Grid resilience through HVDC technology

Dr. Liliana Arevalo – Senior principal specialist HVDC insulation systems

2022-05-10

Vita Speaker – Liliana Arevalo

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UNIVERSIDAD NACIONAL DE COLOMBIA

UPPSALA UNIVERSITET

Dr. Liliana Arevalo

1997 - 2002 Electrical engineer from Universidad Nacional de Colombia

2002 - 2005 MSc on electrical engineering – emphasis High voltage technologies. Universidad Nacional de Colombia

2005 – 2007 EMC group member, professorship at Universidad Nacional de Colombia, Universidad Central

2007 - 2010 Phil. Licenciate on electrical discharges. Uppsala University

2007 – 2011 Ph. D. on engineering sciences. Specialization in atmospheric discharges. Uppsala University

2011 working at ABB Power Grids HVDC – now called Hitachi Energy:

2011 – 2013 -R&D senior specialist on electrical insulation

2013 – 2018 R&D principal specialist on electrical insulation

2018 – up to now Senior principal specialist on HVDC electrical insulation.

2015 – up to now Adjunct professor “Electrical discharges”. Department of engineering sciences. Division of electricity at Uppsala University

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More than 75 publications in conferences, journals and international standards

Arevalo L, Wu D, Larsson M. “Air humidity factor for external insulation under positive switching impulses – Revisited” Lectures Notes in Electrical Engineering, book series, Springer, volume 599, pp 784 – 794. https://doi.org/10.1007/978-3-030-31680-8_76. ISBN 978-3-030-31679-2. 2019

Larsson M**,** Törnkvist C, Borg K, **Arevalo L**, Wu D. “Non-continuous positive leader propagation in sphere-plane air gaps”. Lectures Notes in Electrical Engineering, book series, Springer, volume 599, pp 1205 – 1214 https://doi.org/10.1007/978-3-030-31680-8_115. ISBN 978-3-030-31679-2. 2019

Arevalo L, Wu D, Diaz O, Larsson M, Tornkvist C. “Influence of extreme low humidity on the dielectric strength of air insulation under critical design voltages”. 2019 CIGRE Canada Conference. Montreal, Quebec, September 2019

Arevalo L, Wu D, Larsson M. “DC air humidity factor for air external insulation revisited” *2019 IEEE CEIDP Conference on Electrical Insulation and Dielectric Phenomena*. Richland, Washington October 2019

Arevalo L, Wu D, Hettiarachchi P, Lobato A, Rahman M, Cooray V. “Streamer region in long air gaps – Experiments and modeling”. *2018 IEEE CEIDP Conference on Electrical Insulation and Dielectric Phenomena*. Cancun, Mexico October 2018

Arevalo L, Wu D, Hettiarachchi P, Lobato A, Rahman M, Cooray V. “The leader propagation velocity in long air gaps” *34th International Conference on Lightning Protection ICLP 2018*; Rewszow – Poland, September, 2018

Larsson M, Tornkvist C, **Arevalo L**, Wu D. “DC and SI breakdown characteristics of air gaps at low humidity” IEEE Electrical Insulation Conference, June 2018

CIGRE WG C24.26. Evaluation of lightning shielding analysis methods for EHV and UHV DC and AC transmission lines. CIGRE guideline, October 2017….

More than 5 patents

Member of IEC and CIGRE Groups: Swedish National committee TK99 “Installation and Insulation coordination”

IEC TC28 MT9 “Insulation coordination - AC” IEC JWG13 “insulation coordination DC”

CIGRE WG C4.410 “Lightning Striking Characteristics to Very High Structures”

CIGRE WG C4.26 “Evaluation of lightning shielding analysis methods for EHV and UHV DC and AC overhead transmission lines”

CIGRE WG D1.45 “Impact of rain on insulator performance”

CIGRE WG D1.50 “Atmospheric corrections”

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Energy system 2050: towards a carbon-neutral vision

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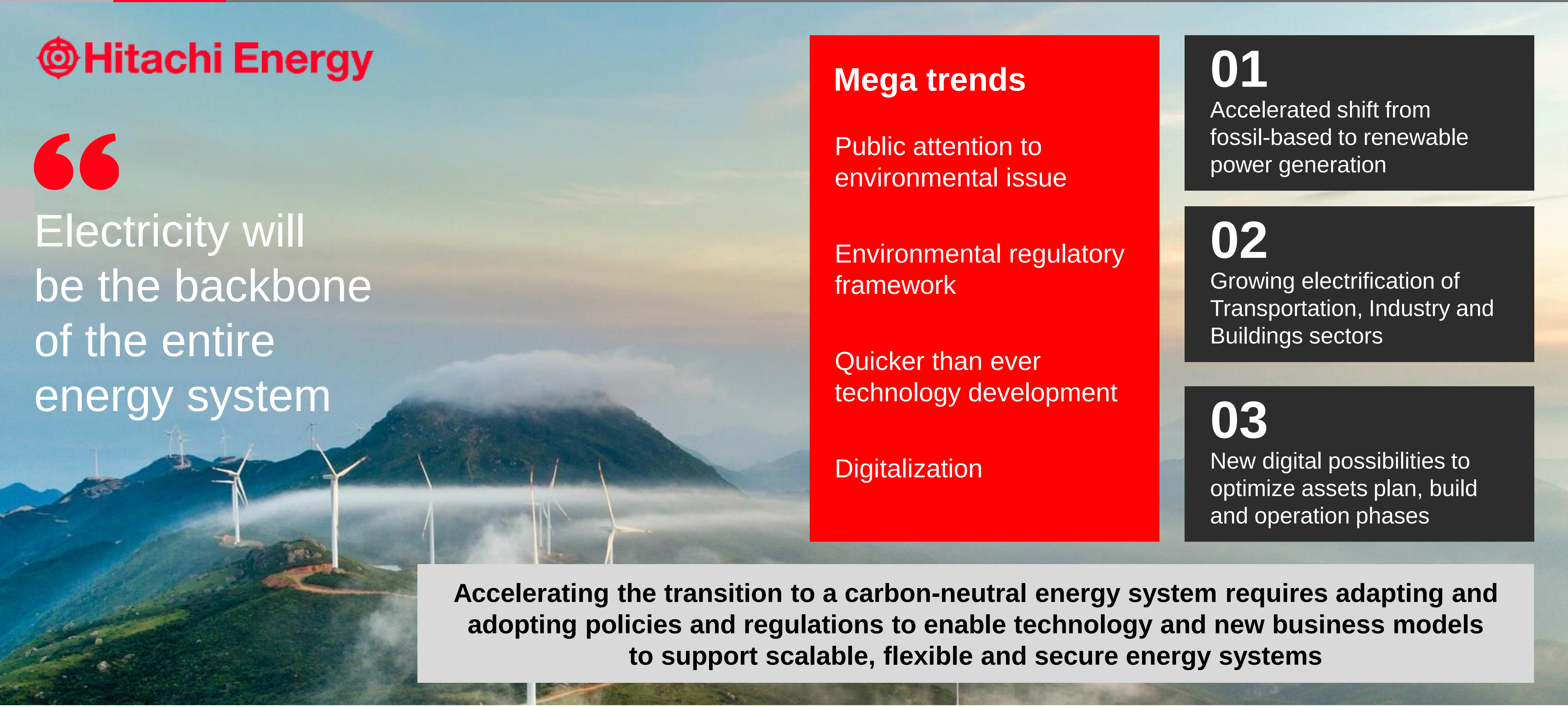

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"Electricity will be the backbone of the entire energy system

Mega trends

- Public attention to environmental issue
- Environmental regulatory framework
- Quicker than ever technology development
- Digitalization

01
Accelerated shift from fossil-based to renewable power generation

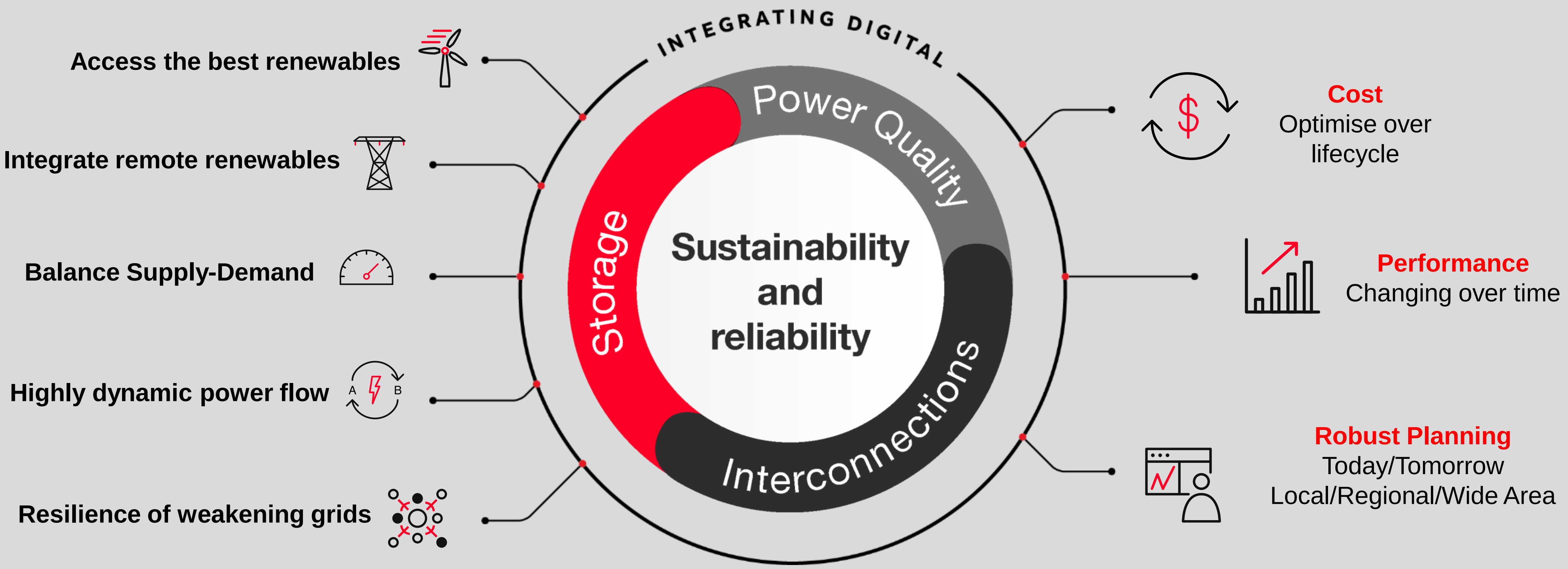
02
Growing electrification of Transportation, Industry and Buildings sectors

03
New digital possibilities to optimize assets plan, build and operation phases

Accelerating the transition to a carbon-neutral energy system requires adapting and adopting policies and regulations to enable technology and new business models to support scalable, flexible and secure energy systems

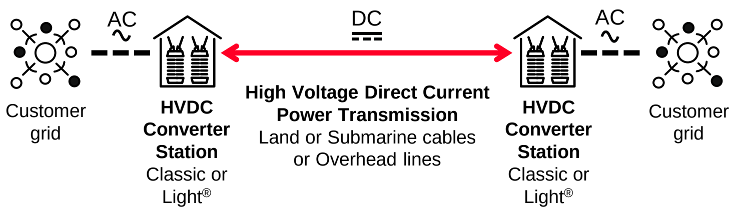
Challenges facing the grid

The conversations that we have every day with customers



Strongly interconnected grids will better manage the energy system transformation

HVDC Interconnecting grids for a sustainable energy system

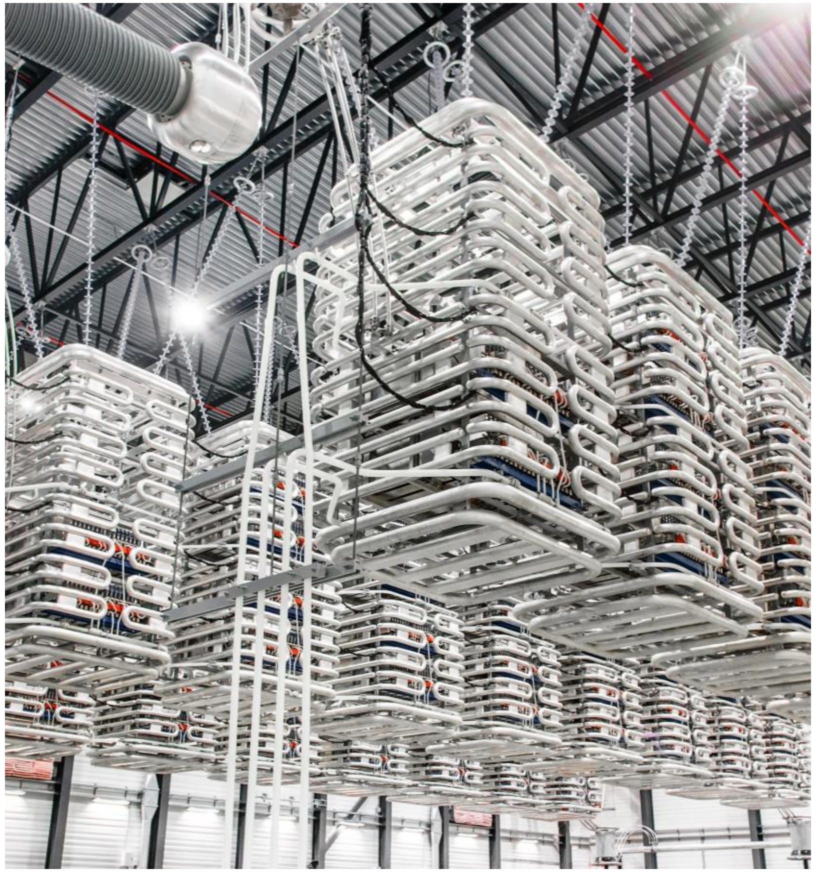


- Connects synchronous grids and asynchronous grids
- Technology of choice for bulk power transmission over long distances with minimum losses
- Controllable power flow enables precis energy trading
- Resolves AC bottlenecks in AC grids
- Ensure stability of the grid
- Minimal environmental impact

Lower losses — **More power**

Smaller footprint — **More sustainable**

Controlled power flows — **More grid stability and versatility**

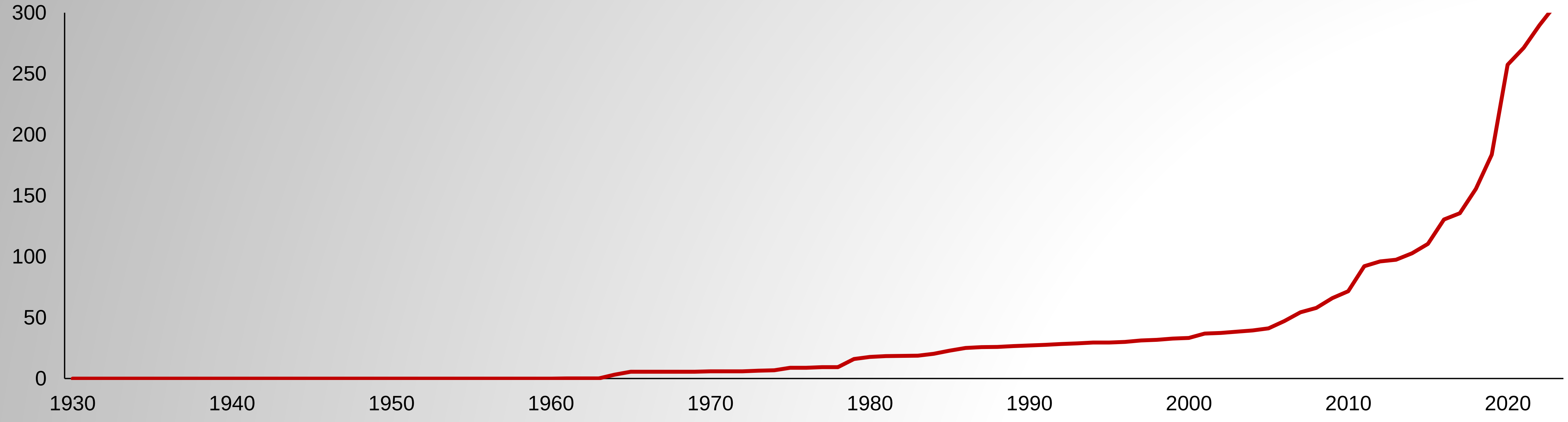


HVDC, the tool of choice to connect, dispatch and trade renewable power for sustainable energy systems

From an idea to global industrialization

HVDC is the solution for today's grid challenge

Cumulated GW installed



1928

Dr Uno Lamm began developing HVDC in Ludvika, Sweden

1954

The world's first commercial HVDC link at Gotland, Sweden

1960s

Mercury arc valves replaced with thyristor semiconductor valves

1997

The world's first VSC[1] HVDC installation

2017

VSC HVDC highest performance ever – 3,000 MW, 640 kV, 2,000 km

Exponential growth has been driven by Technical developments and Grid transformation needs

1. Voltage Source Converter (HVDC Light®)

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HVDC Light®

Your grid challenges, solved by HVDC Light®

Weak network?

- Black start power restoration
- Active/reactive power control
- AC voltage and frequency stabilization (possibly increasing AC grid utilization)

Bi-directional power trade?

- Fast power reversal

Integration of renewables?

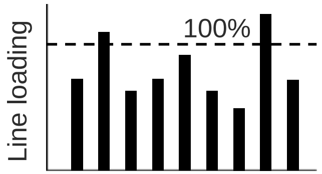
- Power and voltage control
- Compact solution for minimum footprint

Pioneered to answer new industry needs… becoming mainstream in many applications…

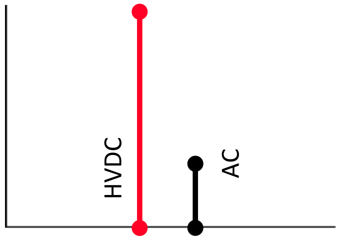
Operational constraints in AC grids

and how HVDC helps

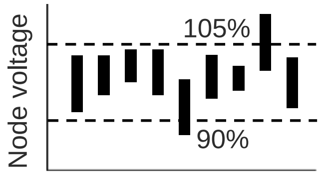
Power system capacity (steady state)



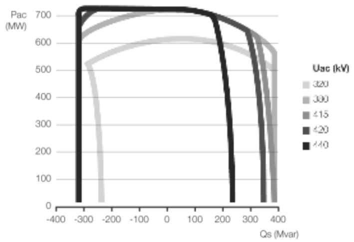
Current limits



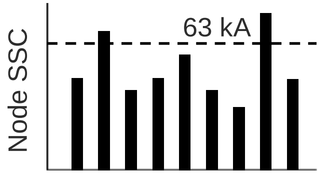
More power
Power flow control



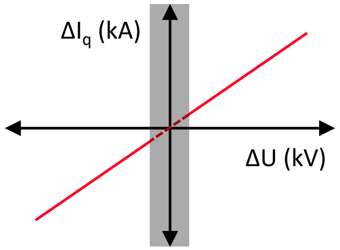
Voltage limits



Reactive power control



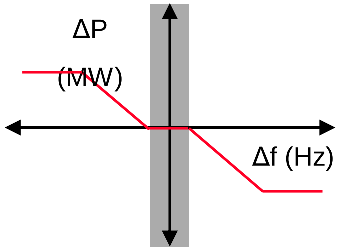
Short-circuit current limits



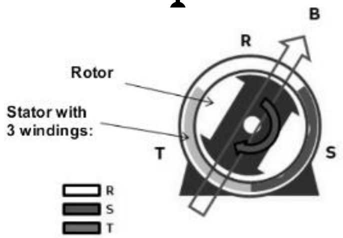
Controlled short-circuit current

Power system stability (transient state)

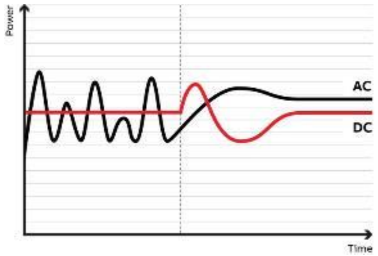
Frequency



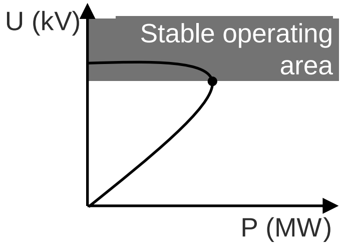
Frequency control



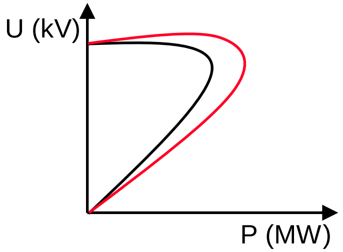
Rotor angle



Damping control



Voltage



Dynamic voltage control

Enhanced system resiliency

Emergency Power Control (EPC)

EPC activated during and directly after contingencies in AC grid

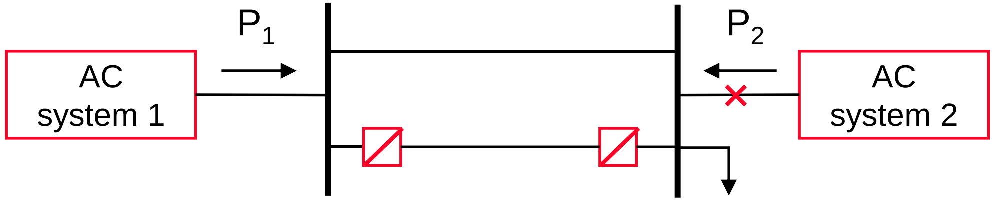
Power flow through HVDC system quickly adjusted in order to return to acceptable operating range for power plants and line loading

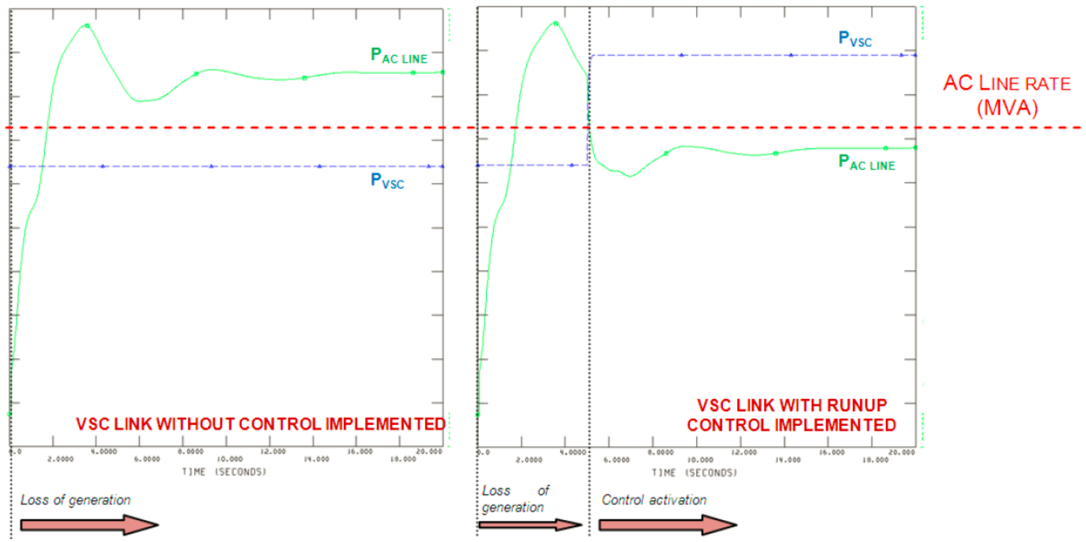
Automatic activation

- Increase/decrease of power order with pre-defined ramp rate
- Automatic frequency control (asynchrounous connections)
- AC line emulation (adjustment of power order based on phase angle difference, see lower graphs)

Manual activation

- Adjustment of power order
- Activation of ramp-up / ramp-down (MW/s)





Resiliency through Cyber Security

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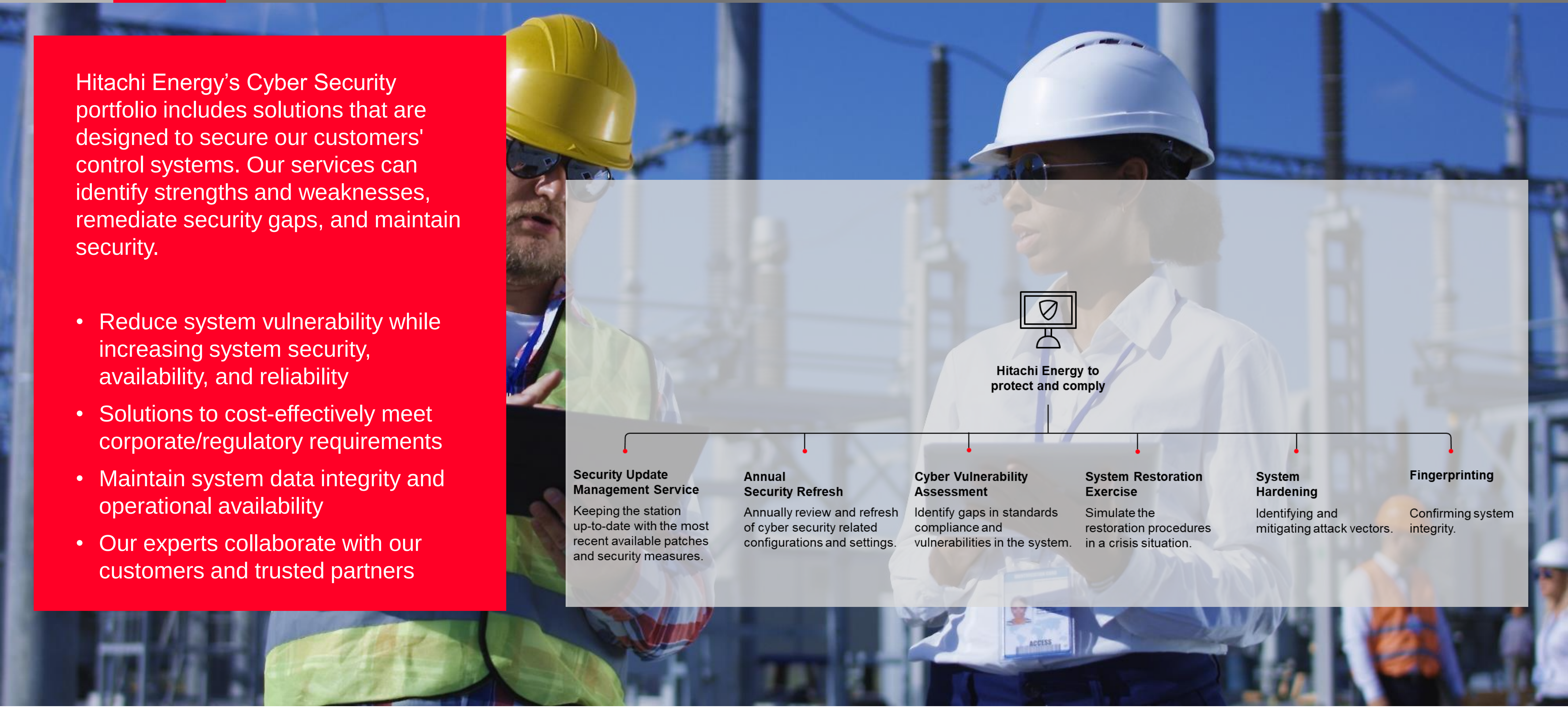

Hitachi Energy’s Cyber Security portfolio includes solutions that are designed to secure our customers' control systems. Our services can identify strengths and weaknesses, remediate security gaps, and maintain security.

- Reduce system vulnerability while increasing system security, availability, and reliability
- Solutions to cost-effectively meet corporate/regulatory requirements
- Maintain system data integrity and operational availability
- Our experts collaborate with our customers and trusted partners

Hitachi Energy to protect and comply

Security Update Management Service
Keeping the station up-to-date with the most recent available patches and security measures.

Annual Security Refresh
Annually review and refresh of cyber security related configurations and settings.

Cyber Vulnerability Assessment
Identify gaps in standards compliance and vulnerabilities in the system.

System Restoration Exercise
Simulate the restoration procedures in a crisis situation.

System Hardening
Identifying and mitigating attack vectors.

Fingerprinting
Confirming system integrity.

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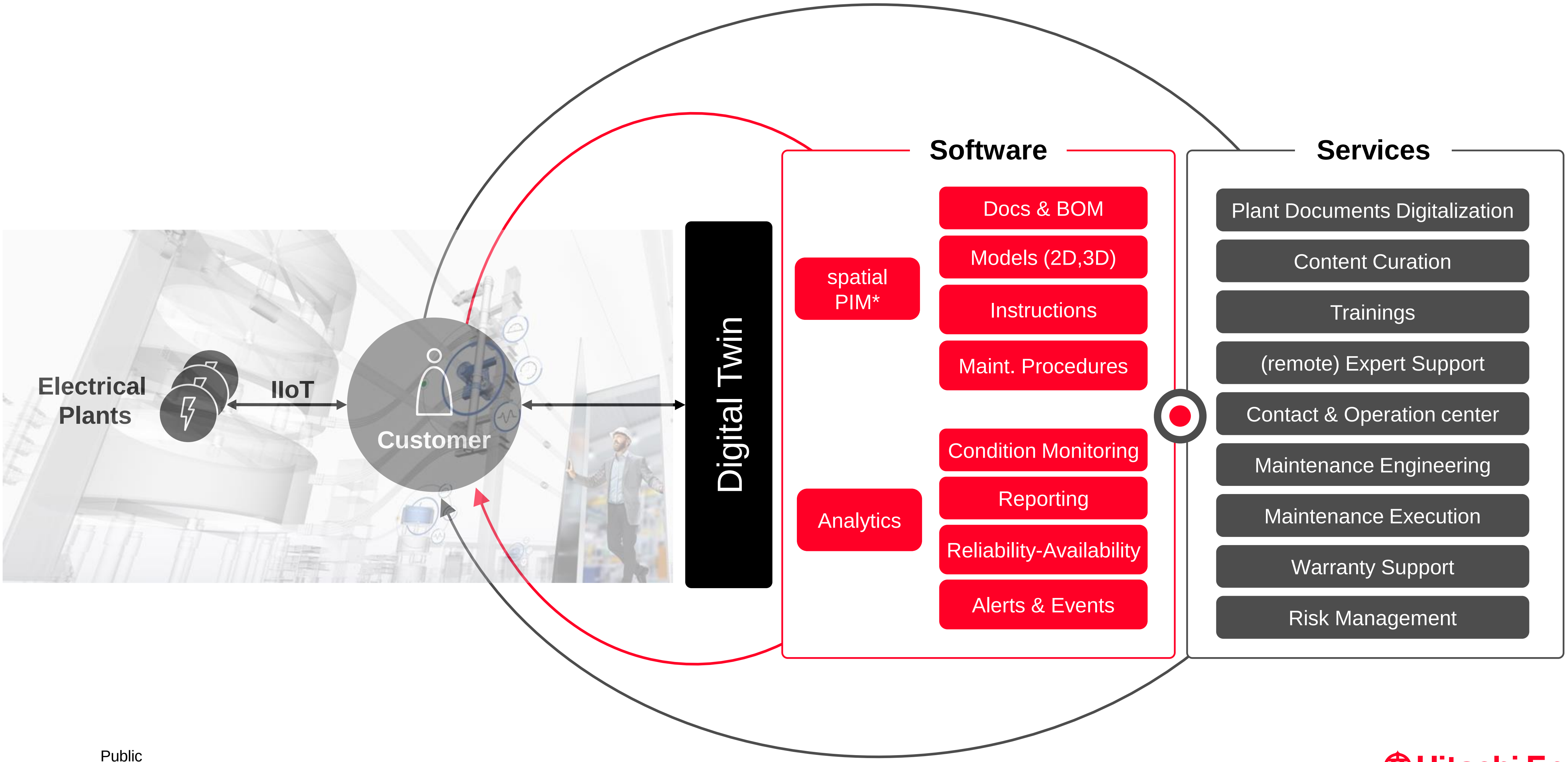
IdentiQ™ | Digital Twin



IdentiQ™ | How does it work?

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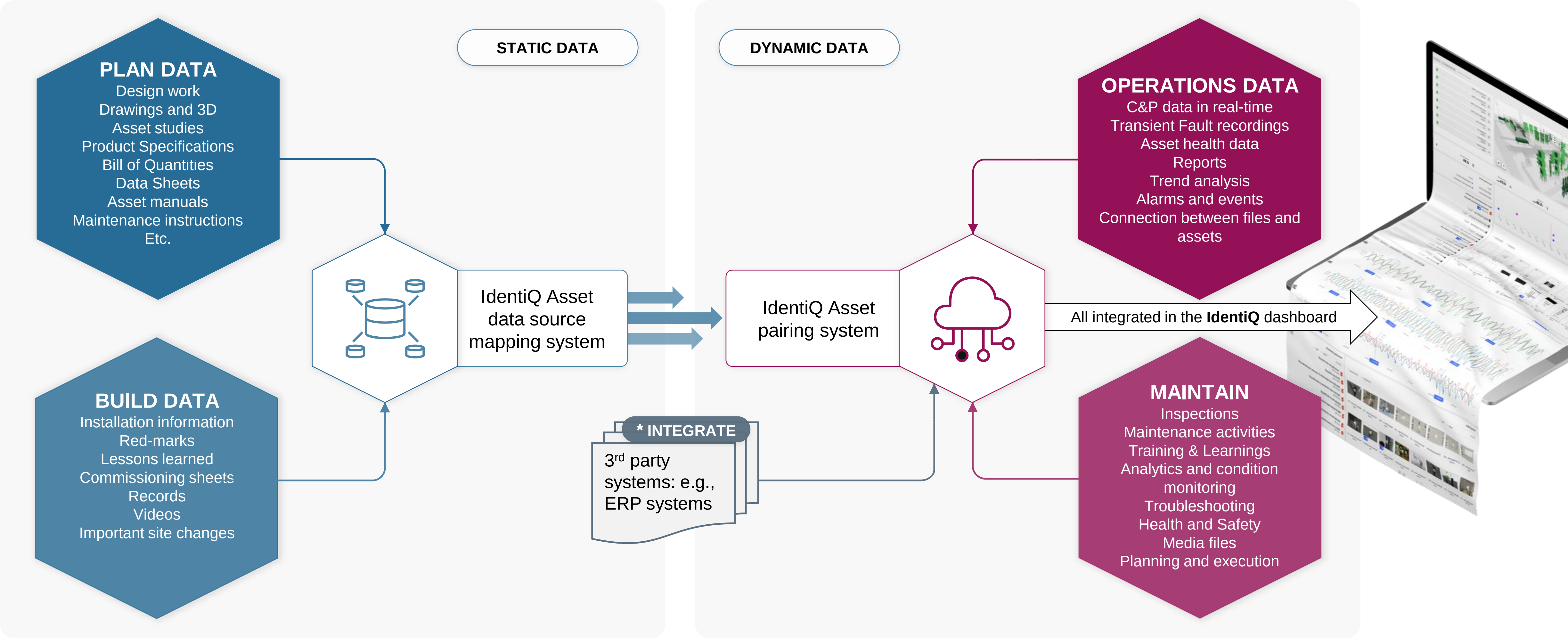
IdentiQ is a system that resides within the space of Operations and Maintenance and leverages information from all plant phases:
Plan, Build, Operate and Maintain.



IdentiQ™ | Turning data into insight. Turning insight into action.

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Quality and operational excellence
Address challenges and opportunities promptly through the ease of information accessibility

Optimizing and reducing O&M spend
Comprehensive planning, execution and prioritization

Increased performance & asset lifetime
Increased plant reliability through advanced condition monitoring

Improved and rapid trouble-shootings
Faster fault detection through the power of data connections

Holistic asset administration and planning
Advanced maintenance features provides clear planning and reduction in mistakes repeated

Knowledge management
We spend 20% of our day looking for and consolidating information. Let IdentiQ fix that.

Web-based Communication
Increased transparency during communication and improved domain knowledge transfer

Workforce continuity and safety
A skilled workforce that are safety observant and are increasing their knowledge, retaining and sharing it

IdentiQ™ | A flexible system of modules to adress all your needs

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Flexibility and modularity, allows You to tailor your own IdentiQ system by selecting and combining the required modules.

Dynamic Documentation
- Find the doc. you need in seconds through interactive 2D/3D filtering together with the spatial viewer module
- Upload and manage all files
- State-of-the-art matching and tagging functionality

Training
- Complete training program can be uploaded
- 3D or VR training with no risks attached
- Dynamic way to create an experience database

Asset properties
- 3D BIM data directly from CAD
- BOM, spares, 3rd party product information
- Currents, loads, voltage levels, network and more

Edge Intelligence
- Data subscription from Main comp. based on signal subscription through MIMS
- IoT real time data and aggregation and storage
- REST-APIs, OPC, Modbus and custom.

Flexible integrations
- 3rd party system integrations
- Pick and choose modules
- Combine features based on your needs
- Customize the dashboard based on the relevant persona

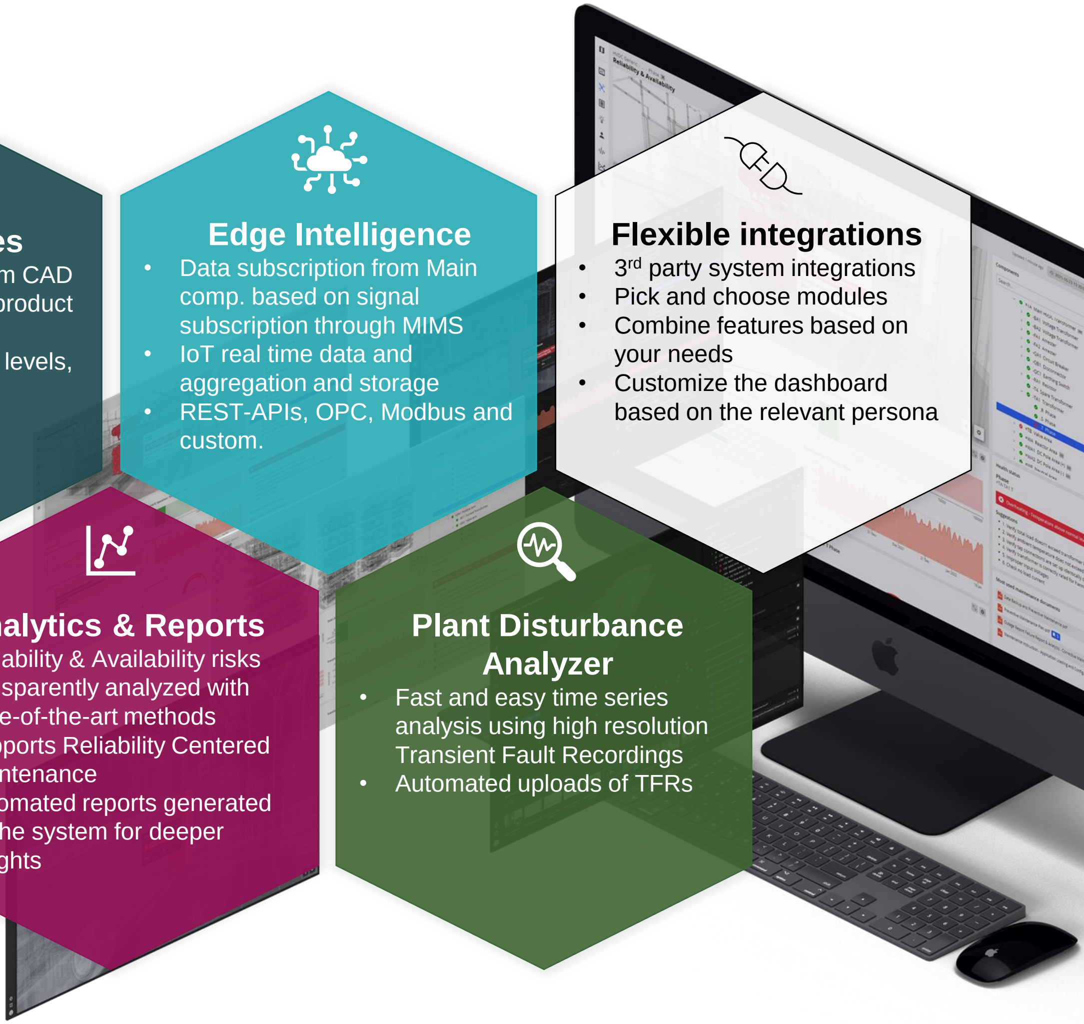
Spatial Navigator
- Detailed dynamic 3D and 2D models in the dashboard
- Connect and pair 3D and 2D models with asset files, signals, alarms and events

Timeline scheduler
- Past, present and future user activities
- Connect files and models to a specific point in time
- Plan and add upcoming tasks

Safety
- HSE color perimeters in 3D for transparency and clarity
- Preparation in 3D before doing it in reality
- Supports work activities e.g., lockout tagout procedures
- Improve your muscle memory

Analytics & Reports
- Reliability & Availability risks transparently analyzed with state-of-the-art methods
- Supports Reliability Centered Maintenance
- Automated reports generated by the system for deeper insights

Plant Disturbance Analyzer
- Fast and easy time series analysis using high resolution Transient Fault Recordings
- Automated uploads of TFRs



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Grid Resilience through HVDC

Some examples

Maritime Link

Customer
Emera Newfoundland & Labrador

Customer needs
- Integration of renewable energy into the grid
- Stabilize the electrical grid in North America

Our response
- Two 500 MW HVDC Light® stations
- Two AC substations at 230 kV and one AC substation at 345 kV

Customer benefits
- Enabling energy to be transmitted from Newfoundland and Labrador to the North American
- Integration of renewables to contribute to Canada's emission-reduction efforts
- Reliable solution for long distances

Year
2018

HVDC Light® converter stations

World's first VSC Bi-pole HVDC Light® interconnection

Overhead line, land and sea DC cable system

The stable, large-scale integration and exchange of renewable power in the North America

Maritime Link

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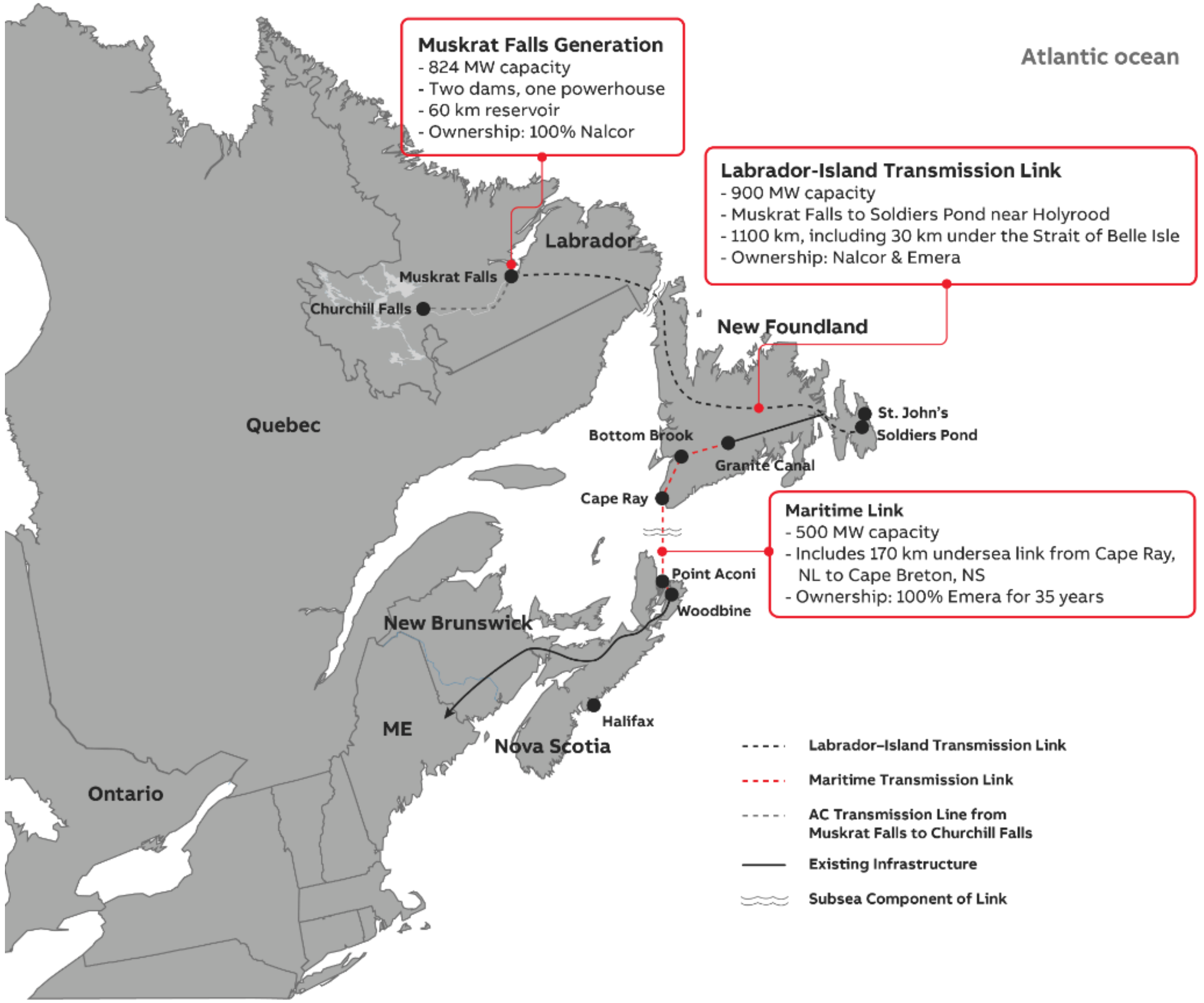
Low short circuit level on both sides

- Newfoundland: Weak AC island system with two HVDC stations
- Nova Scotia: Risk of cascading line tripping East-West corridor
- Emergency power and frequency control schemes for severe contingencies
- Coordinated run-back
- Managed by AC protections or HVDC Control & Protection system

Design of Control and Protection

- Design studies to tune controllers and verify performance.
- Design verification at factory system test with control hardware in the loop at real time simulations.



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CMS - The first regional DC Grid in Europe

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Customer

Scottish and Southern Electricity Networks (SSEN) Transmission

Customer needs

To link Shetland to the UK transmission system

Our response

– First multi-terminal HVDC interconnection in Europe, with option of two more terminals
– 600 MW ±320 kV

Customer benefits

– Multi-terminal HVDC interconnection provides flexibility to transfer power in multiple directions, based on supply and demand, with minimal power losses
– Boost renewable energy and enhance security of power supply
– Help to connect and transmit wind power generated on the islands to the UK
– Contribute to bringing all greenhouse gas emissions to net zero by 2050

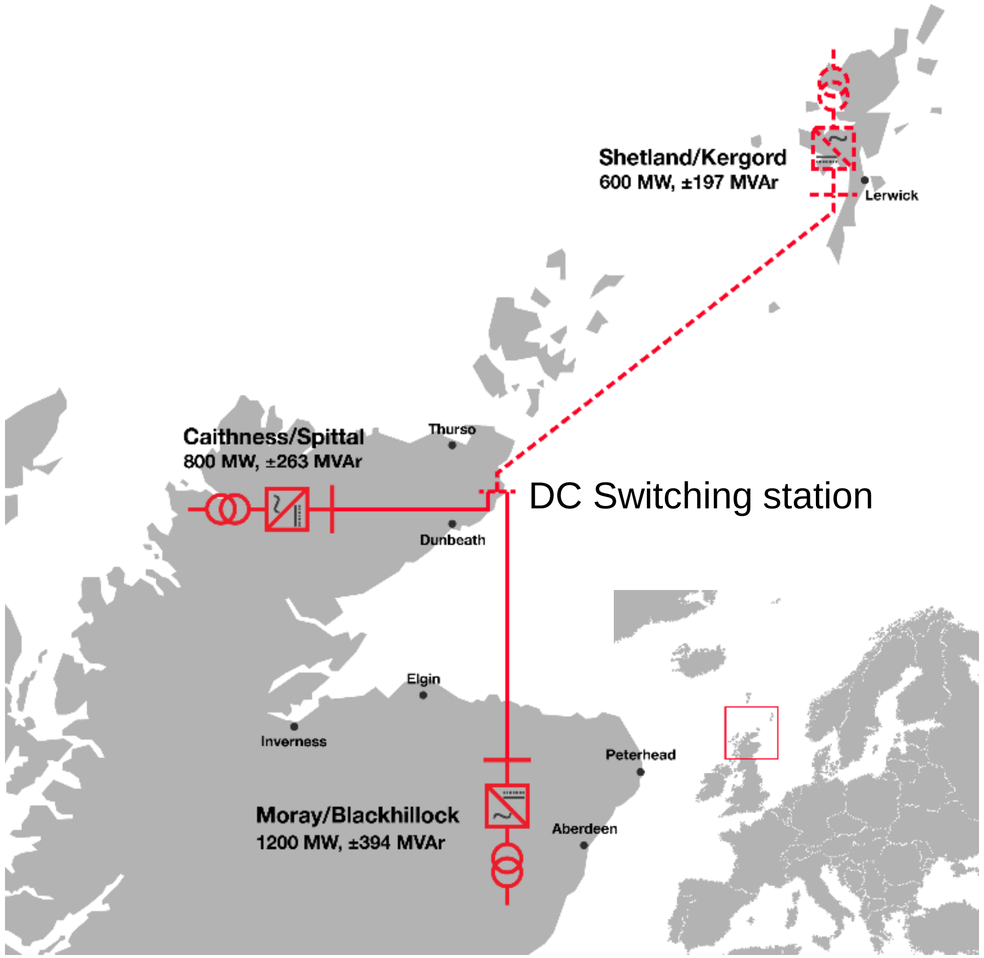
Year

2018 (Caithness-Morey) 2024 (Shetland)

HVDC Light® converter stations

– Symmetric monopole ±320 kVdc
– Blackhillock: 1,200 MW
– Spittal: 800 MW
– Kergord: 600 MW

DC Switching station at multi-terminal connection point



Caithness-Moray-Shetland HVDC Link - Phase 1+2

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HVDC for grid stability and power quality

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HVDC supporting AC voltage stability

CM HVDC Link Performance to date

Spittal Convertor Station Network Screen Print on Handover Date 16 December 2019

Dynamic voltage support during steady state and disturbances

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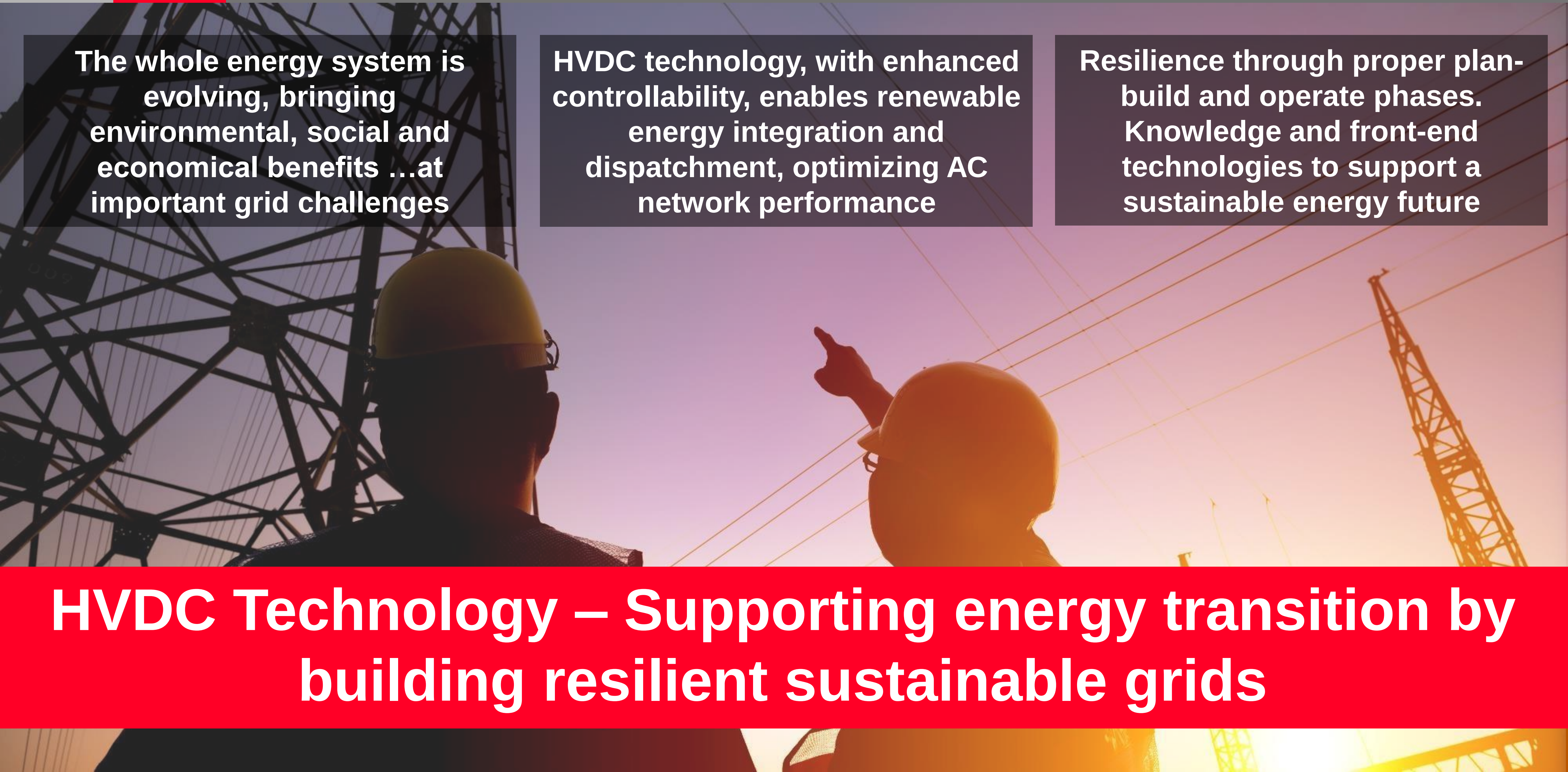
Conclusive remarks



The whole energy system is evolving, bringing environmental, social and economical benefits …at important grid challenges

HVDC technology, with enhanced controllability, enables renewable energy integration and dispatchment, optimizing AC network performance

Resilience through proper plan-build and operate phases. Knowledge and front-end technologies to support a sustainable energy future

HVDC Technology – Supporting energy transition by building resilient sustainable grids

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