



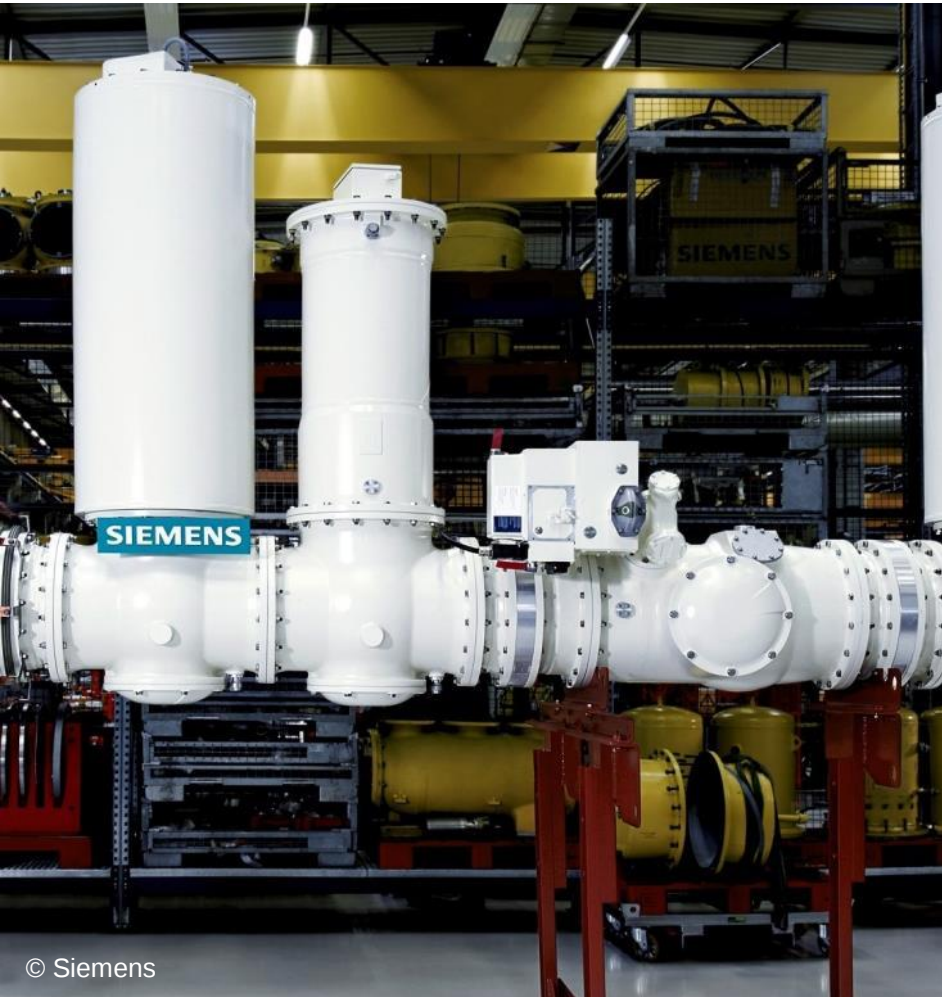
PROMOTiON
PROGRESS ON MESHED HVDC
OFFSHORE TRANSMISSION
NETWORKS

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State of development of gas-insulated HVDC systems

2018-09-20, Arnhem, Workshop HVDC GIS demonstrator
Dr.-Ing. Maria Hering, Siemens AG, Energy Management Division

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Motivation for developing gas-insulated DC systems

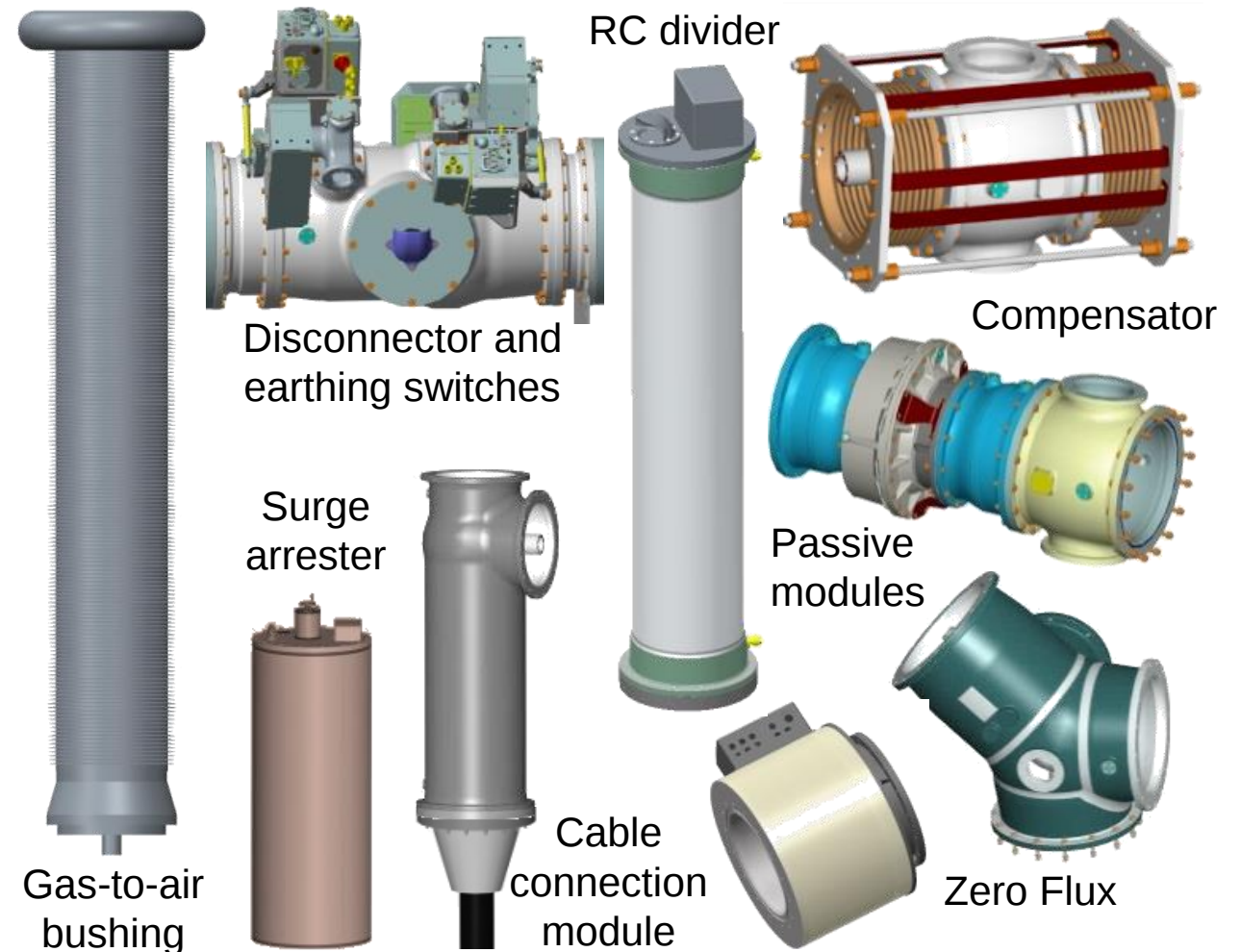
Requirements of modern energy transmission

- Growing energy demand
- Increasing distance between energy generation and load centers
- Lack of space in densely populated areas
- Extreme environmental conditions



Development of gas-insulated DC systems Based on AC GIS with relevant adaptations

- Development of DC GIS was driven by HVDC offshore projects
- DC GIS is based on 550 kV AC GIS modules (8DQ1)
- Main adaption: DC insulator
- Modular design
- Functional integration includes disconnecting, metering of voltage and current, handling overvoltage surges and connecting cable and overhead line



Development of gas-insulated DC systems

Basic research and development tests (selection)

Thermal

- Temperature gradient
- Temperature distribution

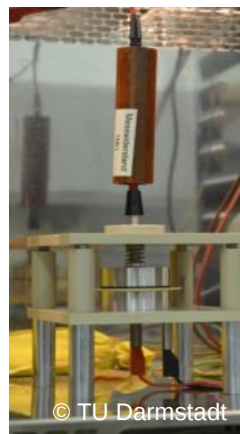
Electrical

- Charge distribution
- Potential distribution
- Influence of particles

Thermal & electrical

- Material characterization (dependent on T and E)
- Influence of charge and potential distribution
- Scalability
- Extreme conditions
- Long-term behaviour

Investigations on model and original arrangements



Gas-insulated switchgear for DC (without circuit-breaker)

Product: DC GIS ± 320 kV

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Direct Current Gas-Insulated Switchgear (DC GIS) ± 320 kV

- Gas-to-air bushing
- Compensator
- Surge arrester
- RC divider
- ZeroFlux
- Disconnecter and earthing switches
- Cable module

Type tested according
to available standards

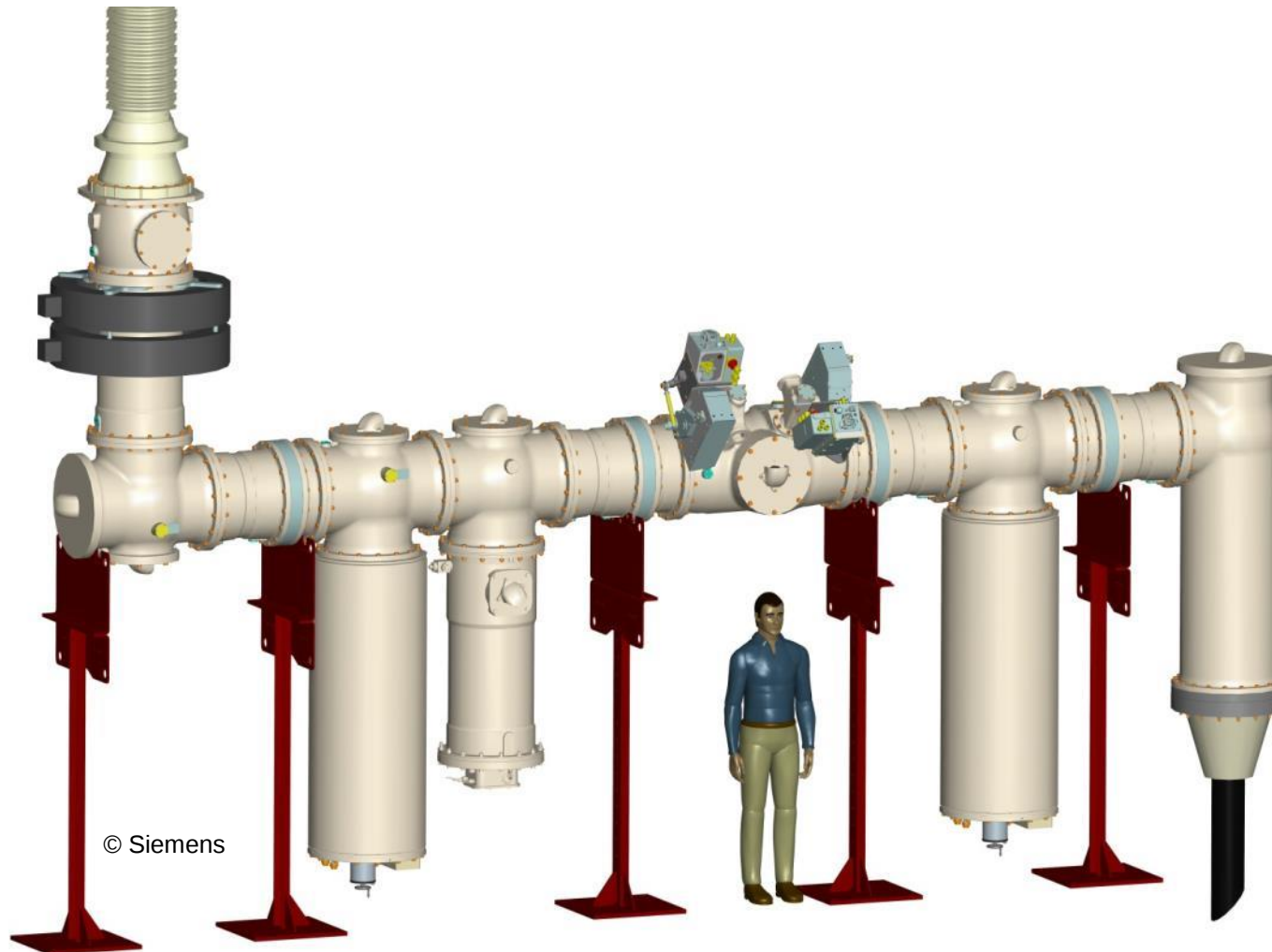


Gas-insulated switchgear for DC (without circuit-breaker) Final stage of development of DC GIS ± 500 kV



Direct Current Gas-Insulated Switchgear (DC GIS) ± 500 kV

- Gas-to-air bushing
- Compensator
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Type testing according
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Gas-insulated switchgear for DC (without circuit-breaker)

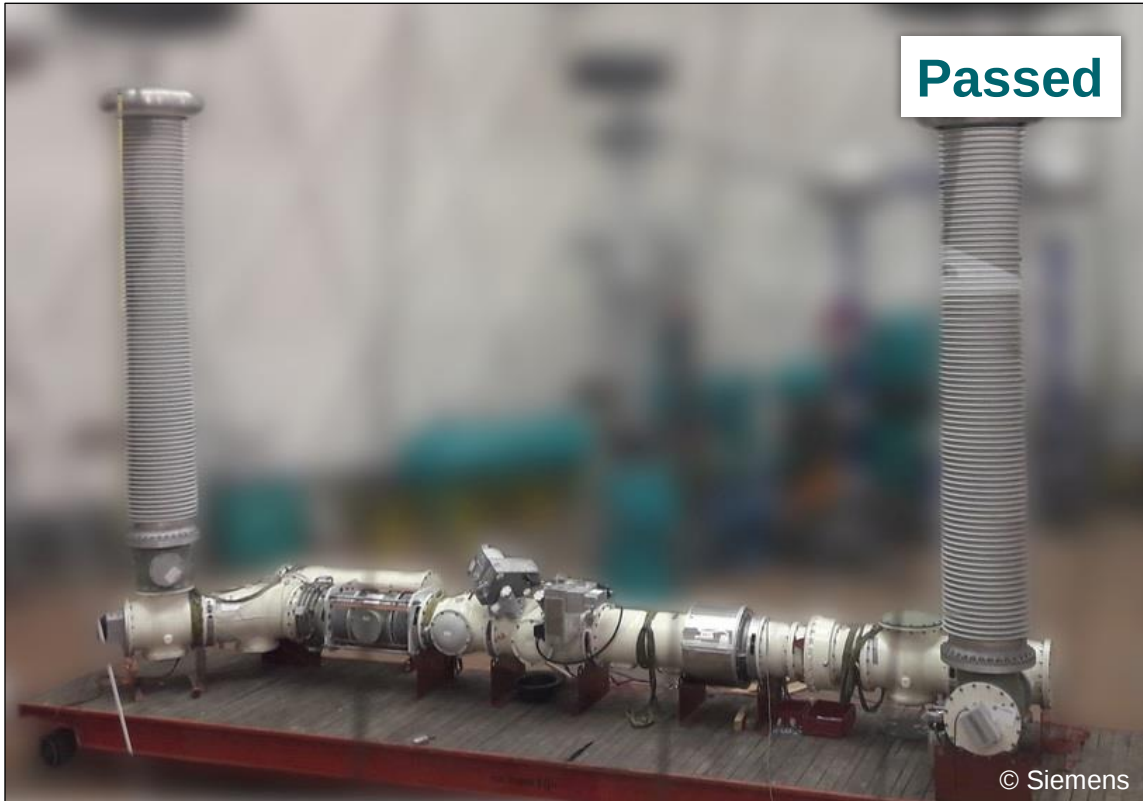
Final stage of development of DC GIS ± 500 kV

Type tests in 2018			
✓ Dielectric test	02/2018	passed	acc. to IEC 62271 -1 -203 -102
✓ Temperature-rise test	04/2018 – 05/2018	passed	
✓ Mechanical switching test	09/2018	passed	
Short-time withstand current and peak withstand current test	10/2018	planned	
✓ Arcing test	<i>passed during ± 320 kV development</i>		
✓ Insulation system test (± 550 kV DC) ± 1175 kV SI ± 1425 kV LI	03/2018 – 05/2018	passed	acc. to Cigré JWG D1/B3.57
Insulation system test (± 550 kV DC) ± 1175 kV SI ± 1550 kV LI	07/2018 – 10/2018	on-going	

Gas-insulated switchgear for DC (without circuit-breaker)

Final stage of development of DC GIS ± 500 kV

Dielectric test



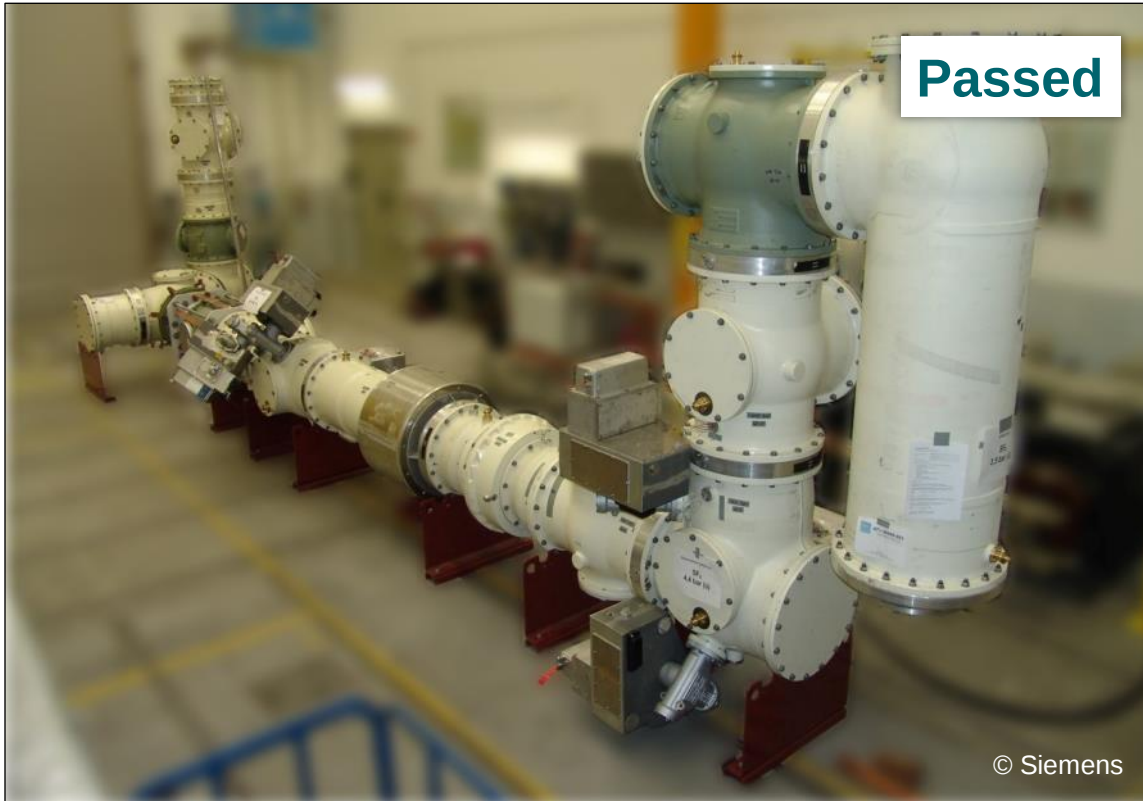
02/2018, Schaltwerk Berlin, all relevant modules

Test	Level
AC withstand voltage test with PD measurement	700 kV AC 467 kV AC (TE)
DC withstand voltage test (10 min)	± 825 kV DC
LI withstand voltage test (15 impulses)	± 1550 kV LI
SI withstand voltage test (15 impulses)	± 1175 kV SI
Superimposed voltage test DC and LI voltage with 2 h of DC pre-stress ± 550 kV (15 impulses)	± 550 kV DC & ± 1550 kV LI (all 4 quadrants)
Superimposed voltage test DC and SI voltage with 2 h of DC pre-stress ± 550 kV (15 impulses)	± 550 kV DC & ± 1175 kV SI (all 4 quadrants)
Combined voltage test, DC opposed to LI voltage over the open isolating distance (15 impulses)	± 550 kV DC & ∓ 1550 kV LI (bipolar)
Combined voltage test, DC opposed to SI voltage over the open isolating distance (15 impulses)	± 550 kV DC & ∓ 1175 kV SI (bipolar)

Gas-insulated switchgear for DC (without circuit-breaker)

Final stage of development of DC GIS ± 500 kV

Temperature-rise test



- According to IEC 62271-203
- Measurement of temperatures at > 100 positions
- Different current levels

Test	Level
Temperature-rise test with AC 50 Hz	2500 A 3150 A 4000 A 5000 A
Temperature-rise test with DC	2500 A 3150 A 4000 A 5000 A

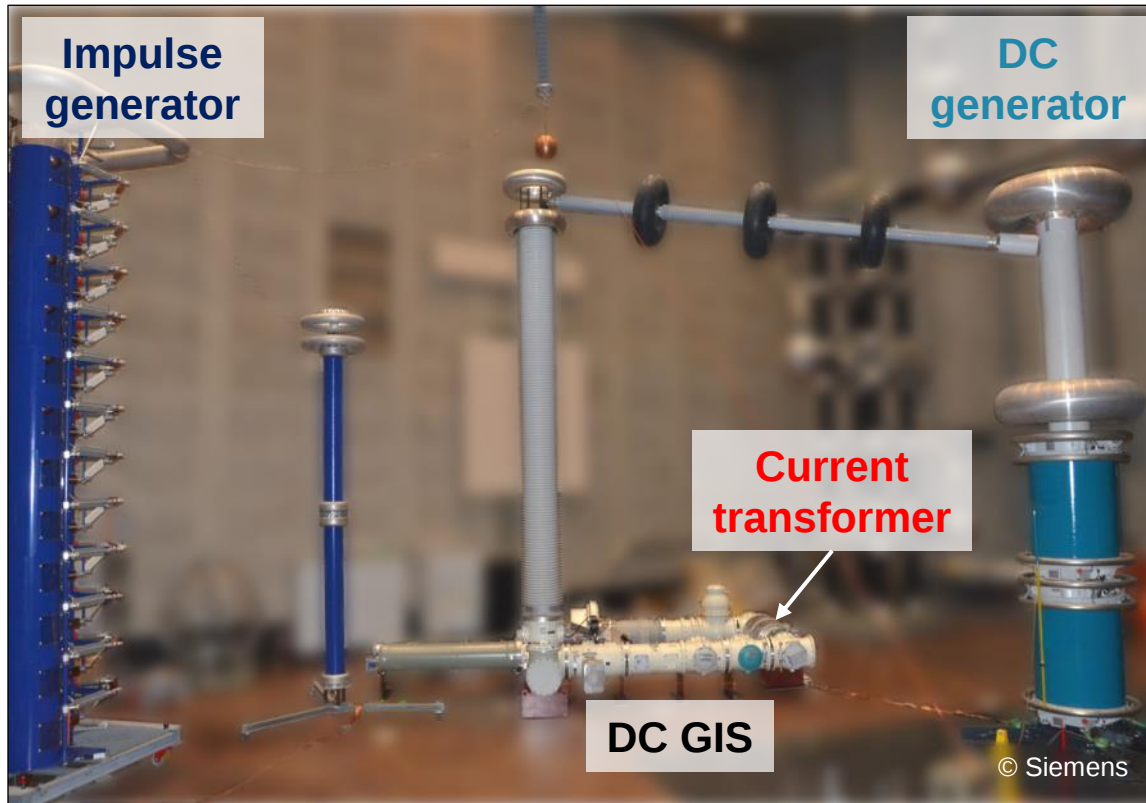
- Relevant input for Cigré insulation system test when using AC current for heating
- All temperatures within permissible limits

04-05/2018, Schaltwerk Berlin, all relevant modules

Gas-insulated switchgear for DC (without circuit-breaker)

Final stage of development of DC GIS ± 500 kV

Cigré insulation system test



- Thermo-electric test according to the recommendations of Cigré JWG D1/B3.57
 - Temperature gradient according to 5000 A DC
 - DC charging until t_{90} (at least 90 % of the DC field at all locations in the insulating system)
 - this case: 5 days
 - Superposition of DC and SI / LI voltage as composite test voltage

03-10/2018, Technical University of Munich

Gas-insulated switchgear for DC (without circuit-breaker)

Final stage of development of DC GIS ± 500 kV

Cigré insulation system test



Pre-test

(zero load – without temperature gradient)

Test	Level
AC withstand voltage test (1 min)	700 kV AC
DC withstand voltage test (10 min)	± 825 kV DC
LI withstand voltage test (15 impulses)	± 1550 kV LI
SI withstand voltage test (15 impulses)	± 1175 kV SI

Insulation system test

(high load – with temperature gradient)

Test	Level
Superimposed voltage test DC and LI voltage with >120 h of DC pre-stress ± 550 kV (3 impulses)	± 550 kV DC & ± 1425 1550 kV LI (all 4 quadrants)
Superimposed voltage test DC and SI voltage with >120 h of DC pre-stress ± 550 kV (3 impulses)	± 550 kV DC & ± 1175 kV SI (all 4 quadrants)

Gas-insulated switchgear for DC

Application fields

Converter station



Space-saving installation, modular design, aesthetic station planning, independent from environmental conditions, no fire hazard, container solution

Transition station

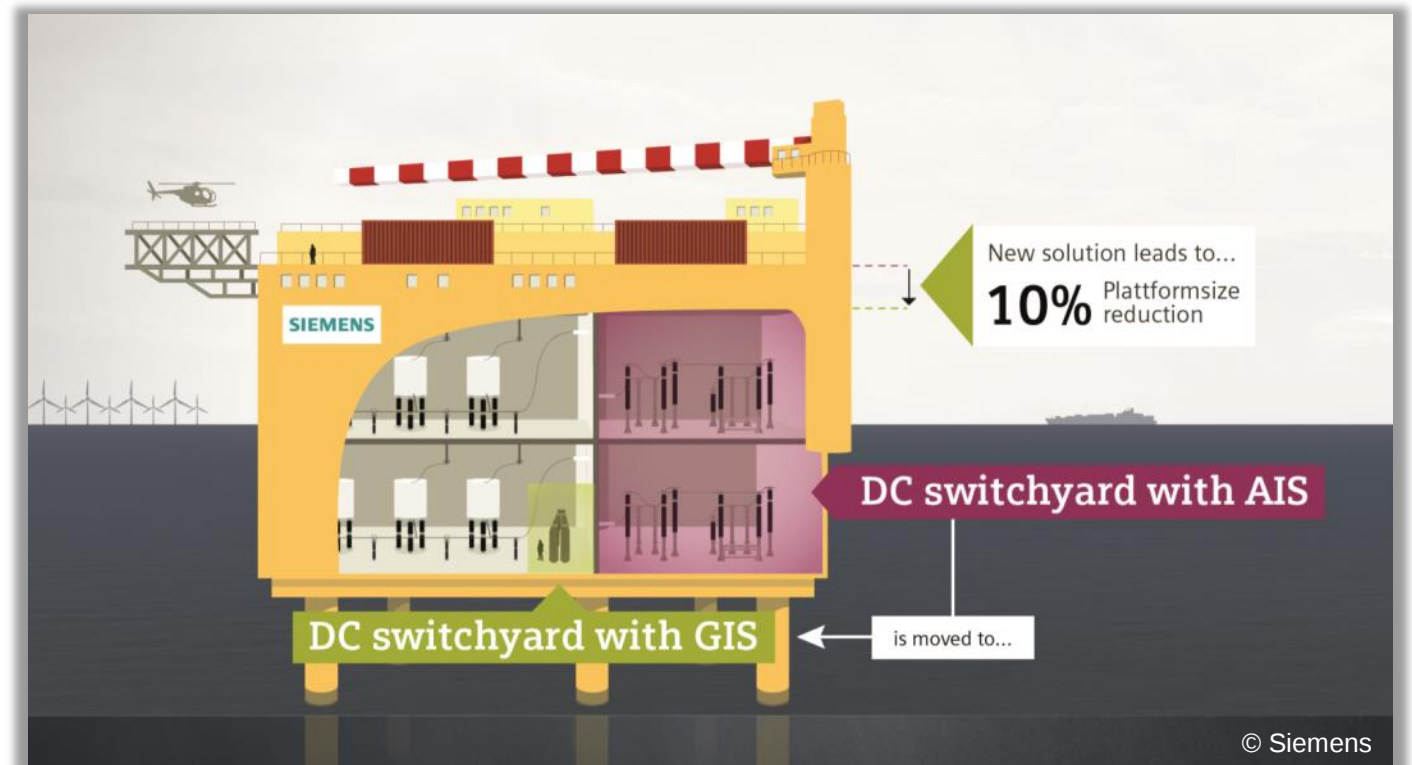


Application fields

Converter station – Offshore platform

- DC GIS leads to significant space reduction in contrast to AIS solutions
- (70 ... 95) % volume reduction of the DC switchyard → 10 % size reduction of the platform

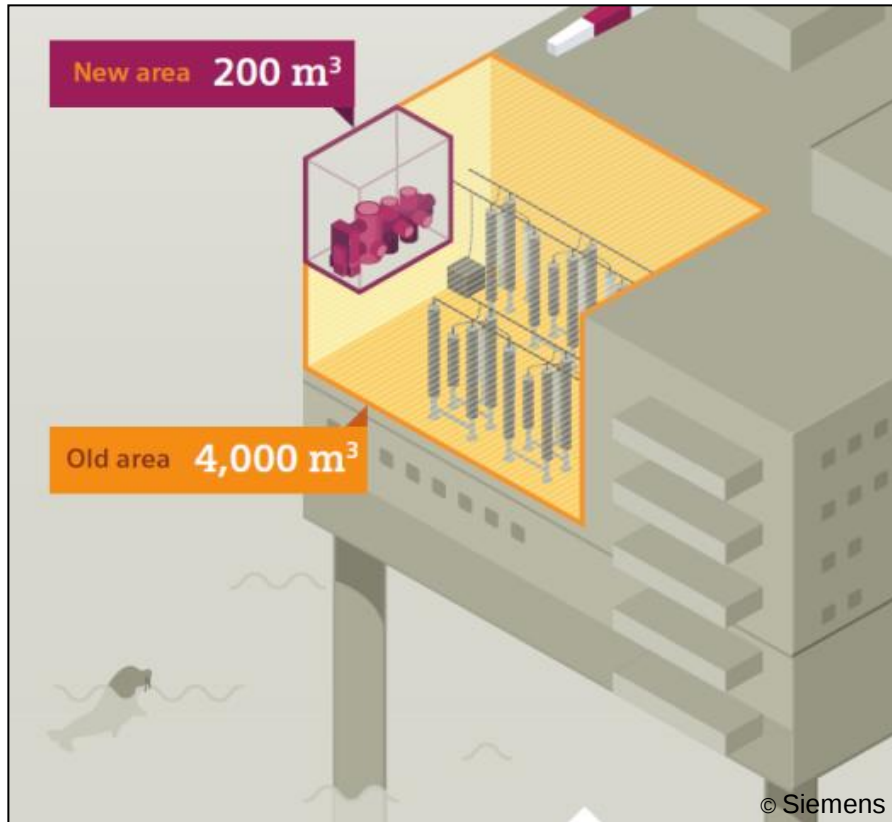
- DC GIS integrated in another technology room, e.g. reactor hall



Application fields

Converter station – Offshore platform

DC switchyard – air-insulated vs. gas-insulated



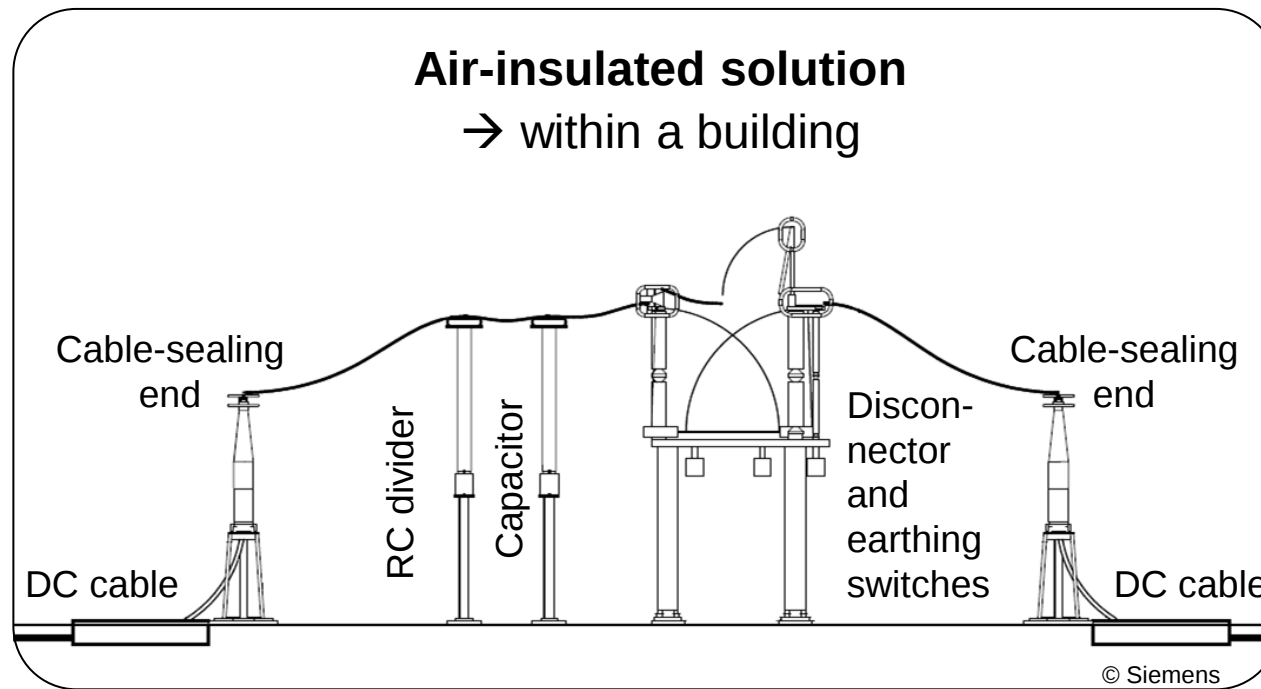
Space reduction of the DC switchyard $\approx (70 \dots 95) \%$

Application fields

Transition station – Cable-cable

Functional integration for cable-cable transition station:

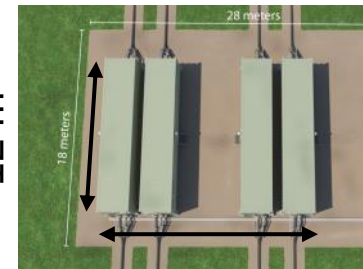
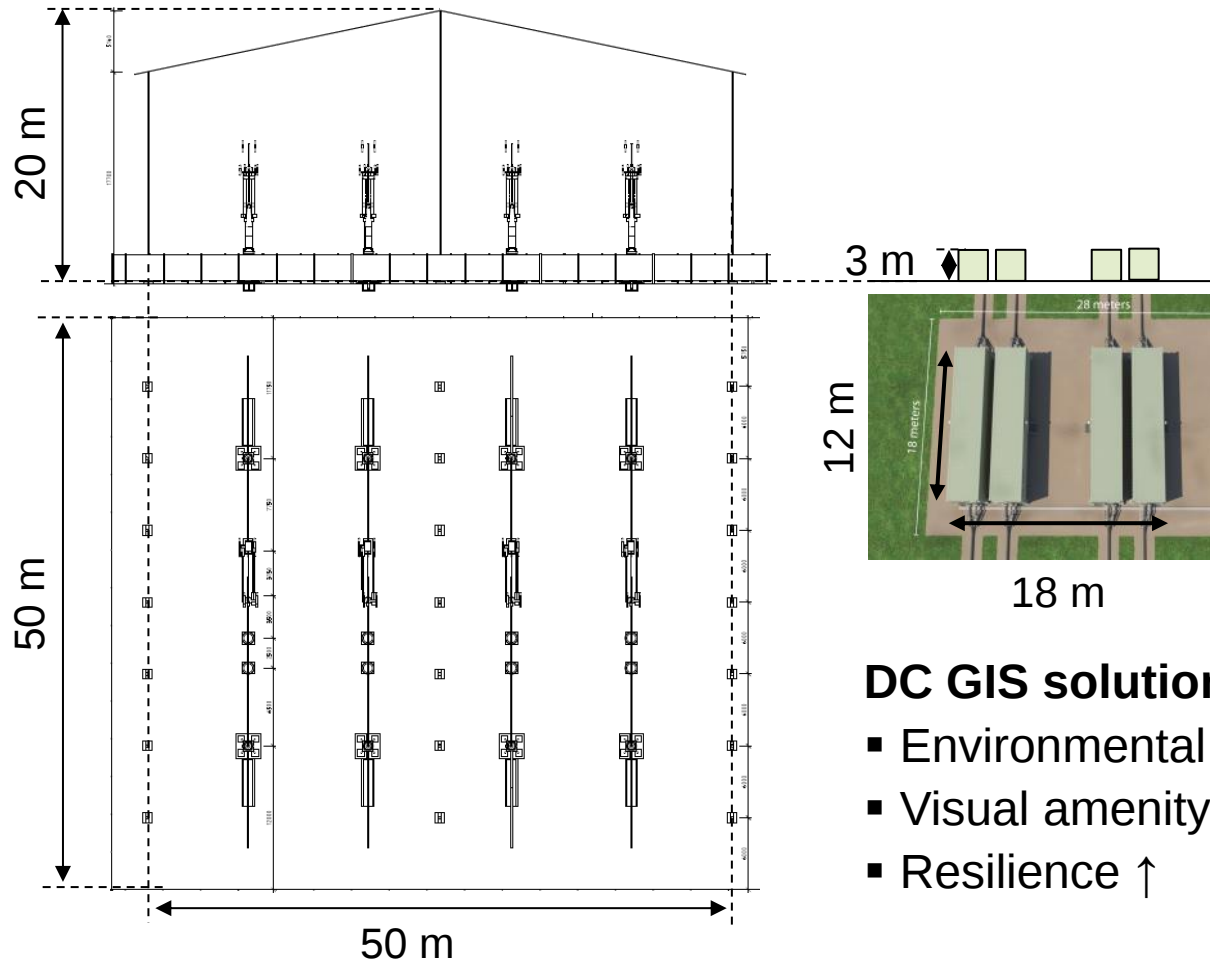
- Separation and safe earthing of the line sections
- Measurement of voltage and current
- Line fault location



Application fields

Transition station – Cable-cable

Solution for 4x ± 320 kV DC cable-cable connection (2 systems)



DC GIS solution

- Environmental impact ↓
- Visual amenity ↑
- Resilience ↑



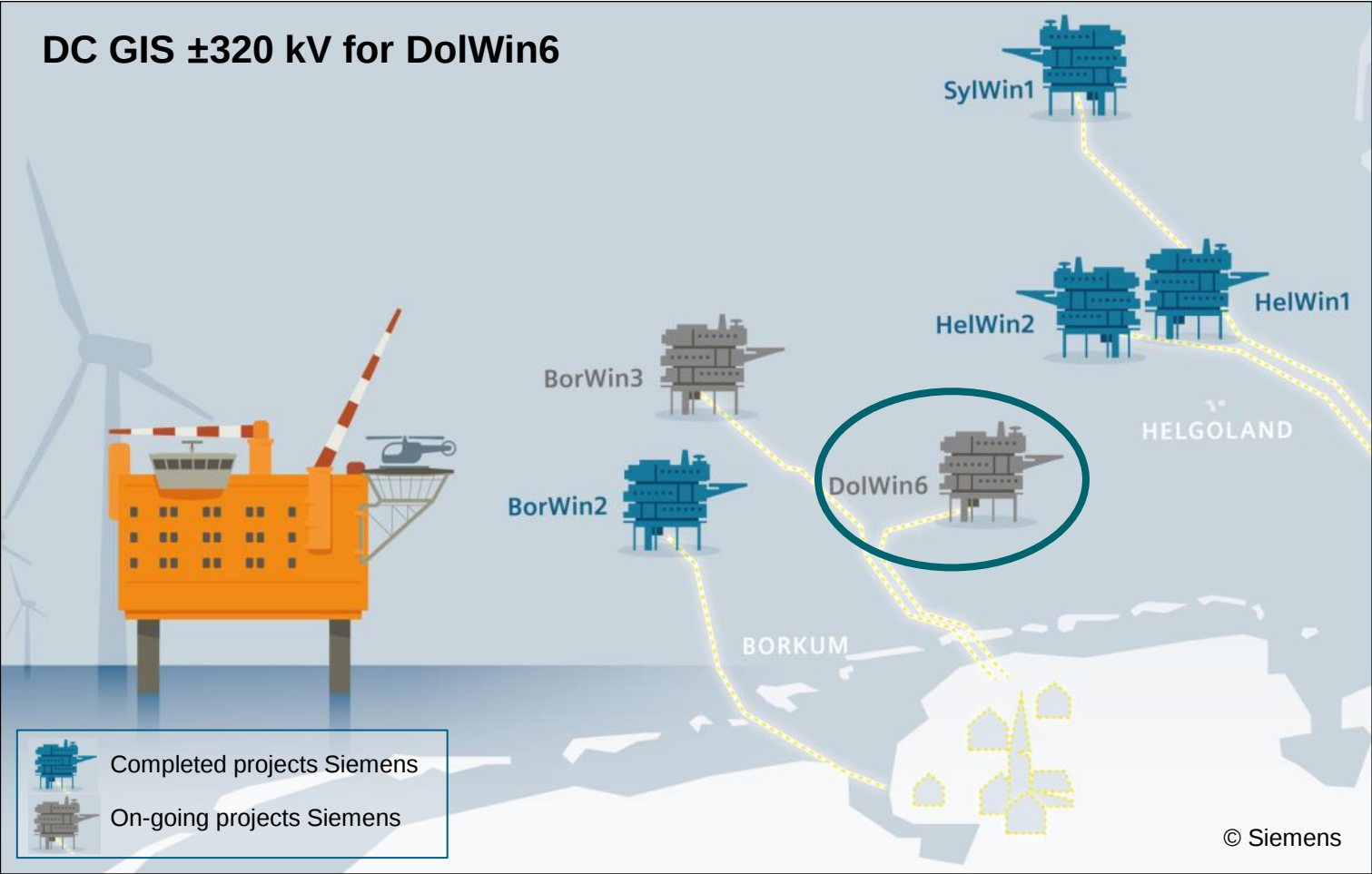
Containerized solution for cable-cable transition

Comparison footprint „buildings“

- AIS: 2500 m²
- GIS: 216 m²
- Reduction by 90 %

DolWin6 HVDC grid connection

Converter platform DolWin kappa

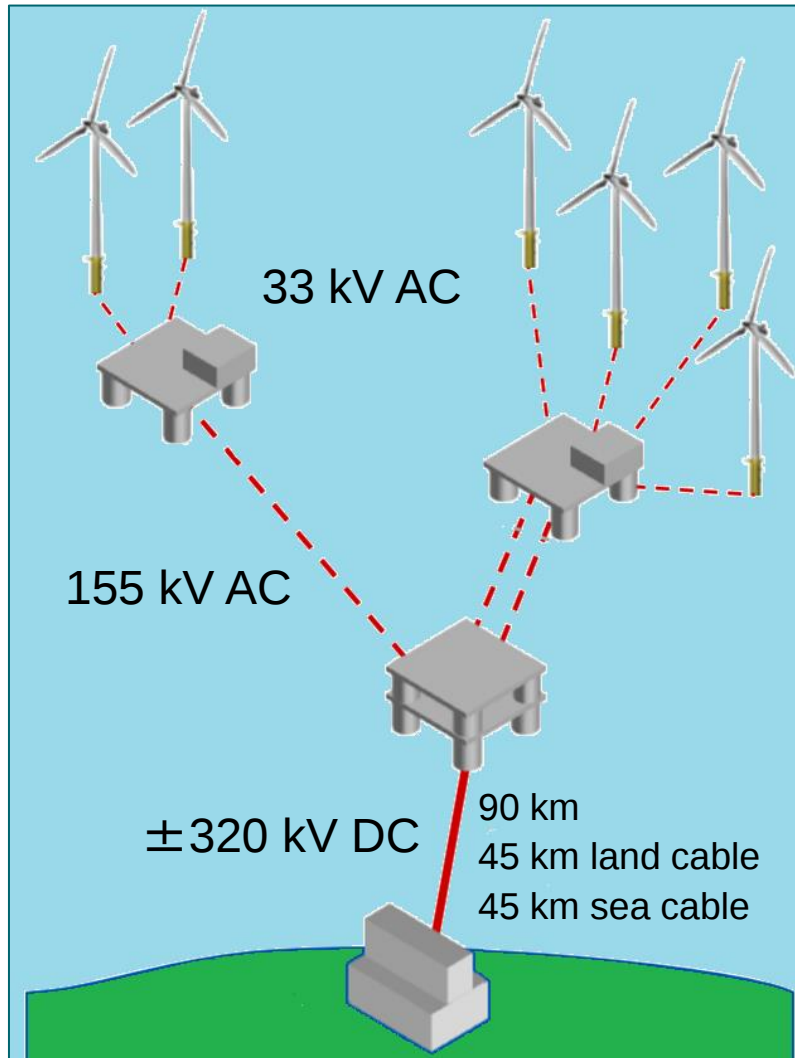


Customer for DolWin6	TenneT Offshore GmbH
Power	900 MW
Voltage	±320 kV DC
Award of contract	2017
Commissioning	2023



DolWin6 HVDC grid connection

Converter platform DolWin kappa



Windparks
„Gode Wind 3“
& others

AC platform

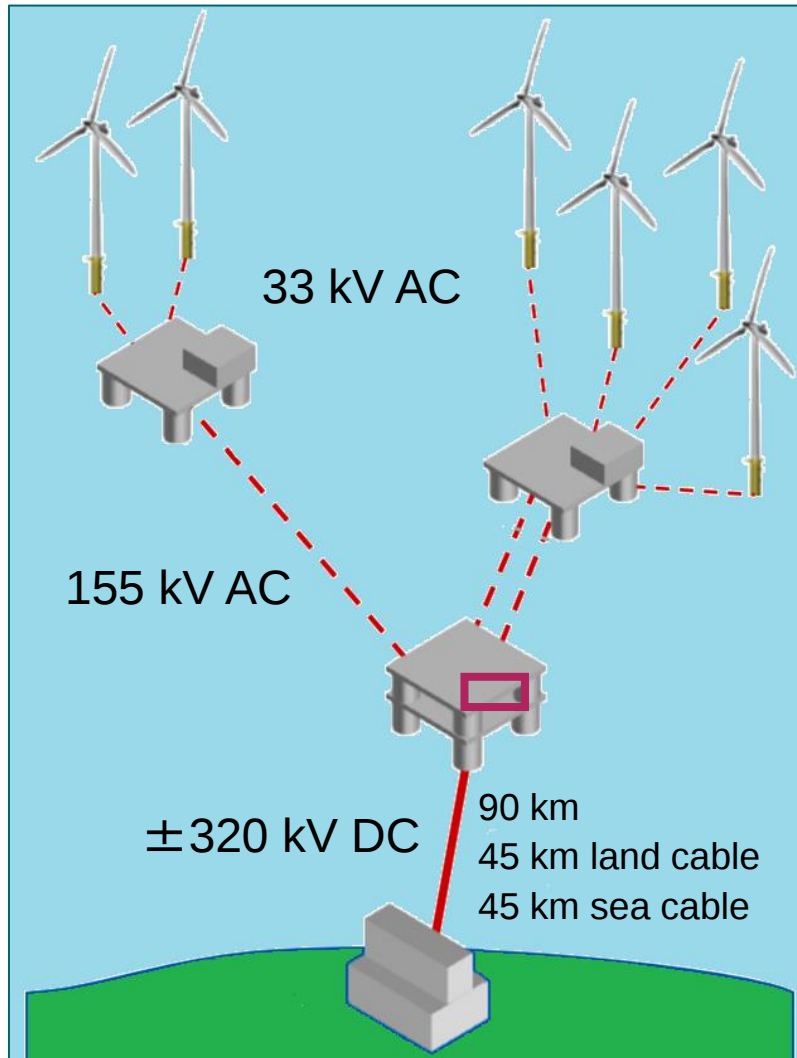
**DC platform with
offshore converters**
„DolWin kappa“

Onshore converters
„Emden/Ost“



DolWin6 HVDC grid connection

Converter platform DolWin kappa



Windparks

„Gode Wind 3“
& others

AC platform

**DC platform with
offshore converters**
„DolWin kappa“

Onshore converters
„Emden/Ost“

Current status of DC GIS for DW6:

- Design freeze
- Start of production: 2019

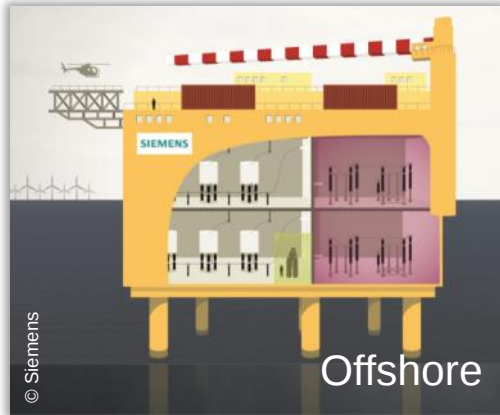
Application of DC GIS leads to:

- Space-saving DC switchyard by 95%
- Space-saving converter platform by 10%

DC gas-insulated switchgear (DC GIS)

Summary

Converter station



- Development of DC GIS based on AC GIS with newly developed insulator design
- DC GIS ± 320 kV for project DolWin6
- DC GIS ± 500 kV in final development stage
- Application potential of DC GIS within converter and transition stations

Transition station



DC gas-insulated switchgear (DC GIS)

Which questions do you have?



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