SIEMENS

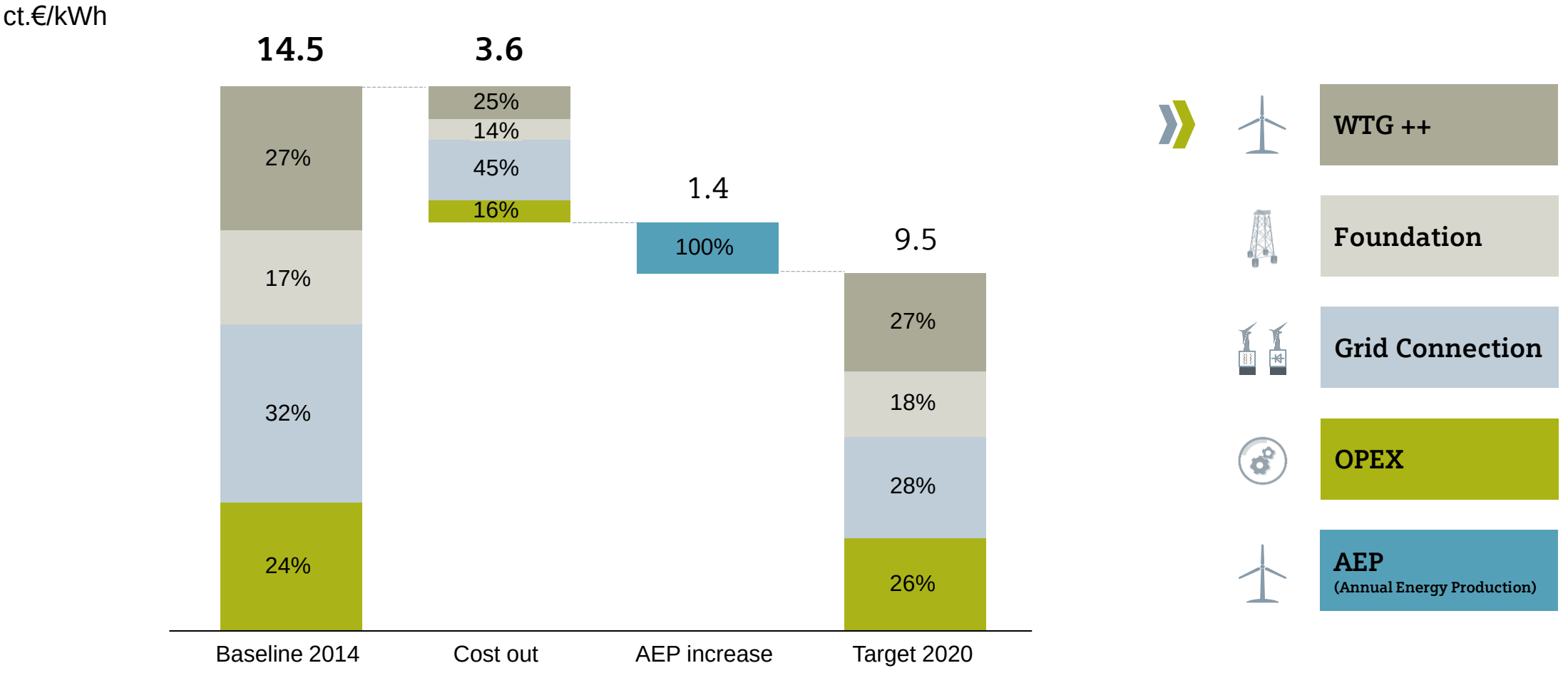
October 14th, 2015

2nd generation DC grid access for large scale offshore wind farms

Supported by

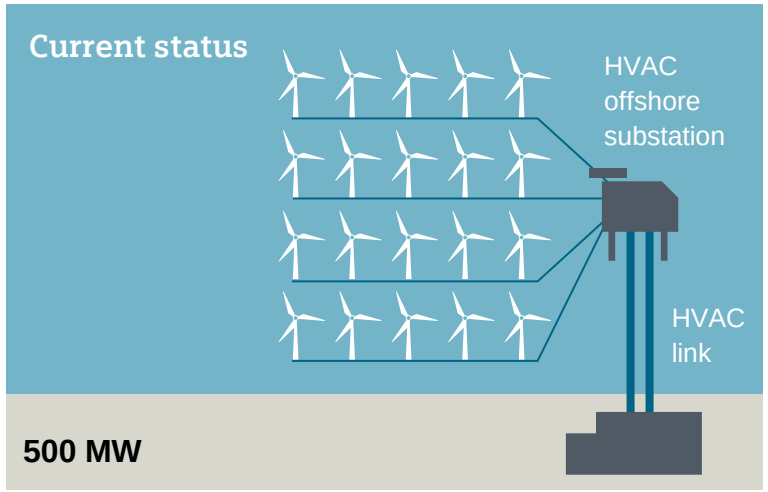
Bundesministerium für Wirtschaft und Energie

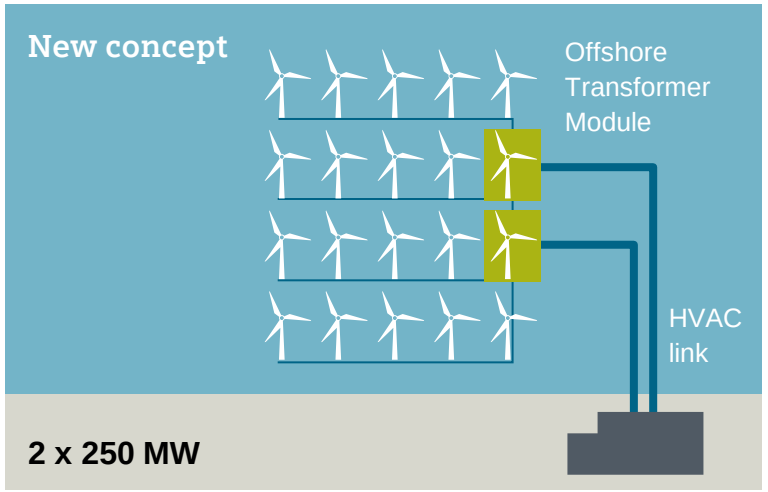
Cost reduction is a must to make Offshore Wind a competitive renewable energy source: Reaching LCoE below 10 ct.€/kWh by 2020



Based on the SWT-6.0-154 turbine; Offshore project 1 GW, 50m water depth, 100 km from shore

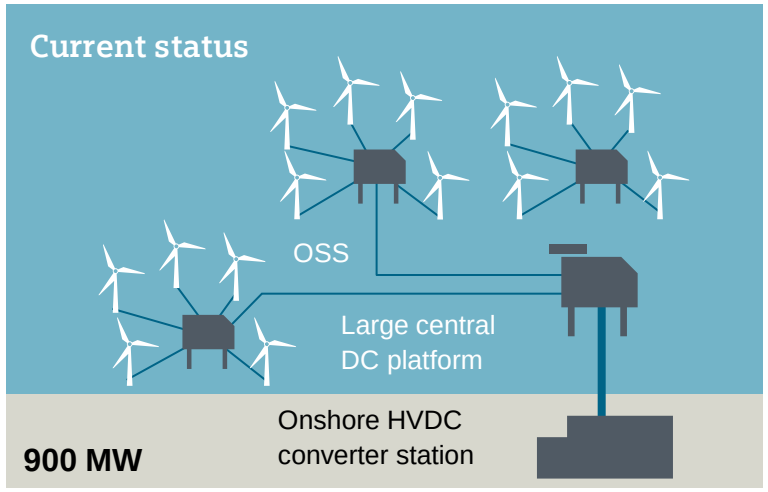
For significant cost saving in the grid access part we need paradigm shifts!

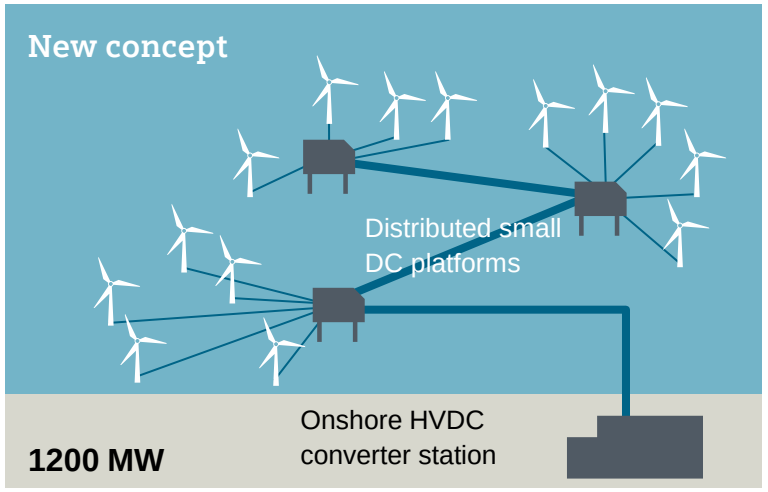




New AC grid access attaches the electrical equipment to the turbine foundation

- Official launch at the EWEA Offshore conference 03/2015

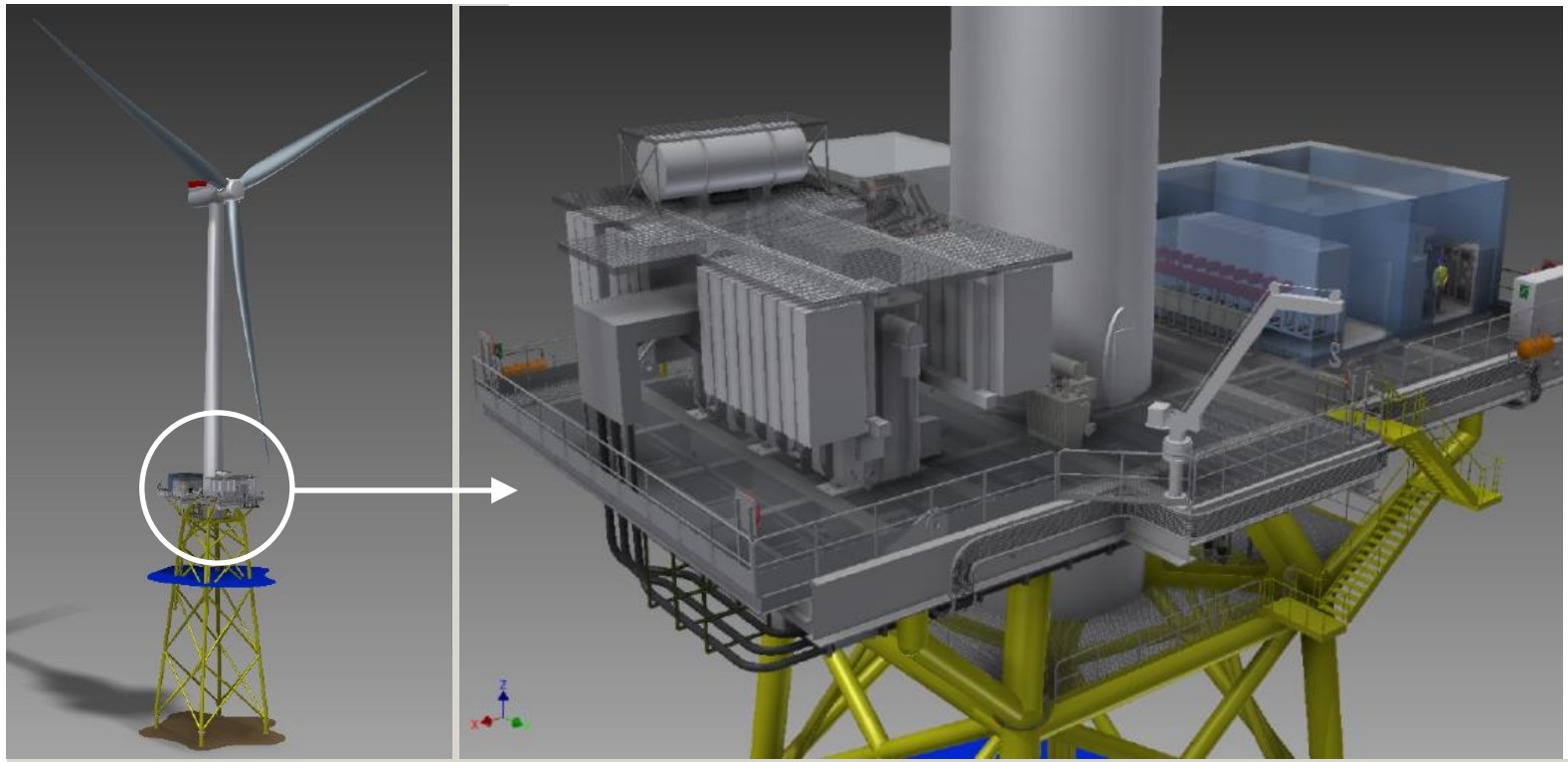




New DC grid access uses distributed small DC platforms

- First presentation to the offshore wind industry at the EWEA Offshore conference 03/2015.
- Official launch 10/2015 at “Nationale Maritime Konferenz“ in Bremerhaven

New Siemens AC Grid Access Solution (SGA-AC) uses an Offshore Transformer Module



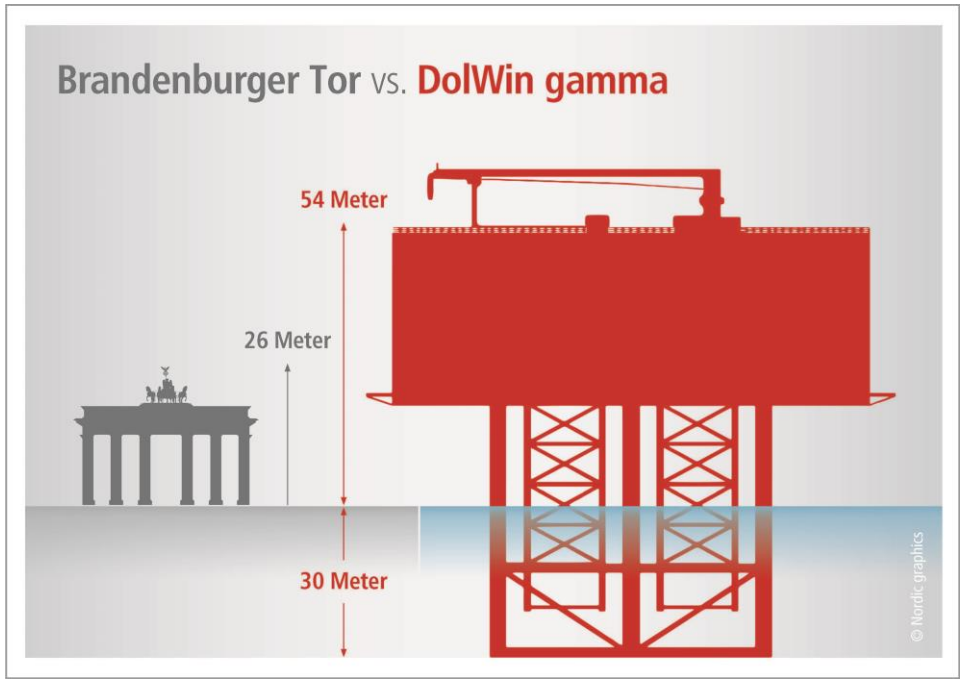
The new SGA-AC consists of an OTM attached to a booster turbine

- ✓ Distributed transmission asset in incremental 250 MW blocks
- ✓ Compact and rugged design
- ✓ Electrical components optimized from our accumulated lifecycle experience
- ✓ Modular approach
- ✓ Installation with wind turbine foundation or independently
- ✓ Can be implemented with every wind turbine supplier
- ✓ Environmentally Friendly
- ✓ Low Maintenance
- ✓ Flexibility and choice for customers: Optimized conventional platform also available

✓ 40% Cost reduction and

✓ One third smaller in size and weight compared to a traditional substation

DC grid access in the German bight today

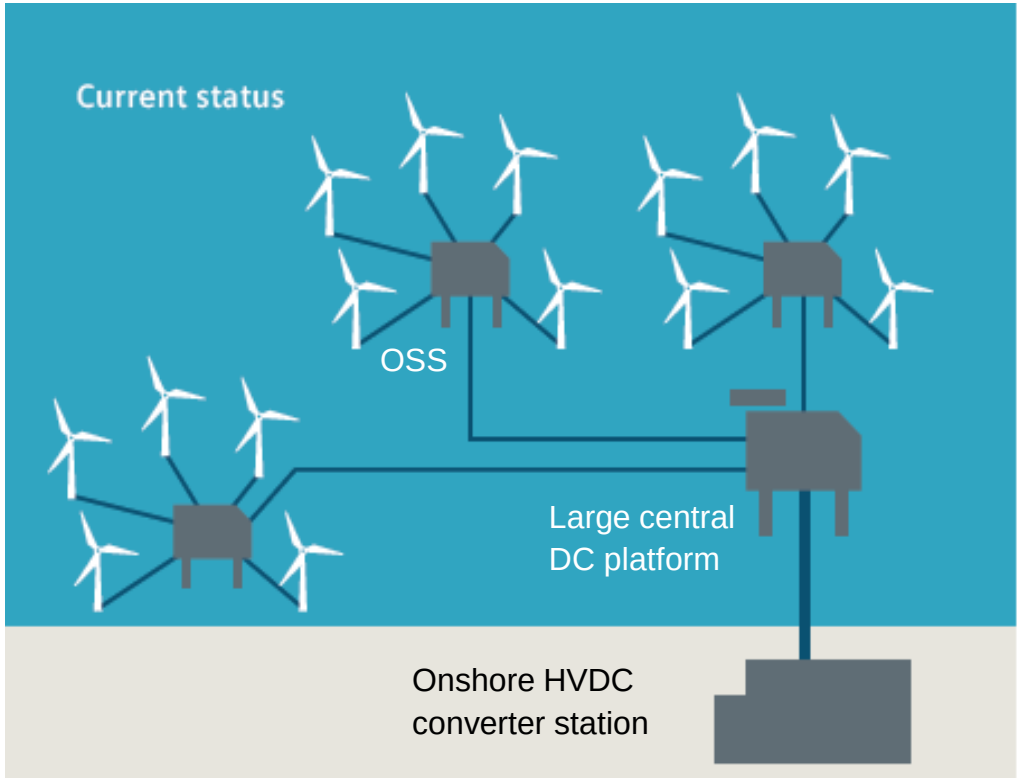


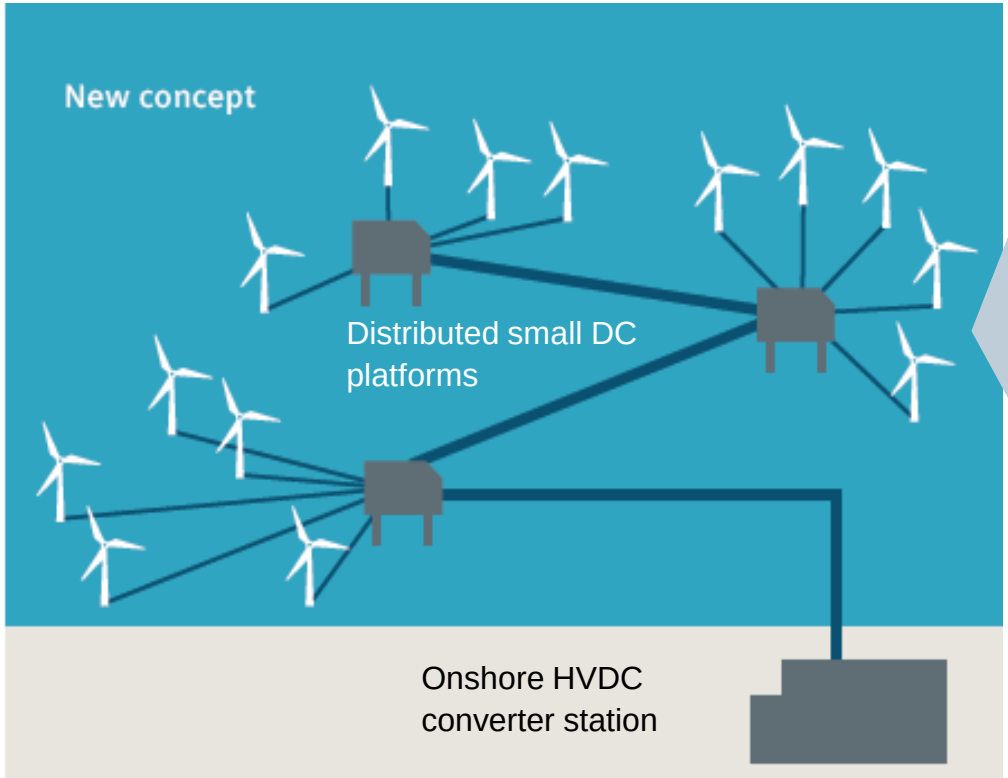
DolWin gamma, 900MW, in construction by Alstom, Picture from Overdick

We have learned our lessons from the German bight!

- We looked at the whole system from the very beginning (from blade to shore)
- We kept the offshore equipment as simple and robust as possible
- We kept the offshore platform sizes and weights in ranges good to handle
- We sticked to what developers and operators are used to from AC grid access in terms installation and maintenance

The new DC grid access concept: Siemens Grid Access using a Diode Rectifier Unit (SGA-DRU)



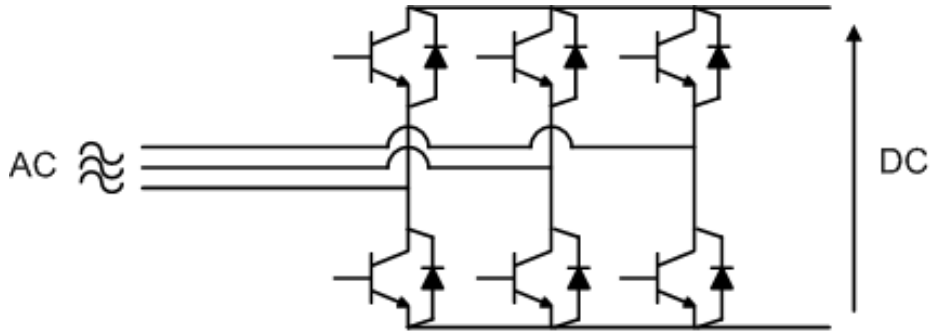


- First presented at EWEA conference in Copenhagen, March 10th.
- Official launch 10/2015 at "Nationale Maritime Konferenz in Bremerhaven"

Total topside volume:	-80%	Transmission losses:	-20%
Total topside weight:	-65%	Transmission capacity:	+30%
Installation time:	-20%	Costs:	-30%

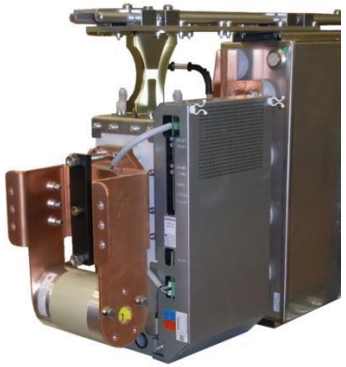
The root for the large DC platform is the air insulated converter and air insulated DC switchgear

Current approach

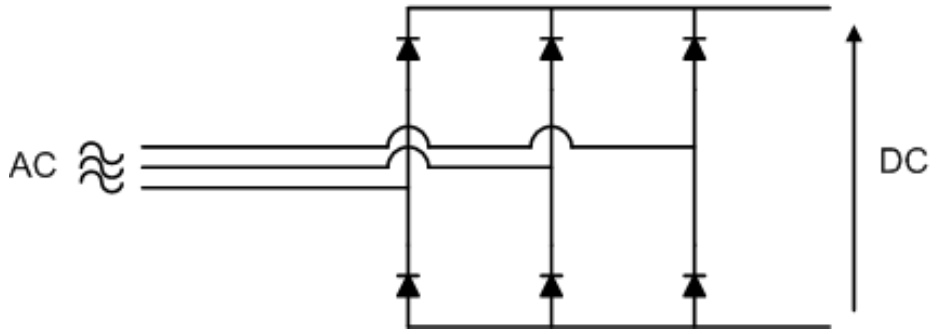


Converter

- Bi-directional power flow
- But
  - Complex
  - Large
  - Air insulated



New Grid Access solution

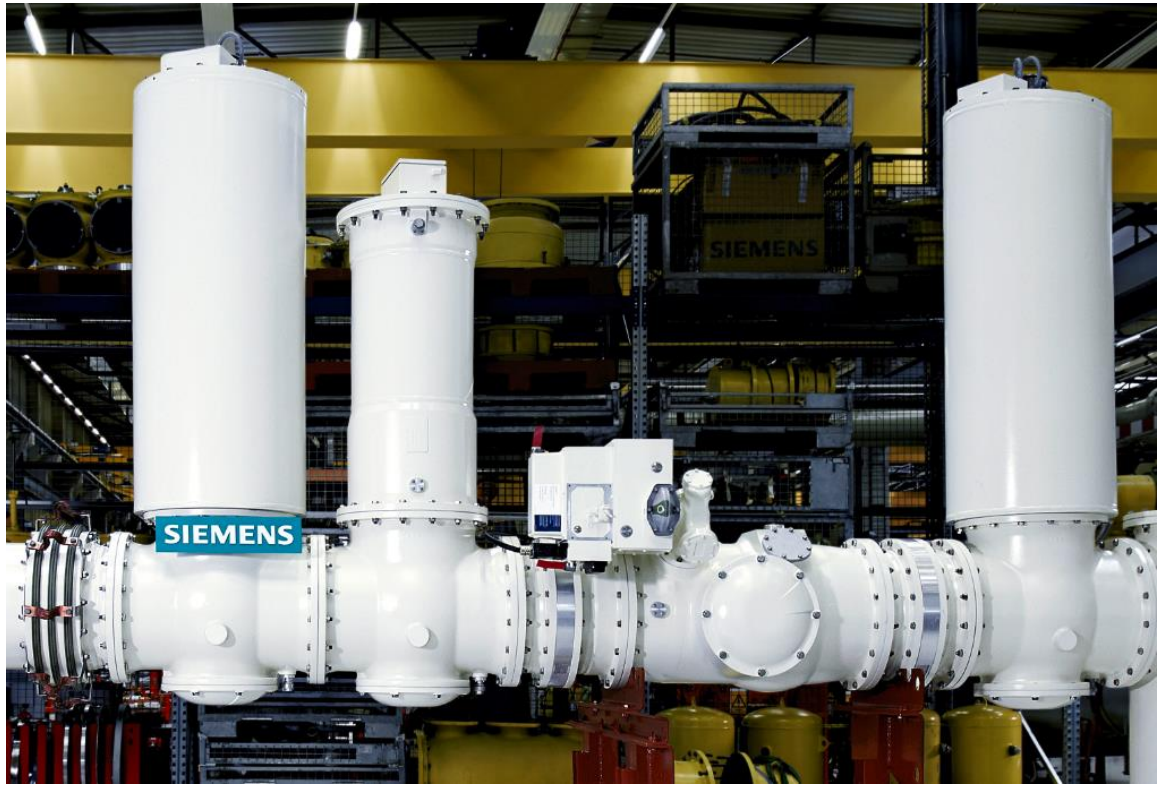


Rectifier

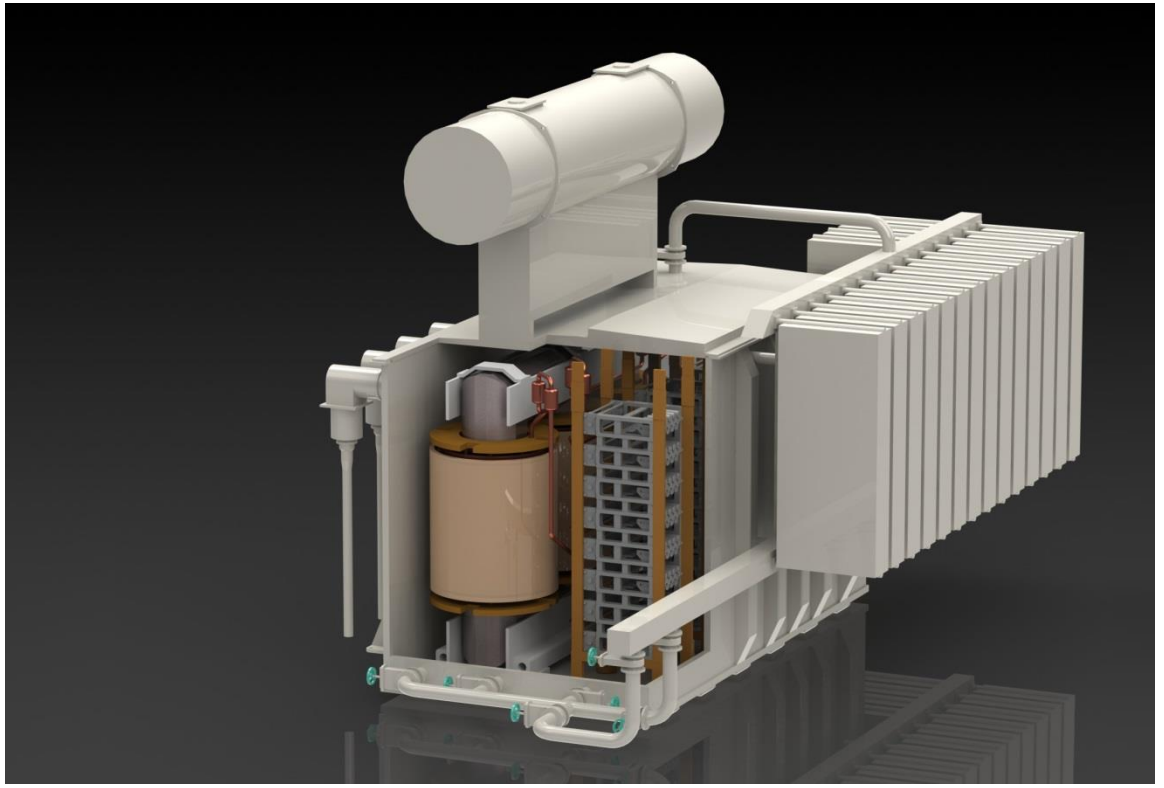
- Simple
- Robust
- Low losses
- Low maintenance costs
- Encapsulated
- But
  - One way power flow
  - AC voltage control by WTGs

Major reductions in weight and volume can be achieved by encapsulating all HVDC equipment

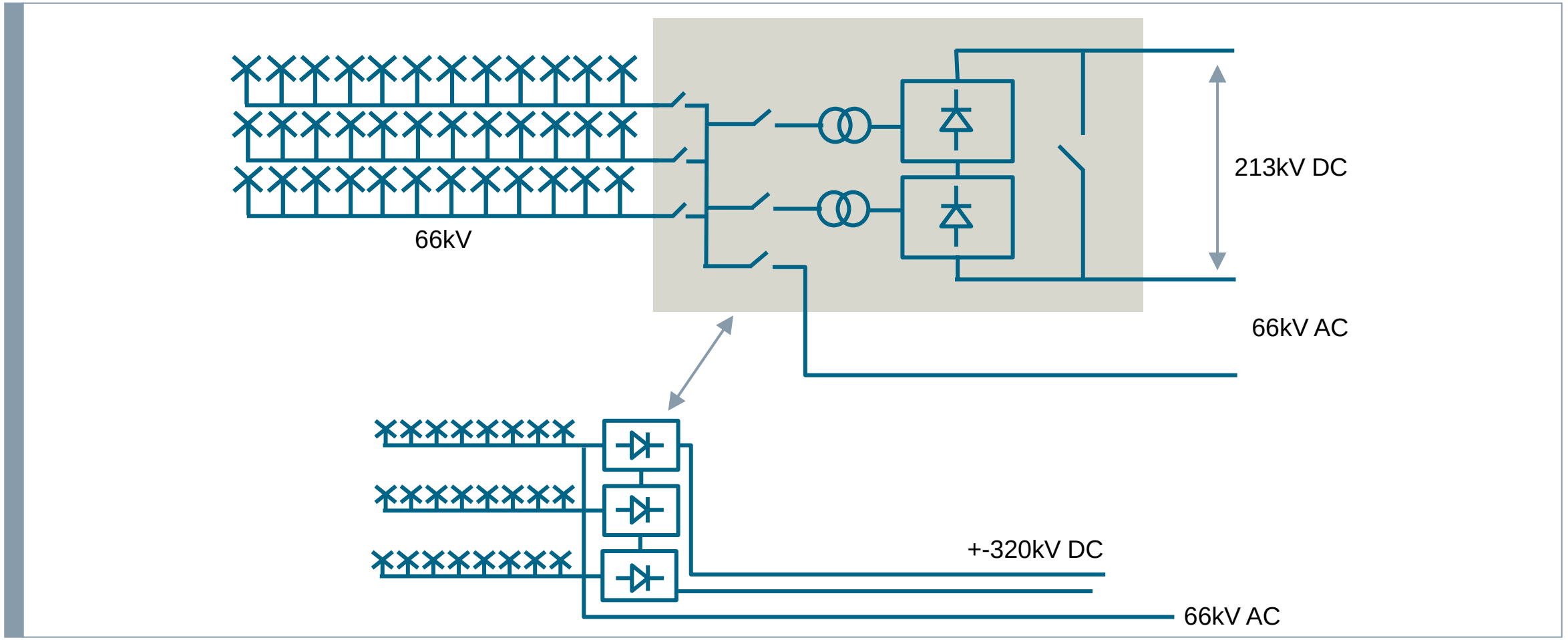
DC Compact Switchgear



Diode Rectifier Unit with flame retardant and biodegradable insulation

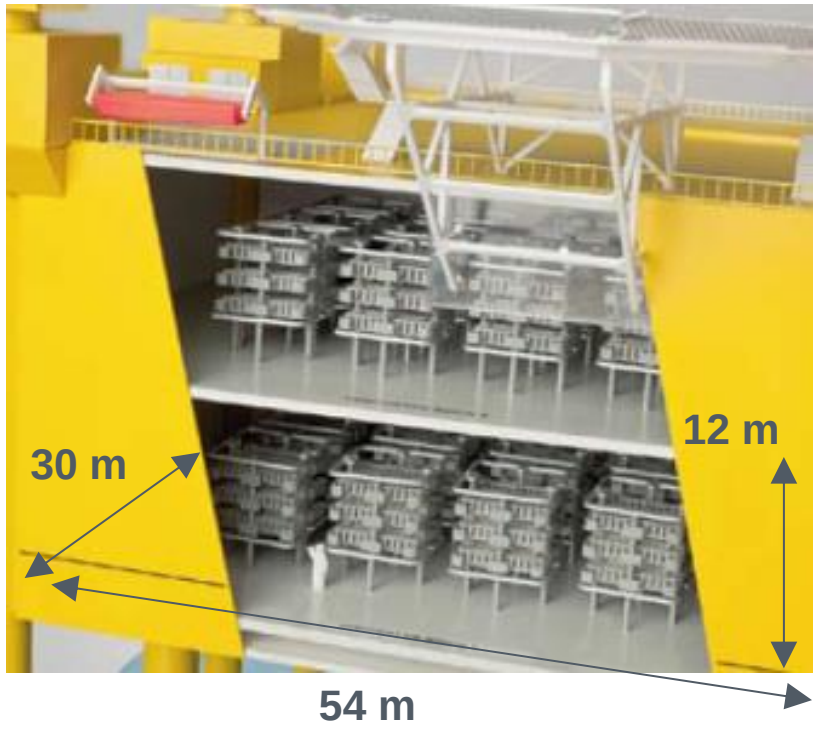


Simplified single line diagram of NGA 1200 MW



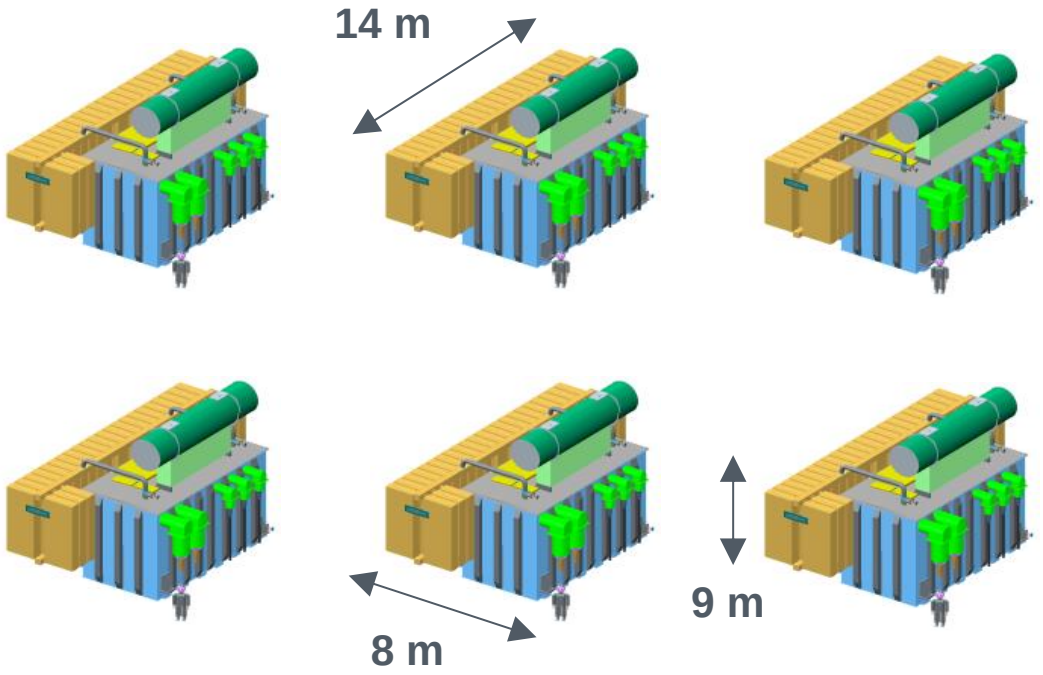
Size reduction enabled by the encapsulated rectifier

Current approach (900 MW)



Space required for converter, Xformers and reactors: 50.000 m³

New Solution (1,200 MW)

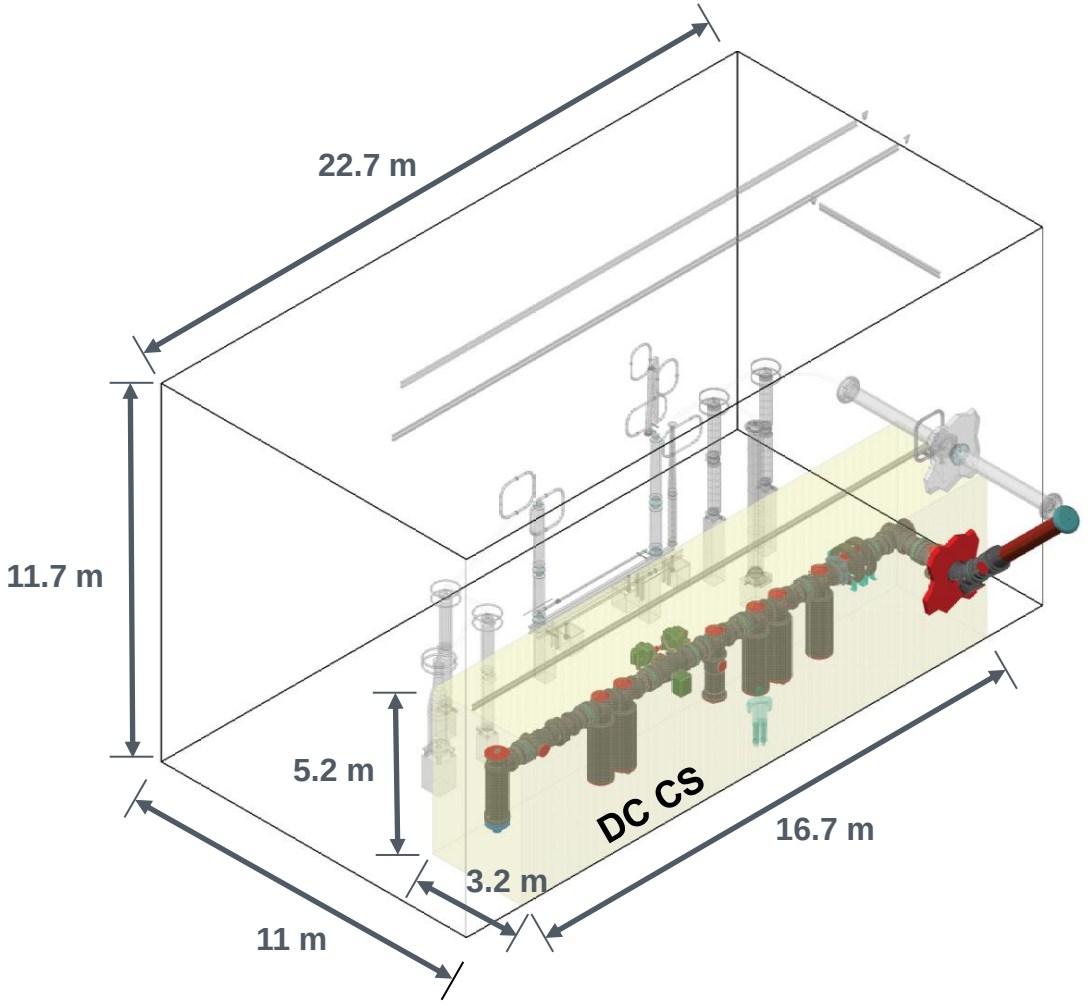


Space for the rectifier module: 3 x 2200 m³ = 6.600 m³

DC Compact Switchgear

Required volume compared to an air insulated approach

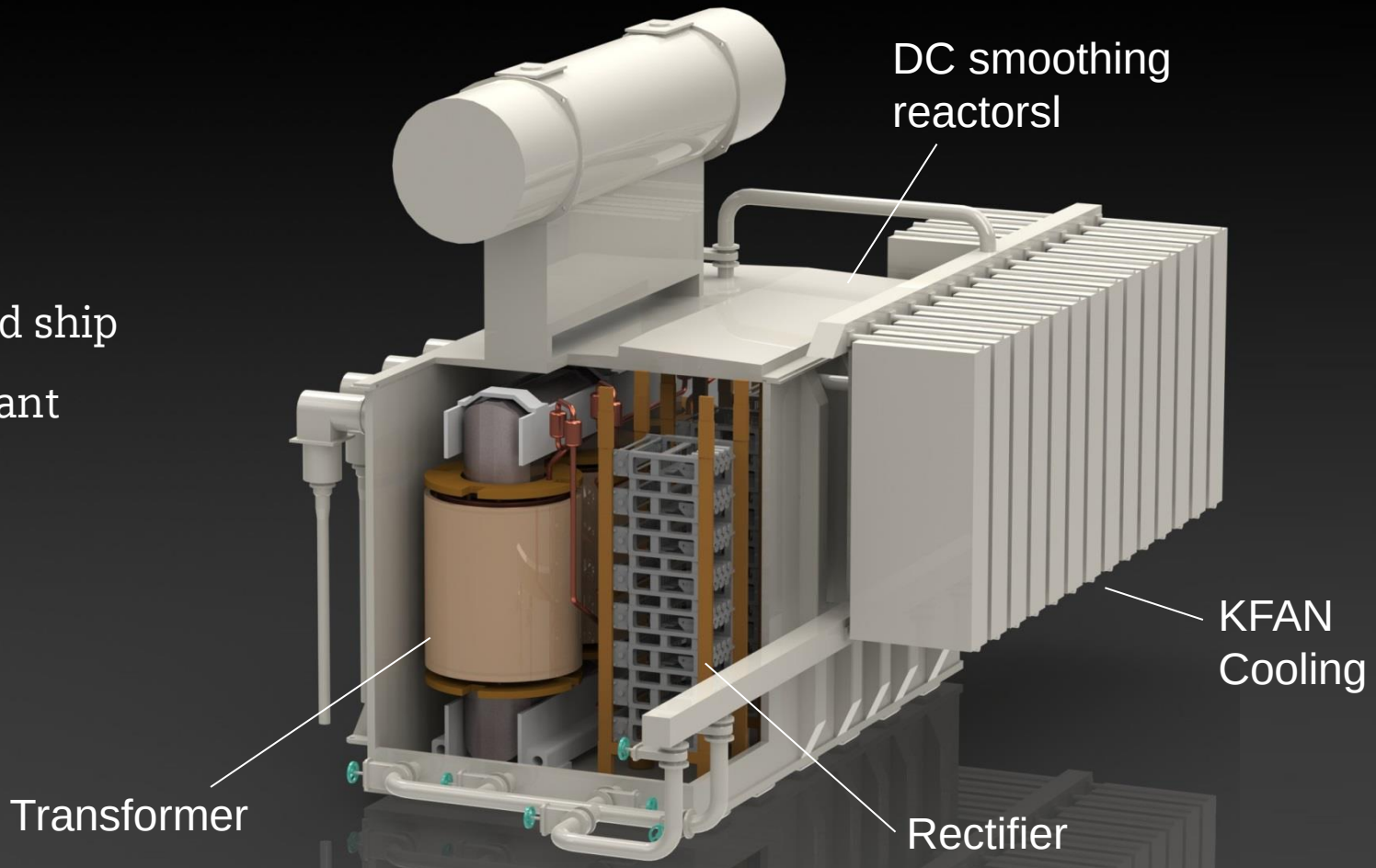
reduced by 90%



Diode Rectifier Unit (DRU)

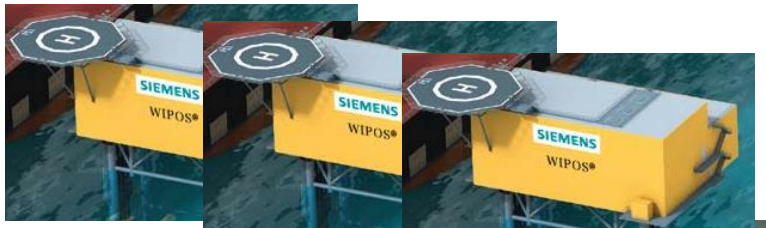
The new core grid access component

- Nominal power: 200 MW
- Nominal voltage AC: 66 kV
- Nominal voltage DC: 106,7 kV
- Size fits for transport by road and ship
- Bio degradable and flame retardant ester insulation



The resulting reductions in weight (topside)

Current approach (900 MW) 26.000 t



3.000t[1)] 3.000t[1)] 3.000t[1)]

17.000t[2)]

New Solution (1,200 MW) Ca. 9.000t

3.000t

3.000t

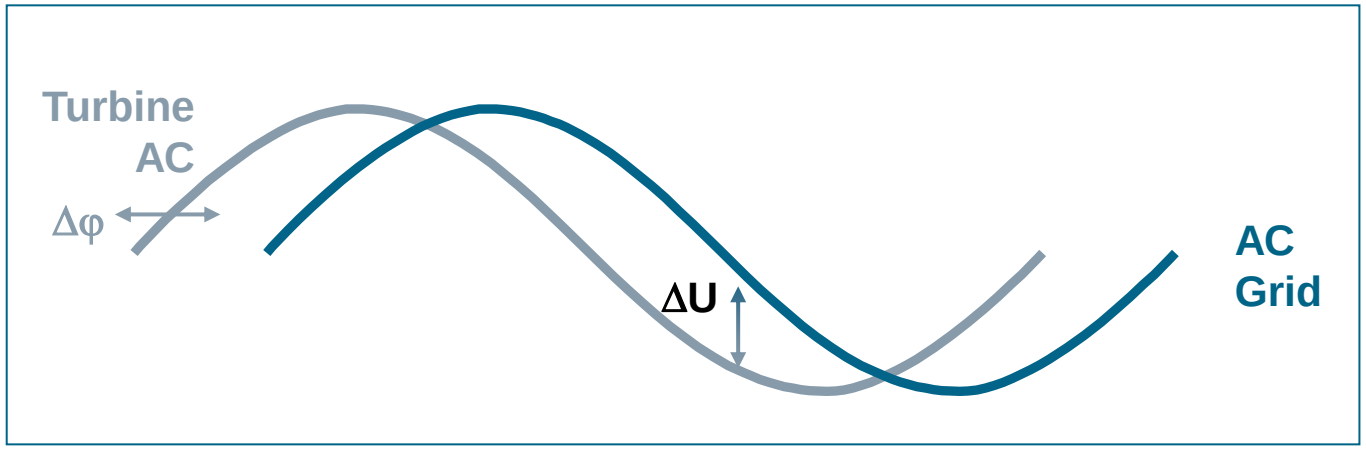
3.000t

1) AC platforms installed/under construction, 2) Current BOR3, 3) GA-New Solution

The new DC platform

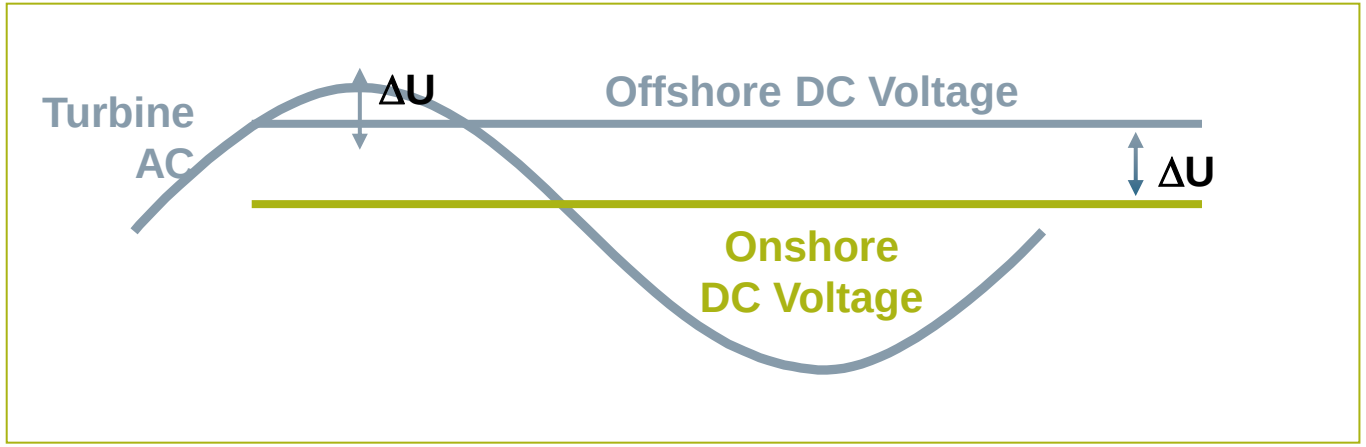
The new WTG control concept

Old vs. new WTG control concept



Old

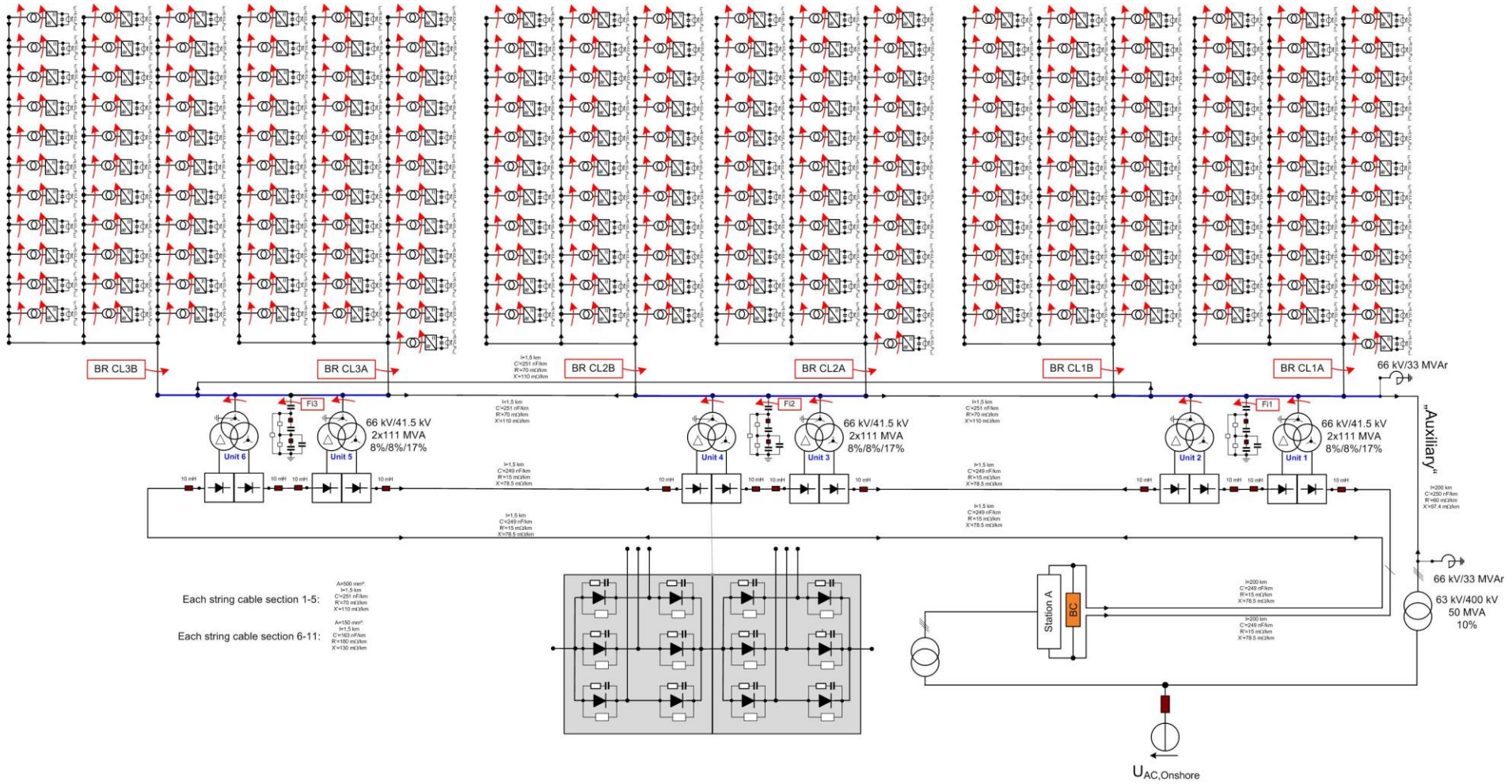
Load flow is controlled by WTG phase angle



New

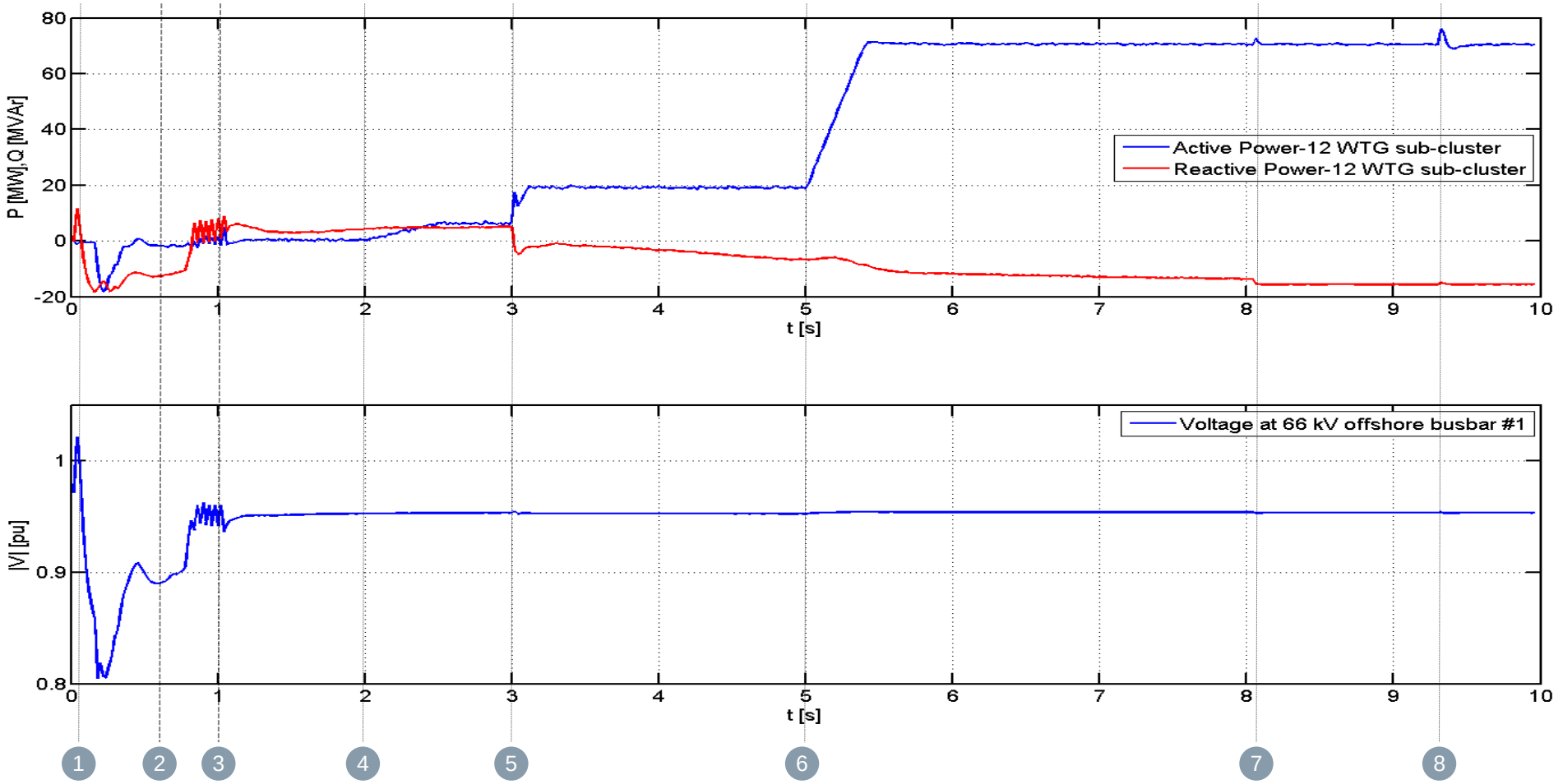
Load flow is controlled by WTG voltage magnitude

Simulated NGA System with HVDC+ Station (Distance 200 km to Onshore Grid Connection Point)



Location of switching operations referenced by ↺,

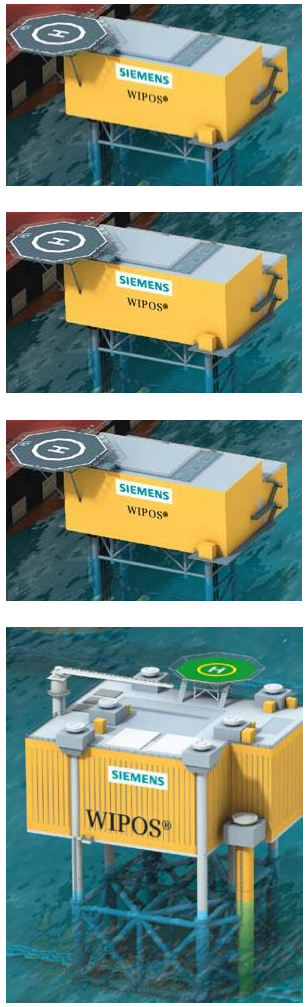
Example: Energization of one out of the 18 wind turbine strings (with 12 WTGs)



1. Energization of string cable
2. WTGs TR energized WTGs in SVC mode
3. DRU unit energized and connected
4. First WTG operated in P prod. mode
5. Energ. of Filter, 11 WTG at P mode 20 % Pn.
6. 11 WTGs ramped to nominal P
7. Umbilical Cable disconnected
8. Freq. operation point adjustment (without Umb.)

Fast ramp up of active power in connection with delayed umbilical cable disconnection => worst case scenario for system stability!

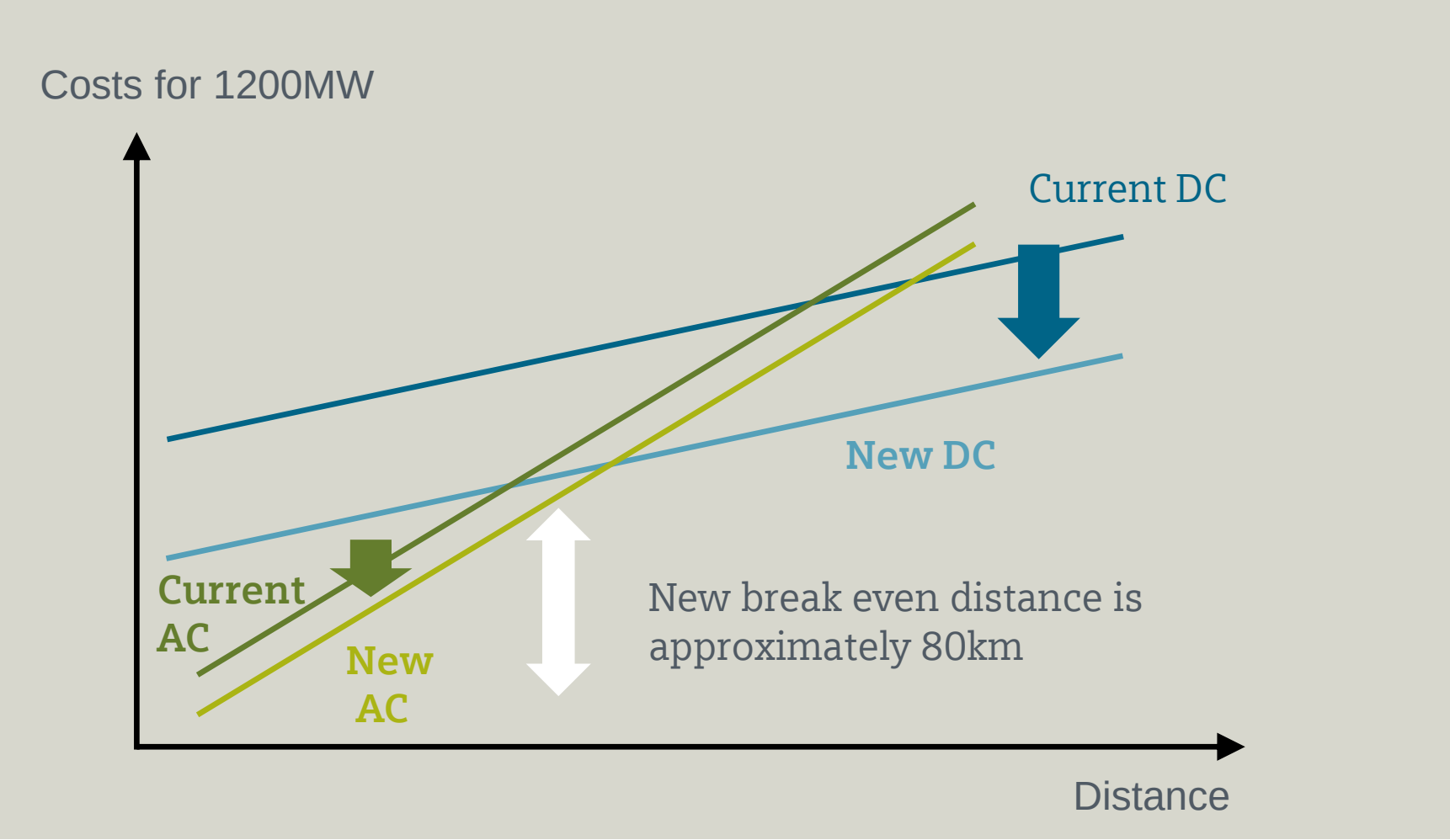
Benefits of the new DC grid access solution



- Encapsulated, rugged equipment
- Simple and robust power electronics
- Low flammable, biodegradable insulation liquid
- Easy transport and installation
- High reliability, minimal maintenance
- No offshore DC converter as single point of failure
- Shorter delivery times
- Stepwise offshore installation feasible
- Fast commissioning of WTG auxiliary power
- Up to 1200MW DC

Major reductions in CapEx and OpEx

AC vs. DC Break Even Distance for 1200MW



- For smaller power ratings AC is more beneficial.
- For small ***and*** distant farms there is no cost-effective grid access technology existing