BUILDING EFFICIENT, SUSTAINABLE AND RESILIENT GRID BY CONTROLLING THE EDGE

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OUTLINE

- Technology Megatrends & Future of Electricity
- Consumer Centric Power Grid
- Role of the Grid Edge
- Grid Edge Control Technology

TECHNOLOGY MEGATRENDS SHAPING THE FUTURE

People & Internet	Association and interaction with the web
Computing, Communications & Storage Everywhere	Ability to easily interface with digital technology
Internet of Things	Instrumentation of the physical world
Artificial Intelligence &Big Data	Ability to access & analyze vast data, and to make decisions based on it
Sharing Economy	Direct exchange of services, goods and money
Digitizing The Matter	3D printing, & creating materials on the spot

"Deep Shift: Technology Tipping Points and Societal Impacts", World Economic Forum, September 2015

FUTURE OF ELECTRICITY

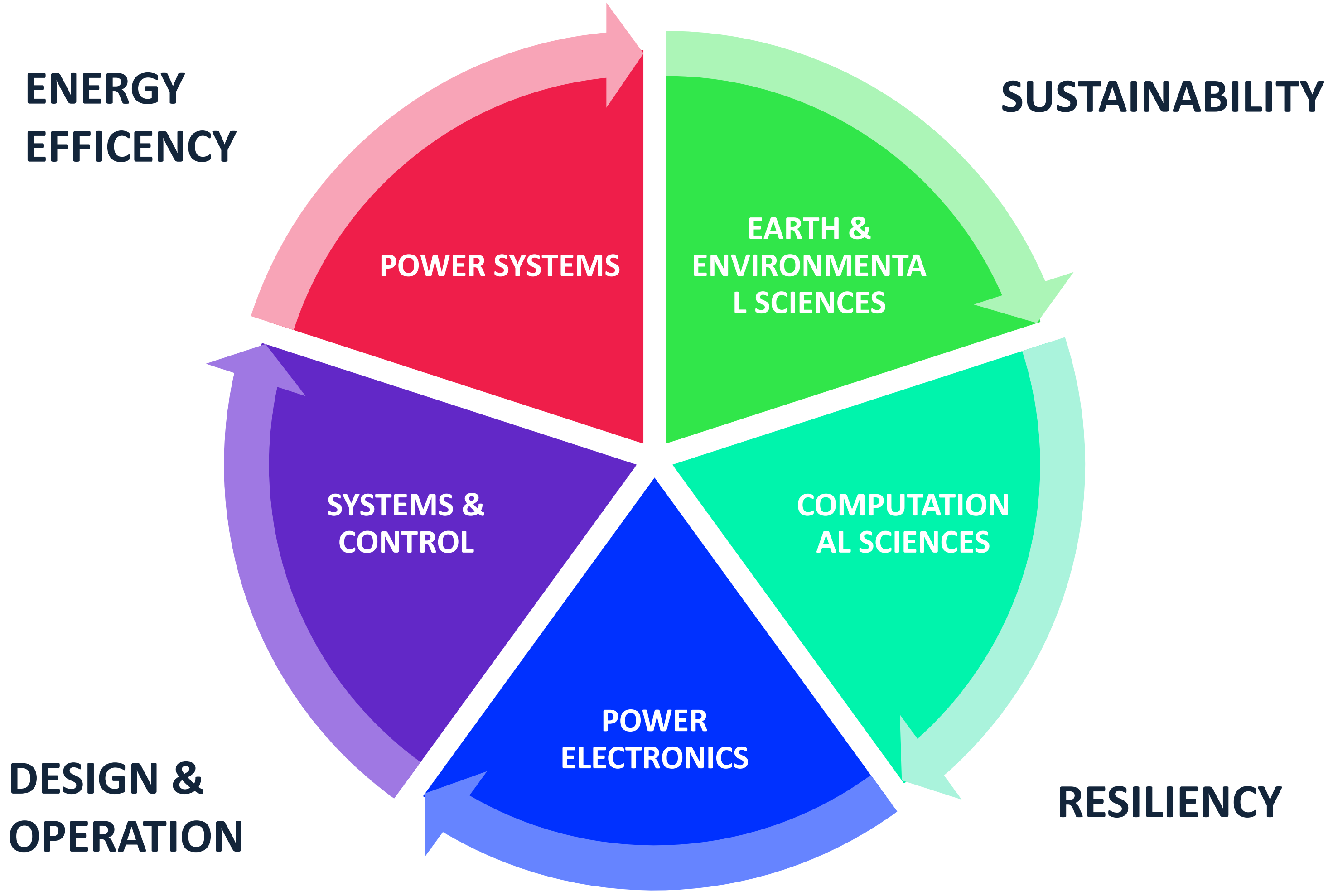
De-carbonization

Decentralization

Digitalization

Democratization

NEW TECHNOLOGIES

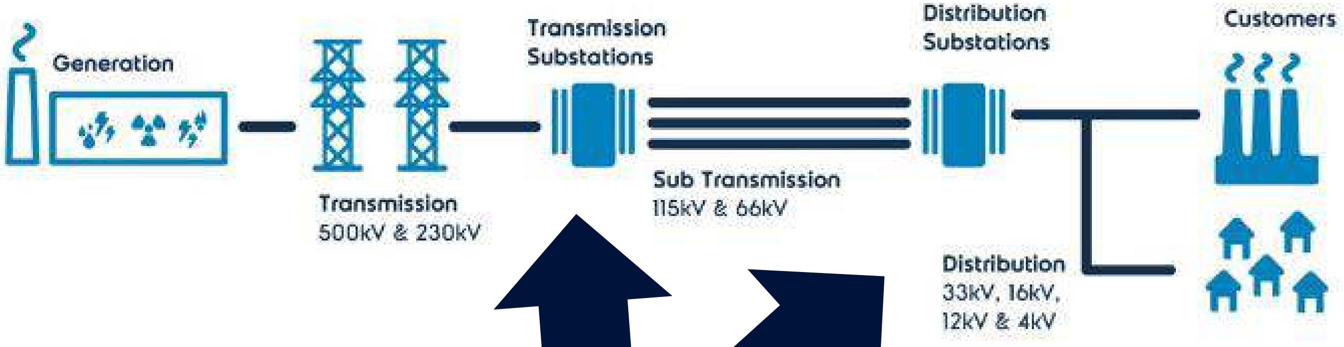


THE FARADAY GRID

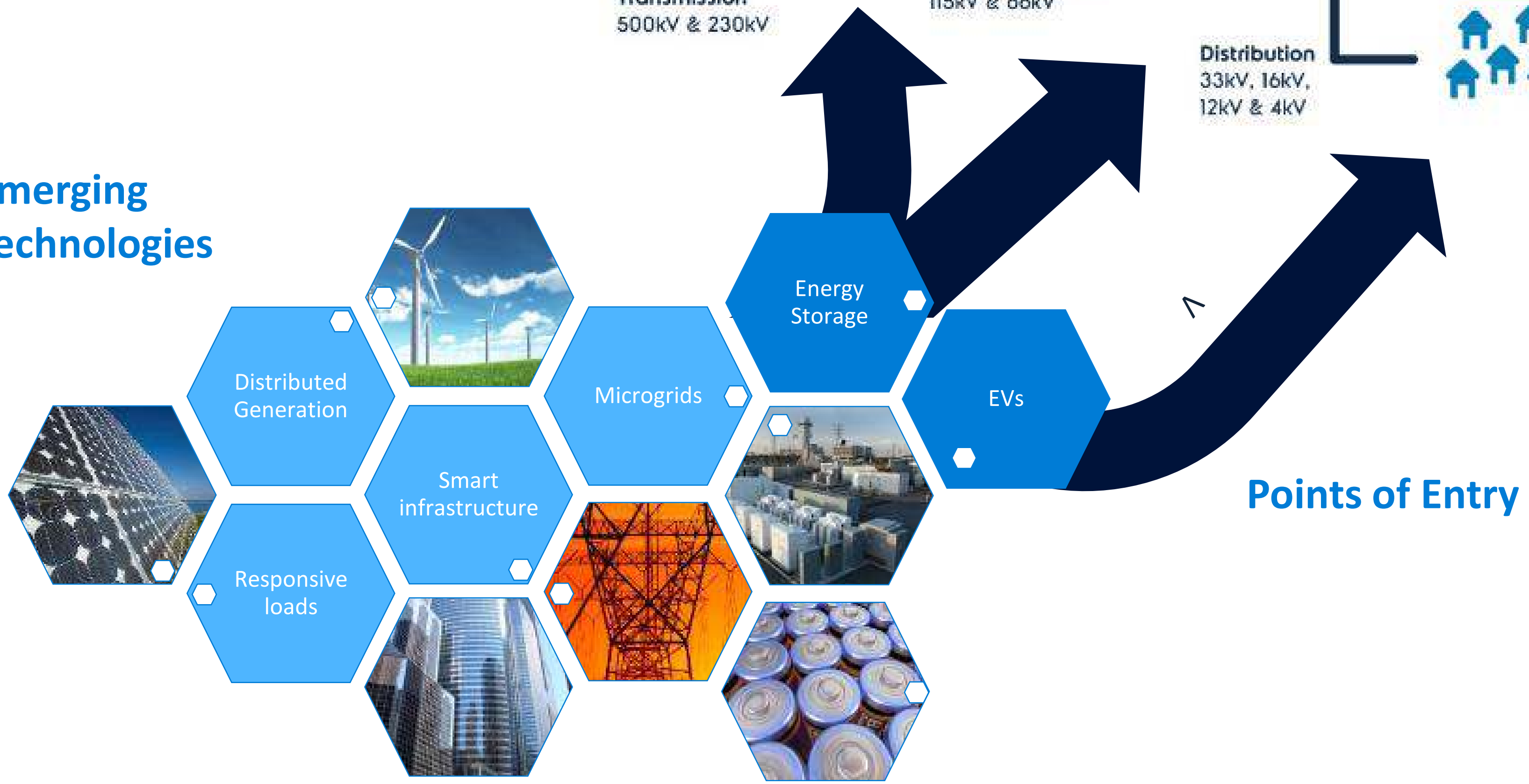
CONSUMER CENTRIC POWER GRID

THE POWER GRID IS CHANGING

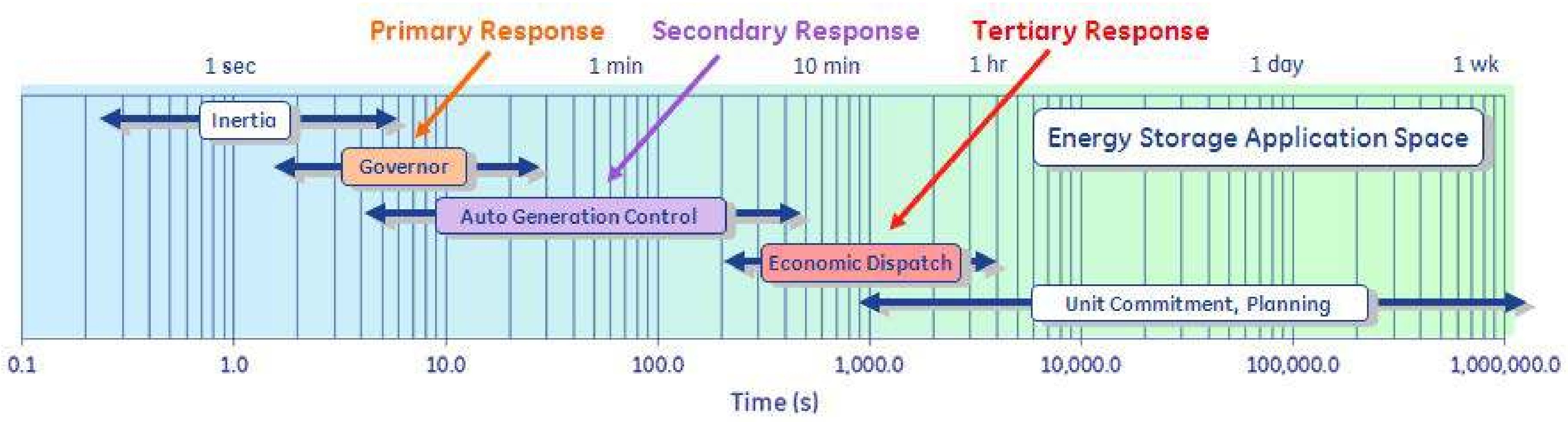
Current Grid Structure



Emerging Technologies



GRID OPERATION | TIMESCALES



- **Unit Commitment** - deciding which units will be operational at a given time (hours to days)
- **Economic Dispatch** - distributing loads among already-operating units (minutes to hours)
- **Frequency regulation and ancillary services** - only on certain participating generators (sub-seconds to seconds)

DERS GRID INTEGRATION CHALLENGES

Dispatched generation → **Intermittent generation**

Predictable load → **Variable Net-Load**

Capacity available → **Capacity constrained**

EMERGING GRID OPERATION PARADIGMS

ISO & DER aggregators

- ISO manages transmission & wholesale
- Aggregated DERs bid into bulk market

ISO & DSO

- ISO manages transmission & wholesale
- DSO manages distribution & retail

Network of micro-grids

- Locally supply power
- Grid supplies backup

Super Grid

- Global, interconnected, renewable energy grid
- Energy backbone

BUSINESS MODEL TRANSITION

- DER providers starting to participate in wholesale markets
- Utilities shifting from ROI toward performance-based & network-driven incentive business models
- Utilities becoming a platform delivering services

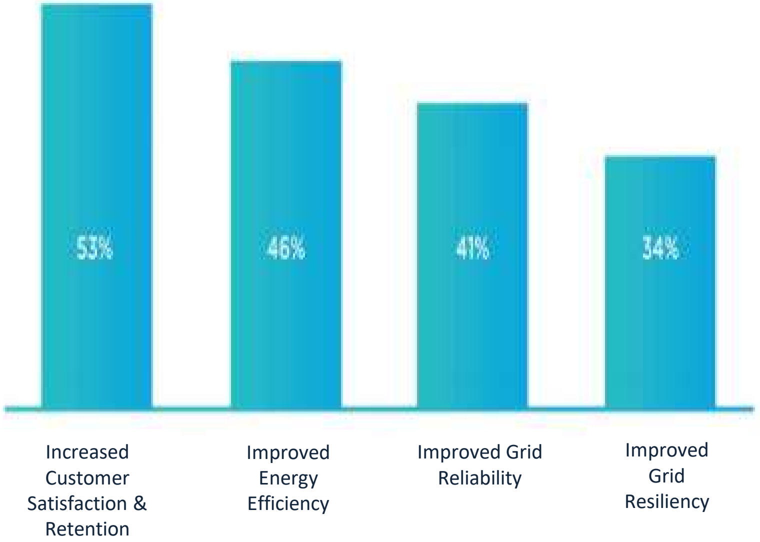
solarpowerworldonline.com

THE FARADAY GRID

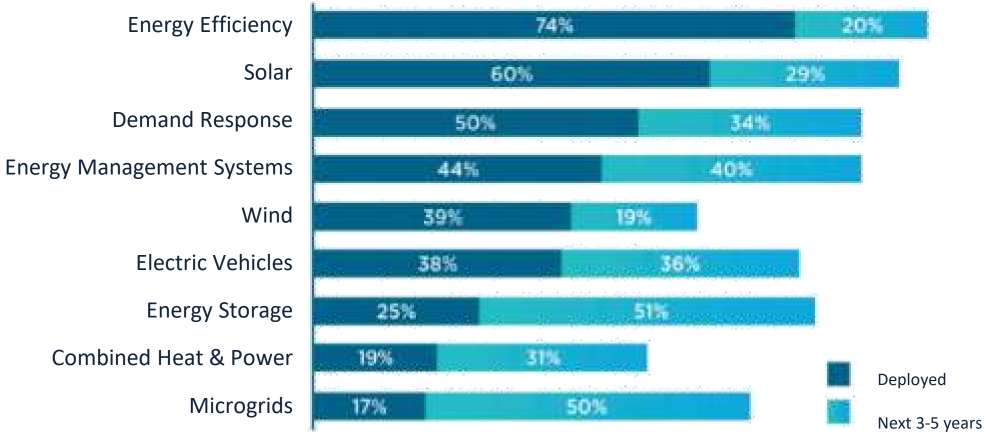
THE ROLE GRID EDGE

DISTRIBUTED ENERGY RESOURCES (DERS) AND THE RISE OF THE GRID EDGE

Benefits of DERs



DER Deployment Status



"The Utility View of Achieving Agility in the Distributed Energy Era Through a Holistic and Flexible Digitalization Approach", 2017

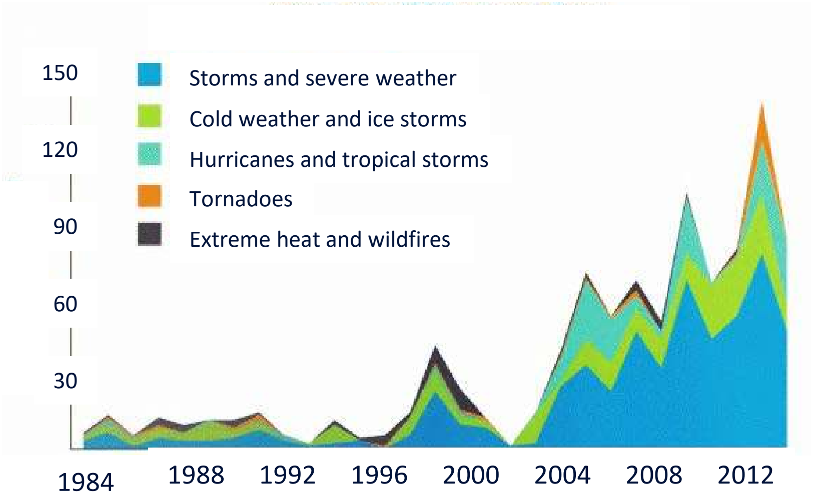
SIEMENS

THE INCREASING IMPORTANCE OF RESILIENCY

Resiliency - System improvements that prevent or reduce the impact on reliability and ability of the system to recover quickly after adverse events

Resiliency is more than reliability

- Prevent and minimize damage
- Enable continued operation
- Rapidly return to normal



http://www.climatecentral.org/news/weather-related-blackouts-doubled-since-2003-report-17281

$18B to $33B annual cost

"Economic Benefits of Increasing Electric Grid Resilience to Weather Outages", EOP 2013

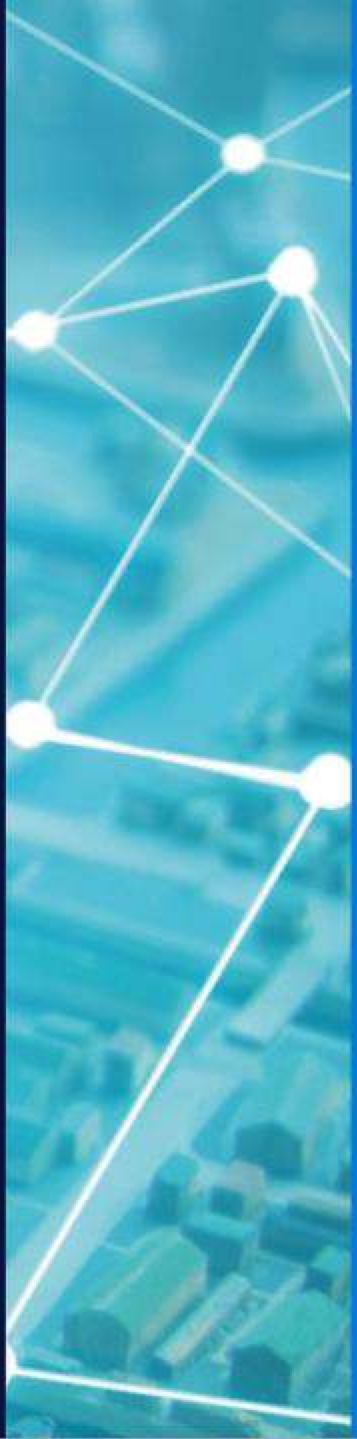
INCREASED GRID COMPLEXITY CHALLENGES

- Enabling millions of end-use devices to cooperate for real-time supply/demand balance without jeopardizing grid reliability
- Effectively integrating Transmission & Distribution to better utilize demand side technology to improve grid resiliency
- Bridging the spatio-temporal gap between real-time feedback control and system-wide energy management

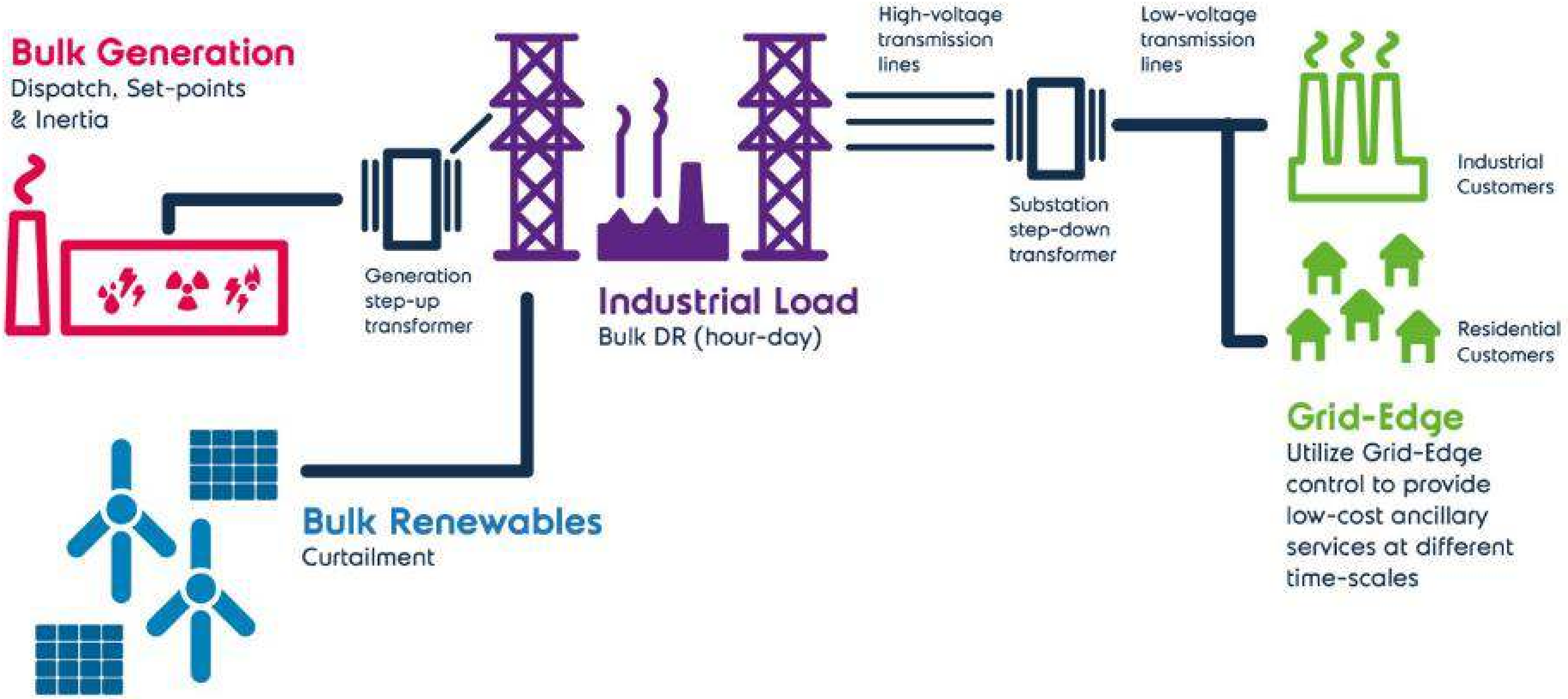



INCREASED GRID COMPLEXITY CHALLENGES

ACTIVE CONTROL OF GRID-EDGE ENABLES EFFICIENT, SUSTAINABLE AND RESILIENT GRID



WHAT DO WE WANT TO CONTROL?



THE FARADAY GRID

GRID EDGE CONTROL TECHNOLOGY

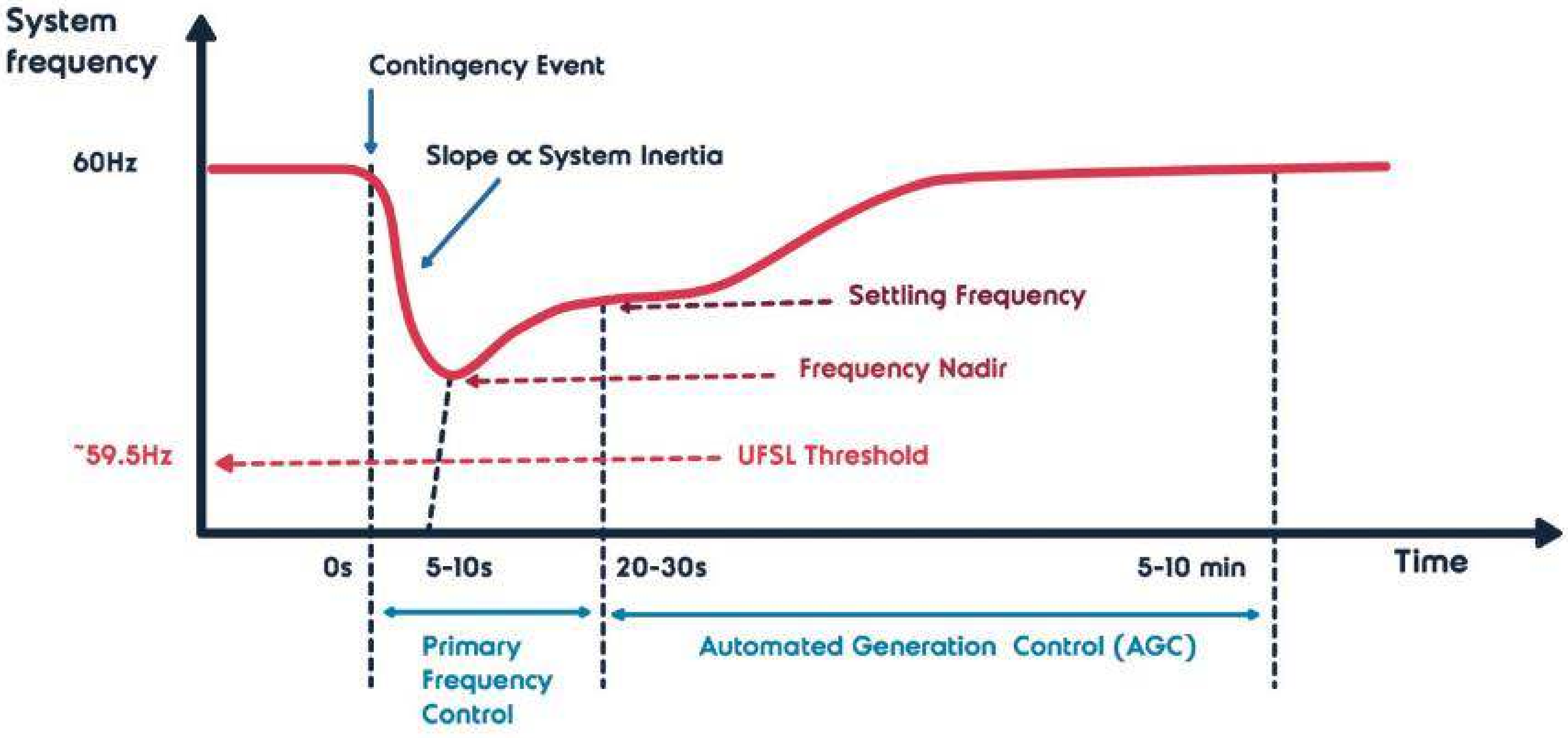
WHAT DOES CONTROLLING THE GRID-EDGE MEAN?

- Dispatching distributed generation in coordination with bulk generation
- Shaping net load over different time scales
- Coordinating large numbers of heterogeneous types of demand side technologies

- Self-Balancing
- Adapting to real-time variability

GRID RELIABILITY - FREQUENCY STABILITY

Directly affected by generation-demand balance



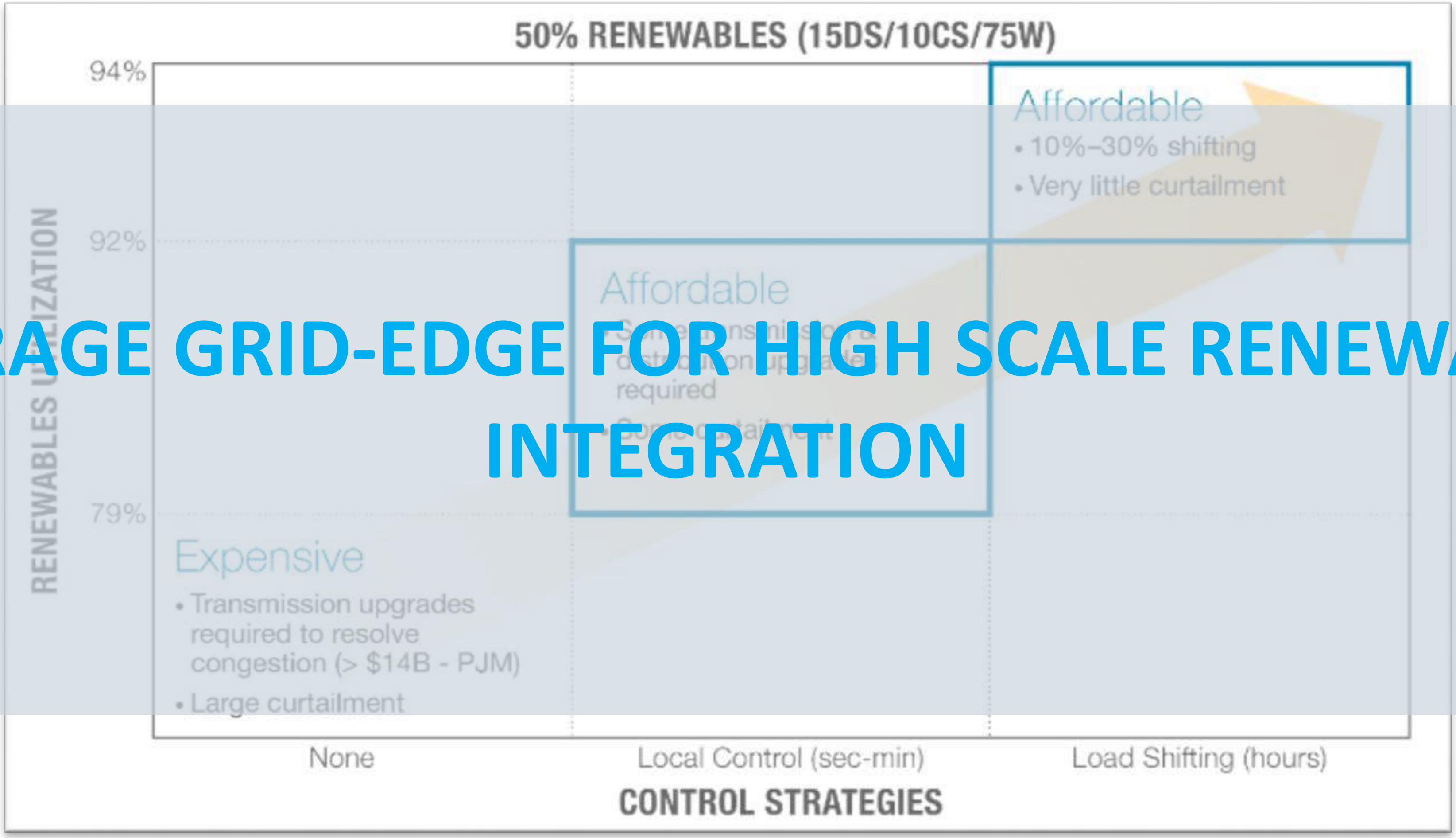
GRID-EDGE CONTROL IMPACT STUDY

- **Use DERs for Regulation**
  - Use controllable load to induce inertia-like response
  - Use controllable load to induce governor response
  - Engage in response to frequency measured at resource POC
  - Response times:
    - Inertia = Seconds
    - Governor = Tens of Seconds
- **Actively Reshape Net-Load**
    - Load magnitude flexibility factor > 30%

- Objective: use renewables as much as possible
- Constraint: keep average daily load the same

"Grid of the Future: Quantification of Benefits from Flexible Energy Resources in Scenarios With Extra-High Penetration of Renewable Energy", J. Bebic at. El., 2015

LEVERAGE GRID-EDGE FOR HIGH SCALE RENEWABLES INTEGRATION



"Grid of the Future: Quantification of Benefits from Flexible Energy Resources in Scenarios With Extra-High Penetration of Renewable Energy", J. Bebic at. El., 2015

INCREASED GRID COMPLEXITY CHALLENGES

GRID EDGE CONTROL STUDY OUTCOME

LEVERAGE GRID-EDGE FOR HIGH SCALE RENEWABLES INTEGRATION

NODES: NETWORK OPTIMIZED DISTRIBUTED ENERGY SYSTEMS

Mission

Reliably manage dynamic changes in the grid by leveraging flexible load and Distributed Energy Resources (DERs) capability to provide ancillary services to the electric grid at different time scales.

Goals

- Improve overall grid efficiency and reliability
- Enable renewables penetration at >50%
- Reduce CO_2 emissions
- **Guarantee Level-of-Service to the grid**
- **Guarantee customers' QoS**

Project Categories	Response Time	Ramp Time	Duration
C1: Synthetic Frequency Reserves	< 2 sec	< 8 sec	> 30 sec
C2: Synthetic Regulating Reserves	< 5 sec	< 5 min	> 30 min
C3: Synthetic Ramping Reserves	< 10 min	< 30 min	> 3 hr

DE-FOA-0001289: Network optimized distributed energy systems (NODES)

TECHNOLOGY

THE FARADAY GRID DESIGN SOLUTION | A SYSTEMIC APPROACH

Emergent Transactional Platform: Transactional Distributed Ledger

A system of control that balances supply and demand across the entire energy system, using price as the key operational mechanism. It is built on an integration of software with patented Faraday Grid technology. This unique combination of hardware and software creates a system allowing any device or person, with the right technical support, to trade energy with other parties.

✓Allows any supported device or agent to participate in the trading of energy.

✓Runs as a software protocol over the top of the Faraday Grid.

Faraday Grid: Platform Architecture

Provides primary frequency response to maintain network stability. It autonomously and continuously adapts to variations throughout the network, and maintains an optimal equilibrium, functioning as an emergent order.

✓Is a network of Faraday Exchangers across electricity distribution.

✓Solves short term volatility, provides synthetic inertia.

✓Lifts the tolerance of the grid for renewables and variable, distributed energy sources.

Faraday Exchanger: Underpinning Device – *the router for an energy "internet"*

A hardware device which operates in isolation and independent of any central network management. The primary function of the Exchanger is bi-directional power flow, with each device managing its immediate network area to maintain grid stability.

✓Acts as an autonomous system node, like a router in the internet.

✓Is the underpinning technology for the Faraday Grid and Emergent Transactional Platform.

✓Is located in the network at any point of connection.

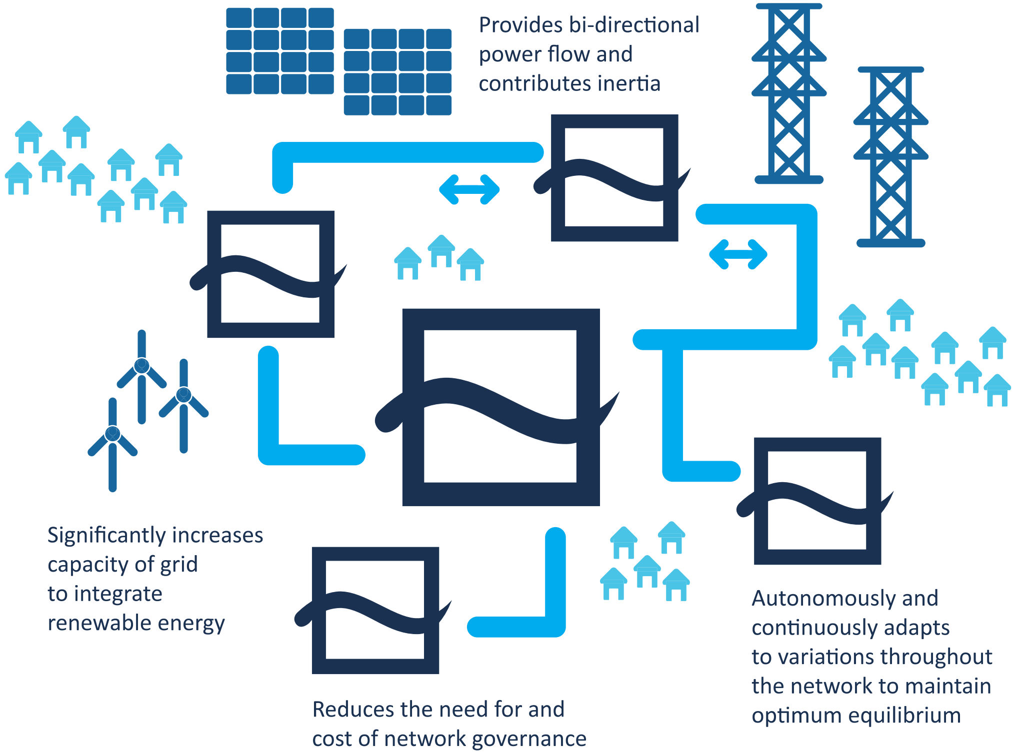
TECHNOLOGY OVERVIEW | THE FARADAY GRID PLATFORM ARCHITECTURE

Poles, wires and
FARADAY EXCHANGERS

Platform with
DISTRIBUTED CONTROL

ENERGY
anywhere
to anyone

↓ CO_2
emissions directly
and indirectly



80%+
integration of non-synchronous renewable energy generation

↓34%
reactive power generation requirement

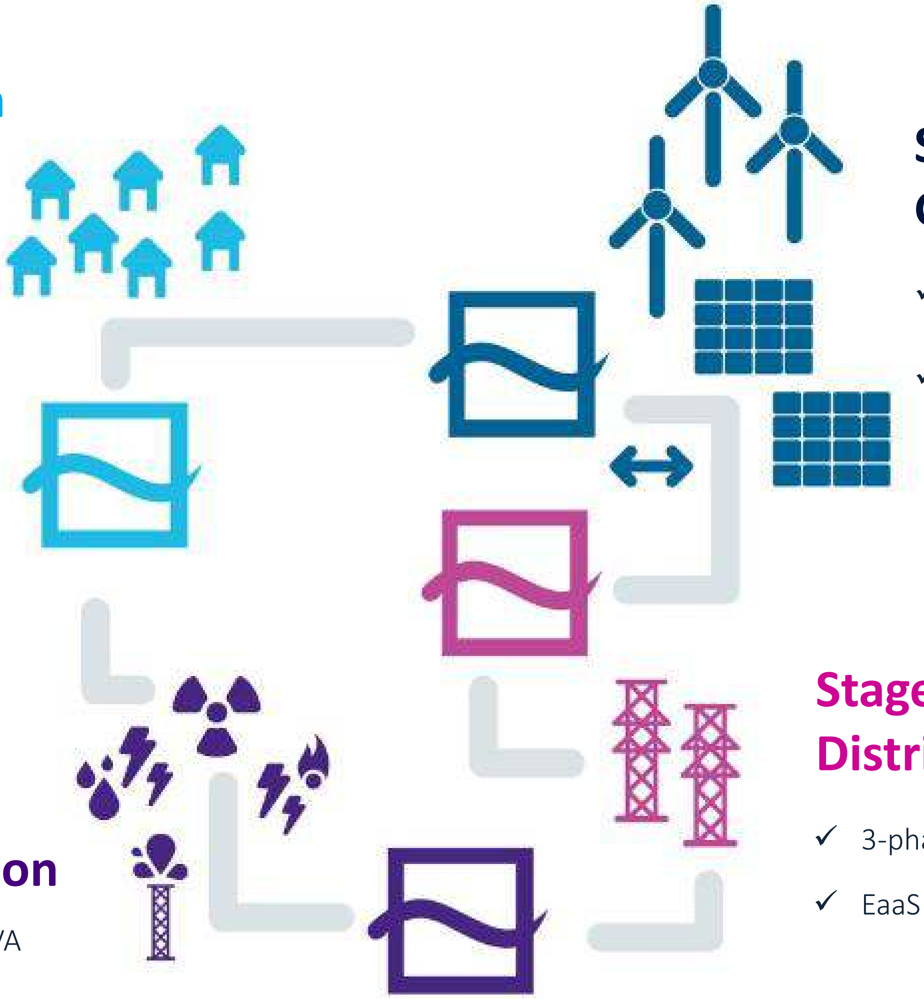
↑25%
network carrying capacity of the grid

↓7%
network losses

TECHNOLOGY OVERVIEW | THE FARADAY GRID POTENTIAL GRID NODES

Stage 1: Distribution to Low Voltage

- ✓ 3-phase LV pad-mount
- ✓ 3-phase LV pole-mount
- ✓ 1-phase LV pole-mount
- ✓ EaaS Platform Software
- ✓ Emergent Platform Software



Stage 2: Renewable Generation Integration

- ✓ 3-phase LV pad-mount, to 20 MVA
- ✓ EaaS Platform Software

Stage 3: High Voltage Distribution & Transmission

- ✓ 3-phase pad-mount to >200MVA
- ✓ EaaS Platform Software

Stage 4: Large Scale Generation Integration

- ✓ 3-phase pad-mount to >200MVA

WHAT IS NEEDED FOR SUCCESS?

Domain Knowledge

Scientific Rigor

Talent Pool

Energy Eco-System

JOIN OUR TEAM

THANK YOU!

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