Power System Flexibility, DERMS

Needs for Energy Transition & Power Systems of Future

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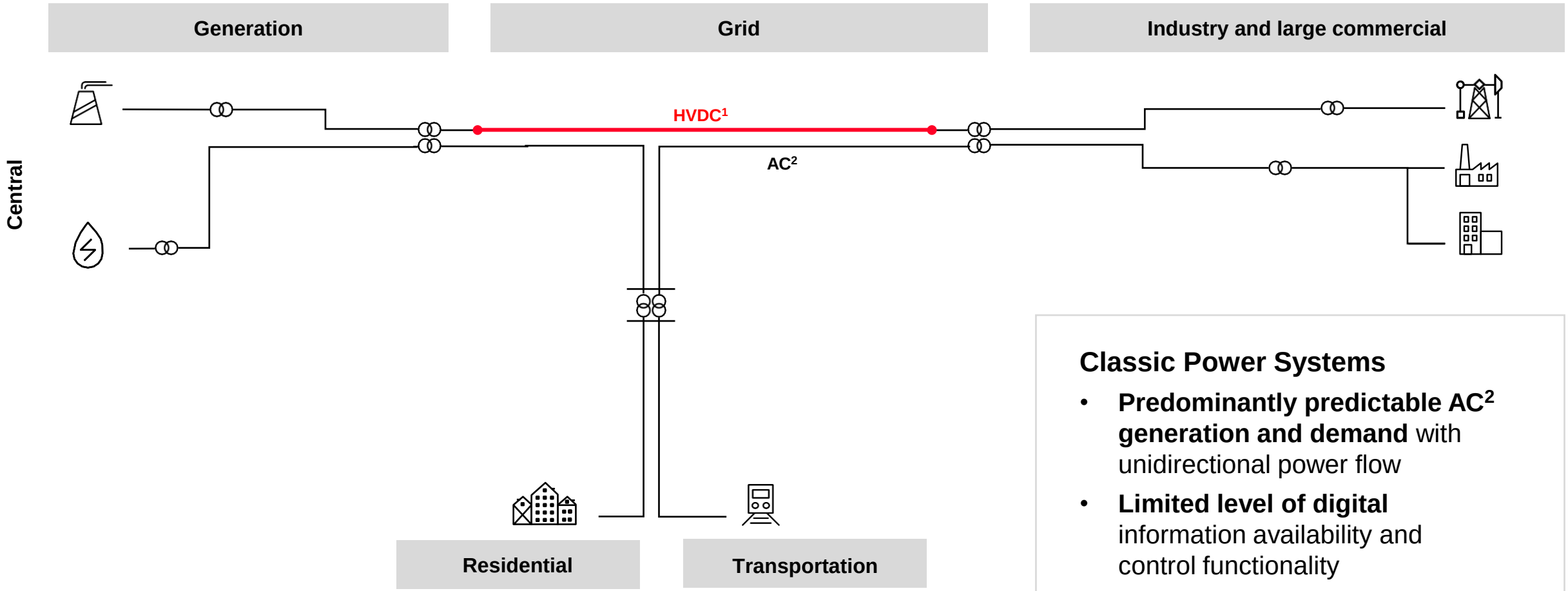
The Power System Evolution - Classic Power Systems



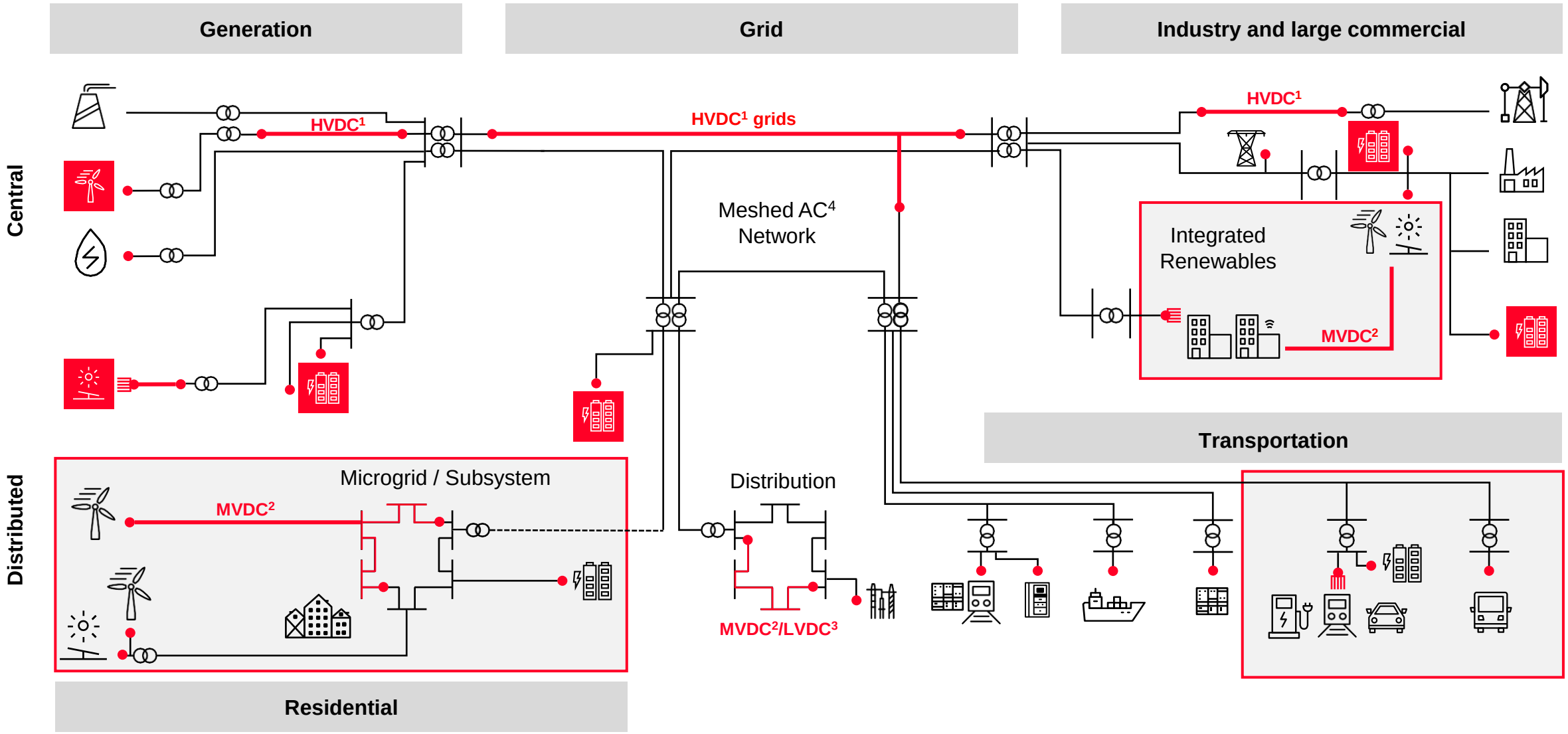
Classic Power Systems

- **Predominantly predictable AC[2] generation and demand** with unidirectional power flow
- **Limited level of digital** information availability and control functionality

The Power System of the Future will be significantly bigger, more interconnected and much more complex

1. High-Voltage Direct Current
2. Alternating Current

The Power System Evolution - Future Power Systems



1. High-Voltage Direct Current
2. Medium-Voltage Direct Current
3. Low-Voltage Direct Current
4. Alternating Current

Future Power Grid - Sustainable Energy Ecosystem

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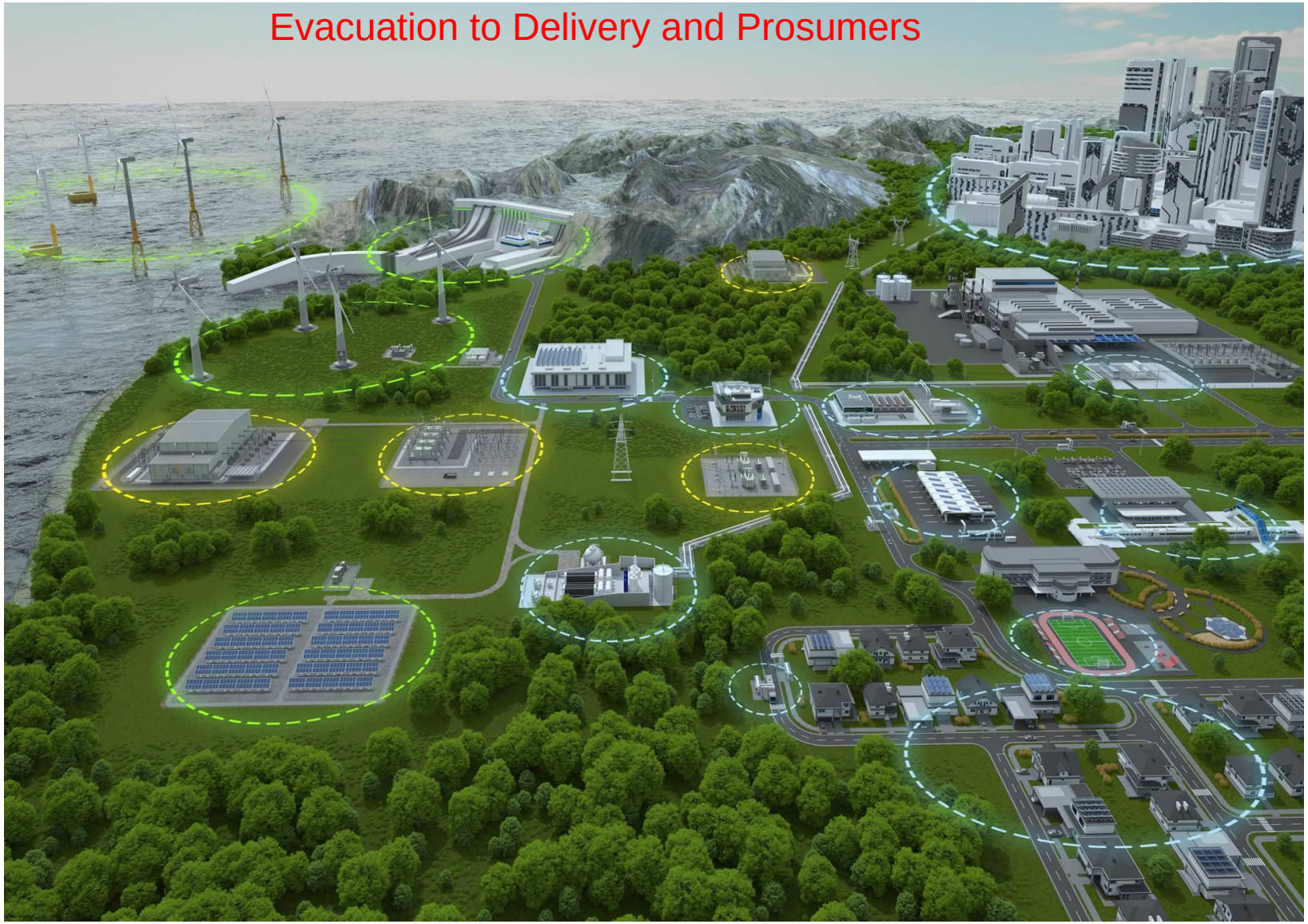

Generation
- Offshore wind
- Onshore wind
- Solar
- Hydropower
- Conventional

Transmission and distribution
- Converter station, HVDC, FACTS
- Transmission substation
- Distribution substation

Consumption
- Hydrogen consumption
- Hydrogen production
- Data center
- Transportation (Metro, EV, and rail station)
- Commercial by industry

Sectors
- Utilities
- Renewables
- Transportation
- Data centers
- Industries
- Buildings

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Four Levers of Flexibility - Digital and Power Electronics at the Core

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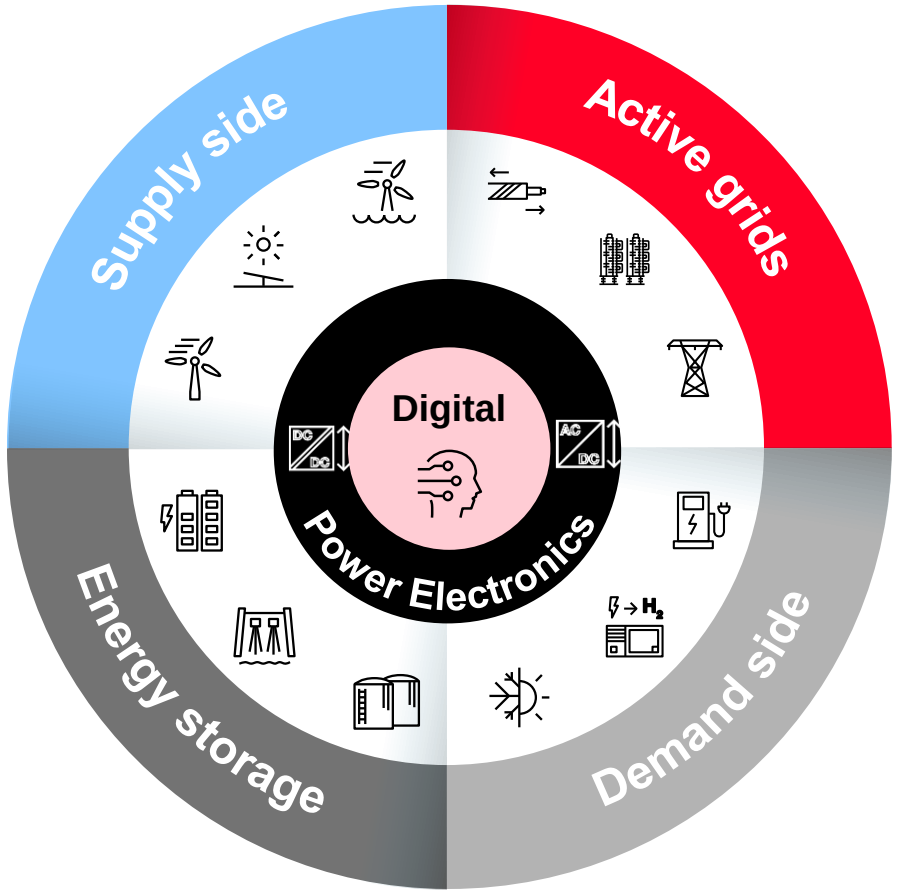

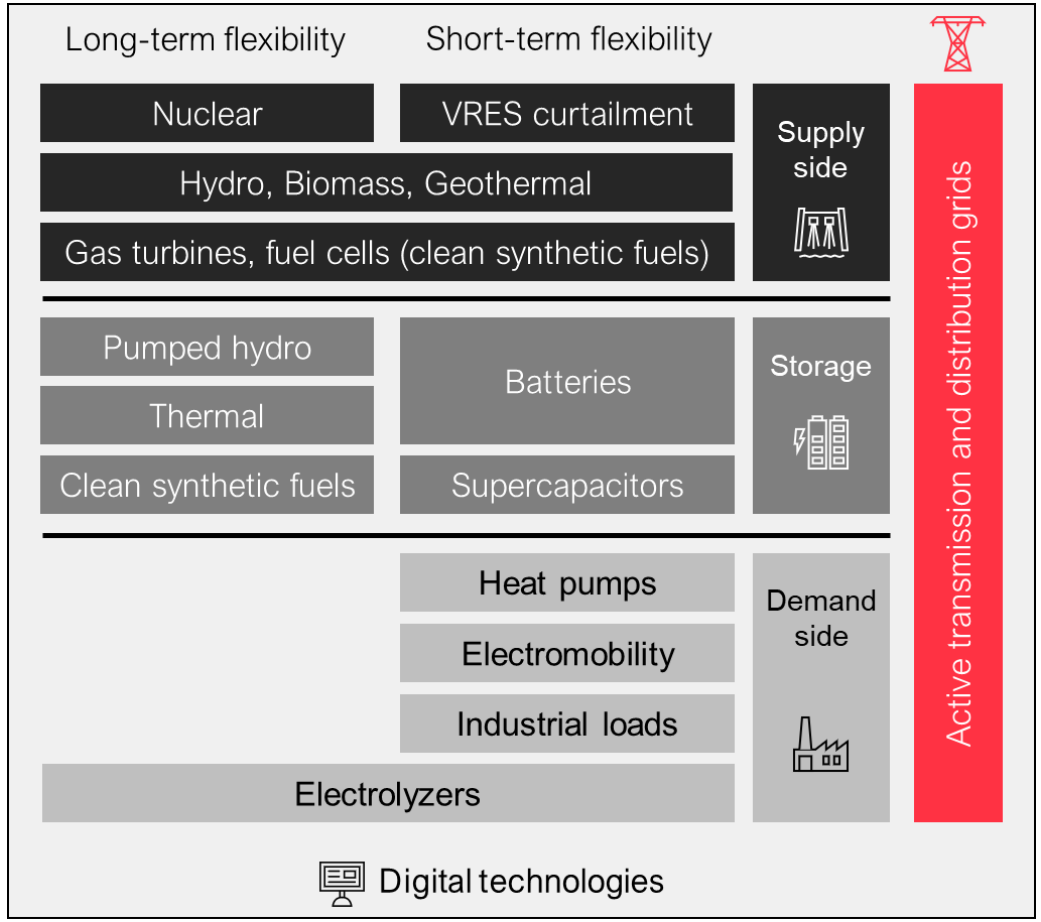

Three fundamental technology areas for the Power System evolution:
Power Electronics, Digitalization and Sustainable Products and Solutions

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Technologies Enabling Future Power System - Power Electronics

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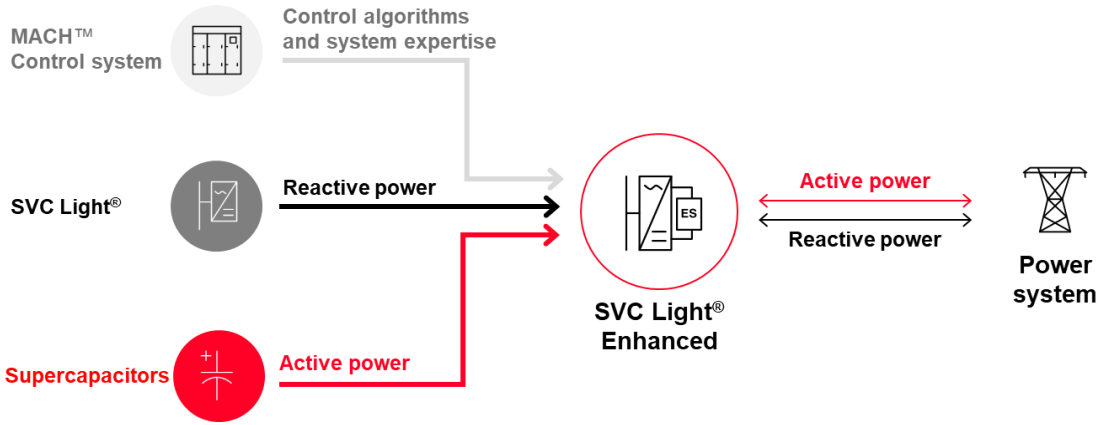
From grid following to grid forming converters

- Creating system voltage and frequency
- Contribution to inertia and fault level
- Sink for harmonics and unbalances
- Supporting black start

AC

STATCOM & Enhanced STATCOM



DC

HVDC

- Renewable integration
- Remote generation/load
- Interconnection
- DC links in AC grid & upgrades
- City center infeed
- Power from shore

AC & DC

Grid Edge

- Microgrids
- Mobility
- Industrial electrification
- Renewable integration
- Storage

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BESS and Renewable Integration - Grid Forming Converter Control

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World's largest Battery Energy Storage System

Challenge

New South Wales aging, coal-fired power plants are expensive, inefficient, hazardous to the environment, and require costly ongoing maintenance.

Solution

The 850MW/1680MWh Waratah Super Battery (WSB), with 288 eks Energy PCS, acts as "shock absorber" for the electrical grid and improves system reliability.

Dalrymple ESCRI (Australia): The world's largest autonomous microgrid

Challenge

To improve the reliability of supply in the lower Yorke Peninsula, which is prone to lightning strikes, while supporting the integration of renewables.

Solution

Virtual Synchronous Machine with energy storage to stabilize the electricity grid and seamlessly island the region to enhance reliability and utilize local wind power.

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New Energy Eco-system - distributed energy resources - examples

ElectraNet Pty Ltd

Transmission company with 5,591 km of HV transmission lines in South Australia

Solution: Wind (90 MW), Distributed rooftop solar, PowerStore Battery (30 MW/8 MWh), e-mesh Control System

Installed in a complex & large-scale energy network in South Australia, the solution strengthens power grid and improves reliability services, including fast-acting power response to better balance the overall network.

Skagerak Energi AS

Norwegian utility company serving 176k grid customers

Solution: 5,700 m2 of solar modules (800 kWp), PowerStore Battery (800kVA/1MWh), e-mesh Control System, e-mesh EMS energy management system

Skagerak Energilab includes solar-powered grid edge solution, creating first of its kind power grid that also provides the neighborhood with locally produced electricity and readiness for V2G.

Woodside Energy Ltd.

Largest operator of oil and gas production in Australia

Solution: Gas Turbines (5 x 3.5 MW), PowerStore Battery (2.8 MW/1.43 MWh), e-mesh Control System, Remote monitoring

Developed to support on offshore platform, this solution greatly reduces dependency on diesel, lowering gas consumption by 2000 tons/year, while also lowering CO2 emissions by 5%.

Department of Tourism, ZA

Promoting tourism to islands and remote communities in South Africa

Solution: Solar PV (667 kWp), Diesel (1 x 500 kW), PowerStore Battery (500 kW/837 kWh), e-mesh Control System

Robben Island microgrid enables the island to operate mainly on solar power, using the diesel only as backup, and reducing fuel costs and carbon emissions by approximately 75%.

HVDC Evolution towards Multipurpose Interconnection

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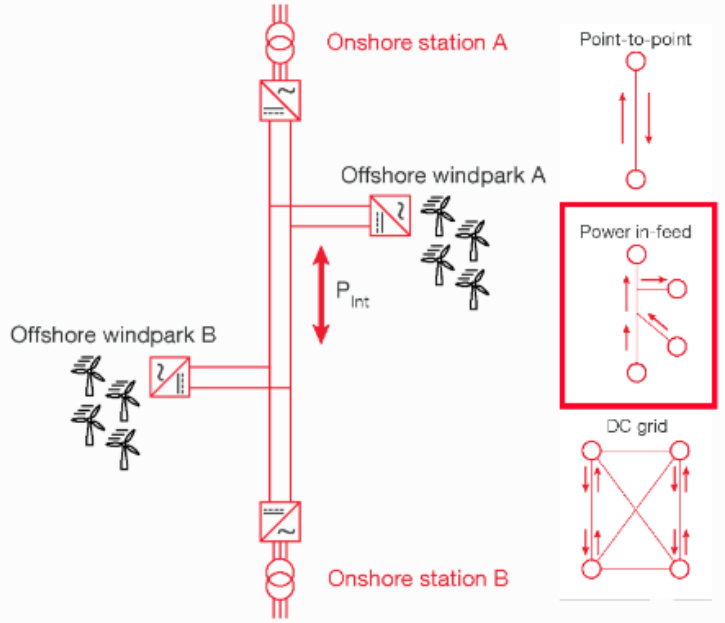
Multipurpose / Multiterminal interconnection

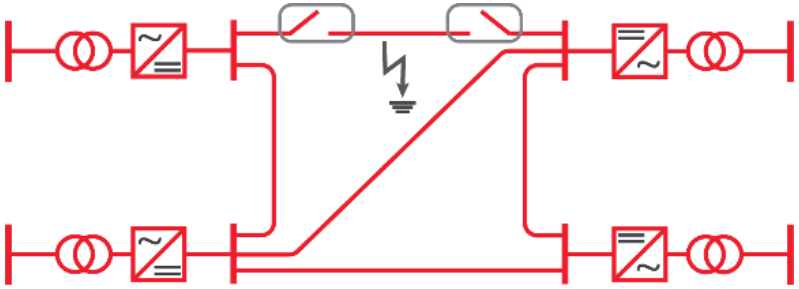
- Connects flexibly two (or more) regions or energy markets
- Integrates (renewable) power sources along the corridor
- And/or efficiently supplies load along the corridor

A regional HVDC grid is a system that comprises one protection zone for DC earth faults



HVDC grid: Multi-Multiterminal interconnections

Regional HVDC grids can be further extended by connecting multiple Multiterminal interconnections, and using HVDC Breaker technology for protection



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Power Electronics & Advanced Control - Key Technologies for Future

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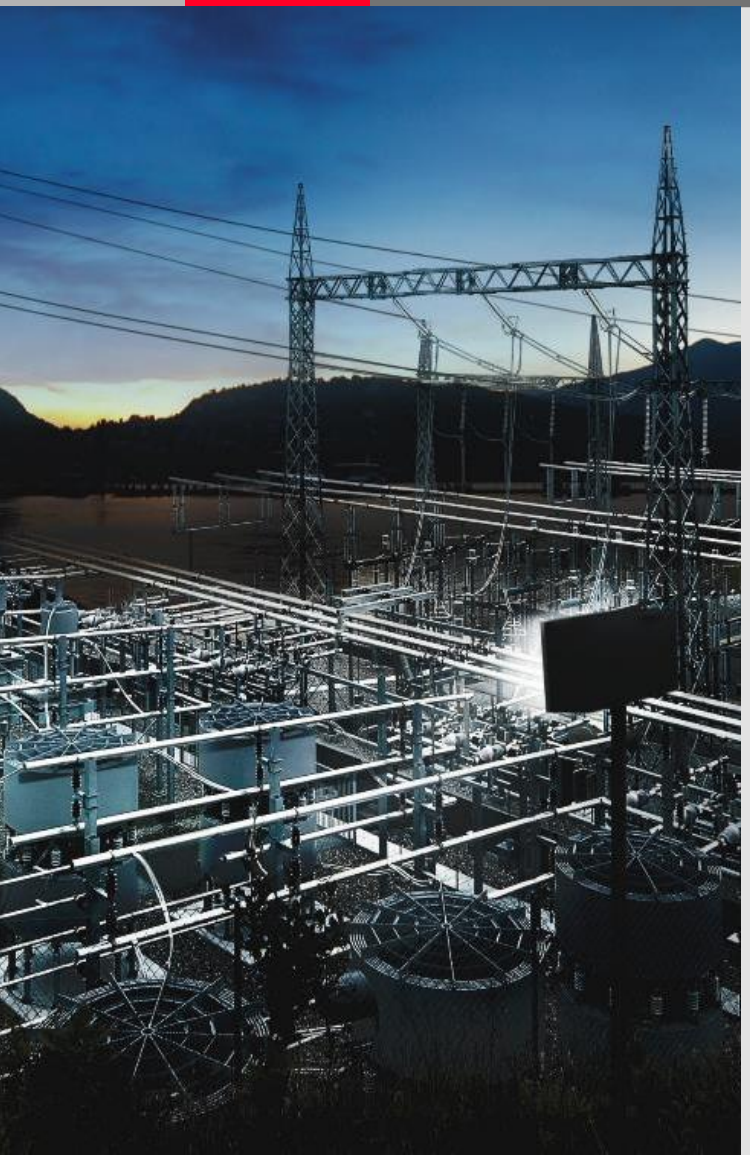

STATCOM & enhanced STATCOM technology

HVDC & MVDC technology

Energy storage & Microgrid solutions

Power Electronics

Power Electronics technology allows the fast and secure conversion and control of energy flows

- Higher power density
- Higher switching frequency

Advanced Control Systems

Advanced Control System providing the required flexibility, strength, inertia and interoperability

- Grid forming
- Synthetic inertia
- Fast frequency response
- Interoperability

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Distributed Energy Resources Management System (DERMS)

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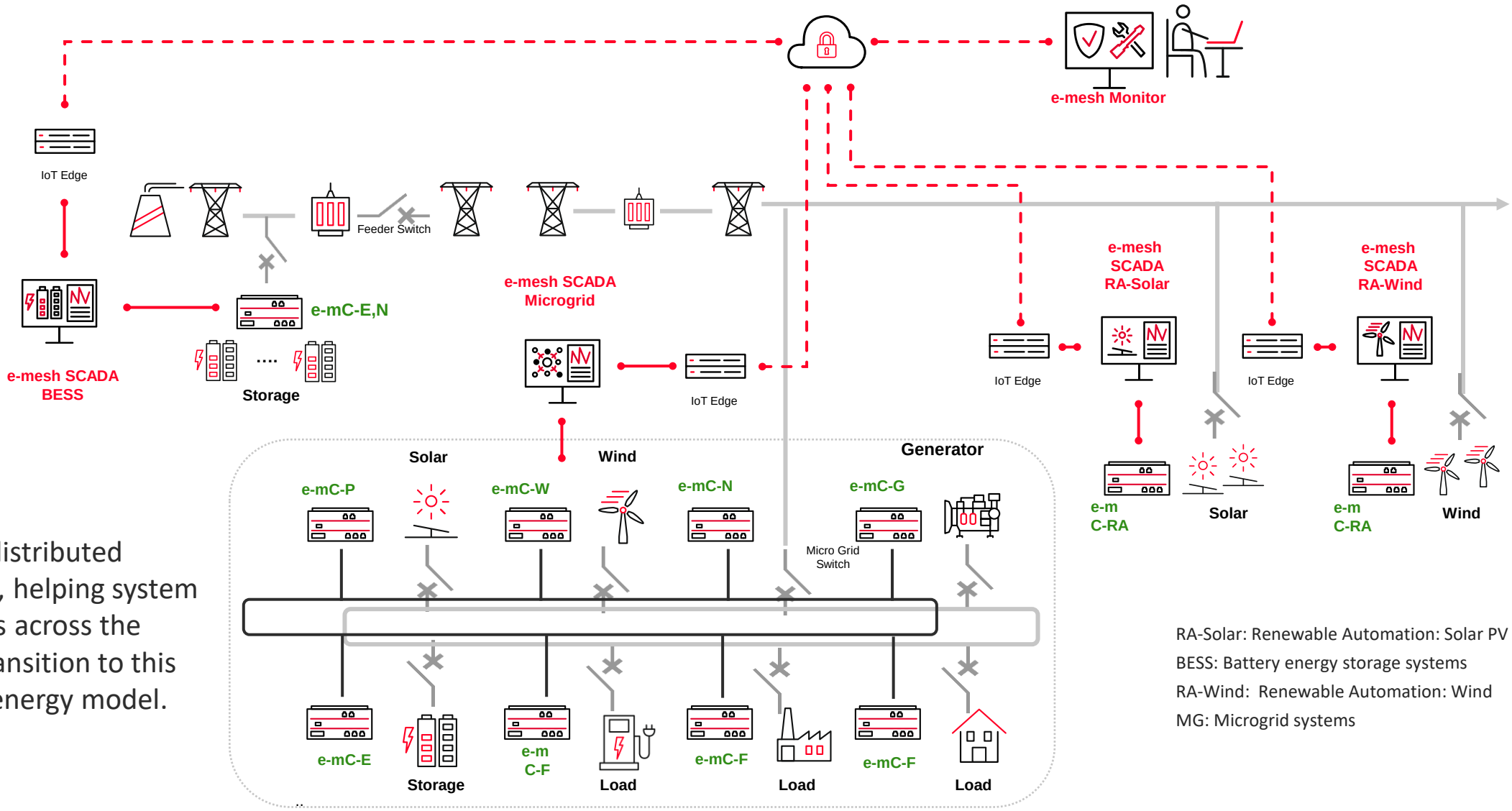
e-mesh™

Infinite insight into distributed energy resources



Digitalization of distributed energy resources, helping system owners-operators across the globe to easily transition to this new distributed energy model.

RA-Solar: Renewable Automation: Solar PV
BESS: Battery energy storage systems
RA-Wind: Renewable Automation: Wind
MG: Microgrid systems

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New Grid Conditions - Driving Additional Digitalization Needs

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Examples of change drivers

- Larger, more distributed systems
- Higher system complexity
- Speed of action remains or even increases
- New types of equipment
- Classic equipment exposed to new types of stress
- Forecasting of various parameters (technical, weather, markets, …)

Value creation utilizing data requires a broad, holistic approach

	Central generation and storage	Transmission grid	Distribution grid	Demand and Distributed Energy Resources
Long-term strategic planning	**Planning** for future flexibility demand			
Short-term operation planning	**Forecasting** short-term flexibility needs			
	Trading flexibility solutions across different markets			
Real-time operation	**Measuring** flexibility needs in real-time			
	Delivering the optimal response from multiple flexibility sources			

Digitalization offers grid operators a more future-proof way to control energy systems with speed, flexibility and reliability as the landscape becomes more complex

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Digital Technologies - Enabler for Flexible Power System Operation

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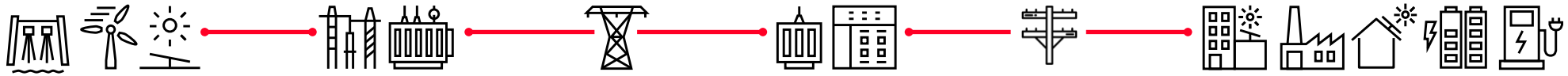

Central generation and storage	Transmission grid	Distribution grid	Demand and Distributed Energy Resources
Long-term strategic planning	Data processing and advanced analytics		Secure communication technologies
Short-term operation planning	Various forecasting technologies		Probabilistic simulations and optimization
Real-time operation	Active grid topology management		Real-time background scenario calculation

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