laboratory based on IEC61850 standard

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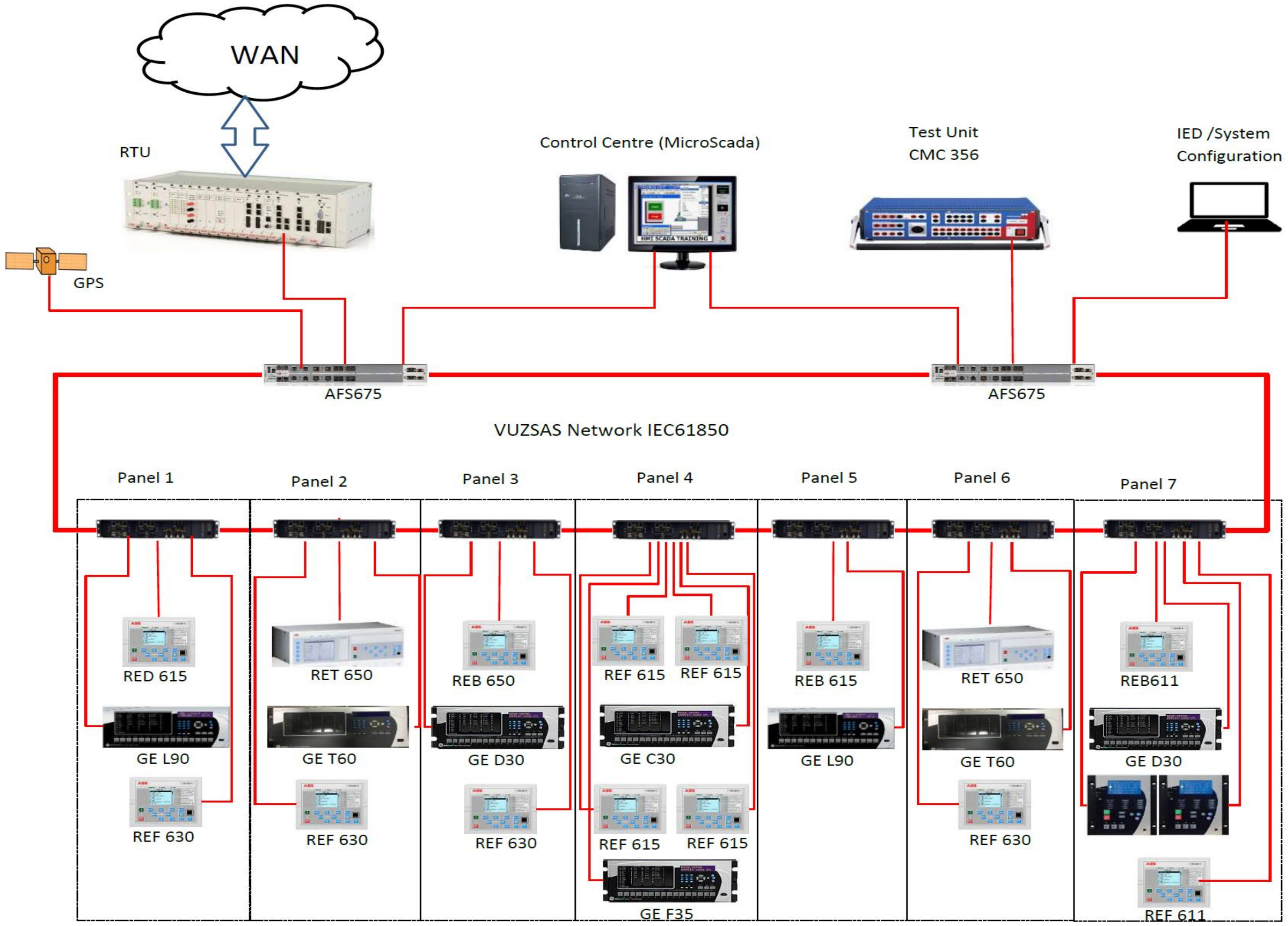

Comms Efficiency


Training / Seminars room

Advanced Substation Technologies

Enable new functionalities, new topologies, and enhanced control of power flow and voltage can increase the grids:

- Reliability;
- Resiliency;
- Efficiency;
- Flexibility; and
- Security.

Solid State Power Substation (SSPS)

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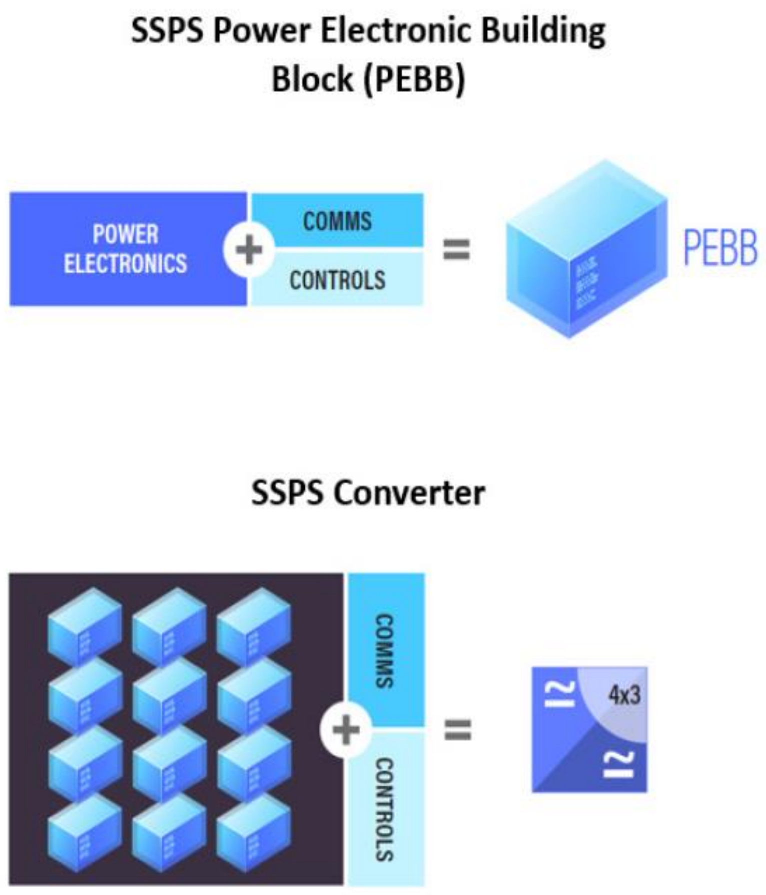
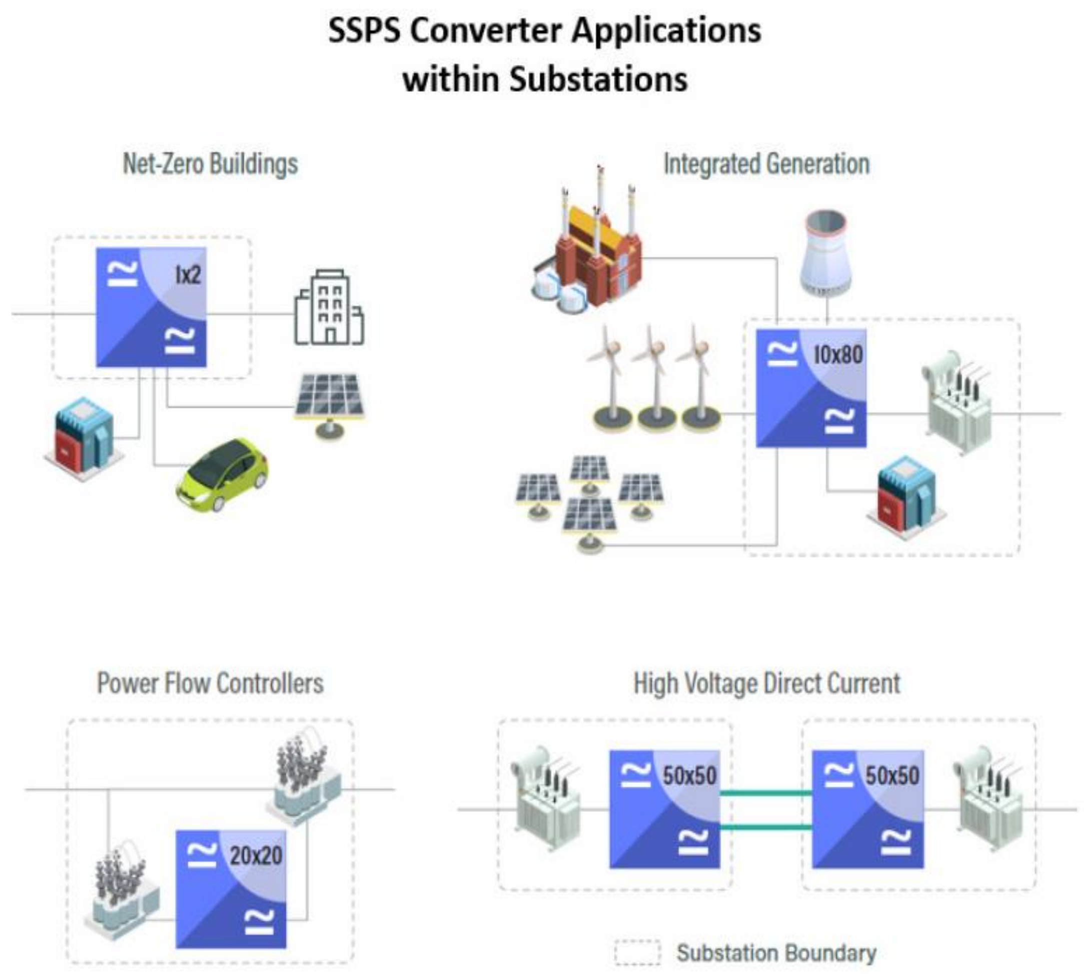
- Defined as a substation or “grid node” with the strategic integration of high-voltage power electronic converters, can provide system benefits and support evolution of the grid.
- Design and development of a flexible, standardized power electronic converter that can be applied across the full range of grid applications and configurations can enable the economy of scale needed to help accelerate cost reductions and improve reliability.

Vision for SSPS Converters





SSPS Converter Classification and Defining Functions and Features (1/3)

CONVERTER CLASSIFICATION	DEFINING FUNCTIONS AND FEATURES
SSPS 1.0 UP TO 34.5 KV 25 KVA–10 MVA	• Provides active and reactive power control • Provides voltage, phase, and frequency control including harmonics • Capable of bidirectional power flow with isolation • Allows for hybrid (i.e., AC and DC) and multi-frequency systems (e.g., 50 Hz, 60 Hz, 120 Hz) with multiple ports • Capable of riding through system faults and disruptions (e.g., HVRT, LVRT) • Self-aware, secure, and internal fault tolerance with local intelligence and built-in cyber-physical security

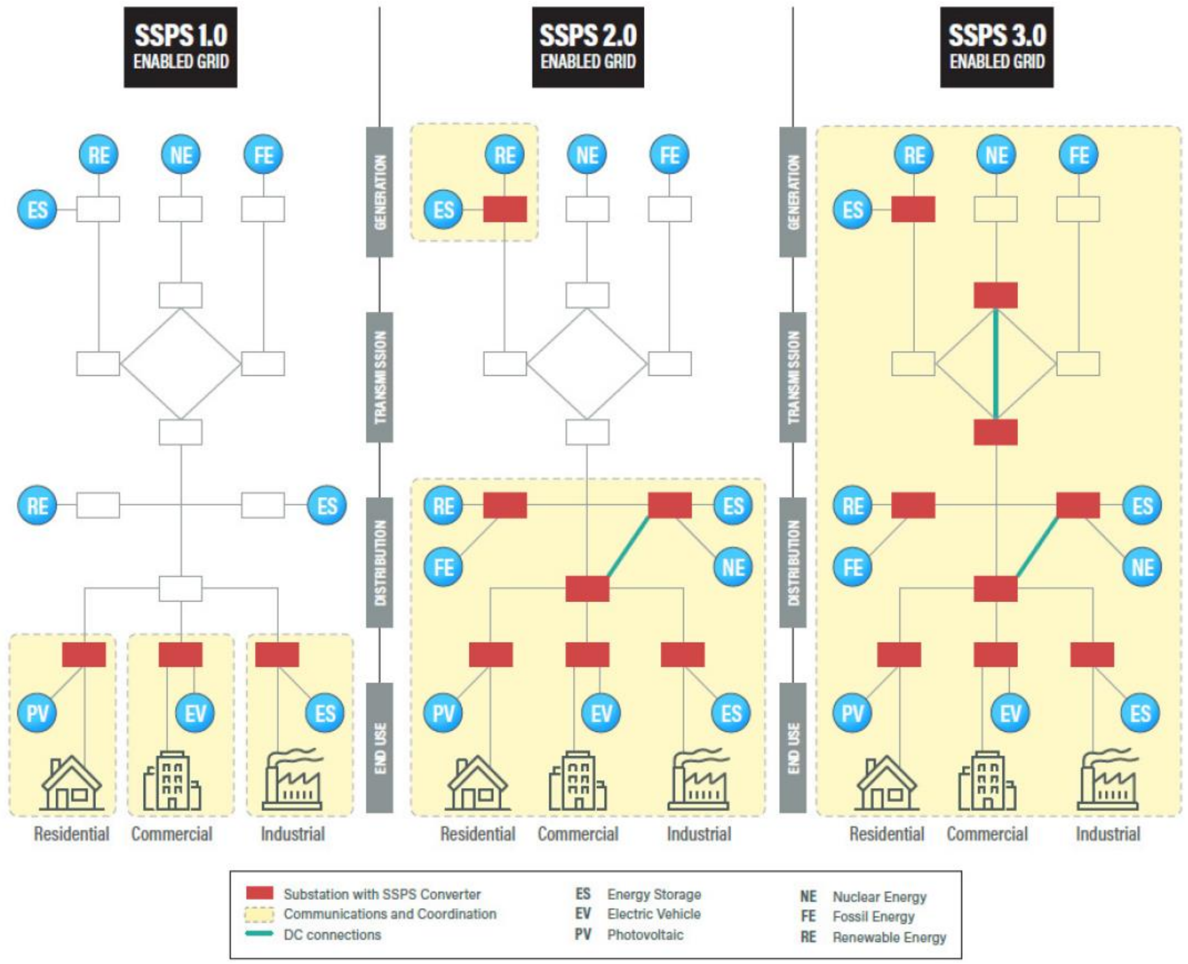
SSPS Converter Classification and Defining Functions and Features (2/3)

CONVERTER CLASSIFICATION	DEFINING FUNCTIONS AND FEATURES
SSPS 2.0 UP TO 138 KV 25 KVA–100 MVA	+ Capable of serving as a communications hub/node with cybersecurity + Enables dynamic coordination of fault current and protection for both AC and DC distribution systems and networks + Provides bidirectional power flow control between transmission and distribution systems while buffering interactions between the two + Enables distribution feeder islanding and resynchronization without perturbation

SSPS Converter Classification and Defining Functions and Features (3/3)

CONVERTER CLASSIFICATION	DEFINING FUNCTIONS AND FEATURES
SSPS 3.0 ALL VOLTAGE LEVELS ALL POWER LEVELS	+ Distributed control and coordination of multiple SSPS for global optimization + Autonomous control for plug-and-play features across the system (i.e., automatic reconfiguration with integration/removal of an asset/resource from the grid) + Enables automated recovery and restoration in blackout conditions + Enables fully decoupled, asynchronous, fractal systems

SSPS Enabled Grids Through Its Evolution (5, 10, 20 years)



THANK YOU

"The best thing about the future is that it only comes one day at a time."
– Abraham Lincoln

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Q&A

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