PUBLIC

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Hochspannungsprodukte für Netzanforderungen der Zukunft

Hochspannungssymposium Stuttgart, 2024

Gerhard Salge, CTO Hitachi Energy

11.6.2024

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Electrification is growing like never before

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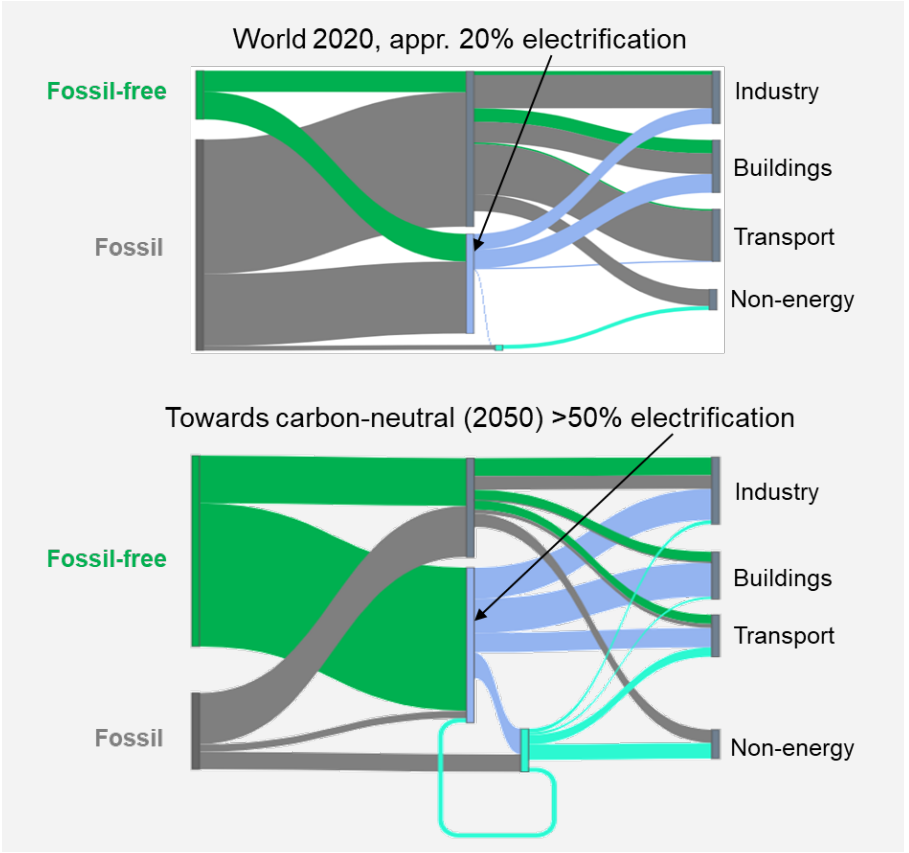
Carbon emission reduction, energy security and energy efficiency are driving electrification growth

64 countries that account for 89% of global emissions have announced net-zero targets

Country with net-zero target announcement



The global power system of 2050 will require four times power generation capacity and will need to transfer three times as much electrical energy compared to 2020

Sources: Hitachi Energy analysis of IEA Net Zero by 2050, Energy Outlook studies by IEA, BNEF, DNV and IRENA; McKinsey Energy Insights Global Energy Perspective 2023

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The Power System Evolution – Future Power Systems

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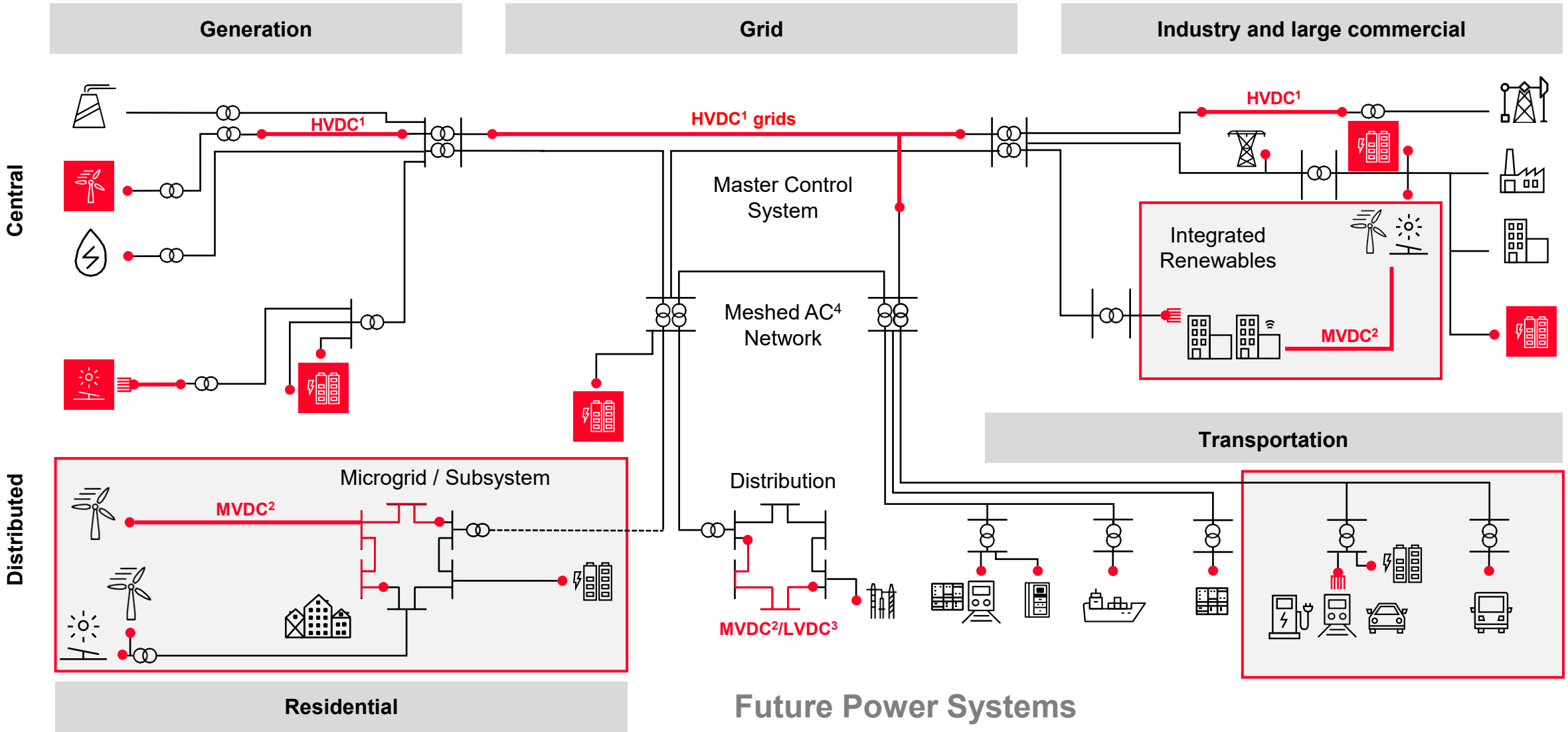

1. High-Voltage Direct Current
2. Medium-Voltage Direct Current
3. Low-Voltage Direct Current
4. Alternating Current

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Transitioning energy landscape

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While reliability and stability remain foundational principles of power system operations, the evolving energy landscape has necessitated a broader focus that includes flexibility and resilience

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Operational challenges in power systems with a high VRES share

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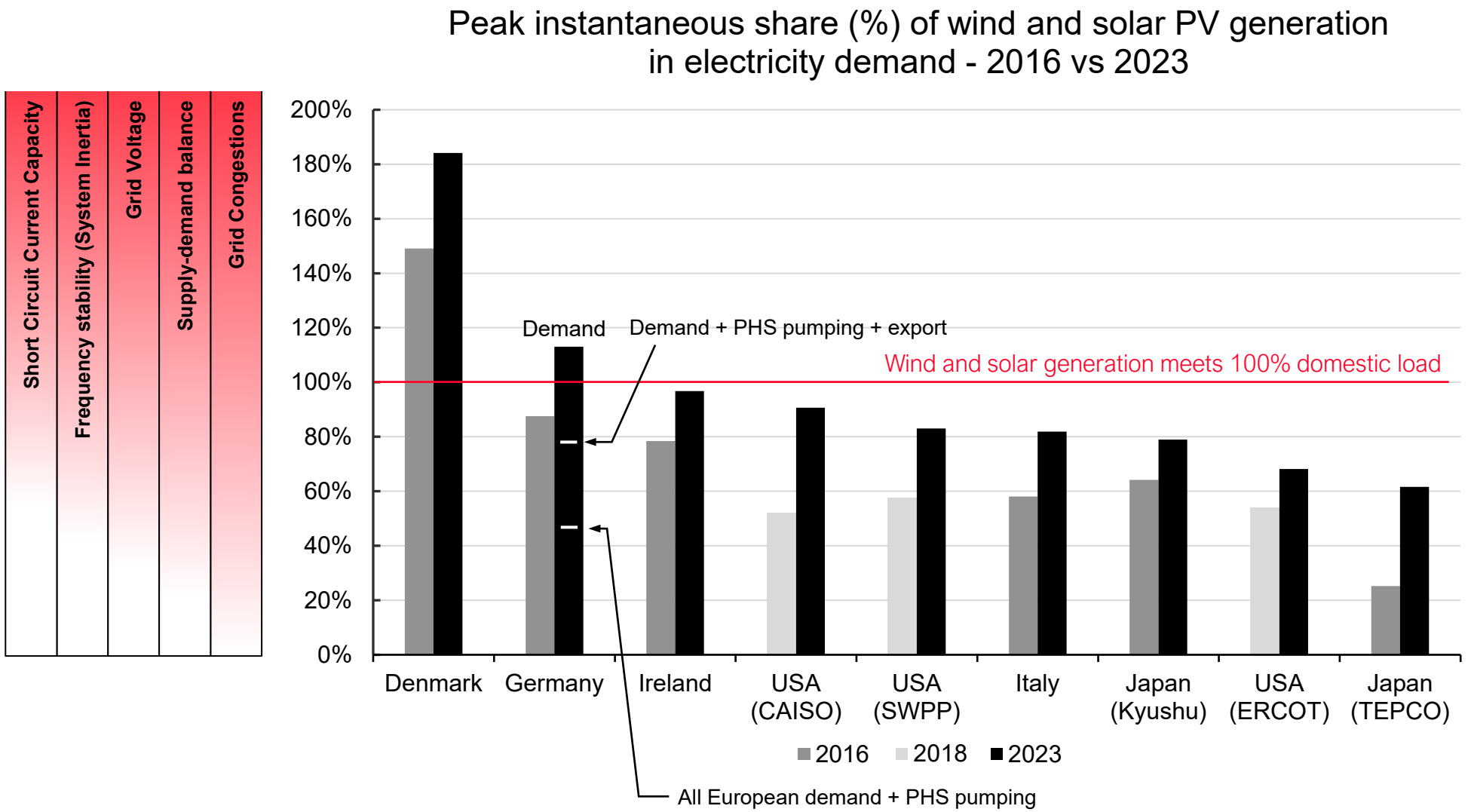

Sources: ENTSO-E transparency platform; Energy Information Administration (EIA); OCCTO

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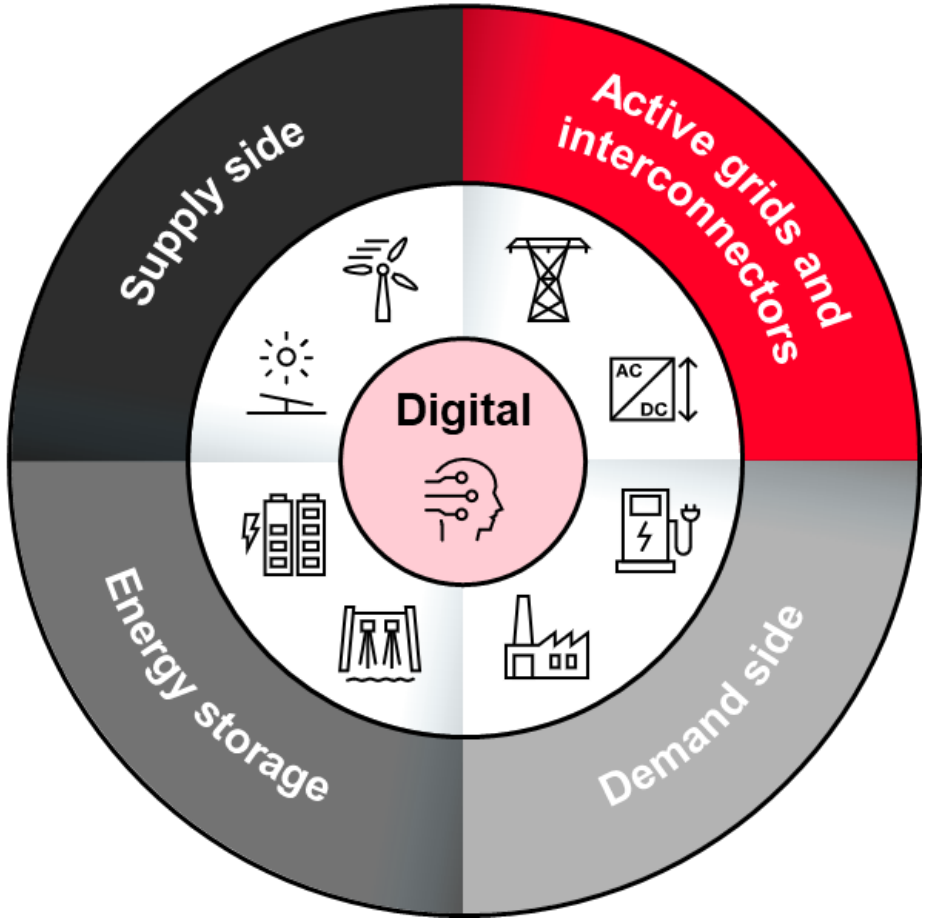
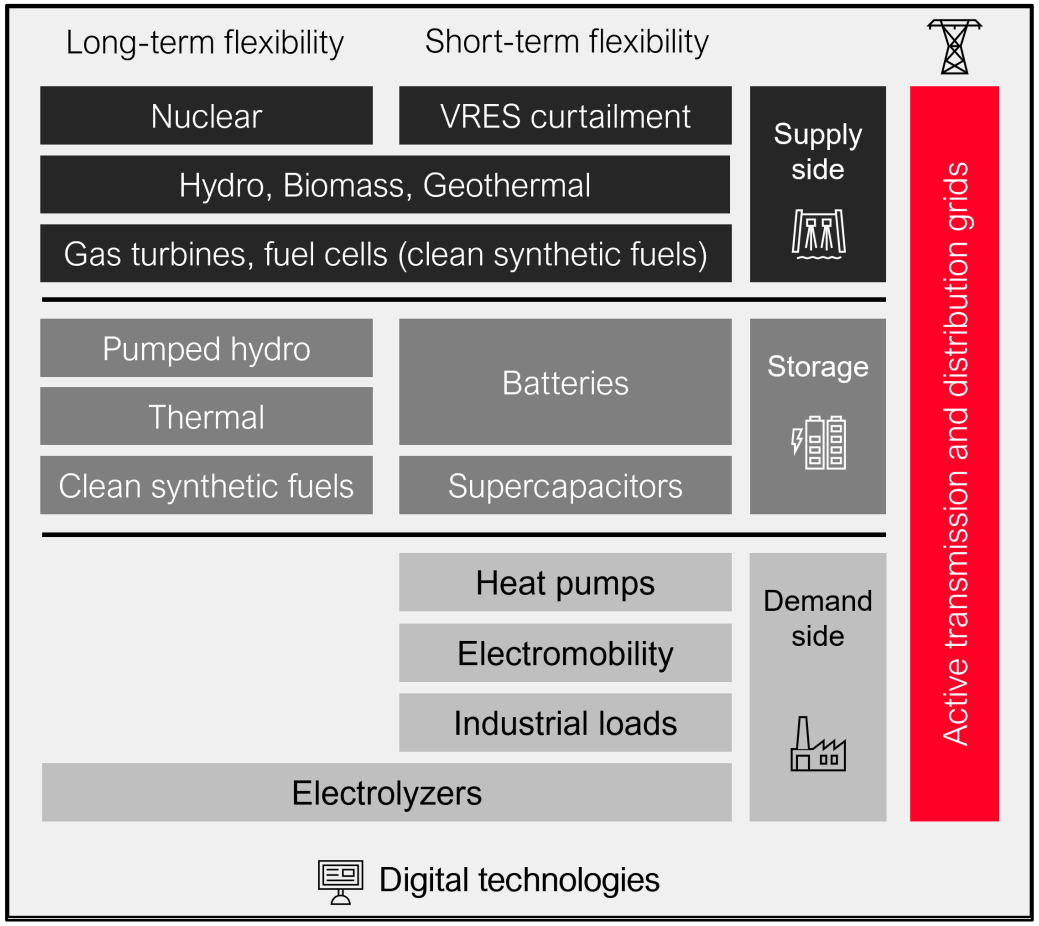
Four levers of flexibility with digital technology at the core





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

Technologies enabling the future Power System of Systems

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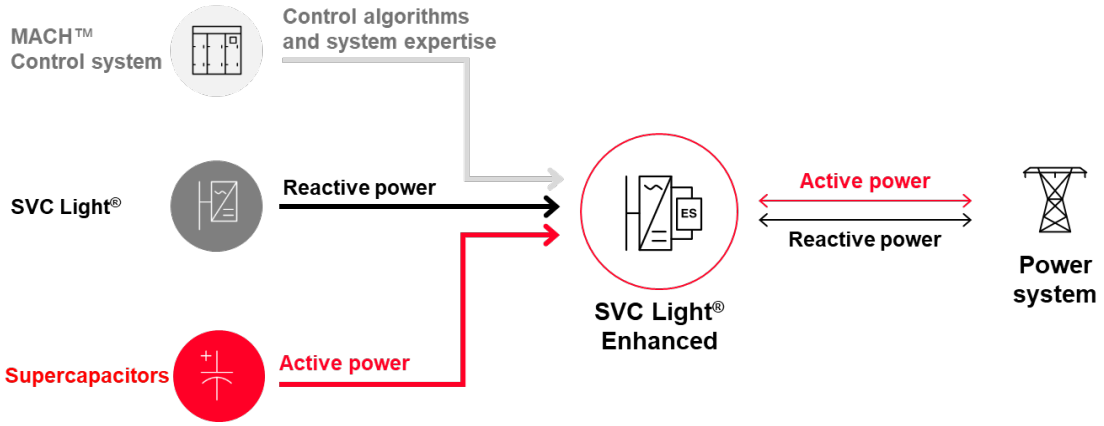
From grid following to grid forming converters

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

AC

(Enhanced) STATCOM



HVDC

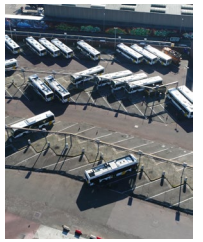
DC

- 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



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Frequency stability within future power systems

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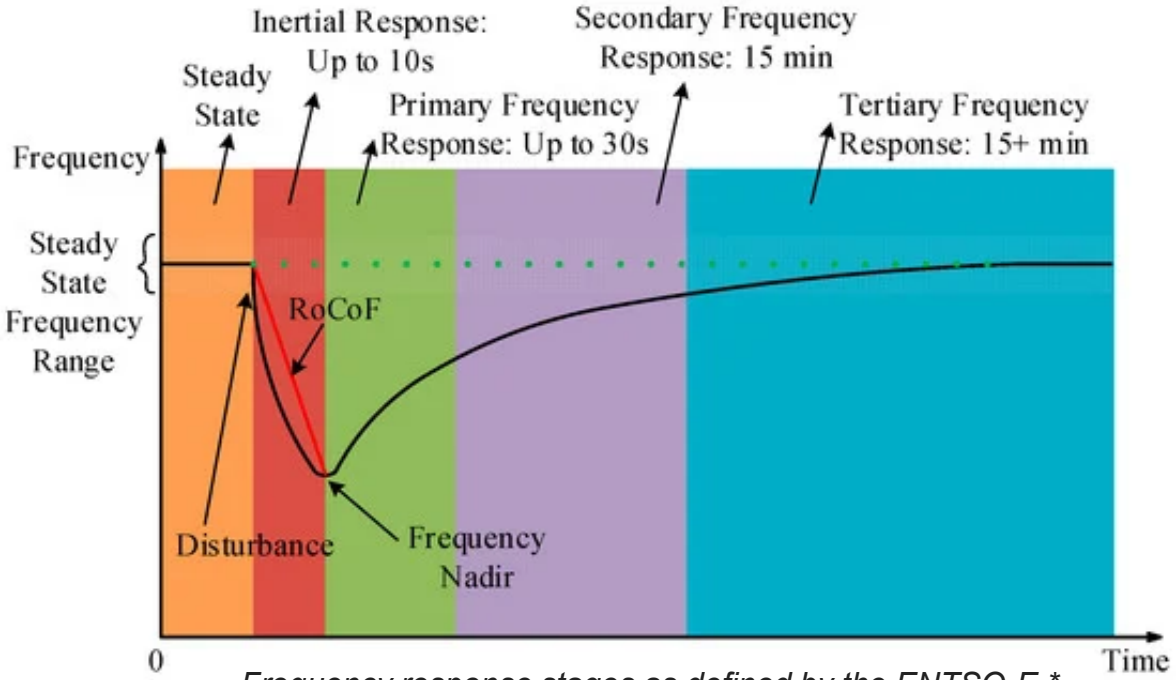
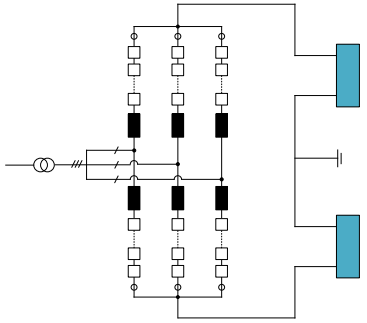
The Need

Networks with a high degree of power electronic interfaced renewable generation will face problems with low inertia and will require new types of services.



*Frequency response stages as defined by the ENTSO-E **

Enhanced STATCOM



- STATCOM with active power capability for synthetic inertia, fast frequency regulation and grid support
- Choice of storage medium depends on power and energy requirements

Characteristics	STATCOM	Synchronous Condenser
Operational power losses	< 0.1% @ 0 MVAr ~ 1.0 % @ max	~ 1.0% @ 0 MVAr, ~ 1.5-2% @ max
Short-circuit power contribution	Low (defined by power electronics overloadability)	4-5 times machine rating
System inertia (Frequency) support	Only in combination with additional storage	Natural due to rotating mass, can be increased with flywheel

* MDPI Open Science: Assery, Zhang and Chen: Large-Scale BESS for Damping Frequency Oscillations of Power Systems with High Wind Power Penetration, December 2023

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Synchronous Condenser and STATCOM – Stored energy & Scalability

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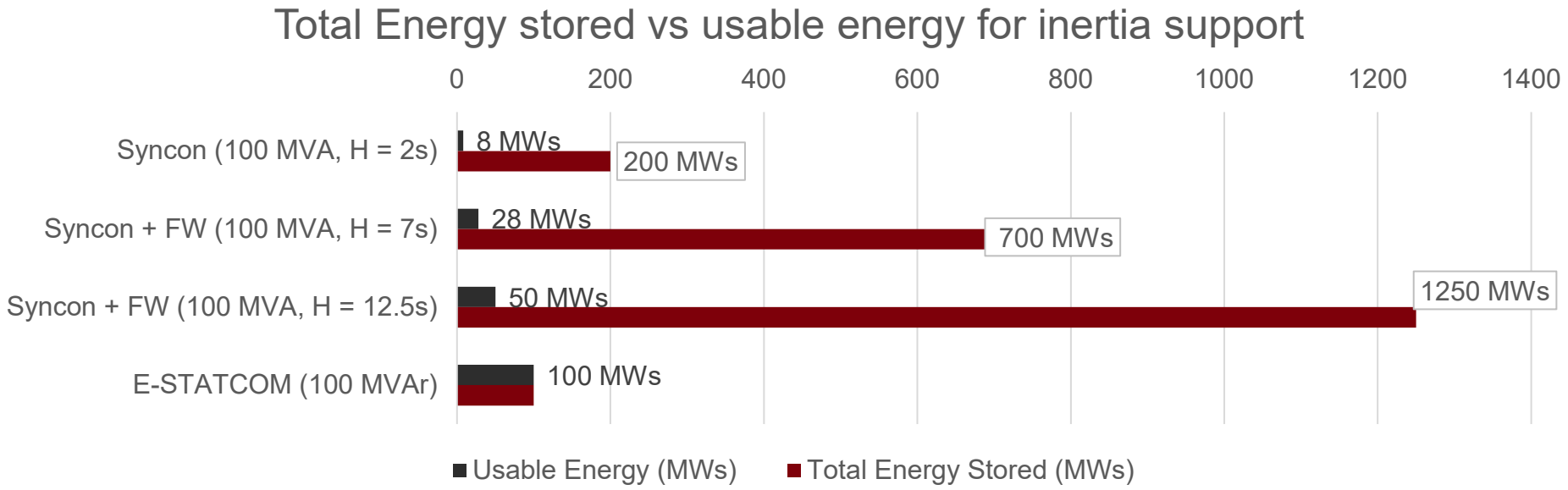
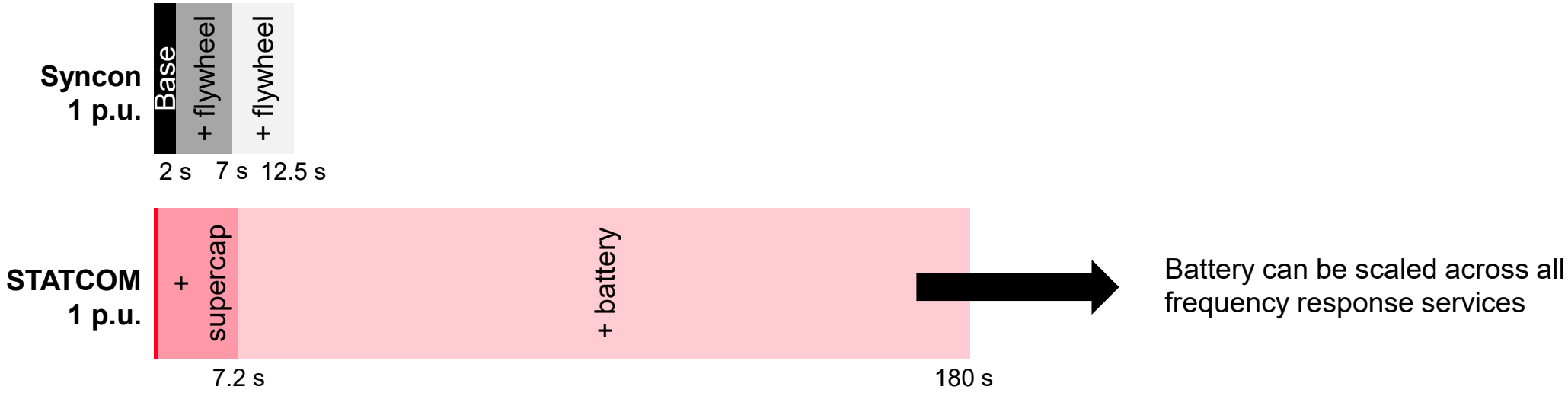


Scalability



Syncon: Synchronous Condenser; FW: Flywheel; STATCOM: Static VAR Compensator; H factor is indicating the ratio of kinetic energy in MWs and reactive power in MVAr available from the given plant or equipment, in this case synchronous condenser

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Record-breaking HVDC technologies

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1,100 kV
Changji-Guquan

The world's most powerful UHVDC connection

720 km
North Sea Link

World's longest subsea electricity interconnector

PFS
Power From Shore

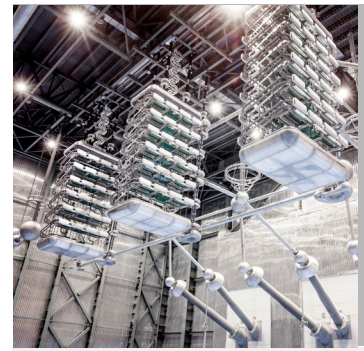
First-of-its-kind subsea power transmission network in the MENA region

3.6 GW
Dogger Bank Wind Farm

Connecting the world's largest offshore wind farm to the UK

1 GW
Mumbai city infeed

Bring almost 50 percent more power to 20 million people in India



800 kV
North-East Agra

The world's first multi-terminal UHVDC transmission link

Customer handover years: CG 1100 2018, North-East Agra 2017, NSL 2022, Dogger Bank 2023-2025, PFS 2024, Mumbai city infeed 2025

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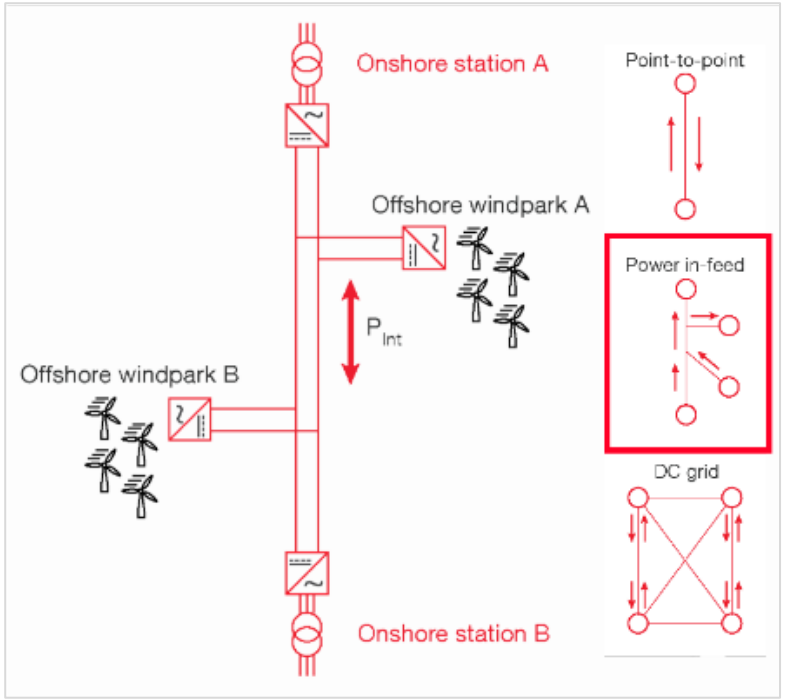
HVDC evolution towards Multipurpose interconnection

Multipurpose / Multiterminal interconnection

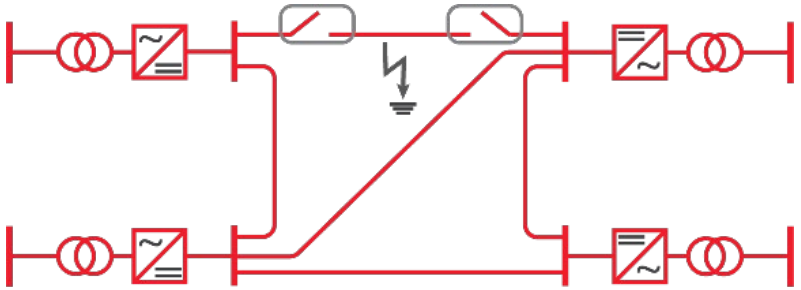
- Connects flexibly two (or more) regions or energy markets
- Integrates (renewable) power sources along the corridor
- And/or efficiently supplies load along the corridor

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

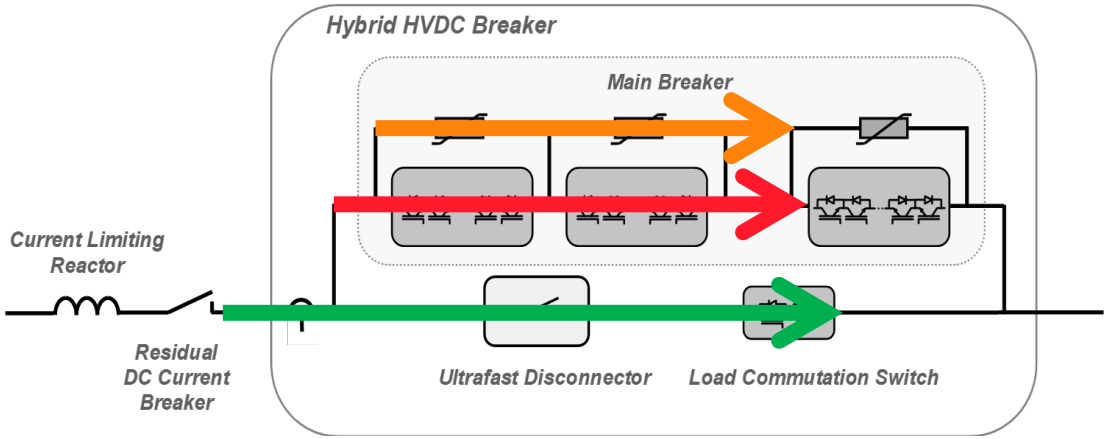
Regional HVDC grids can be further extended by connecting multiple Multiterminal interconnections, and using HVDC Breaker technology for protection



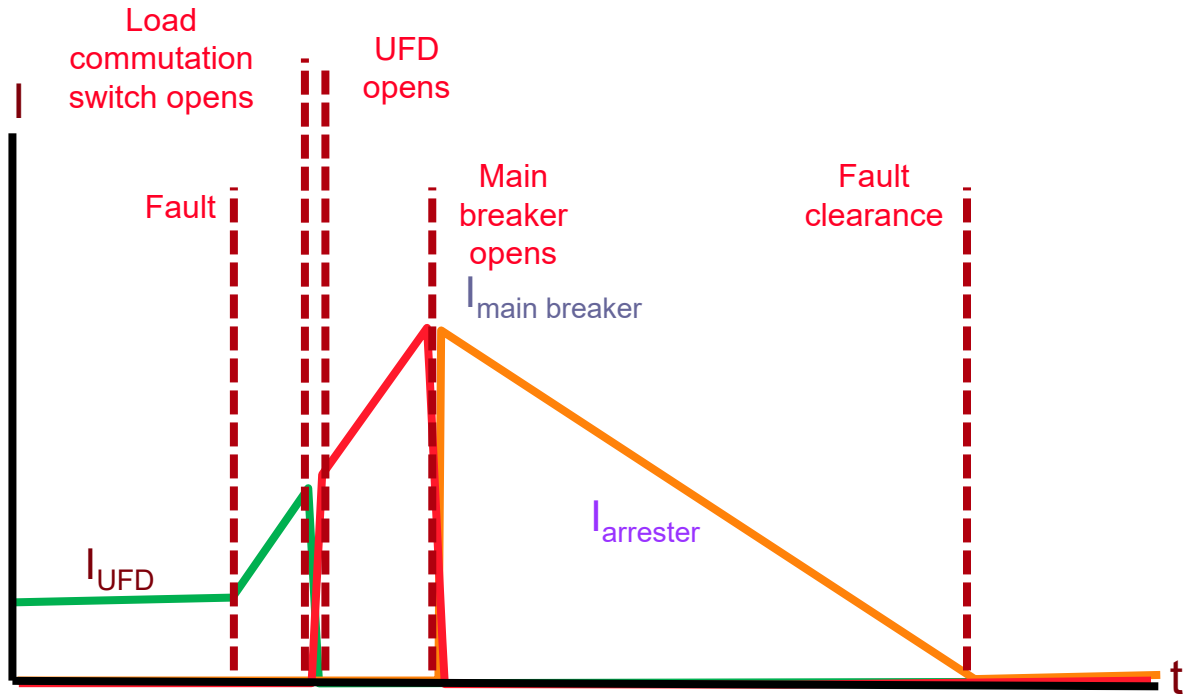
HVDC grid: Multi-Multiterminal interconnections



Hybrid HVDC Breaker operation



Breaking timeline



Towards HVDC meshed grids

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VSC Multi – Terminal

Ability to manage different DC lines from one station

- TRL[1] 8, Hitachi Energy demonstrated the technology
- Multi-terminal ready and multi-terminal prepared
- READY4DC project (interoperability aspects)

HVDC – Breaker

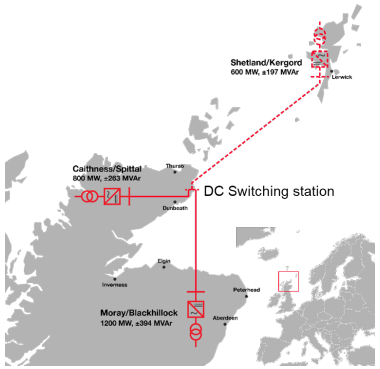
Ability to isolate fault current on DC mesh

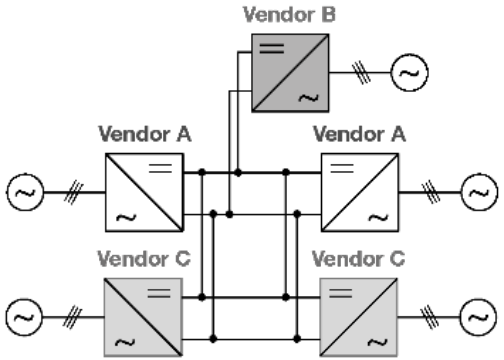
- TRL[1] 7, Hitachi Energy demonstrated the technology
- Demonstration in 2020: 350kV, 20kA power range
- Demonstration as part of EU-funded PROMOTioN project

Grid control & protection

Ability to supervise power flows across a DC meshed grid

- TRL[1] 6, technology development of control and protections algorithms completed
- Project InterOPERA ongoing





Technology is available to start building a meshed HVDC grid

Public

[1] TRL: Technology Readiness Level

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Transformer technologies enabling future Power System applications

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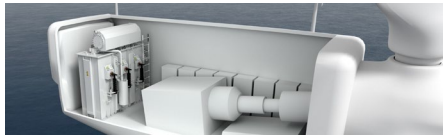
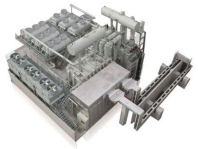
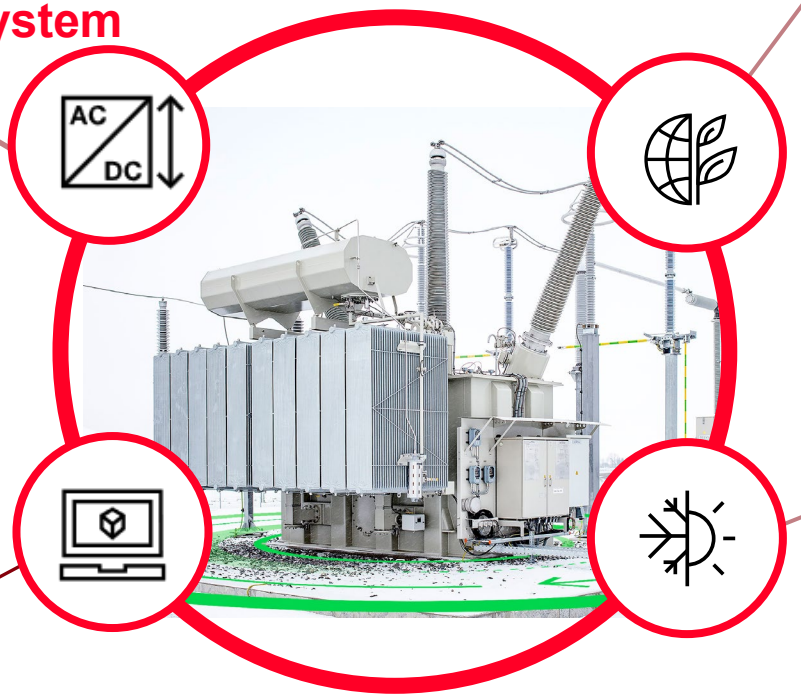




More Power Electronics within the system

- HVDC
- Transient resistivity
- Wind & Solar
- Rectiformer
- Solid-State

Digital asset management providing system flexibility

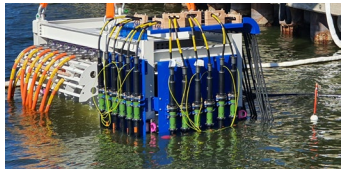


Safety and sustainability

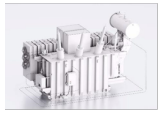
- Fire and fault arc safety
- Total lifecycle sustainability

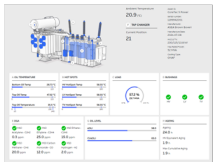
Changing environmental conditions

- Enhanced cooling
- Subsea
- Floating

Power or Distribution transformer + TXpert™ Ready Sensors + TXpert™ Hub = TXpert™ Enabled Transformer + TXpert™ APM software and Services = **Transforming performance**

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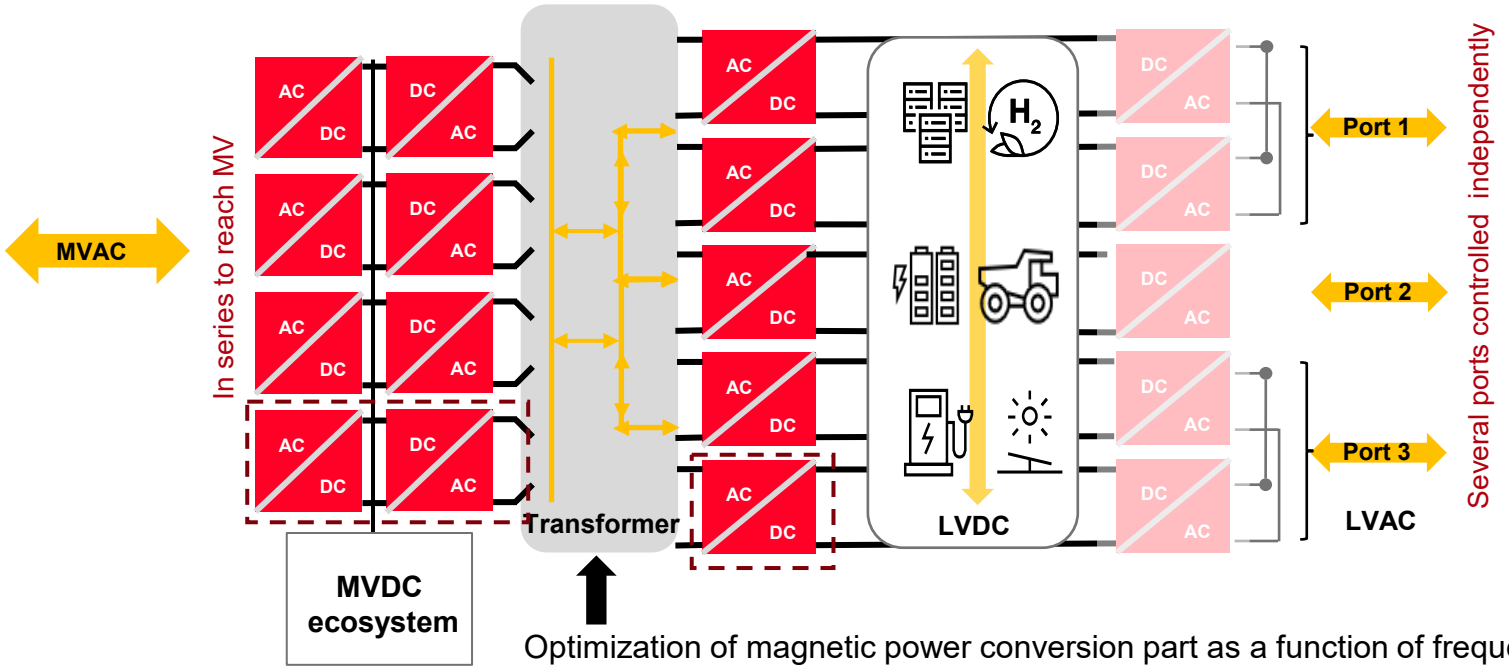
Solid State Transformer – Concept

Solid-State-Transformer (SST) is a solution consisting of a galvanically isolating magnetic power conversion element (Transformer) and a variable number of AC/DC converters.

SST solutions can flexibly connect AC/AC, AC/DC, DC/AC & DC/DC systems at variable voltage ratings with galvanic isolation.



Optimization of magnetic power conversion part as a function of frequency, size, weight, voltage and current

SST is a superior concept for highly flexible energy flow and complex applications across AC and DC sub-systems

Sustainable products and solutions deliver total life-cycle optimization

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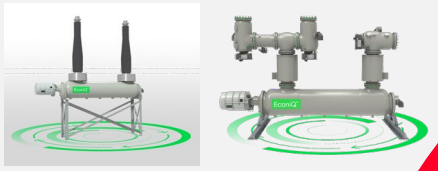
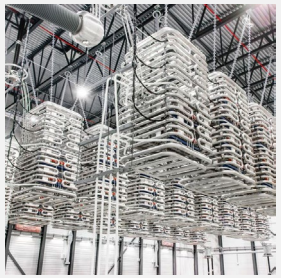
Products

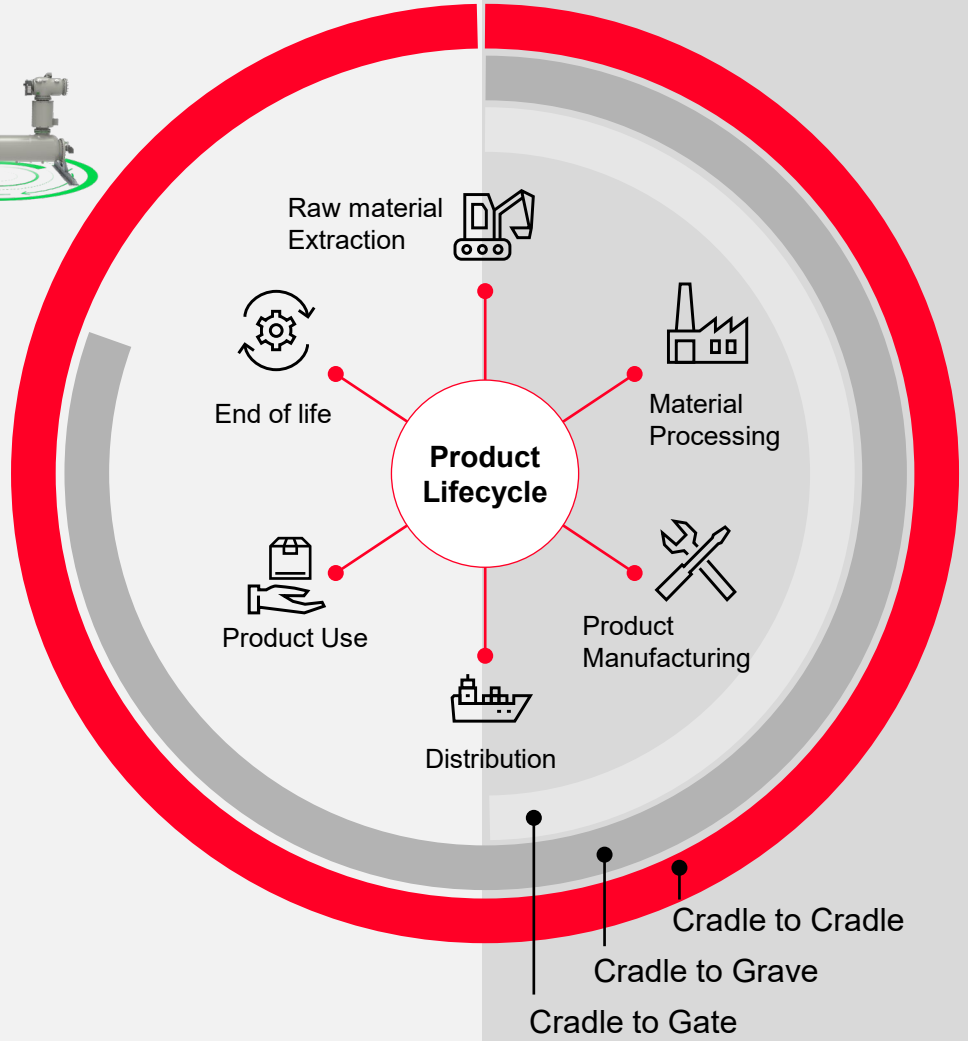
Eco-efficient **Circuit Breaker**



Transformers with enhanced energy efficiency, safety, and biodegradable fluids

HVDC connection with sustainability-optimized design

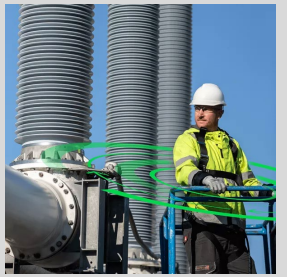




Services

EconiQ™

Consulting services



EconiQ™ retrofill services

Energy Portfolio Management

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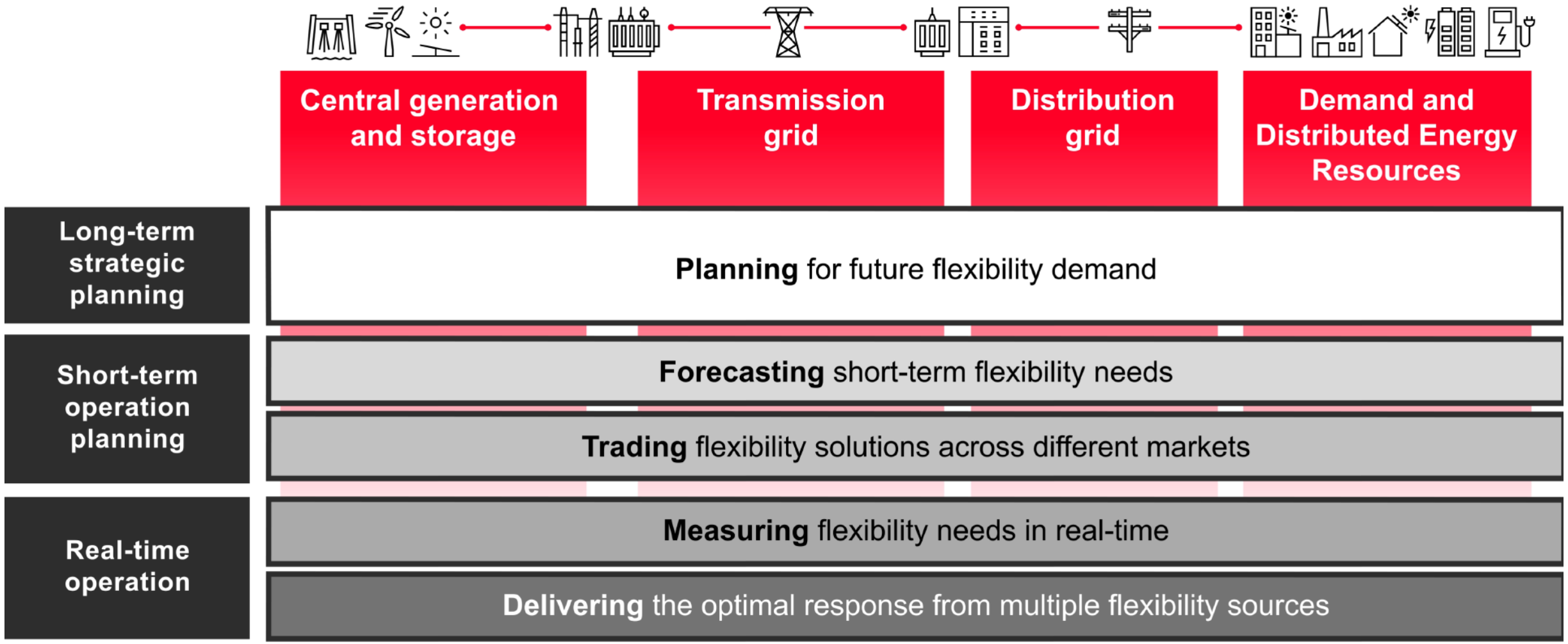
Digital technologies as enabler for flexible power system operation



Digital technologies enabling future Power Systems

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Vegetation Management

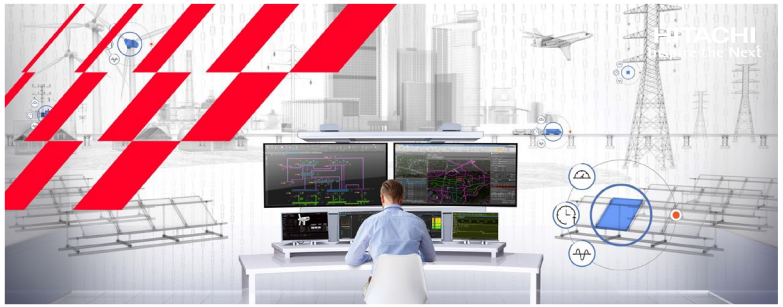
Forecasting & Trading

Core Digital Technologies (examples)

Image & Video Analytics
Operations Research
Digital Signal Processing

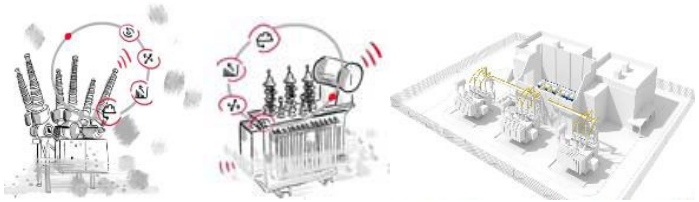
Supported by Machine Learning

Network Management



Asset Management

Fully Digital Portfolio



in combination with an in-depth understanding of the assets and their modeling

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Energy transition needs technologies – and partnerships

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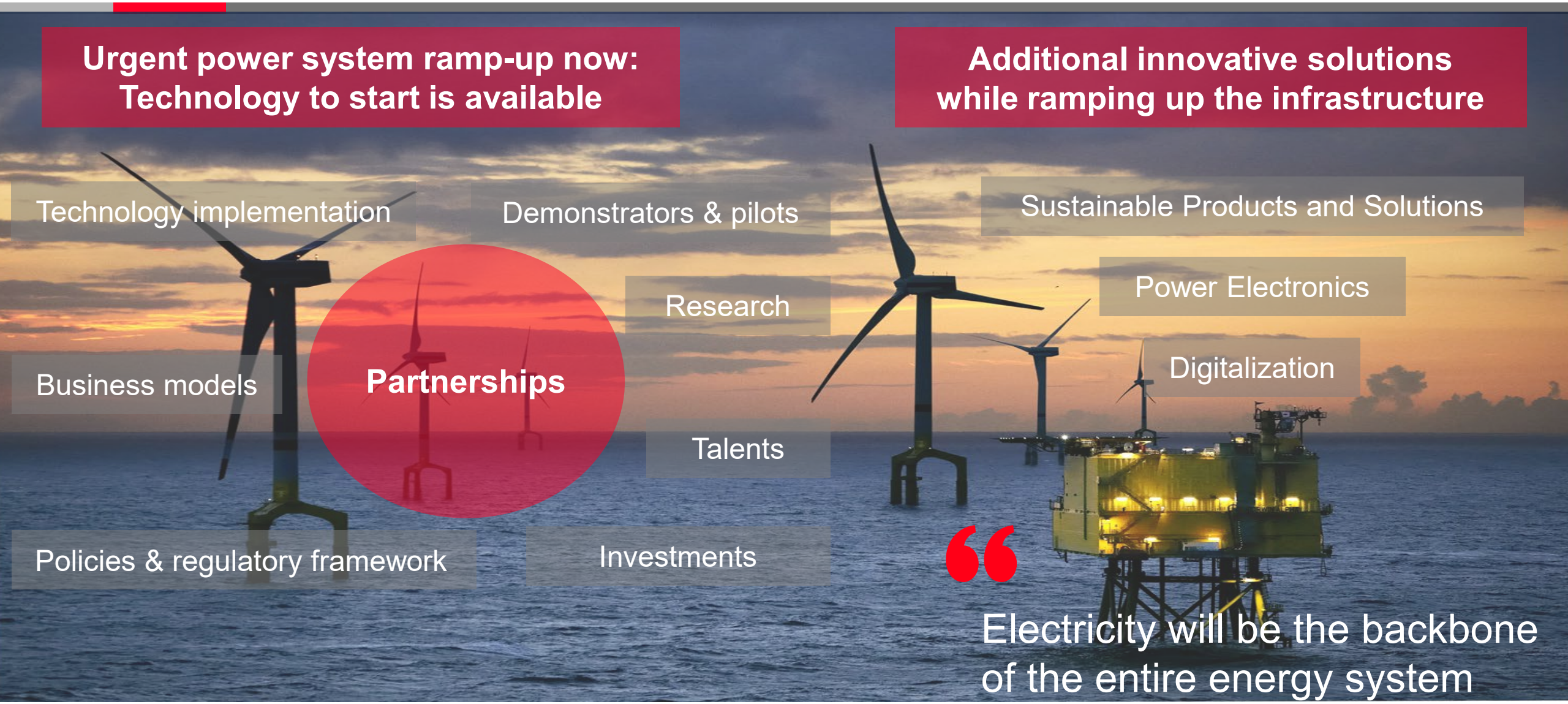

Urgent power system ramp-up now: Technology to start is available

Additional innovative solutions while ramping up the infrastructure

Technology implementation

Demonstrators & pilots

Research

Business models

Partnerships

Talents

Policies & regulatory framework

Investments

Sustainable Products and Solutions

Power Electronics

Digitalization

“Electricity will be the backbone of the entire energy system

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