MVDC PLUS

Managing the future grid

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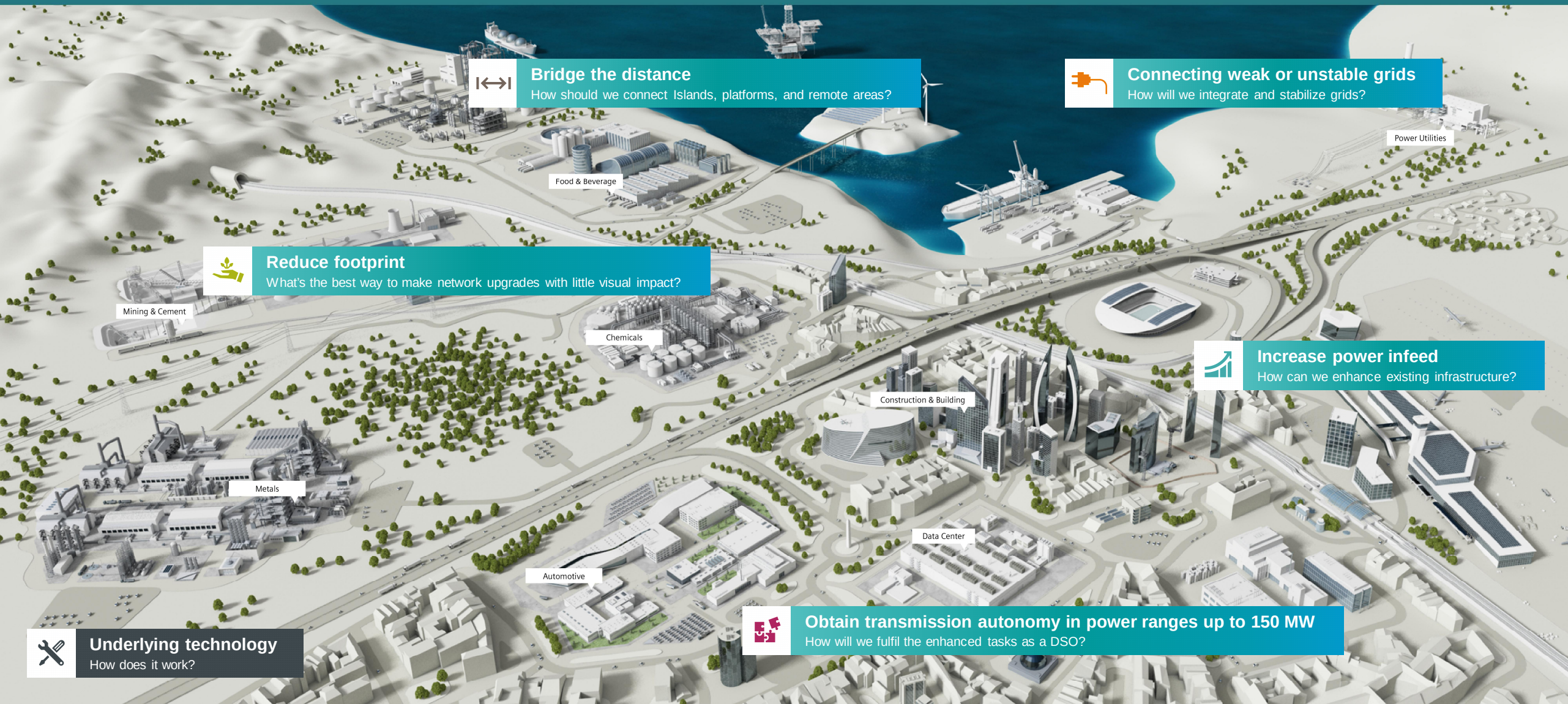


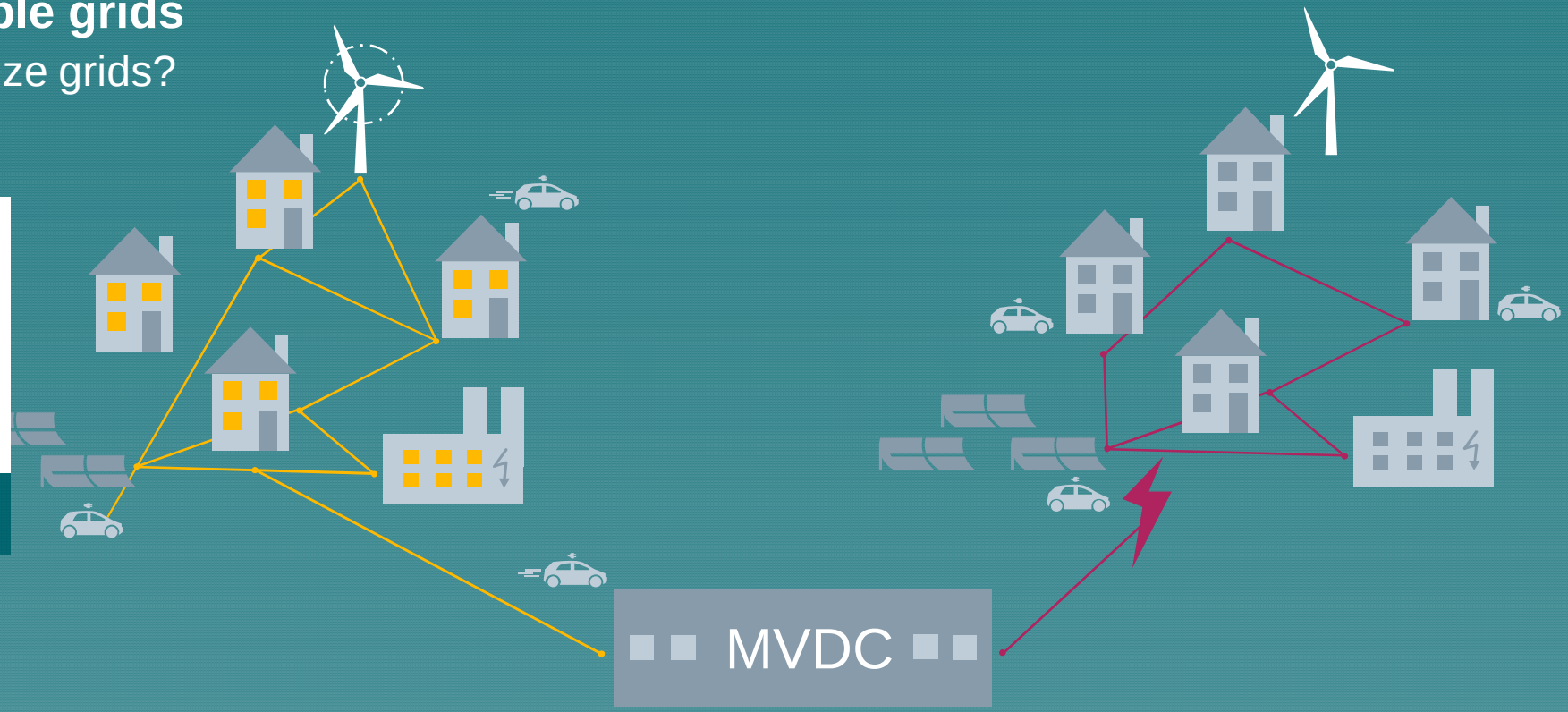
Connecting weak or unstable grids

How will we integrate and stabilize grids?

Challenges

- Growing number of decentralized and volatile energy sources
- Stabilize weak networks
- Provide high-quality power supply
- Optimize and control load flow
- Serve spot markets

Solution



Customer benefits

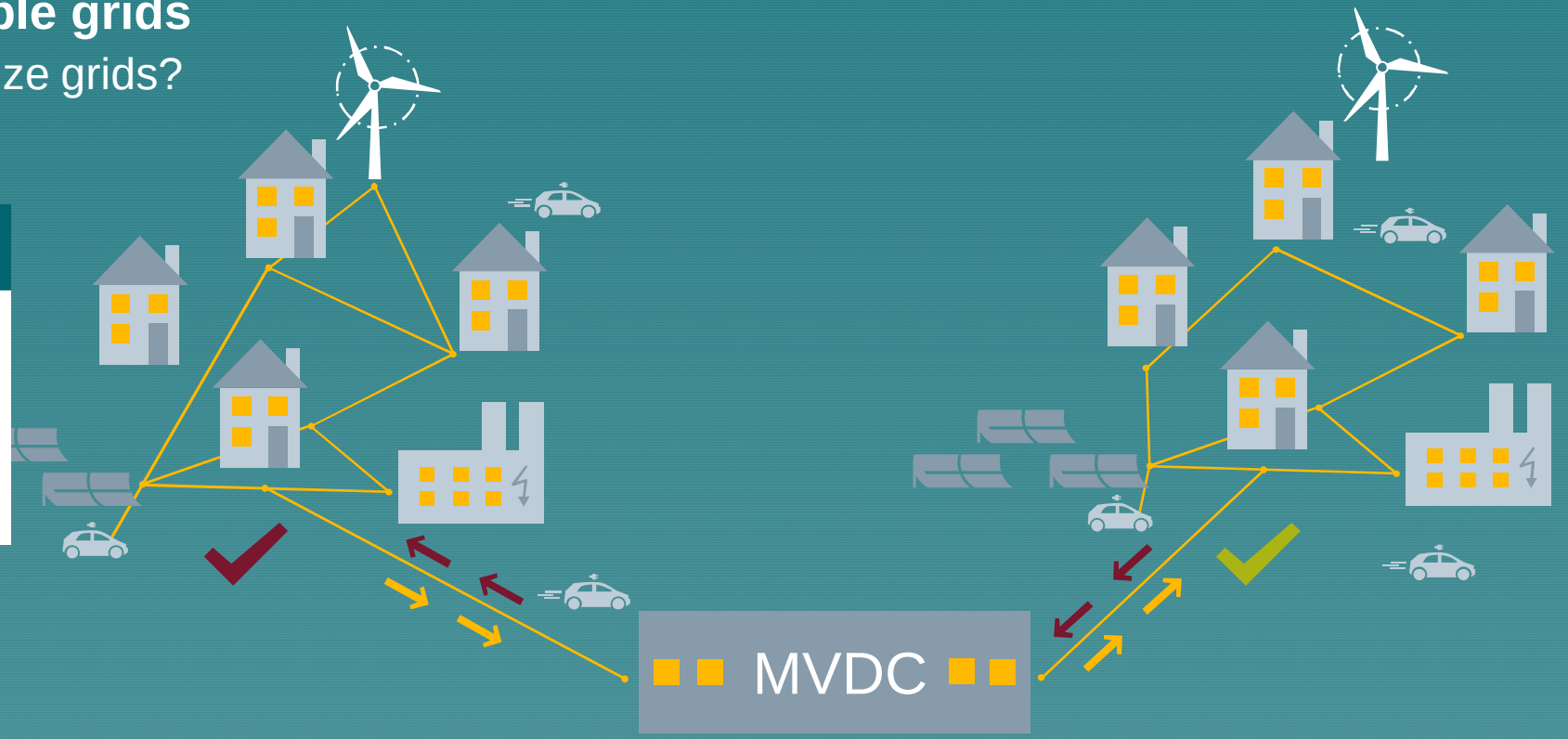
Connecting weak or unstable grids

How will we integrate and stabilize grids?

Challenges

Solution

- Load flow control through MVDC: Connect grids via active elements that control load flow and provide reactive power
- Decouple grids with different frequencies, voltage levels and quality with DC link



Customer benefits

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Connecting weak or unstable grids

How will we integrate and stabilize grids?

Challenges

Solution

Customer benefits

Simple integration of volatile energy sources

Safeguarding the power supply, power exchange between grids to optimize losses and asset utilization

Grid stabilizing, load flow control, grid independence.

Improved grid quality

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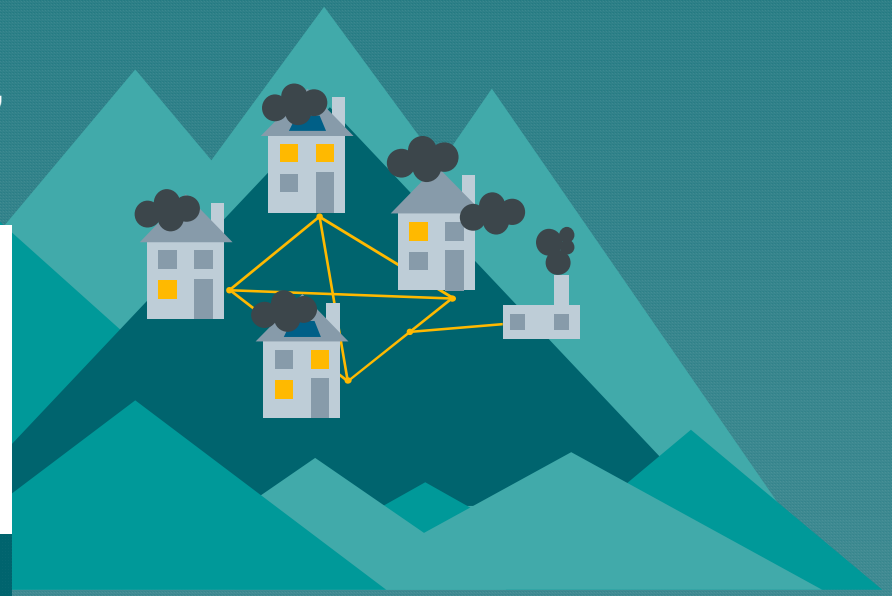
Bridge the distance

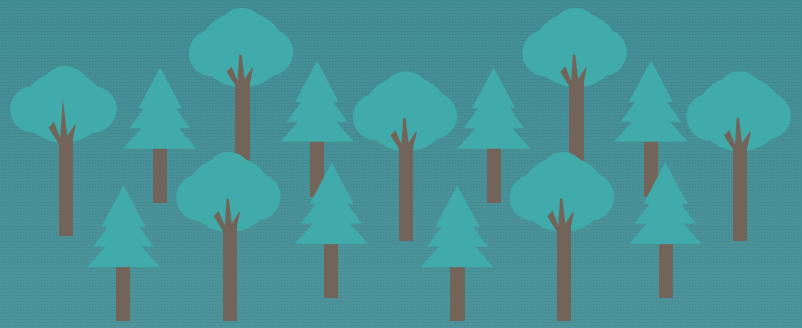
How should we connect islands, platforms, and remote areas?

Challenges

- Connect remote energy loads (for example, islands, industries, small cities)
- Reduce CO_2 footprint and prevent pollution (for example, diesel generators)
- Distance of 110-kV AC lines limited due to reactive power losses

Solution





Customer benefits

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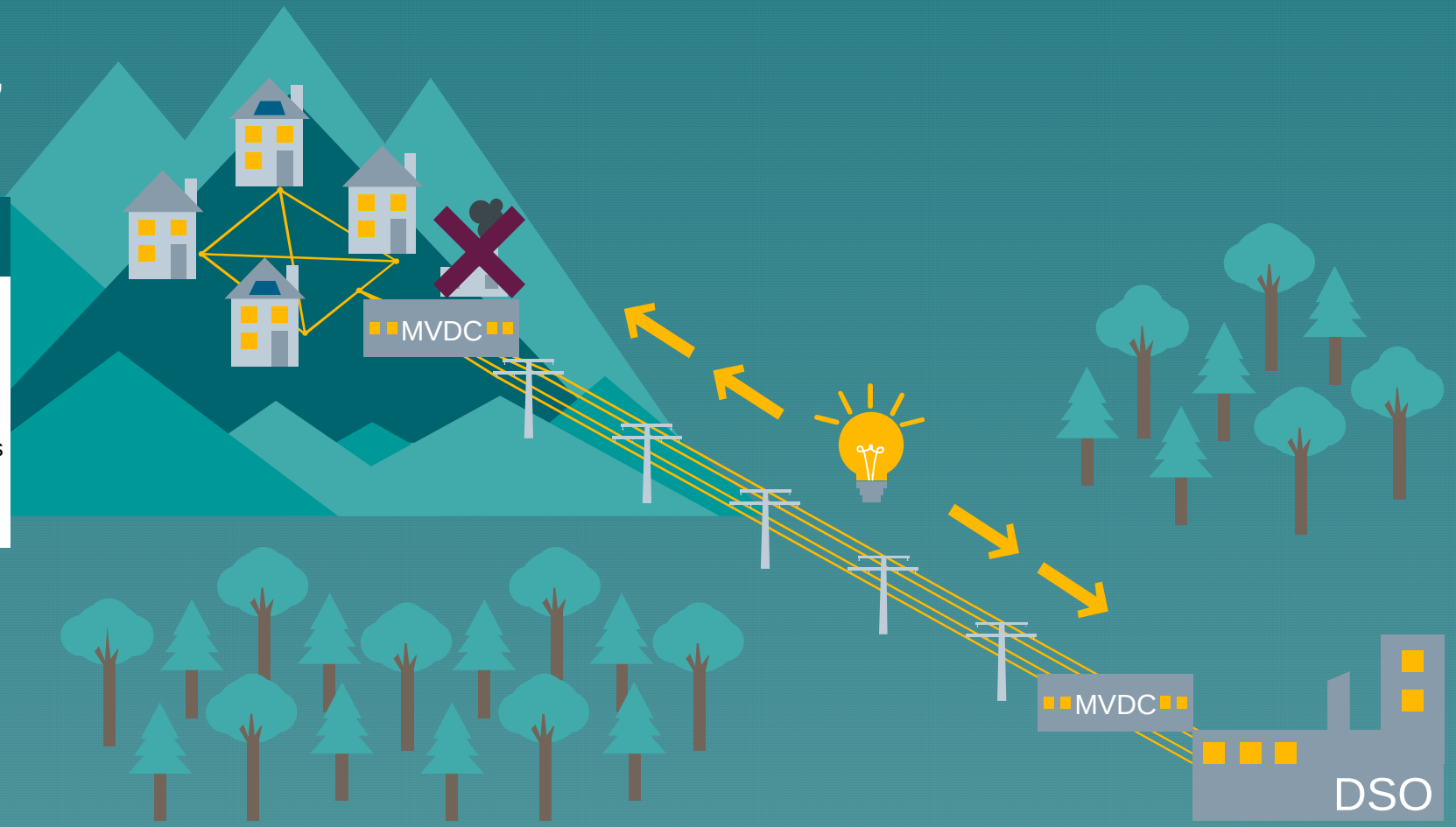
Bridge the distance

How should we connect islands, platforms, and remote areas?

Challenges

Solution

- Install compact and cost-efficient medium-voltage DC connections
- DC Link via cable or compact overhead lines
- Economical power transmission over long distances
- Remote restart of autark areas with taylormade black-start functionality



Customer benefits

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Bridge the distance

How should we connect islands, platforms, and remote areas?

Challenges

Solution

Customer benefits

Reduced costs for transport, storage, and maintenance for diesel generators, for example

Cost advantage due to higher efficiency compared with HVAC

Reduced CAPEX due to larger MV supplier base and commodities

Reduced visual and environmental impact (approvals and CO_2 reduction)

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Increase power infeed

How can we enhance existing infrastructure?

Challenges

- Increase rating of existing lines to satisfy growing power demand
- Connect urban centers with outside transmission system
- Improve grid stability without network expansion

Solution

Customer benefits

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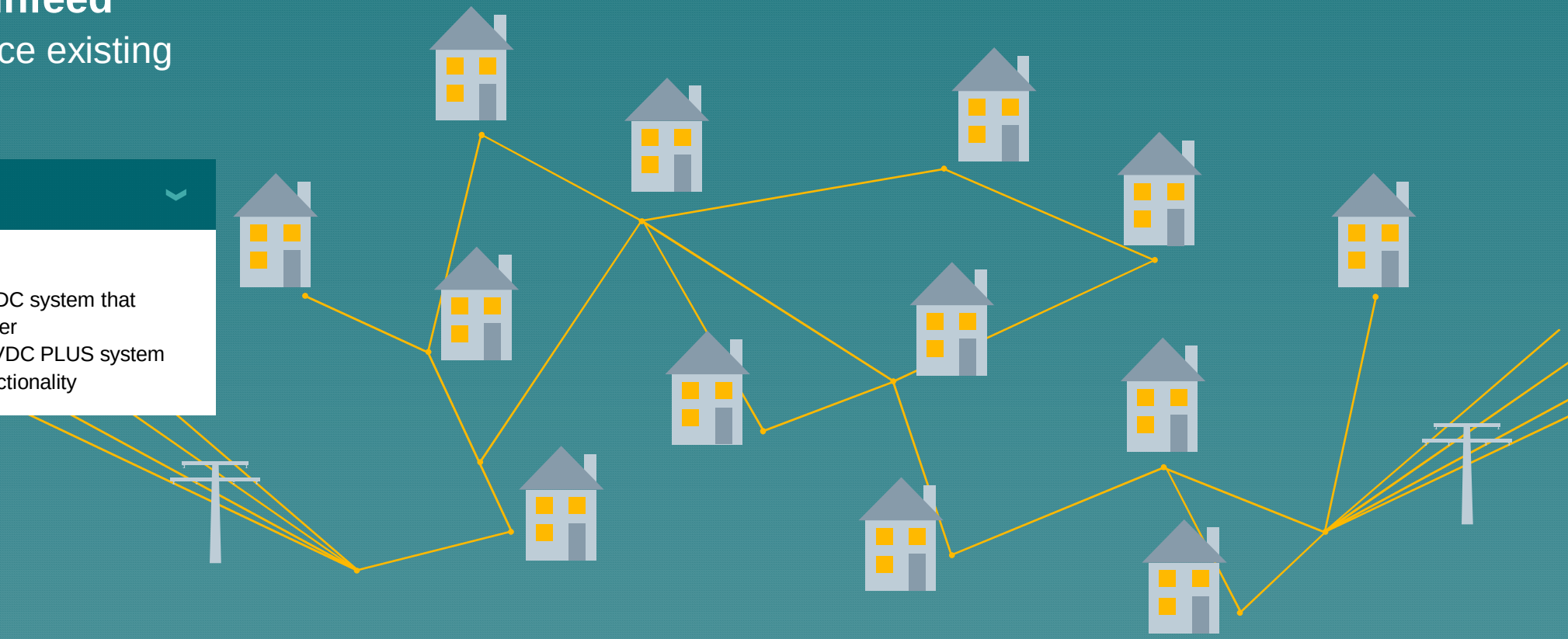
Increase power infeed

How can we enhance existing infrastructure?

Challenges

Solution

- Convert from existing AC to DC system that enables greater power transfer
- Improve grid stability with MVDC PLUS system that provides STATCOM functionality



Customer benefits

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Increase power infeed

How can we enhance existing infrastructure?

Challenges

Solution

Customer benefits

Avoid network expansions

Increased asset utilization by up to 20-80 percent more transmitted power

MVDC PLUS converters provide grid stabilization features

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Obtain transmission autonomy in power ranges up to 150 MW

How will we fulfil the enhanced tasks as a DSO?

Challenges

- Connect regions where no HV connection is available
- Additional connection of energy producers to loaded areas
- Get more transmission autonomy
- Reduce transmission and dispatch fees

Solution

Customer benefits

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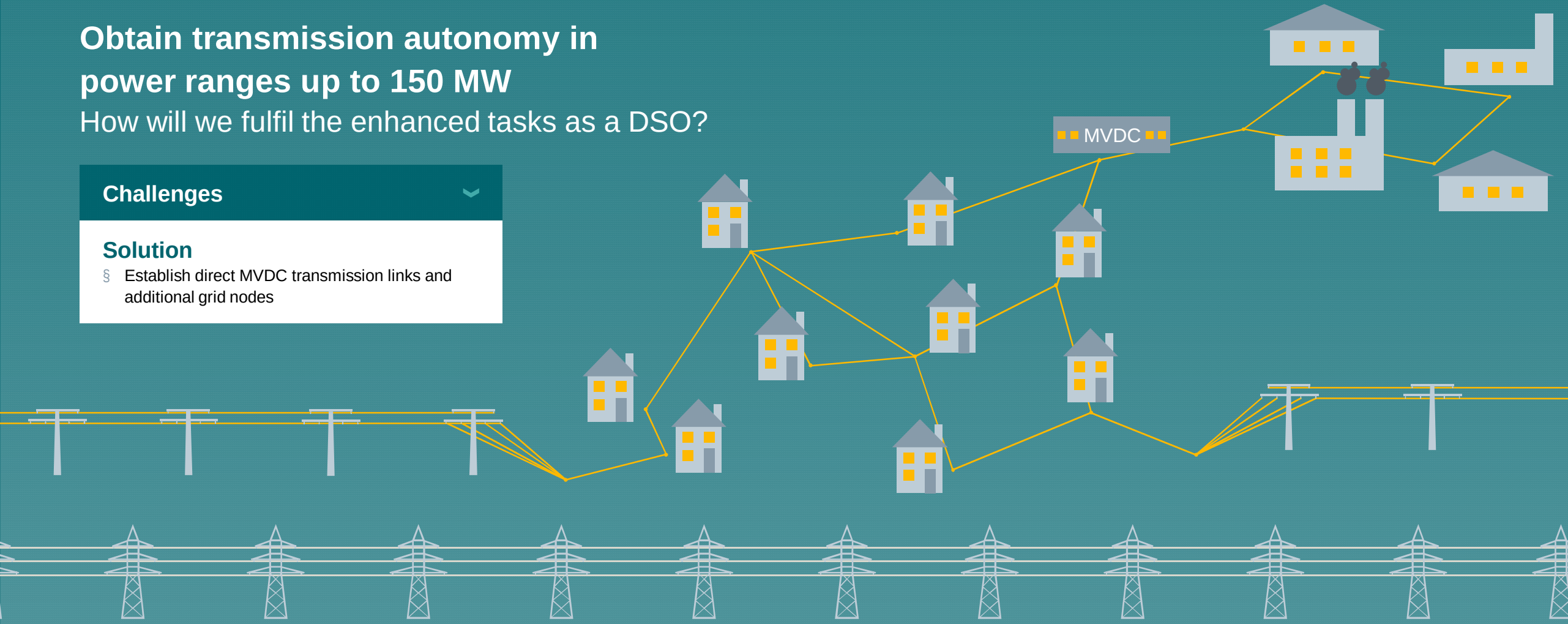
Obtain transmission autonomy in power ranges up to 150 MW

How will we fulfil the enhanced tasks as a DSO?

Challenges

Solution

§ Establish direct MVDC transmission links and additional grid nodes



Customer benefits

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Obtain transmission autonomy in power ranges up to 150 MW

How will we fulfil the enhanced tasks as a DSO?

Challenges

Solution

Customer benefits

Be more independent of HV

More flexibility for line planning

Enhanced possibilities for integrating decentral energy supply

Reduce footprint

What's the best way to make network upgrades with little visual impact?

Challenges

- High visual impact of HV lines with large lattice structures
- Public resistance against high voltage lines
- Getting permits for new HV corridors is becoming nearly impossible

Solution

Customer benefits

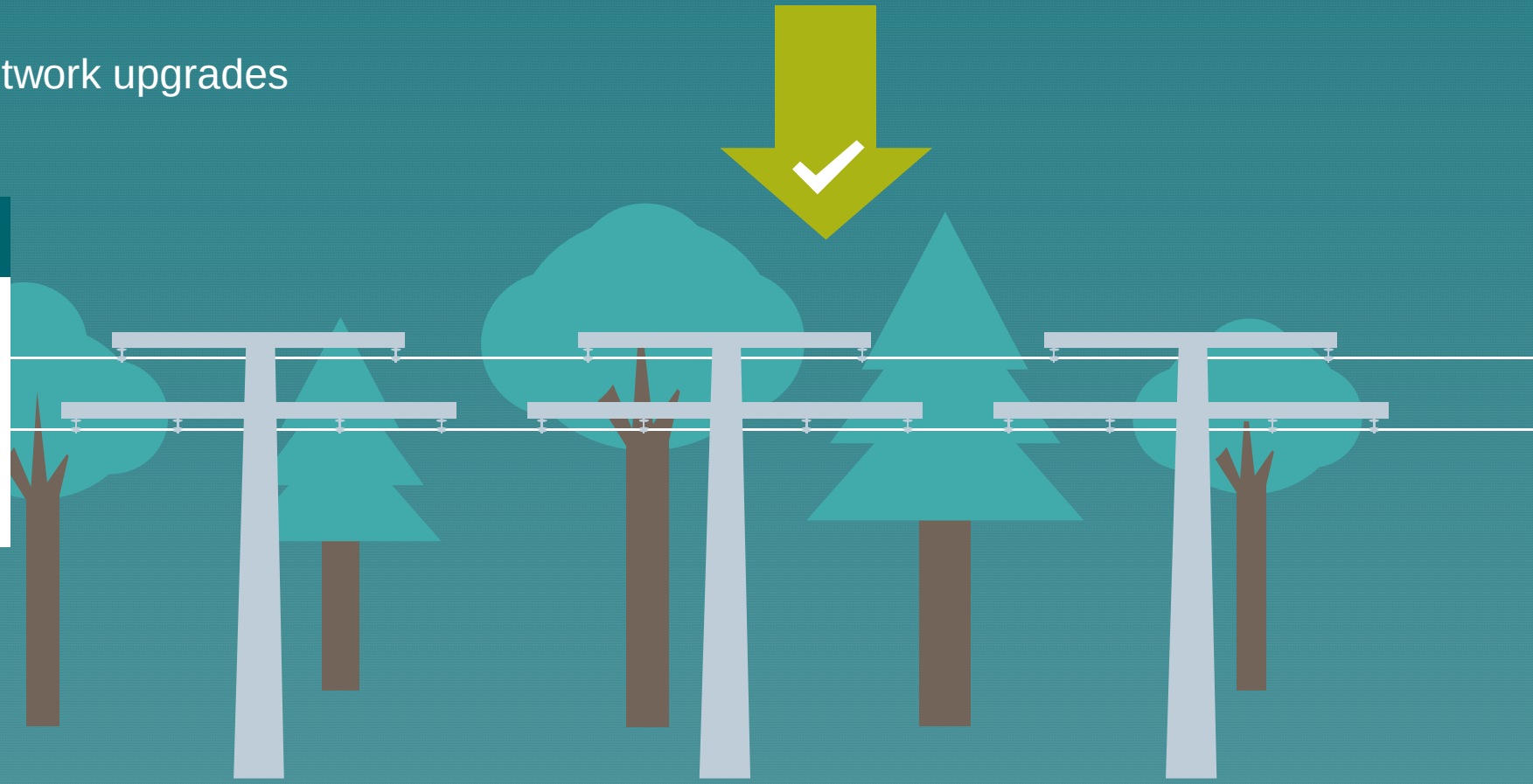
Reduce footprint

What's the best way to make network upgrades with little visual impact?

Challenges

Solution

- Medium-voltage level allows for lines with heights below the treetops (<15 m height)
- Simple MV overhead lines require smaller corridors
- MV overhead lines with wood poles or simple steel structures



Customer benefits

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Reduce footprint

What's the best way to make network upgrades with little visual impact?

Challenges

Solution

Customer benefits

Low visual impact

Faster and less complex implementation that speeds up construction and permitting

Get public acceptance for infrastructure upgrades

Lowering stranded planning investments

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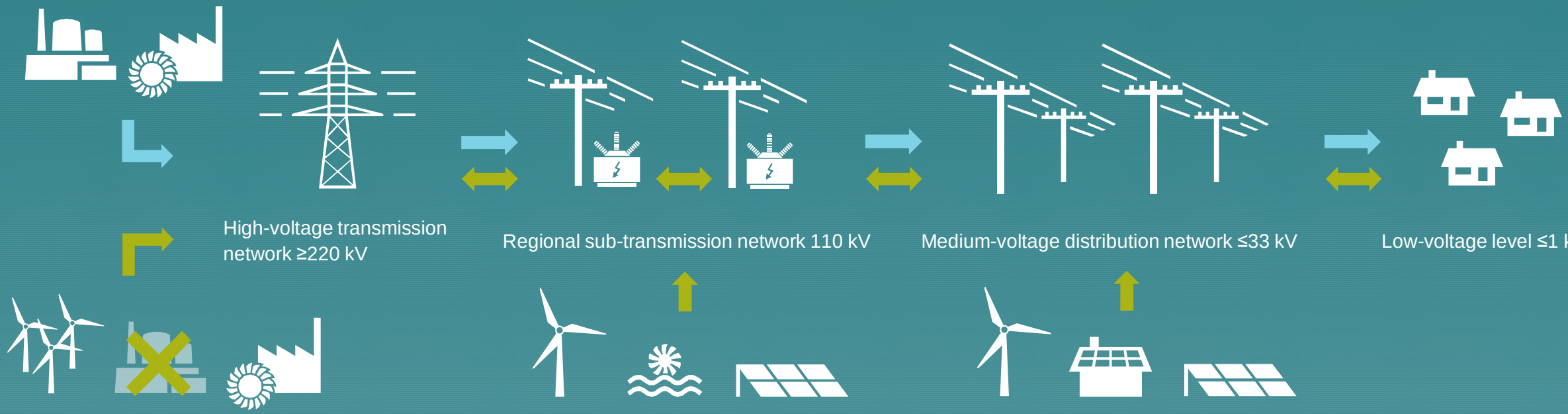
Grids are facing new challenges from decentralization and renewables

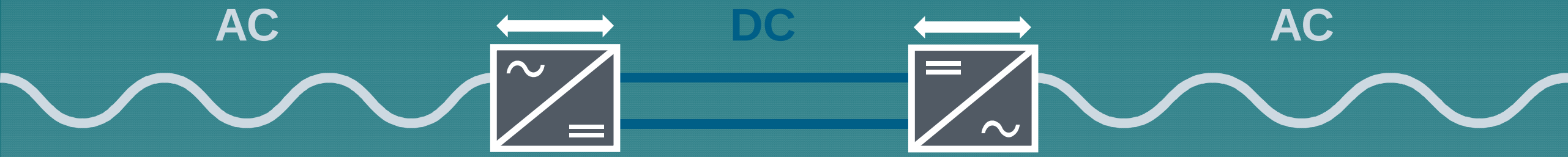
Past: Unidirectional energy flow HV à MV à LV via alternating current (AC)



Future: Omnidirectional energy flows that require control

Distance increases

MVDC PLUS combines the best of AC and DC transmission



Alternating current Direct current

- Simple design
- Robust and reliable technology
- Cheap and can be applied with no power electronics
- Easy integration into existing transmission networks

- Power transmission over long distances
- Same power transfer at lower voltage level possible
- No additional reactive power compensation equipment necessary
- Facilitates connection of asynchronous systems
- Seamless control of the active power flow
- Low contribution to short-circuit currents

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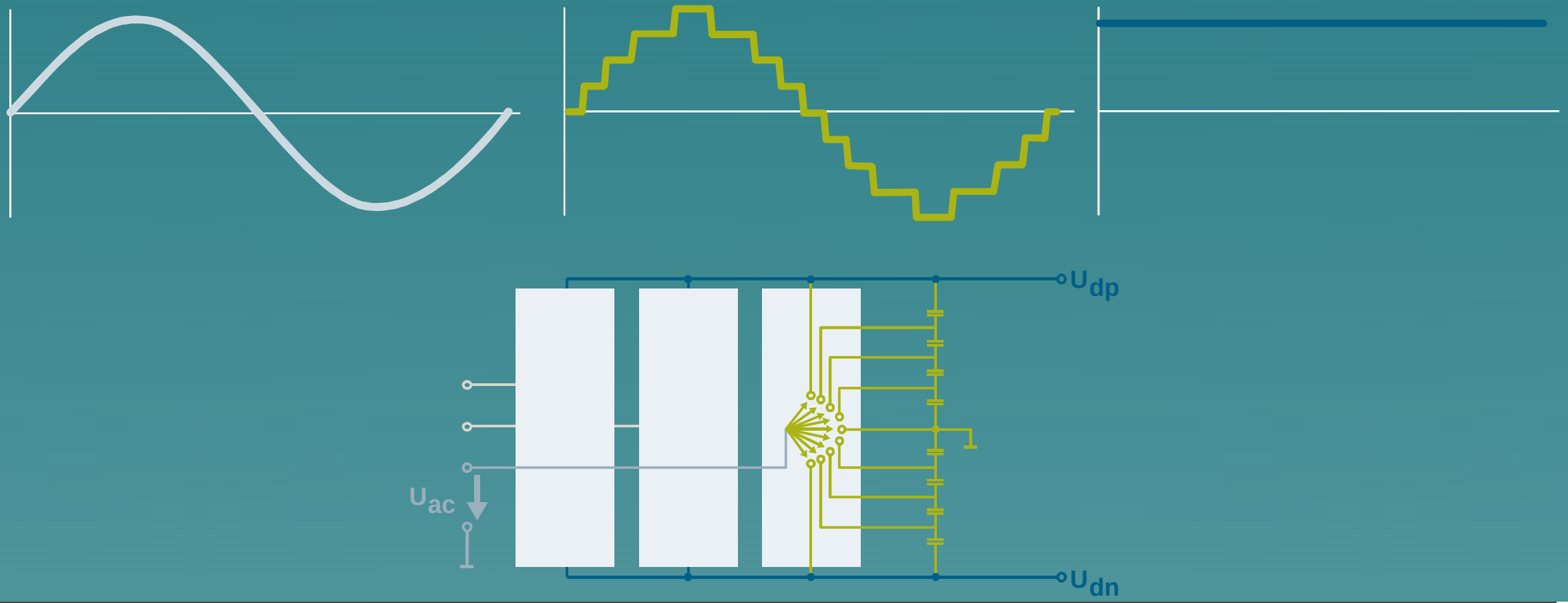
Modular multilevel converter in MVDC PLUS ensures stable power quality



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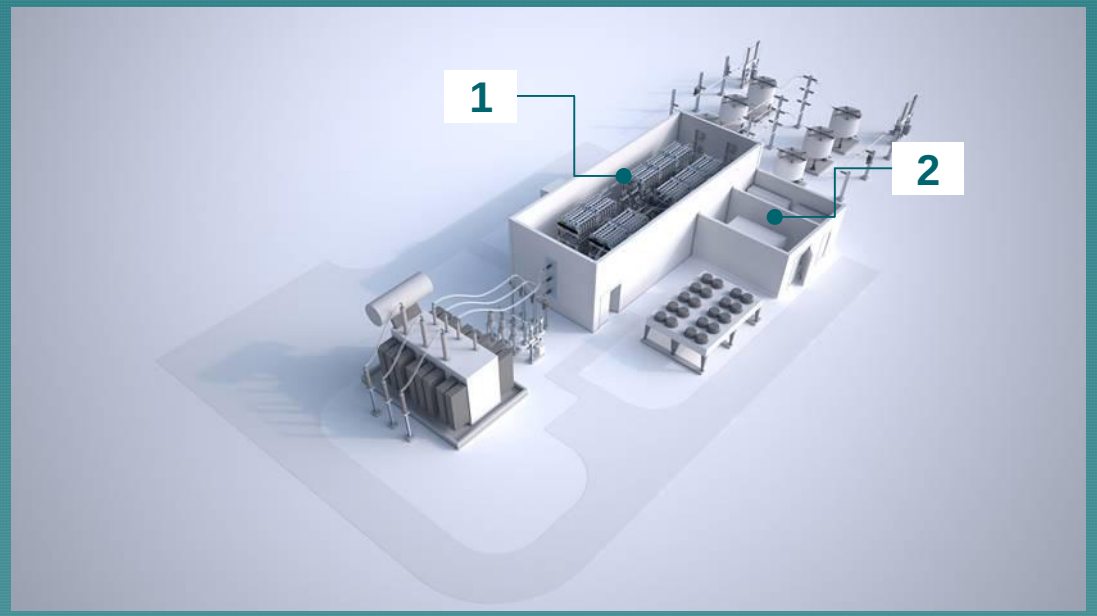
May I introduce myself?
I’m cost-efficient and fast thanks to standardized type ratings

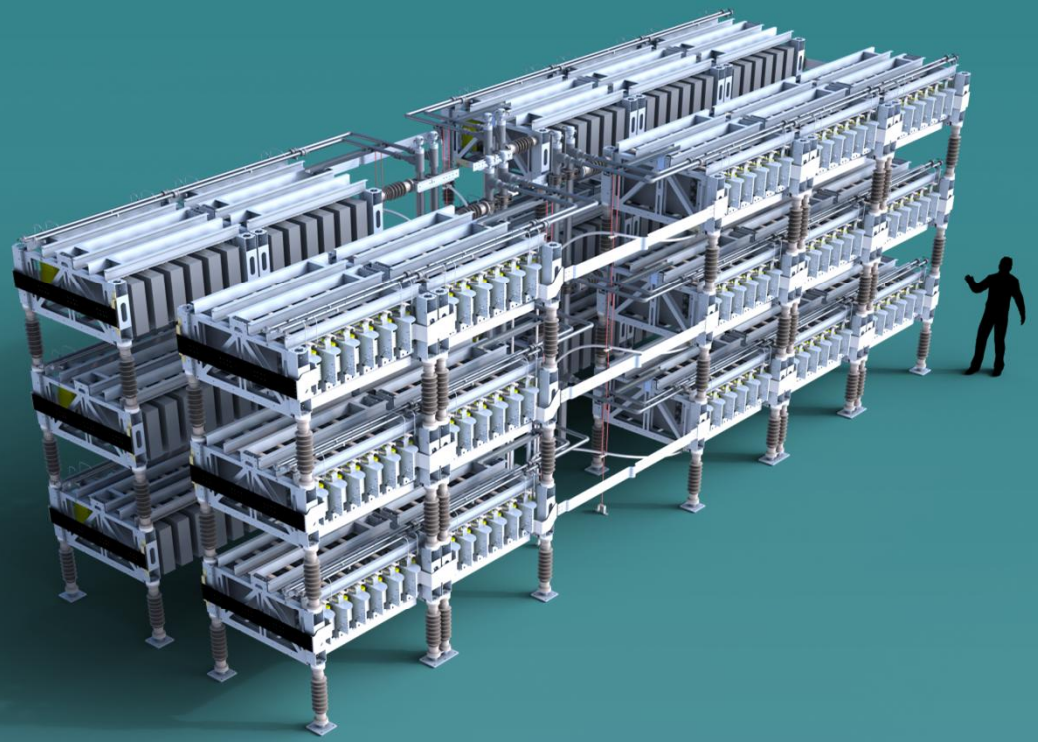


1 Converter tower with IGBT

2 Control & Protection

MVDC PLUS is based on HVDC PLUS technology, standardized for different type rates with positive impacts on costs and execution time

Converter tower with IGBT



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Control and protection system

Operation via operator interface

Switchyard control

Interlocking

Start-up/shut-down

Sequence of event recording

Controller setting

AC feeder protection

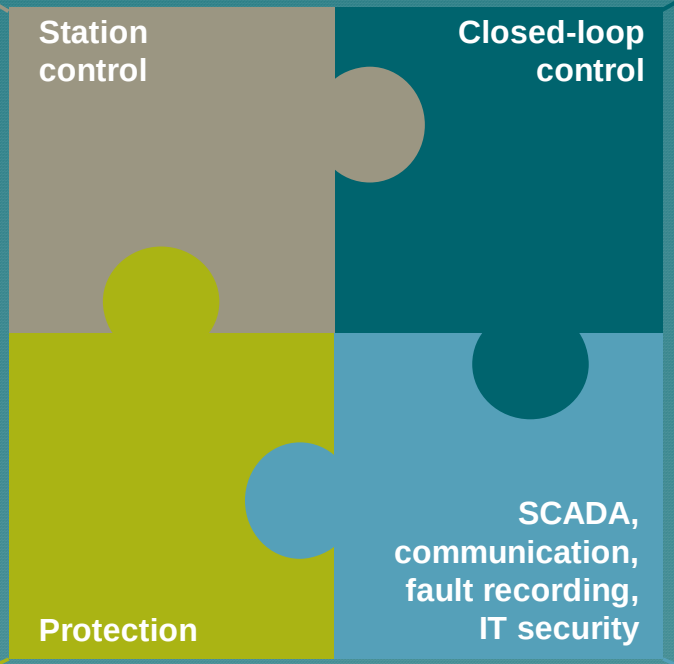
Transformer protection

Converter AC busbar protection

DC supervision

Converter protection

DC line/cable protection



Active power control

Bi-directional power flow

STATCOM operation

AC voltage control

Black start (*)

AC fault ride-through (**)

Communication with SCADA via standard IEC telecontrol

Separated process and service LAN

Signal recording 1 ms time stamp

Remote access routed through firewalls
Terminal server (DMZ) optional

* Optional and customized
** Depending on DC line configuration

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Control and protection system is based on SIMATIC processing systems and PLUSCONTROL

Control and protection system hierarchy

SIMATIC S7 and SIMATIC TDC

Operator level

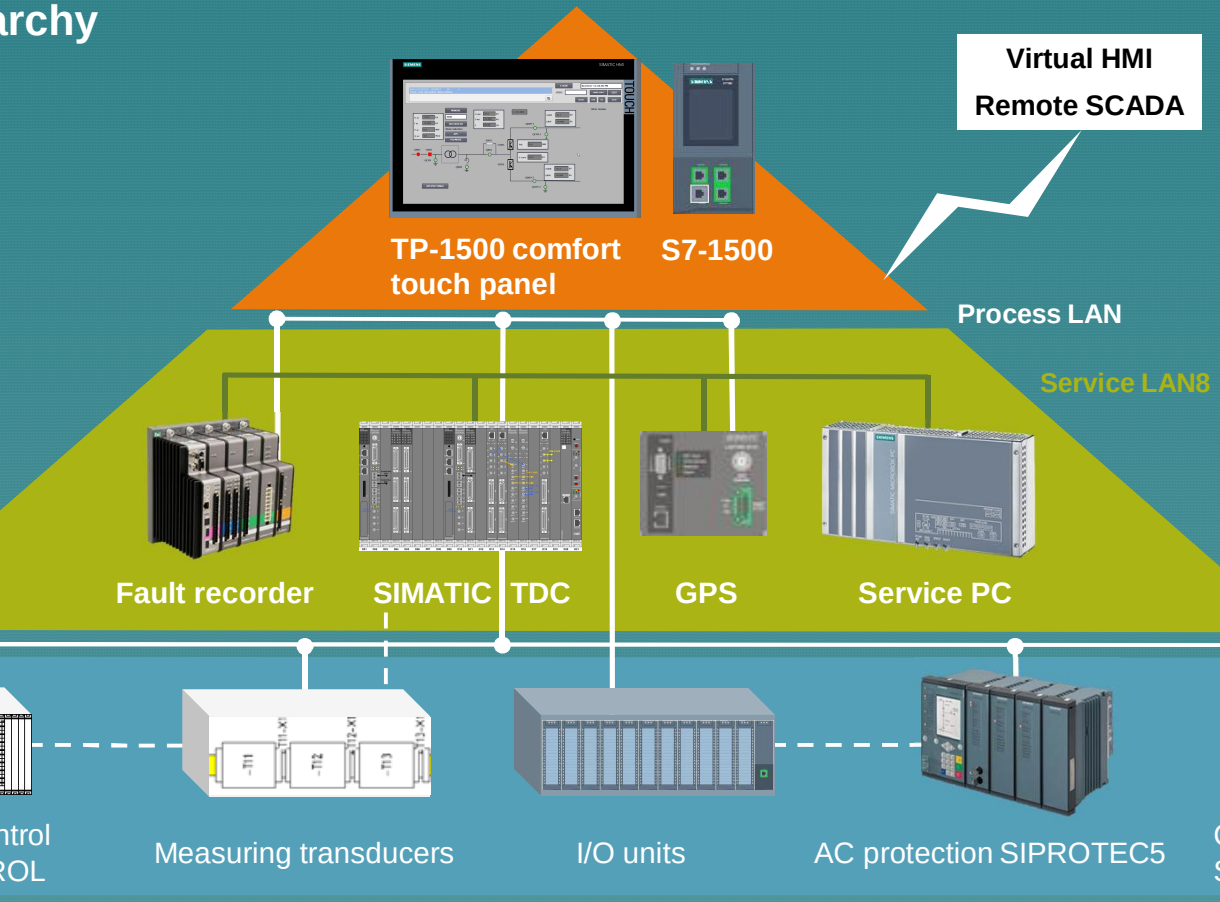
SIMATIC S7-1500 station control & operator interface

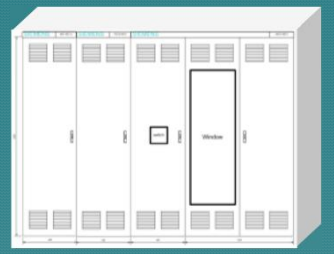
Plant level

Control and DC protection system with time synchronization and fault recording, diagnostic PC

Field level

Converter control,
measuring interfaces,
I/O interfaces,
AC protection relays





Compact panel setup in a 3m x 0.6m x 2.2m row preassembled in kiosk

Panels key-locked