High Voltage Direct Current - HVDC Transmission

Enabling the Energy Transition

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2024-05-14

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Energy system 2050: towards a carbon-neutral vision

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“

Electricity will be the backbone of the entire energy system

01
Accelerated shift from fossil-based to renewable power generation

02
Growing electrification of Transportation, Industry and Buildings sectors

03
Sustainable energy carriers, complementary to direct electrification

Fast facts

“
Global electrification will be more than 50% of total energy demand

“
Electrification improves energy efficiency

“
All market sectors converting towards electrification

“
Energy sector-coupling beneficial

So what?

Digital and energy platforms are needed…

…to manage the enormous power system energy transition challenges:

increased complexity
additional capacity

for reduction of CO_2 emissions

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

The future is HVDC: towards a carbon-neutral vision

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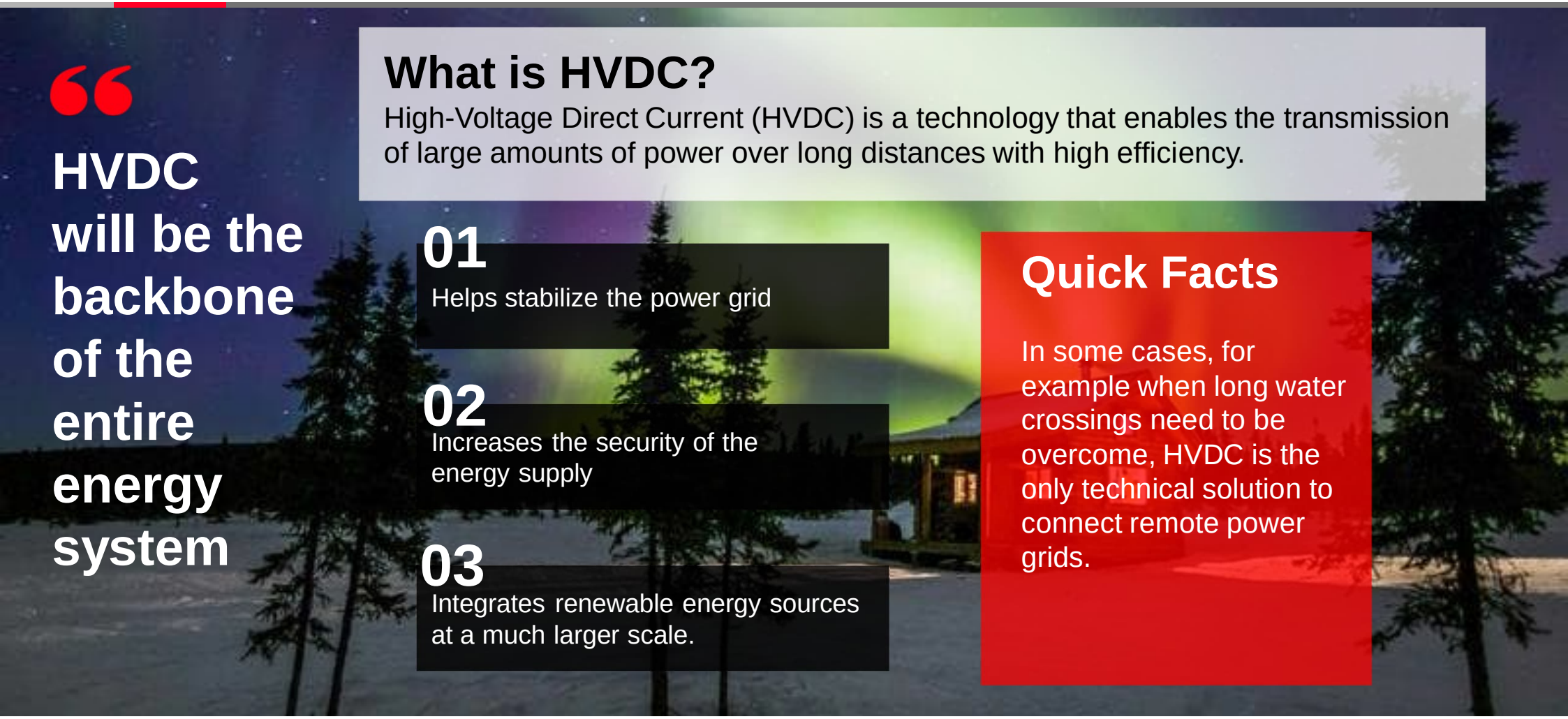

“HVDC will be the backbone of the entire energy system

What is HVDC?

High-Voltage Direct Current (HVDC) is a technology that enables the transmission of large amounts of power over long distances with high efficiency.

01
Helps stabilize the power grid

02
Increases the security of the energy supply

03
Integrates renewable energy sources at a much larger scale.

Quick Facts

In some cases, for example when long water crossings need to be overcome, HVDC is the only technical solution to connect remote power grids.

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HVDC Interconnecting grids for a sustainable energy system

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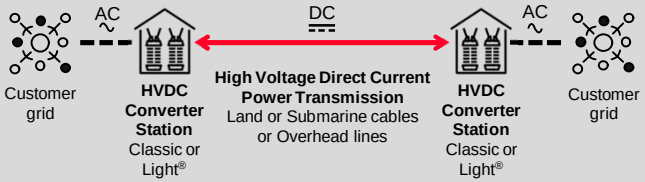

- Connects synchronous grids and asynchronous grids
- Technology of choice for bulk power transmission over long distances with minimum losses
- Controllable power flow enables energy trading
- Resolves AC bottlenecks in AC grids
- Ensure stability of the grid
- Minimal environmental impact

Lower losses

More power

Controlled power flows

More grid stability and flexibility

Smaller footprint

More sustainable

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HVDC: a key enabler for a sustainable future

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~3x
Growth rate vs. world GDP

>300 GW
HVDC Operating World-wide

~50%
World installed base equipped with Hitachi Energy

12GW+
Capacity range of one HVDC installation

70+
years of history

1,500+
HVDC employees in Sweden

Millions tons of CO2 per year reduced

Center of Excellence

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HVDC Transmission systems

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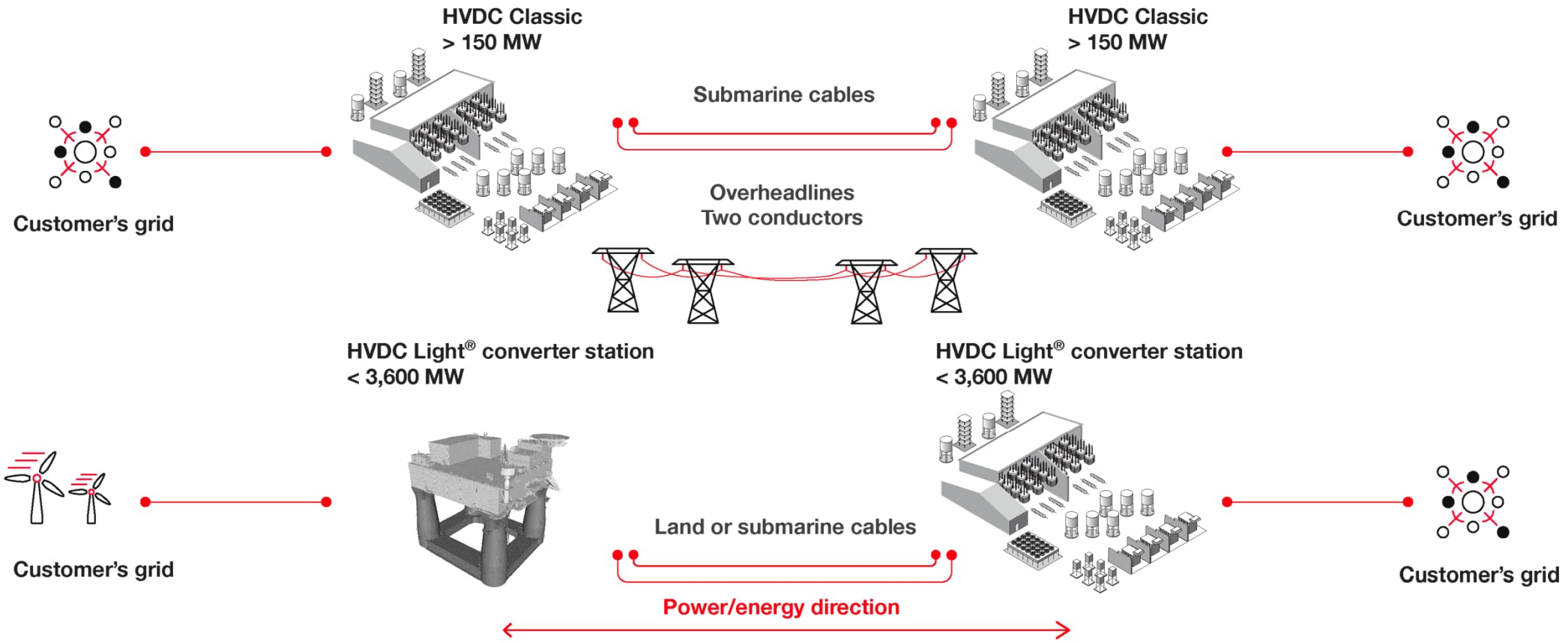

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HVDC Classic

Cost effective, bulk transmission (3 - 12 GW+)

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High power transmission

- Low losses
- High reliability
- High availability
- World’s largest greenfield project experience
- Extensive Service and Upgrade experience

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HVDC Light®

Your grid challenges, solved by HVDC Light®

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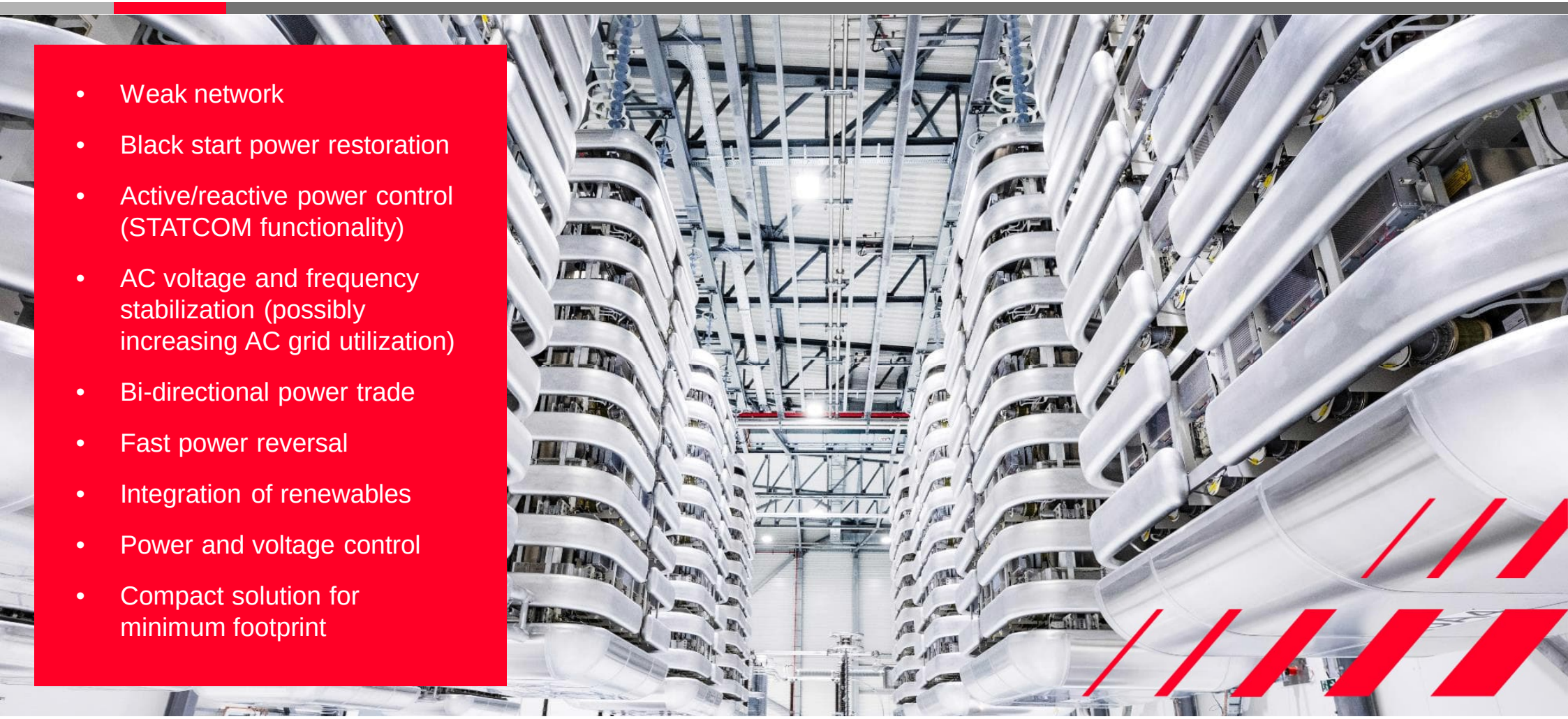

- Weak network
- Black start power restoration
- Active/reactive power control (STATCOM functionality)
- AC voltage and frequency stabilization (possibly increasing AC grid utilization)
- Bi-directional power trade
- Fast power reversal
- Integration of renewables
- Power and voltage control
- Compact solution for minimum footprint

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Todays' HVDC technologies and applications

Shaping the grids of the future

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Connecting remote generation

Offshore wind connections

VSC enabled

Interconnecting grids

DC links in AC grids

Connecting remote loads

Power from shore

VSC enabled

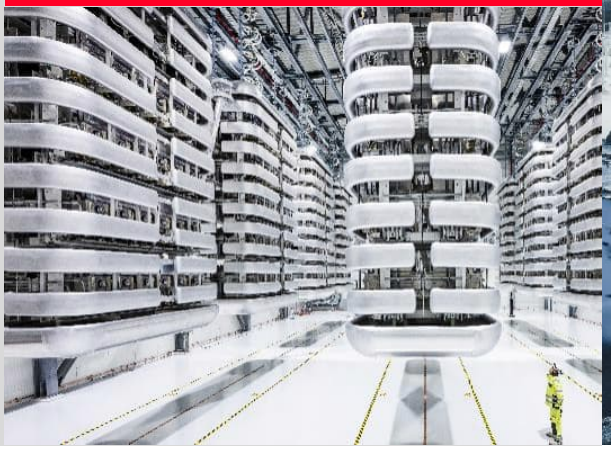
City center infeed

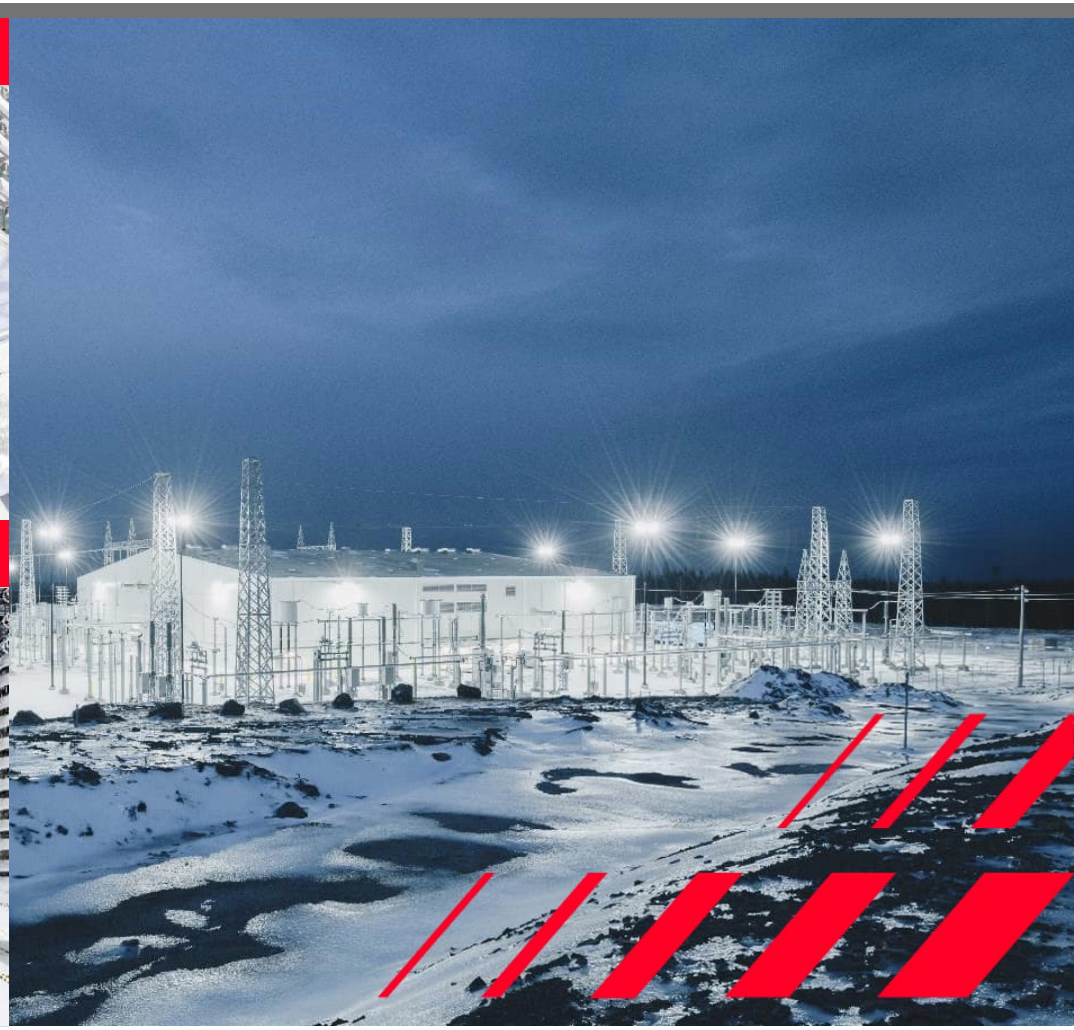
VSC enabled

Upgrades/life-cycle services

LCC (HVDC Classic) 150 – 12,000 MW

VSC (HVDC Light®) 50 – 3,600 MW





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The right rating and system design

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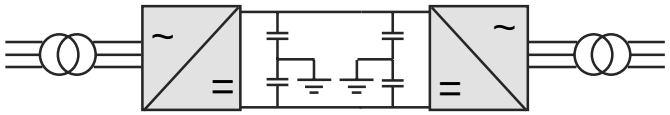
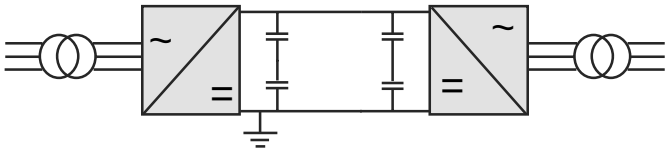
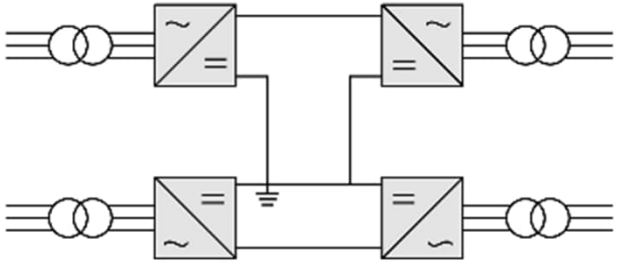


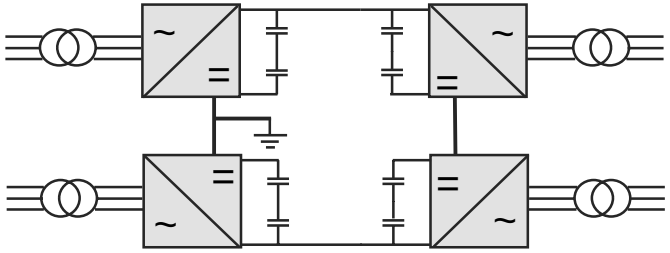
Symmetric monopole



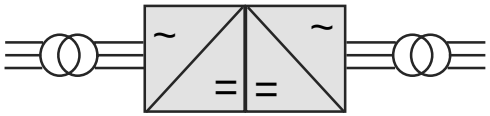
Asymmetric monopole



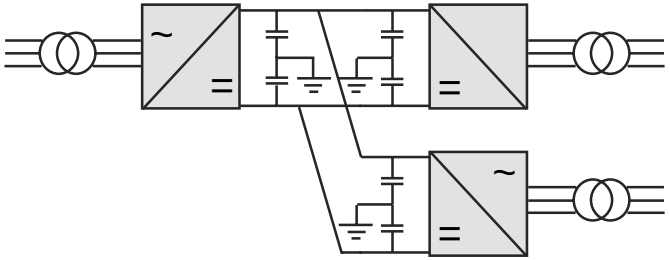
Full Bipole



Rigid bipole



Back-to-Back



Multi-terminal

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Power from Shore

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HVDC – Power from shore

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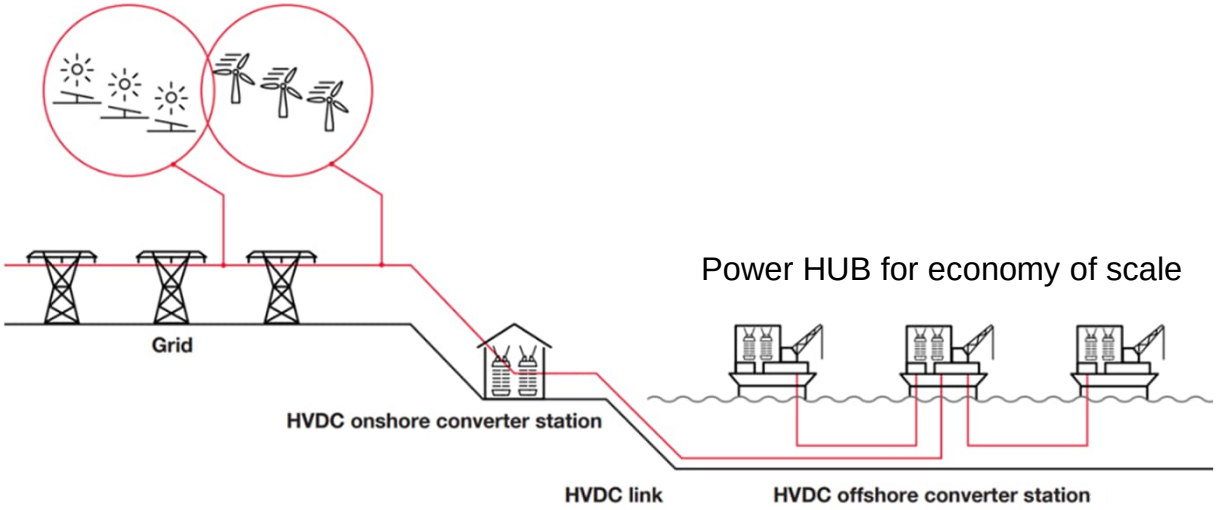
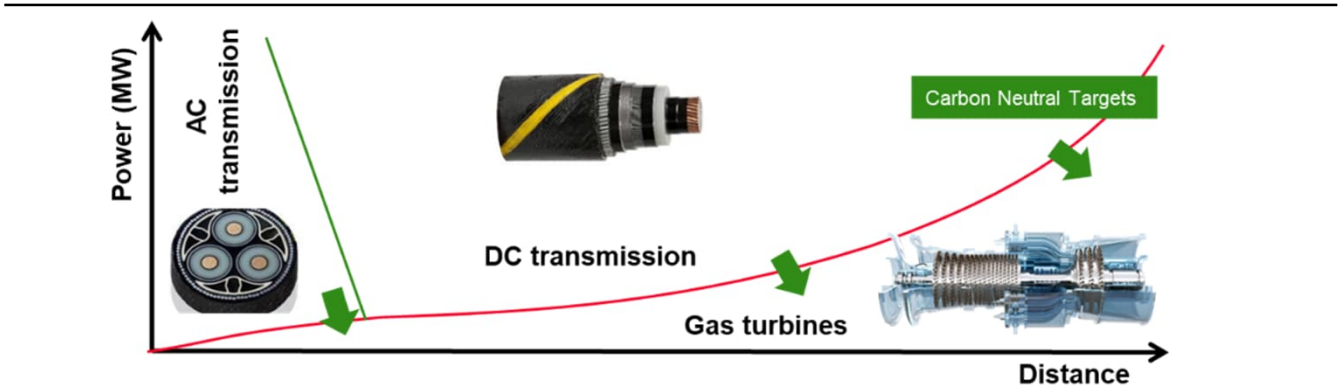
HVDC Platform Electrification

- High availability and reliability
- Reduced operational costs – OPEX
- Lower GHG emissions (CO_2, NOX…)
- Improved Health, Safety and working conditions (noise, vibrations…)
- Compact offshore footprint
- No power or distance limitations
- Simple frequency conversion (50/60 Hz)
- Built in grid support

Platform electrification up to 95% CO_2/barrel reduction[1]
HVDC enables large power and/or long distances transmission





1. Based on LCA analysis done by Power from Shore customers. Data dependent on insourcing energy mix

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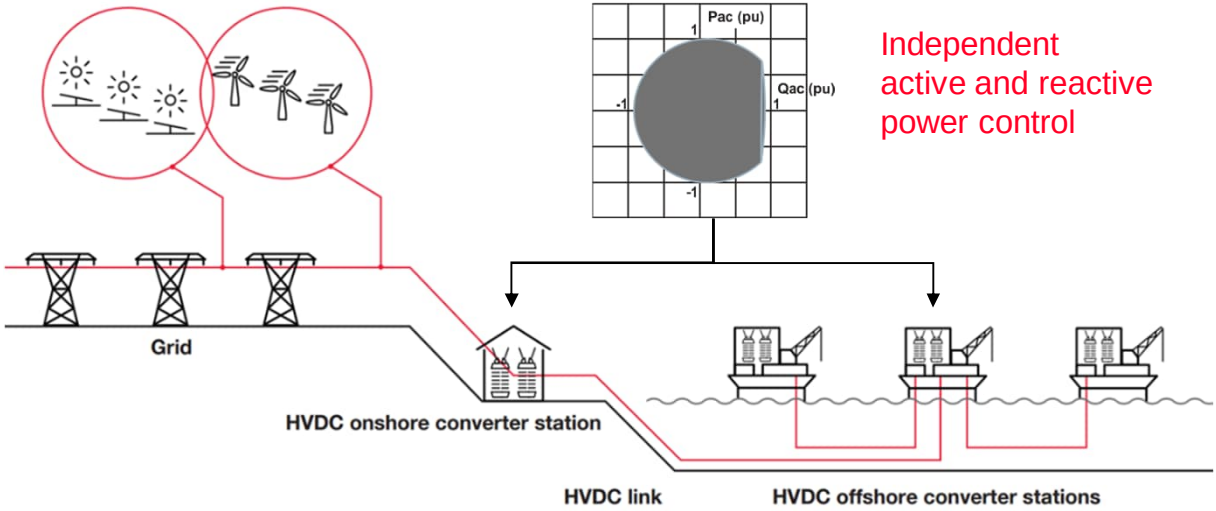
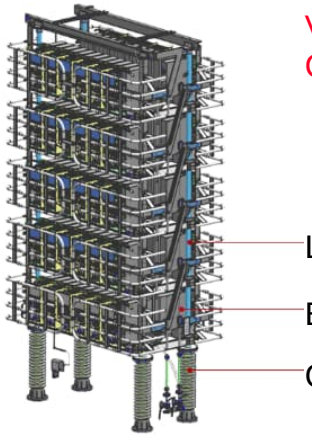
HVDC – Power from shore

HVDC Light®

- Pioneered in 1997 and further developed for Utility, Renewables and Industrial applications
- **Compact** layout, **enhanced controllability**, **high reliability**
- Inbuild redundancy– ride through failures for **long maintenance intervals**
- MMC design**.** May be used on **floating platforms**[1]



Independent active and reactive power control

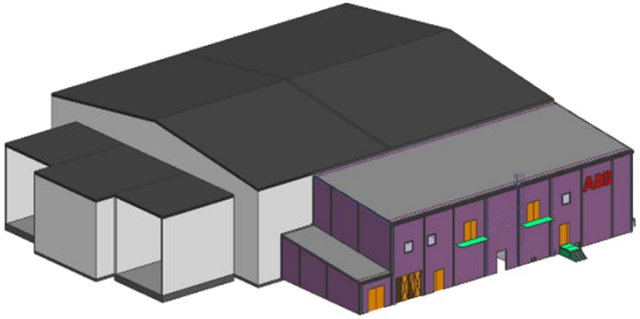


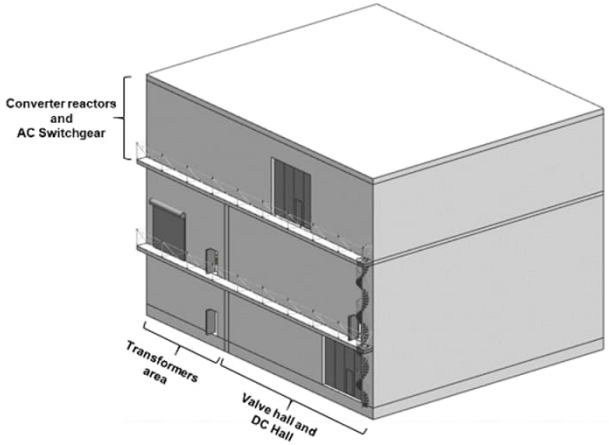
VSC Converter valves

Layer Insulators

BIGT and DC cap

Ground insulators





1. Suitability subject to technical feasibility study against specified operating conditions (accelerations and frequencies)

Nordlink, Wilster, VSC station

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Dogger Bank illustration

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Inside a valve hall

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HVDC Technology looking forward – Global trends

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Technology shift toward Voltage Source Converter for enhanced controllability

Larger and longer links in planning and execution. Aerial and cable transmission

New types of large-scale generation and load to be interconnected

New needs in **extreme environments** – Floating, heat, urban locations

New needs for enhanced grid support

The DC grid of the future, from talks to planning

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From an idea to global industrialization

HVDC is the solution for today's grid challenge

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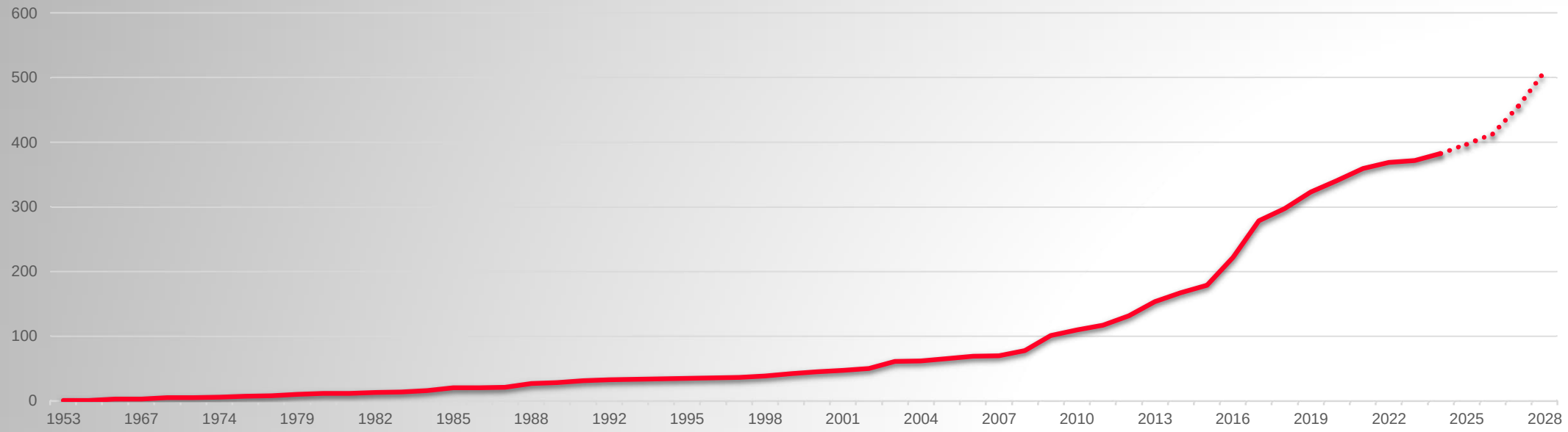
Cumulated GW installed



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 HVDC installation

2017
VSC HVDC highest performance ever – 3,000 MW, 640 kV, 2,000 km

2019
Caithness-Moray HVDC Link - a unique multi-terminal system

2023
Ijmuiden Ver Alpha, first of six OW projects as a part of TenneT's 2GW Program

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

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1 HVDC’s role in a changing energy system

Mega trends and drivers for HVDC connections

2 HVDC technology

Architecture and key characteristics of an HVDC system

3 Market trends and next steps

Toward the future DC grids

4 Case studies

Highlighted HVDC key features

5 Summary

Power from shore

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Project Lightning

Hitachi Energy is supplying four converter stations (two HVDC links): between Mirfa and Al Ghallan (symmetrical monopole) and between Shuweihat and Das (bipole). Total power transmitted will be **3200 MW** and symetrical monopole stations will operate at ±320 kV and bipole stations will operate at ±400 kV.

The first-of-its-kind sub-sea power transmission network in the MENA region.

Troll A 1-4

Four HVDC Light® links of total 188 MW power transmission capacity at ±60 kV are directly connected to the Hitachi Energy very high voltage (VHV) cable-wound motors. **The VHV Motors are governed by the HVDC Light® MACH control system**.

HVDC Light ® saves weight and reduces the space the system takes up on the platform.

Valhall

Gas turbines generating power on the Valhall platform complex were replaced by a **292-kilometer** HVDC Light® cable link that supplies 78 MW of power at 150 kV from the Norwegian mainland to meet the field's electricity needs.

First time HVDC has been used to supply an entire offshore 60 Hz AC power system.

Johan Sverdrup

The Johan Sverdrup installation is expected to become the largest producing oil field in the North Sea by the time it reaches its peak. Hitachi Energy delivers two ±80 kV HVDC Light® links, transmitting a total of 100 MW to the 200 km remote site.

HVDC Light® is the reliable source of power from shore, valued by many customers.

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Project Lightning

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Customer
ADNOC, United Arab Emirates

Customer needs
- Enable power supply from mainland to platform complex to minimize emission of large amounts of CO_2

Our response
- Two HVDC Links with four HVDC Light® converter stations
- Zakum Cluster: Al Ghallan 132 kV (off-shore) and Mirfa 400 kV (on-shore), 2 x 1,000 MW
- DAS Cluster: Das 132 kV (offshore) and Shuweihat 400 kV (on-shore), 2 x 600 MW

Customer benefits
- Enable sustainable, flexible and secure power supply to offshore platforms
- Reduction of carbon footprint for offshore operation
- High power ratings, compactness of converters on islands and long submarine cable distance

Year
2025

HVDC Light® converter stations

- Symmetrical monopole to Al Ghallan island
- Bipole to DAS island

System capacity of 3,200 megawatts (MW)

The first-of-its-kind sub-sea power transmission network in the MENA region advancing a sustainable energy future for Abu Dhabi

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Johan Sverdrup

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Customer
Equinor, Norway

Customer needs
- Enable power supply from mainland to platform complex to minimize emission of large amounts of CO_2

Our response
- Two 100 MW ±80 kV HVDC Light® converter stations

Customer benefits
- Reliable power supply
- Better and safer work environment on platform
- Lower operation and maintenance costs

Year
2019

HVDC Light® converter stations

Symmetrical monopole

System capacity of 78 megawatts (MW)

Undersea link lowers emissions and brings reliable power to offshore oil field

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Enabling the future power systems

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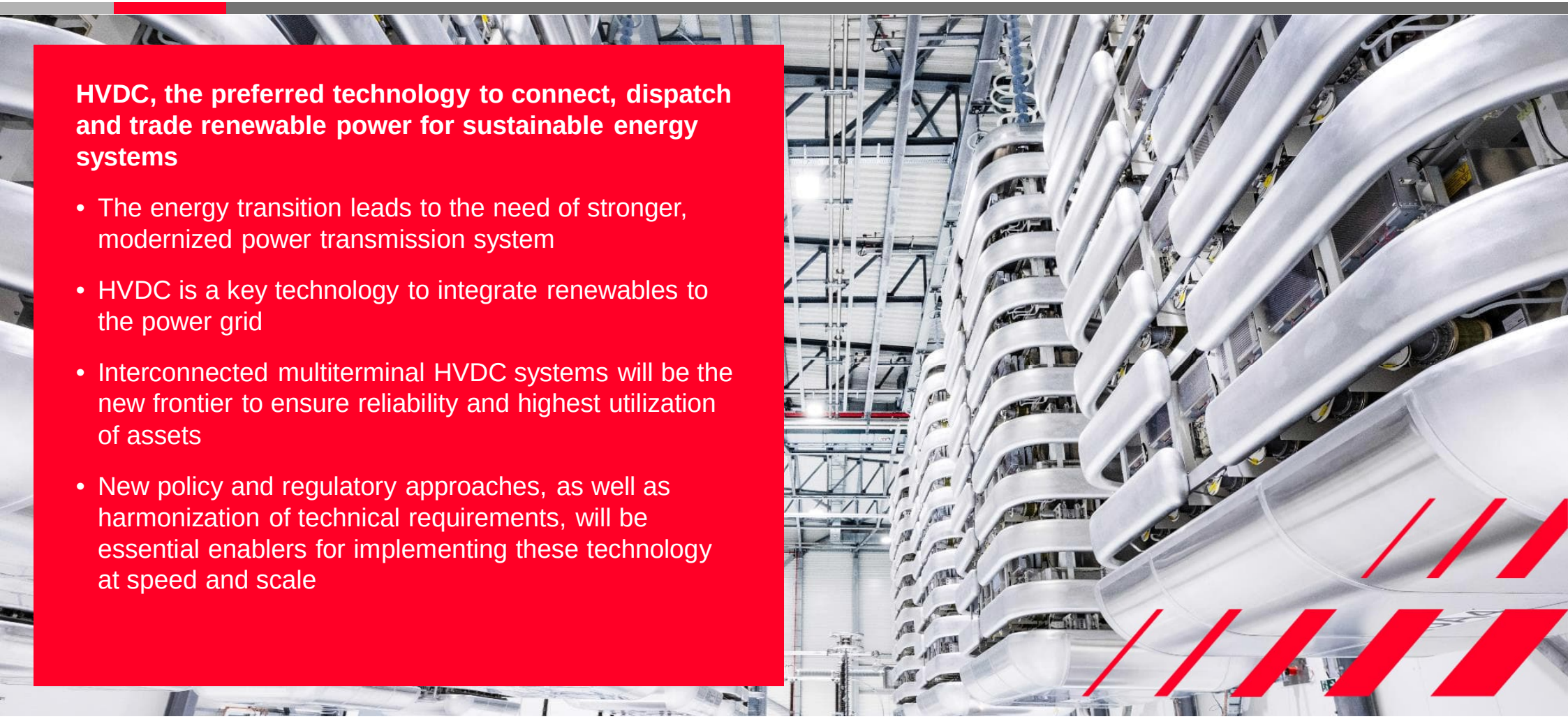

HVDC, the preferred technology to connect, dispatch and trade renewable power for sustainable energy systems

- The energy transition leads to the need of stronger, modernized power transmission system
- HVDC is a key technology to integrate renewables to the power grid
- Interconnected multiterminal HVDC systems will be the new frontier to ensure reliability and highest utilization of assets
- New policy and regulatory approaches, as well as harmonization of technical requirements, will be essential enablers for implementing these technology at speed and scale

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