US Offshore Grid - Connecting Wind Farms with HVDC

IEEE HVDC-FACTS SUBCOMMITTEE

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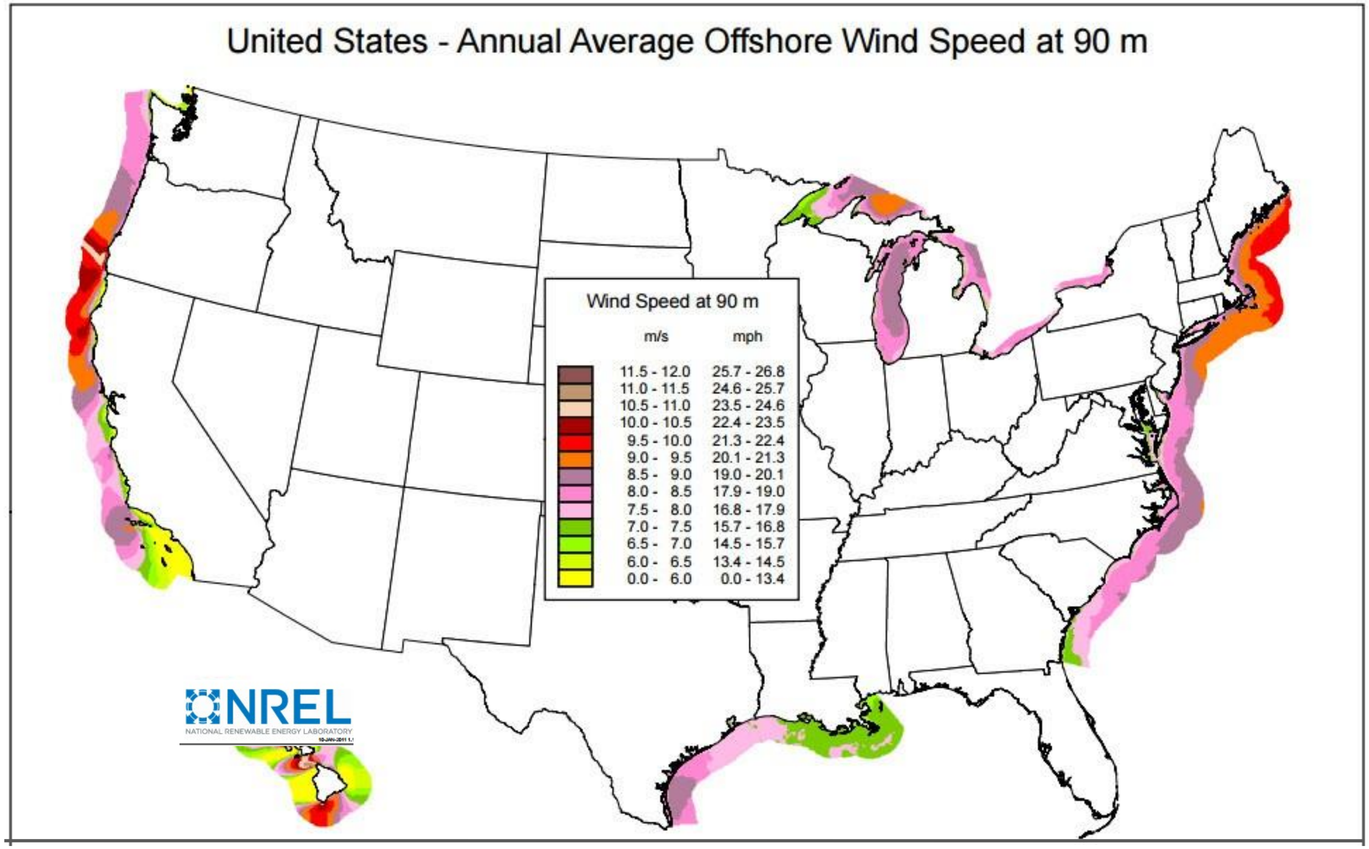
USA Offshore Wind Resources



State	km^2 *(GW)*
California	117,555 *(587.8)*
Connecticut	1,272 *(6.4)*
Delaware	2,940 *(14.7)*
Georgia	12,085 *(60.4)*
Hawaii	127,477 *(637.4)*
Maine	31,311 *(156.6)*
Maryland	10,756 *(53.8)*
Massachusetts	39,997 *(200.0)*
Michigan	96,642 *(483.2)*
Minnesota	4,096 *(20.5)*
New Hampshire	672 *(3.4)*
New Jersey	19,935 *(99.7)*
New York	29,439 *(147.2)*

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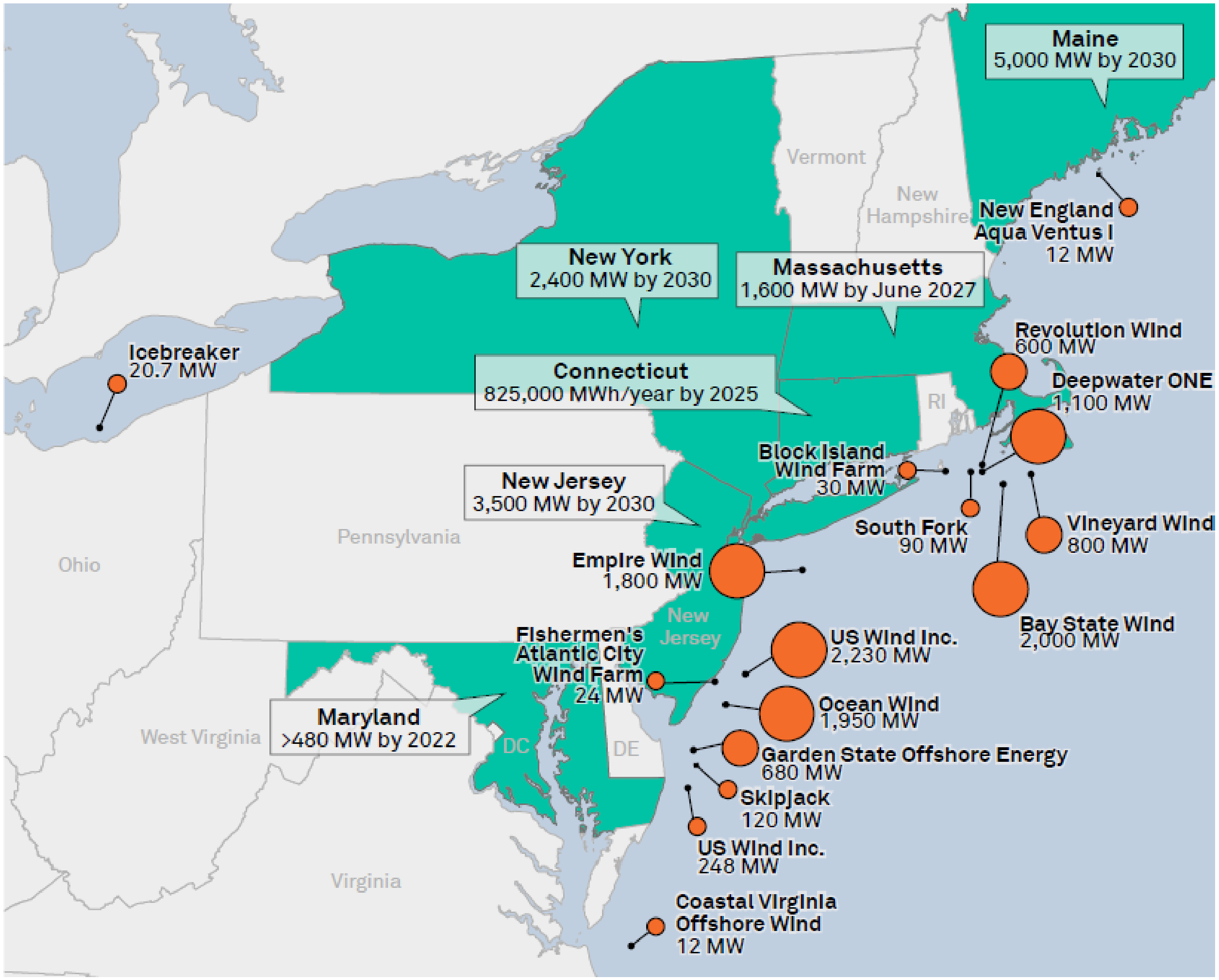
Main Offshore Developments



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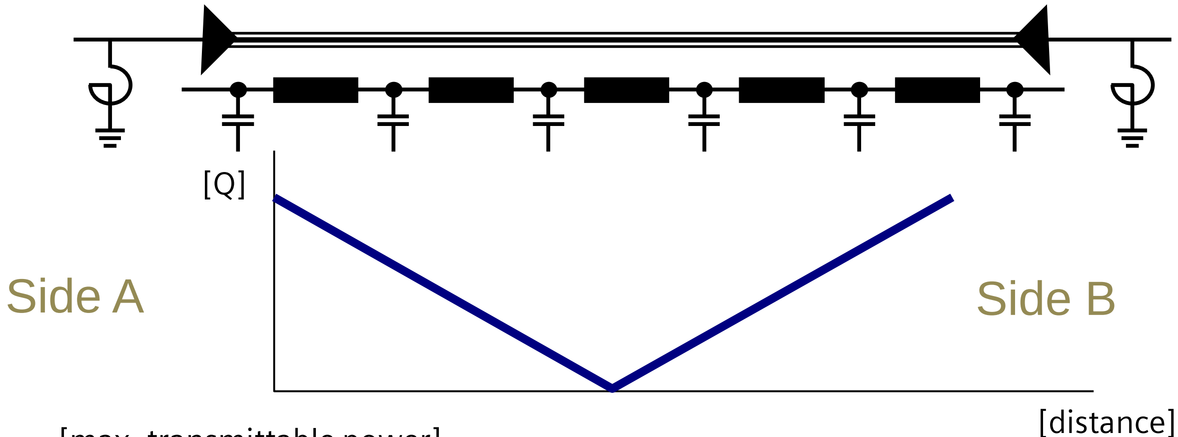
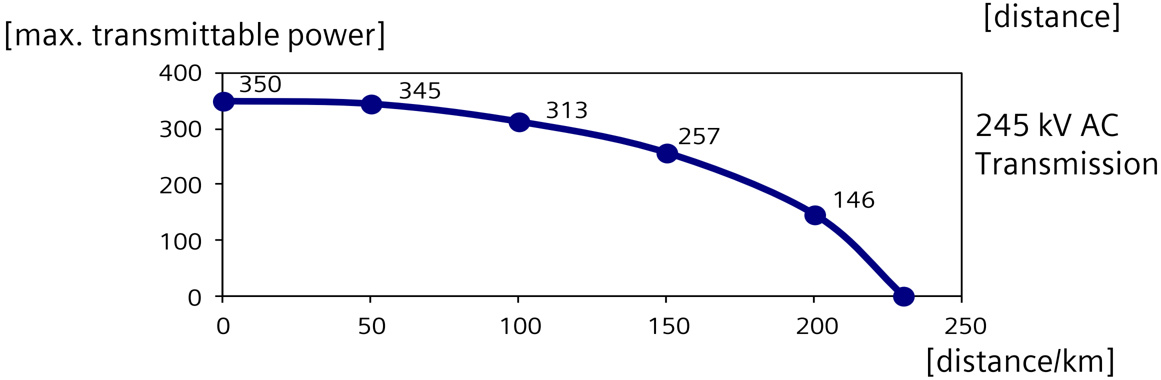
Limits of cable AC Transmission

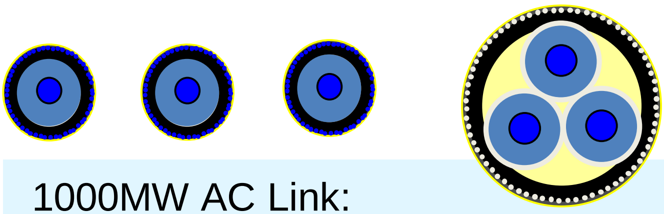




- The longer the cable
- higher the voltage
- higher the capacitance

… more electrons will be trapped / not flowing from A to B but returning to A as soon as the polarity changes.

Indicative Number of Cables



<u>1000MW AC Link:</u>

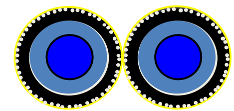
3 x 3ph 220kV AC cables
or **9 x 1ph** 220kV AC cables

<u>1300MW AC Link:</u>

4 x 3ph 220kV AC cables
or **12 x 1ph** 220kV AC cables

<u>2000MW AC Link:</u>

5 x 3ph 220kV AC cables
or **15 x 1ph** 220kV AC cables



<u>1000MW DC Link:</u>

2 x 320kV DC cables

<u>1300MW DC Link:</u>

2 x 320kV DC cables
or **2** x 400kV DC cables

<u>2000MW DC Link:</u>

2 x 500kV DC cables

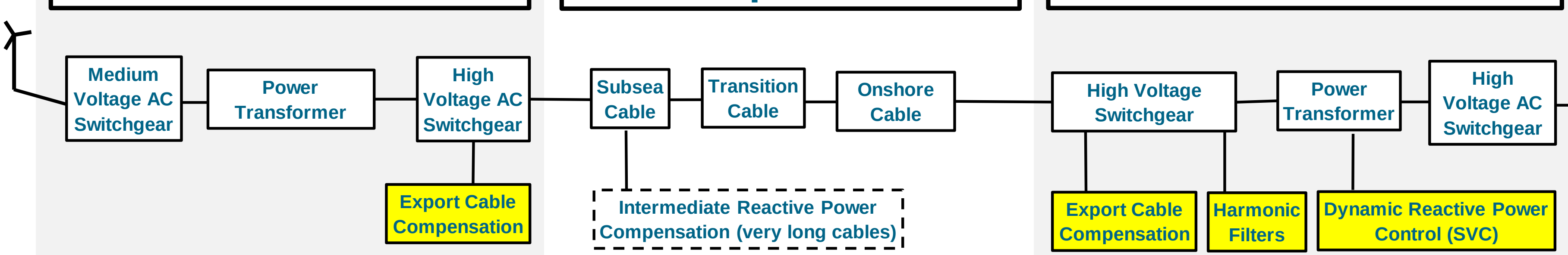
AC Offshore General Configuration

e.g. 3…4 x 220kV 3-core for 1200MW

Offshore Substation

AC Export Cable

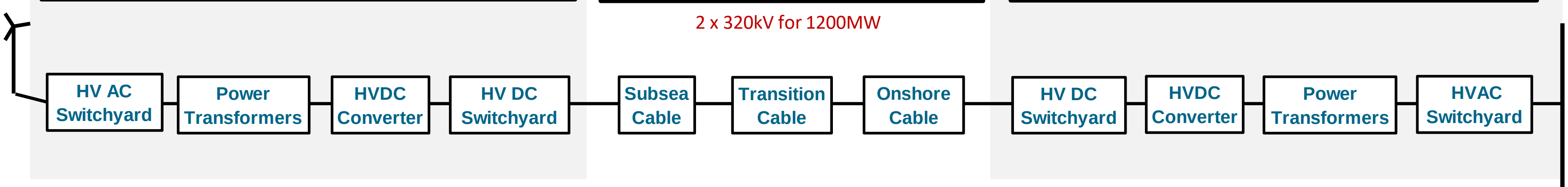
Onshore Station



Configuration with DC Transmission

Offshore Converter Station | **DC Export Cable** | **Onshore Converter Station**

2 x 320kV for 1200MW



Criteria for DC Voltage selection

Converter topics

- ❖ Required Maximum Power Transfer
- ❖ Converter Current Rating
- ❖ Link Topology

But also:

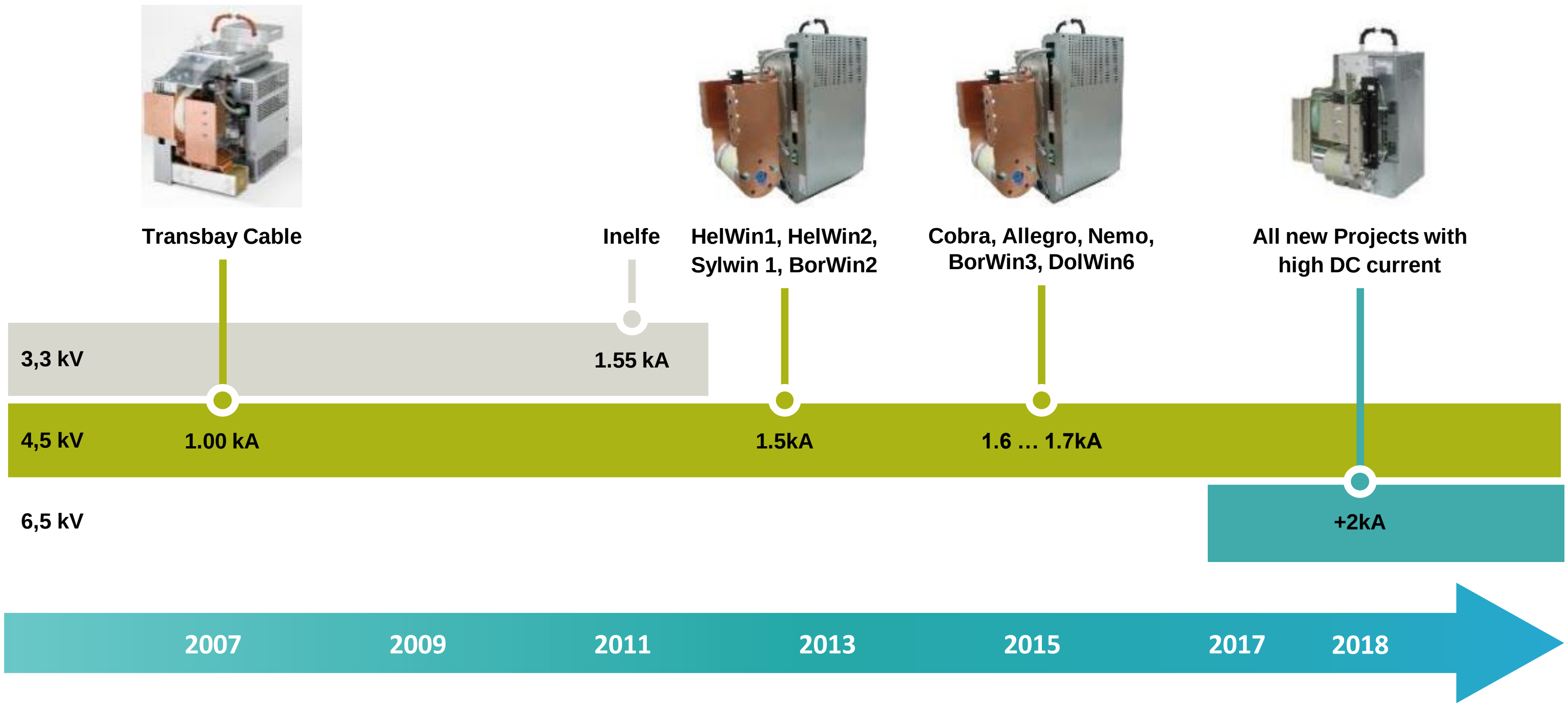
- ❖ Loss Evaluation
- ❖ Limitations in space and volume of converter stations
- ❖ Cable limits (voltage & current)

Cable limits

- Laying Conditions (Thermal conductivity of the soil, temperatures, depth).
- Steady state / overload:
  - Maximum current.
  - Maximum voltage.

❖ An economic design of a HVDC converter station aims to fully utilize the current rating of the converter

Power Converters



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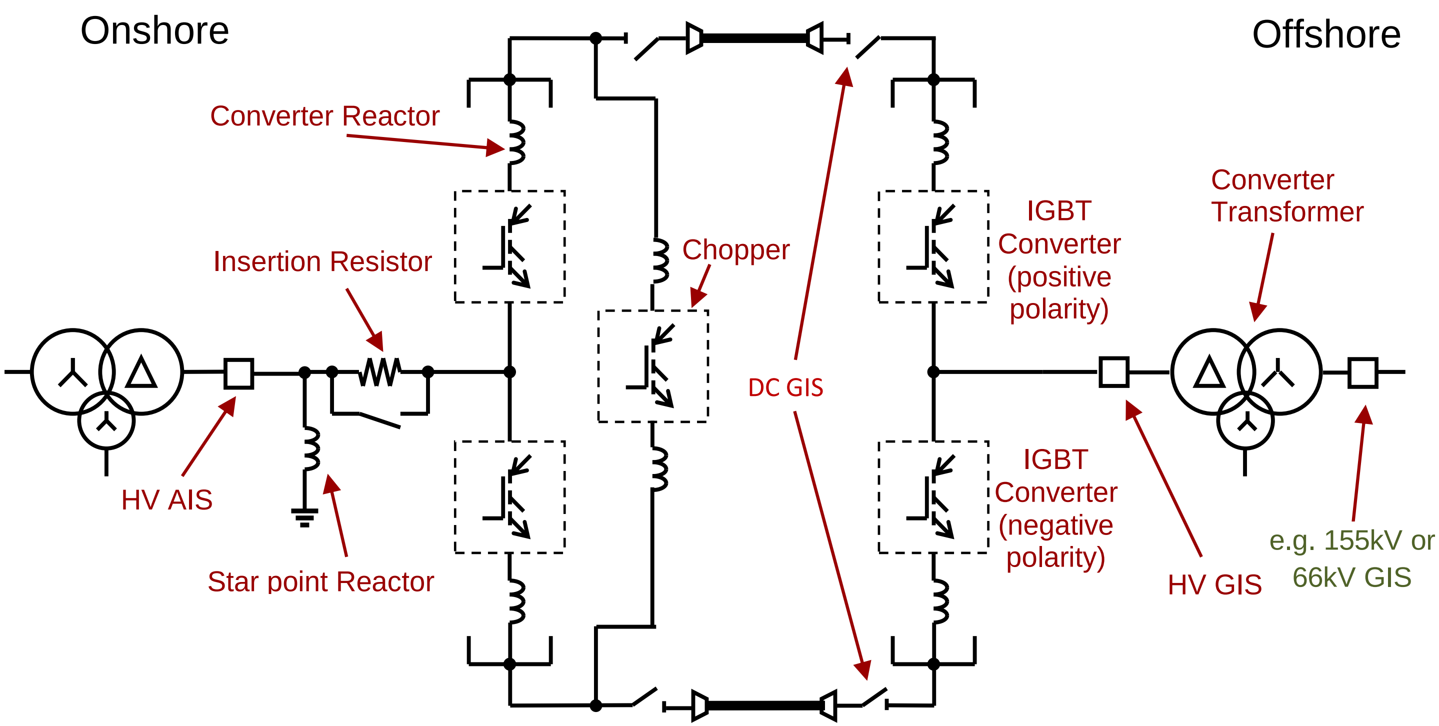
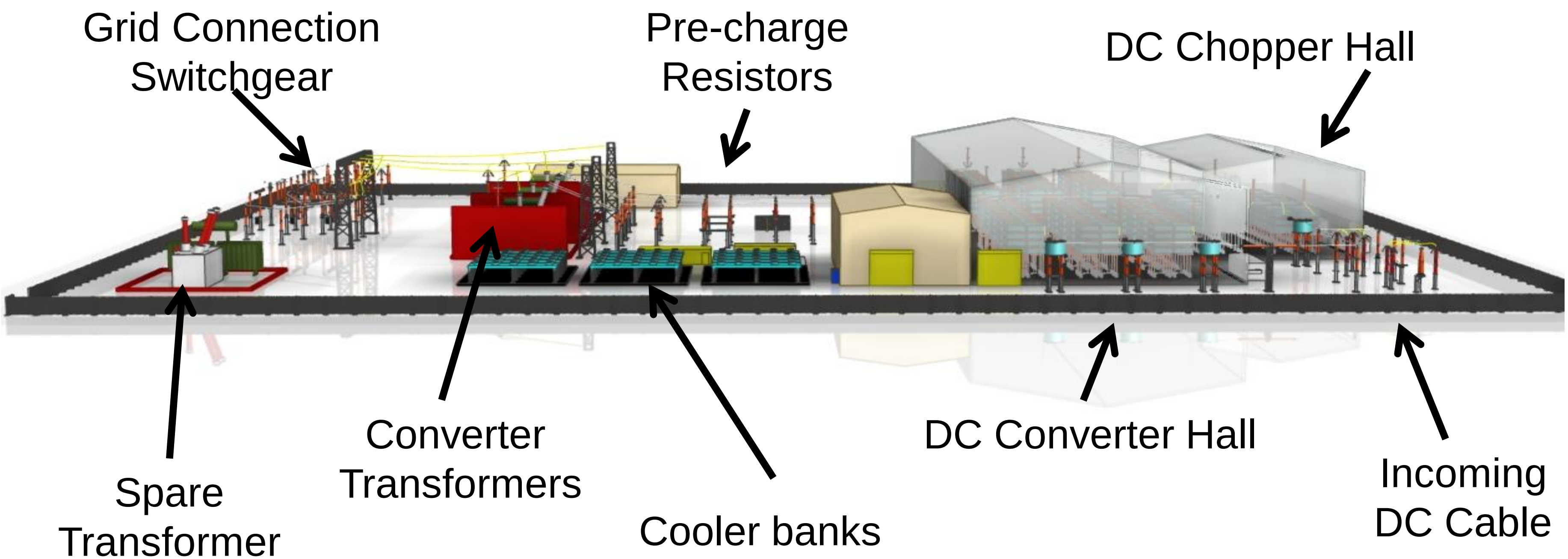
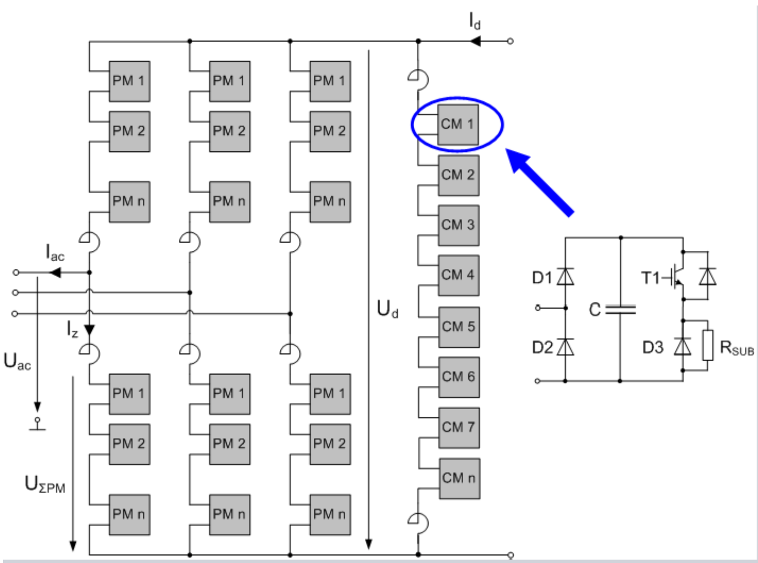
HVDC Converter Single Line



Onshore HVDC Converter Station



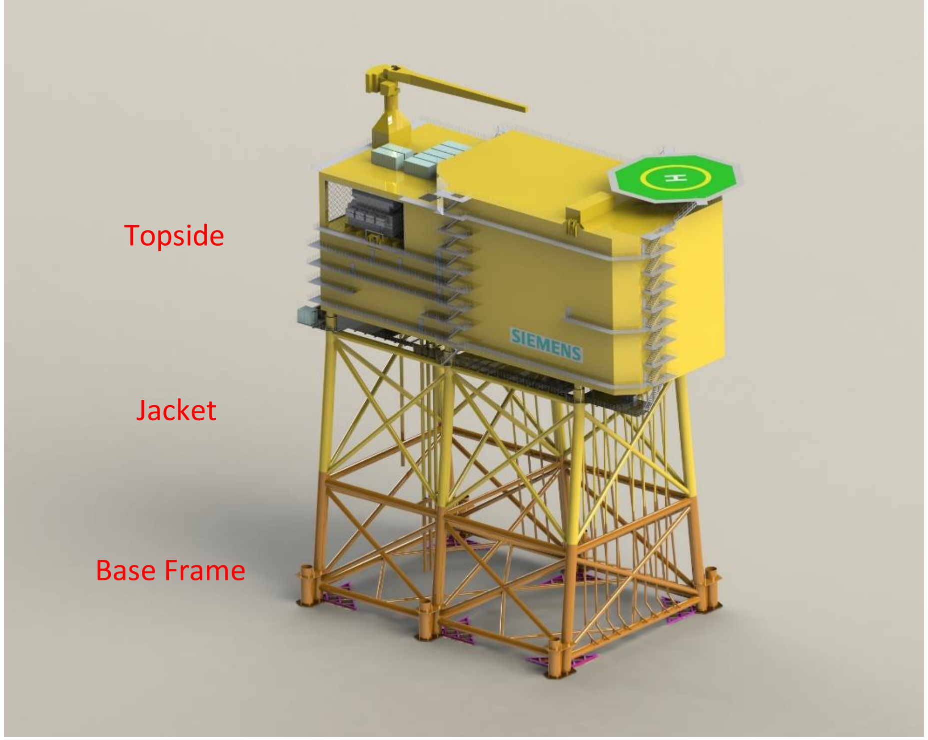
DC Chopper = Dynamic Braking



DC Chopper will dissipate the energy produced by offshore wind farm during a temporary fault in the onshore grid. Alternative would be to trip the entire offshore wind farm.

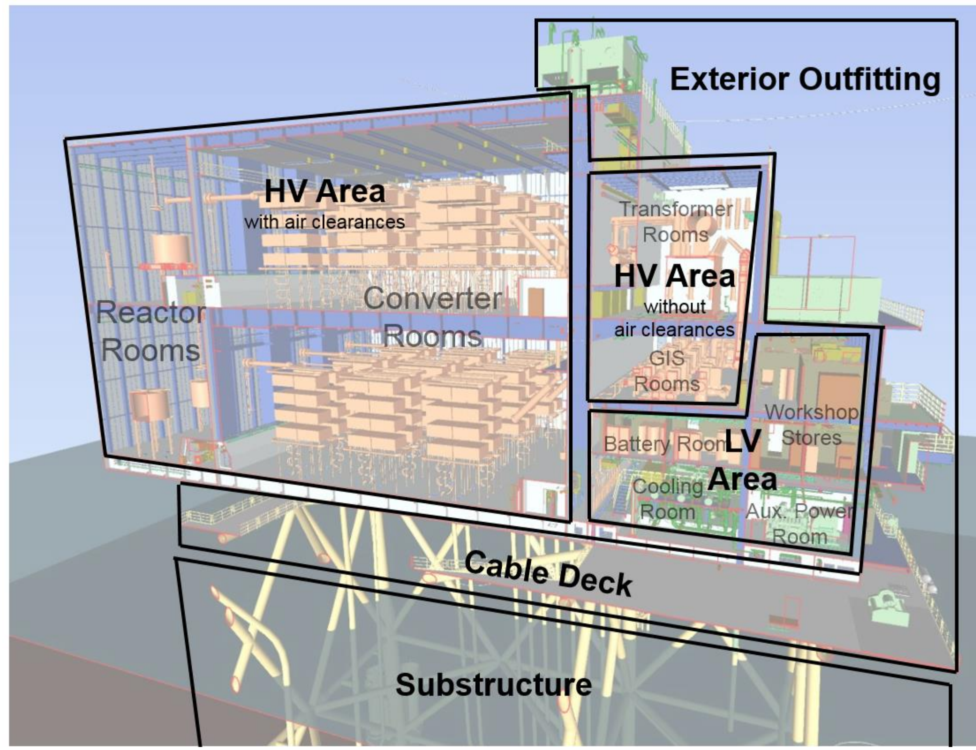
Offshore Converter Design

- Design mainly considers HV transmission system, met-ocean data, regulatory requirements, T&I concept.
- Dimensions of the topside influenced by HVDC system requirements, in particular HV equipment and Air Clearances.
- Normally unmanned operation, except for inspection and maintenance.
- Accommodation Vs Service Operation Vessel.

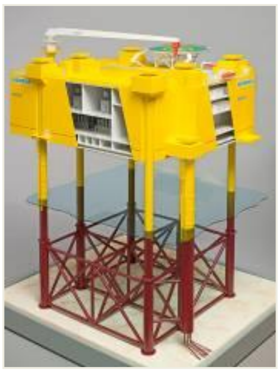


Offshore Platform –Topside areas

- HV main system
- Control and protection
- Auxiliary power
- Lifesaving (top deck / cable deck)
- Fire protection
- HVA/C
- Mechanical piping (deck drain, etc.)
- Cooling (seawater, freshwater, de-ionized water)
- Outfitting (indoor, outdoor)

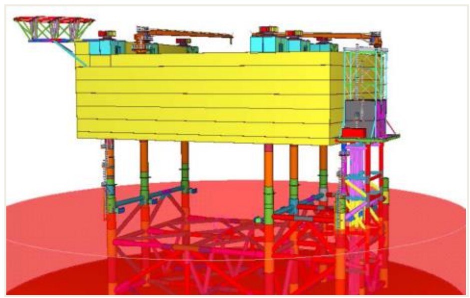


Converter Station T&I Concepts



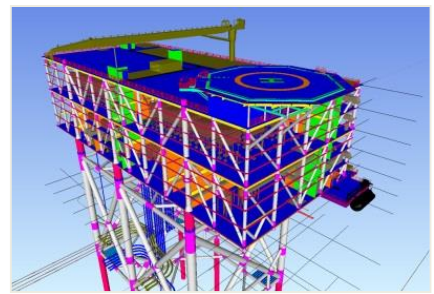
Self lifting

Siemens Projects:
Helwin 1
Borwin 2
(Topsides are designed to float)



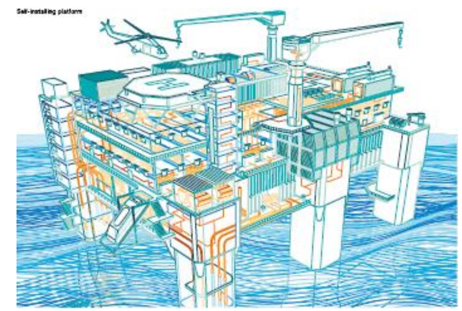
Float over

Siemens Projects:
Sylwin 1
Borwin 3



Lifted topsides

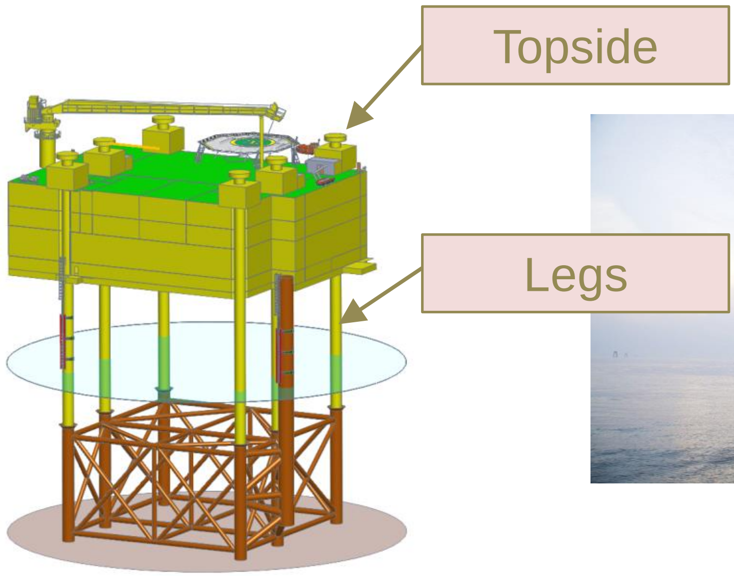
Siemens Projects:
Helwin 2



Semi-submersible

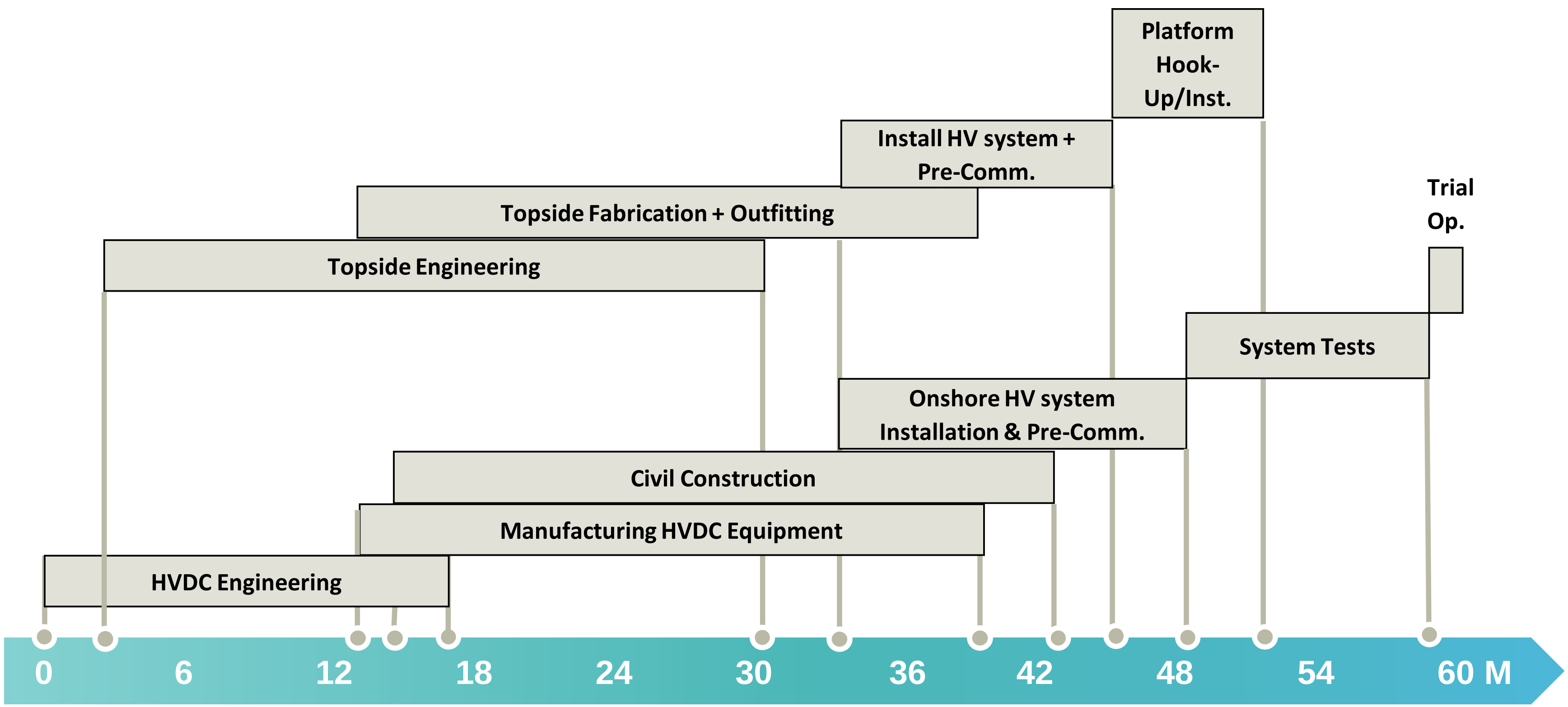
Transport & Installation concepts depend on fabricator’s experience, weight/dimensions and availability of suitable cranes

Design for self lifting installation



Float Over applied by Borwin 3

Typical Time Schedule



Thank you

SIEMENS