TORGUN

Design challenges of offshore wind support structures

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PIANC 5th YP-COM BTV
Ostend, 7 May 2015
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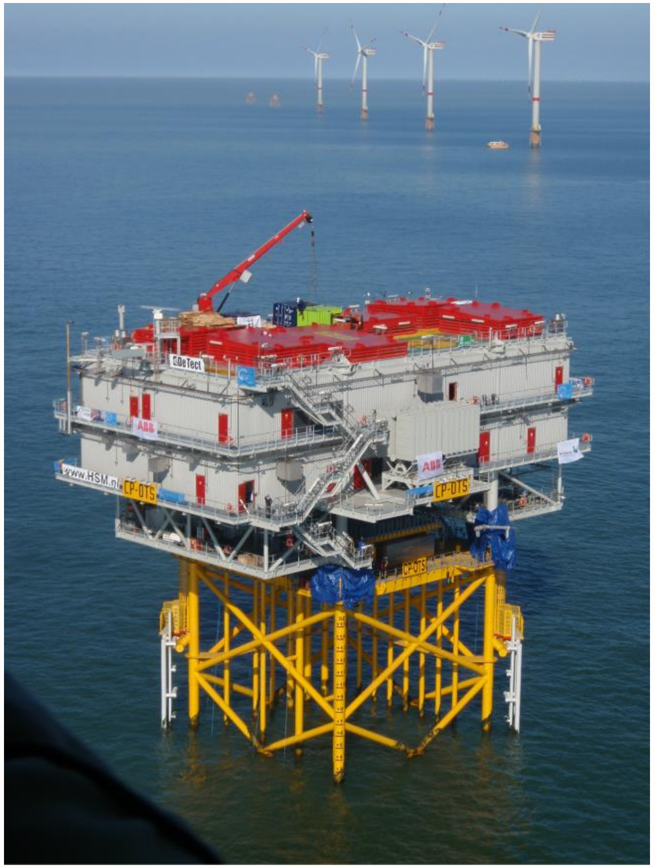
CONTENTS

Synergies and discrepancies in design methodology between:

- ~ WTG support structures; and
- ~ Substation support structures (HVAC)



Source: C-Power

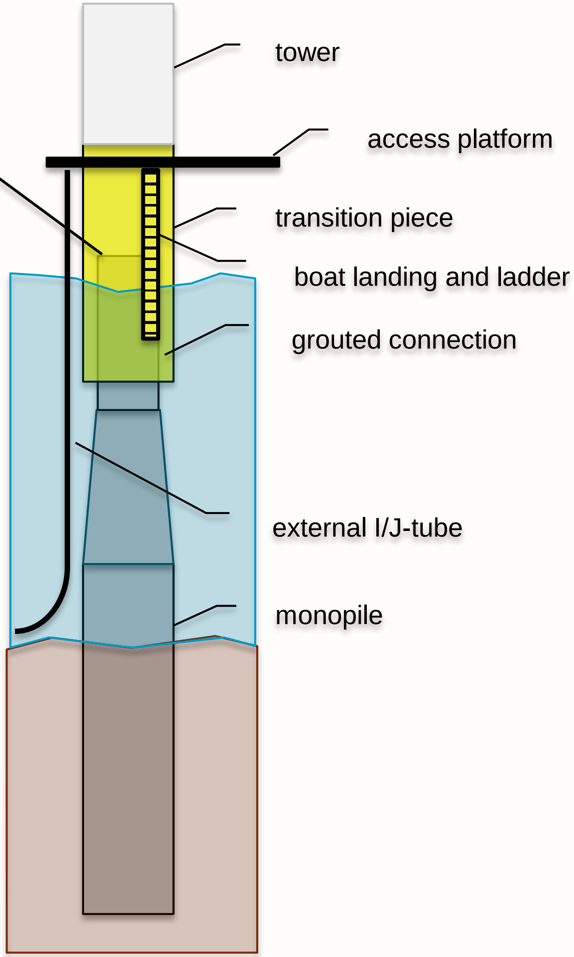
SUPPORT STRUCTURE CONCEPTS

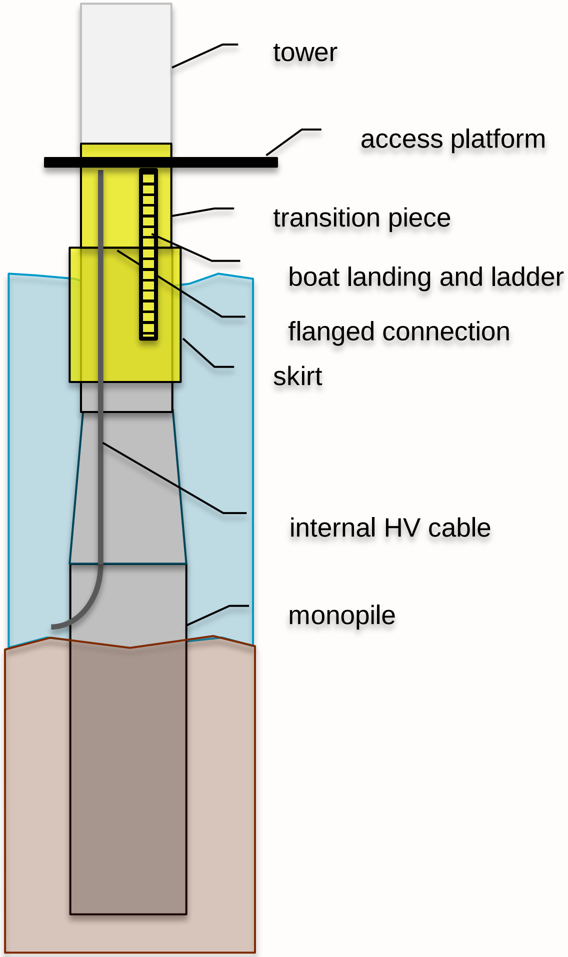
Limited to concepts applicable for WTG and substations

	WTG	SUBSTATIONS
Gravity base foundation	✓ commonly used in shallow waters (semi) self-floating in deeper waters e.g. C-Power	✓ Relatively few – shallow waters e.g. Lillgrund (120 MVA, 670 MT) Anholt (1,710MT)
Monopile + Transition Piece	✓ Wide-spread use	✓ Limited topside weight
4-legged jacket structures	✓ Pre-piling	✓ Most commonly post-piled Pre-piling in some cases 4+ legged jackets

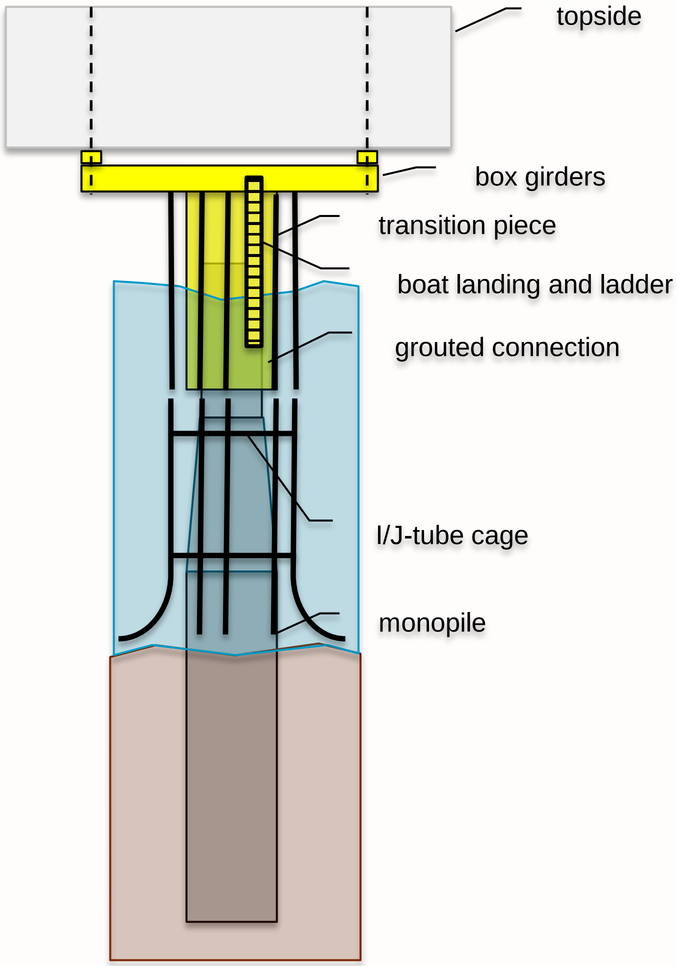
MONOPILE SOLUTIONS for WTG

Source: DEME





MONOPILE SOLUTIONS for substations



Source: Northwind (216 MW – 1,200 MT)

MONOPILE SOLUTIONS
WTG vs Substations

- Synergies:
  - equal TP outer diameter
  - boat landing design
  - access ladders & fall arrest
  - painting systems
  - scour protection

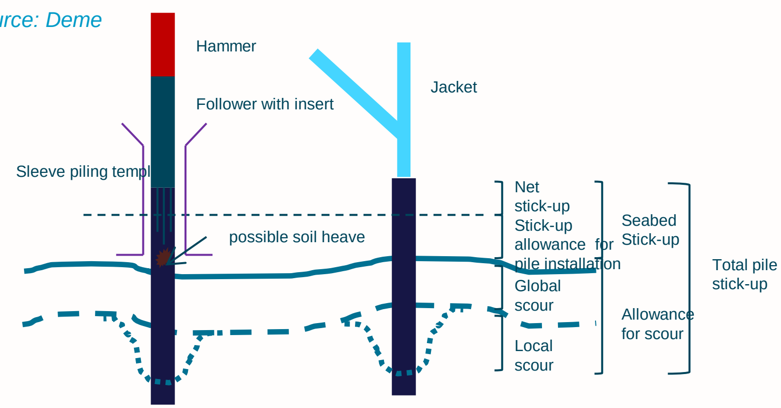
- Differences
  - cross-box girders
  - I/J-tube cage
  - larger MP diameter
  - may need tuned mass damper

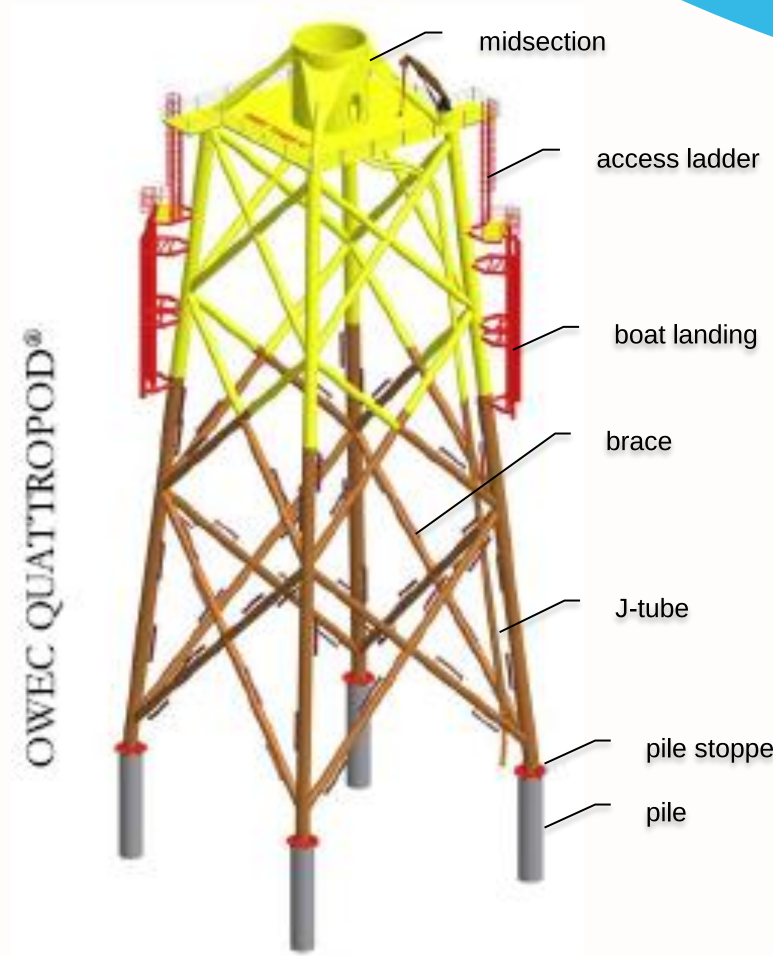
Source: Deme (London Array – 630 MW – 1,260 MT)

JACKET SOLUTIONS for WTG

Pre-piling operation

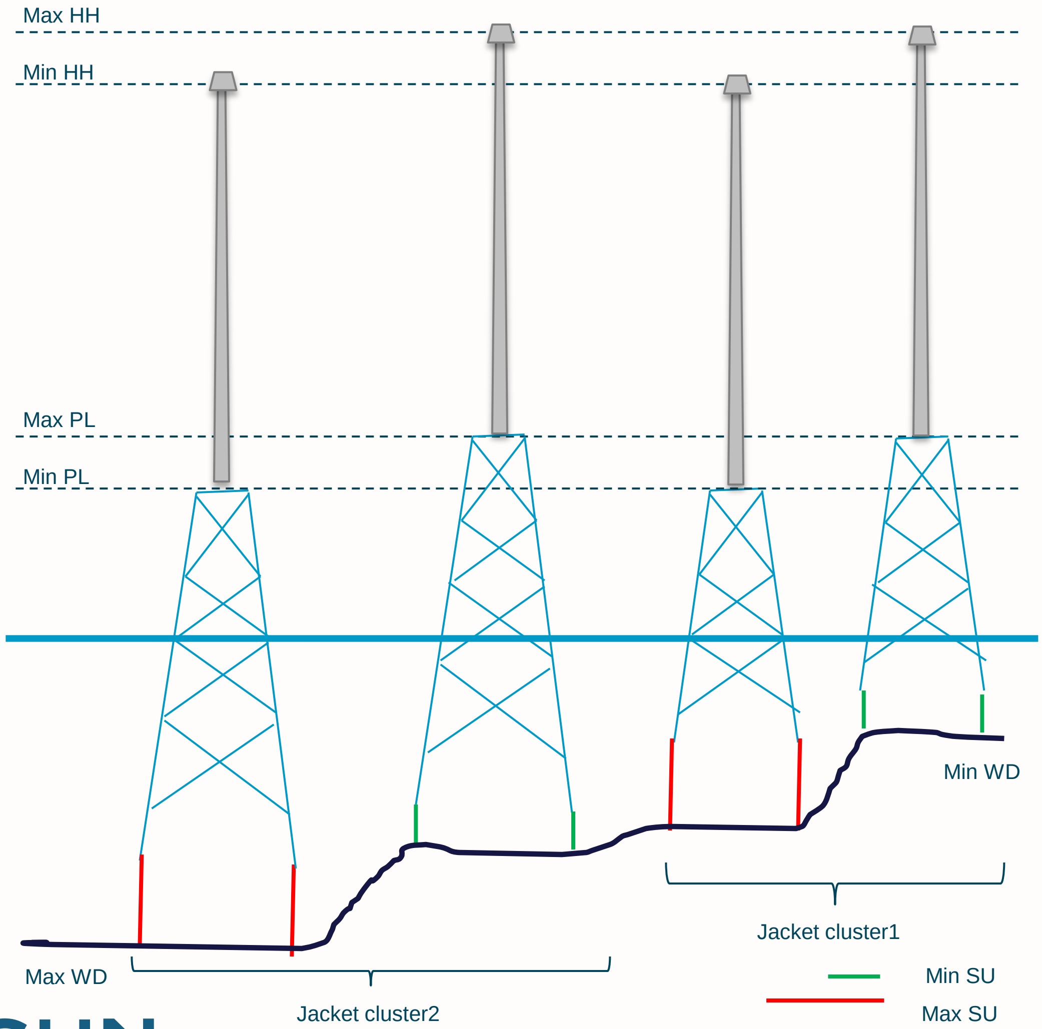
Source: Deme





Source: OWEC

JACKET SOLUTIONS for WTG - clustering



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JACKET SOLUTIONS for substations

Post-piled jacket

Source: 4Cofffshore (Innogy Nordsee 1 – 332 MW – 1900 MT)

Pre-piled jacket

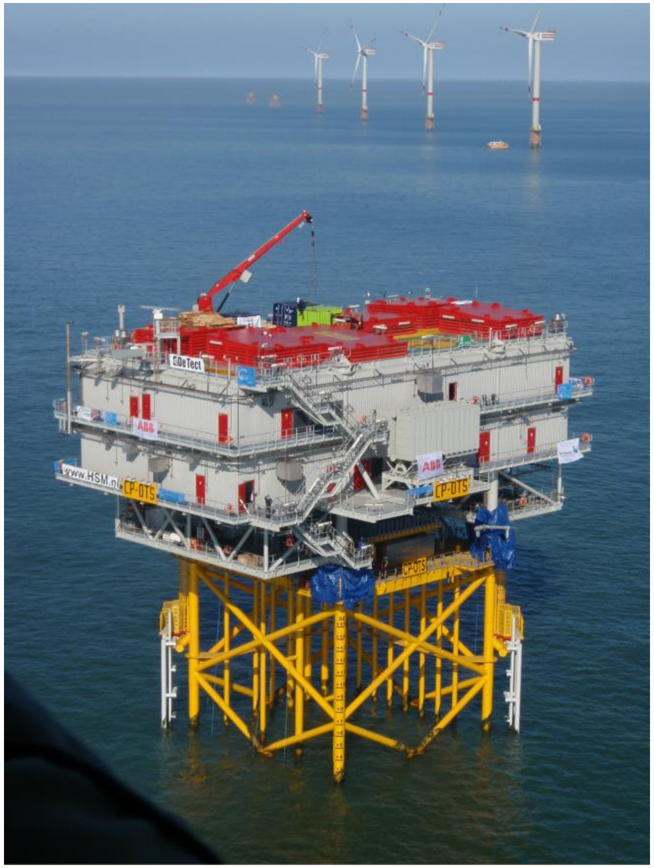
Source: OWEC (C-Power – 325 MW - 2,000 MT)

Source: Deme (Butendiek – 288 MW)

JACKET SOLUTIONS WTG vs Substations

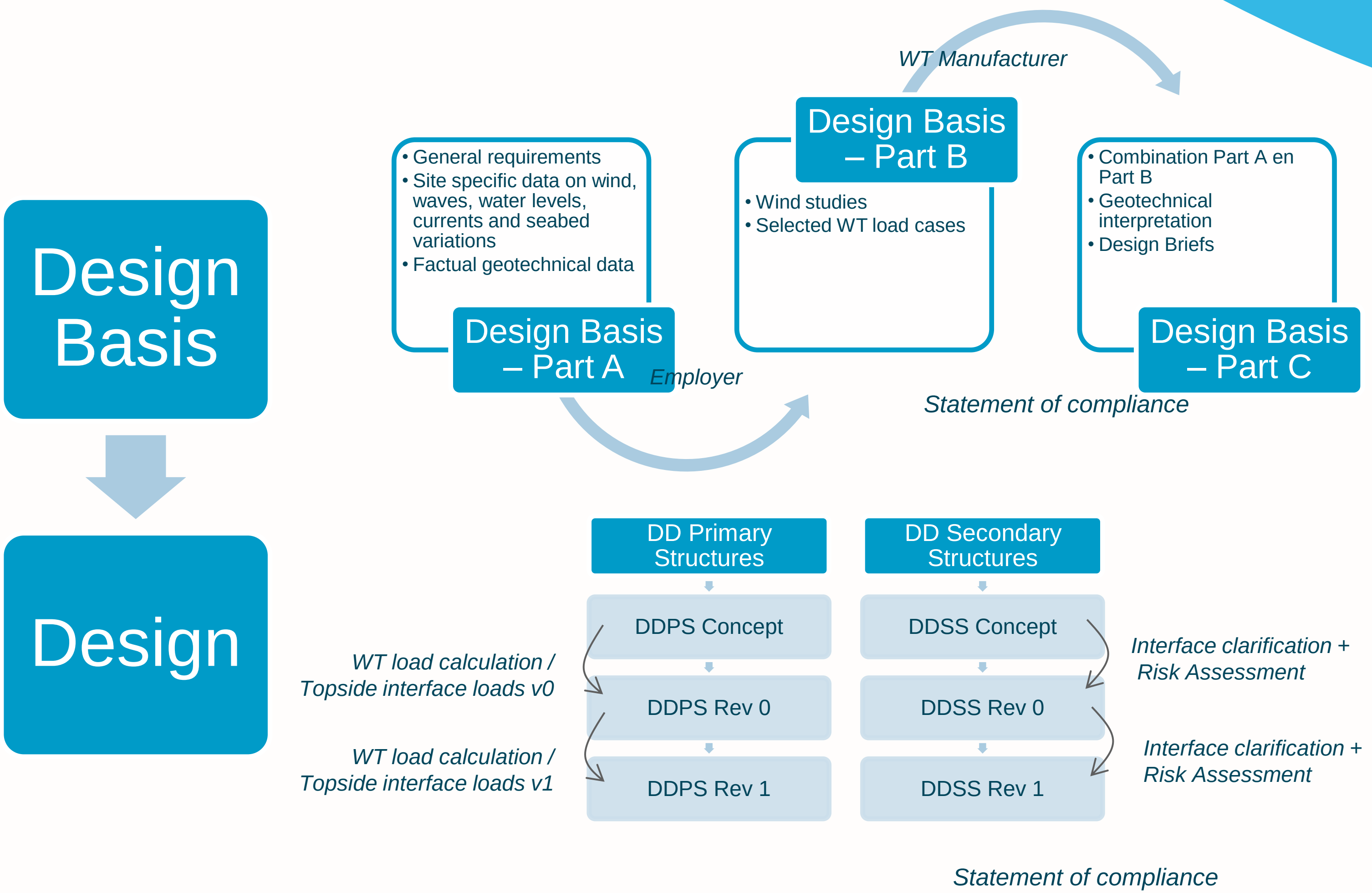
- Synergies (if pre-piled):
  - equal footprint
  - jacket-pile connection
  - access ladders & fall arrest
  - corrosion protection system

- Differences:
  - topside-jacket connection (no midsection)
  - jacket sizing (more flexibility when post-piled)
  - access platform (cable deck in case)



Source: C-Power

DESIGN PROCESS



STANDARDS & GUIDELINES

	WTG	Substation
Design	IEC 61400-3 DNV-OS-J101 (2014) – Design of offshore wind turbine structures GL Guideline for the Certification of OW turbines (2012)	DNV-OS-J201 (2014) – Offshore substations for wind farms DNV-OS-C101 (2014) – Design of offshore steel structures DNV-OS-C502 (2012) – Offshore concrete structures
	DNVGL-RP-0005 (2014) – Fatigue design of offshore steel structures DNV-RP-B401 (2011) – Cathodic protection design ISO 19902 – Petroleum and natural gas industries – Fixed steel offshore structures	
Fabrication	DNV-OS-C401 (2014) – Fabrication and Testing of offshore structures EN 1090 – Execution of steel and aluminium structures	
Transport and installation	Noble Denton Rules marine assurance and advisory rules and guidelines DNV-OS-H10x series – Marine operations DNV-OS-H20x series – Load Transer Operations	

Limited to governing standards – other standards are referred to within standards listed above

BASIC ASSUMPTIONS

	WTG	Substations
Safety class	Normal	High
Manning philosophy	Unmanned	Normally manned / Semi-manned / Normally unmanned (Type A)
Service Life	usually 20 yrs	same as for WTG or higher
Return period of extreme event	50 yrs	100 yrs

Remark: also stricter requirements for air gap and ALS design

LOAD AND RESISTANCE FACTORS

Folllowing DNV-OS-J101 resp. DNV-OS-J201

Set	Limit state	WTG				Substations			
		G	Q	E	D	G	Q	E	D
(a)	ULS	1.25	1.25	0.7(*)	1.0	1.3(**)	1.3(**)	0.7	1.0
(b)	ULS	ψ	ψ	1.35	1.0	ψ	ψ	1.3	1.0
(c)	ULS abnormal wind	ψ	ψ	1.1	1.0	NA			

(*) 1.0 to be used in combination with ship impact loads
(**) 1.2 may be used in cases the load is well defined
For FLS, SLS and ALS γ_f is 1.0

Material parameter - ULS	WTG	Substations
Steel strength	1.10 / 1.20	1.15 / 1.45
Angle of internal friction	1.15	1.2
Undrained shear strength	1.25	1.3
Axial load-carrying capacity	1.25	1.7

DESIGN FATIGUE FACTORS

Folllowing DNV-OS-J101 resp. DNV-OS-J201

Zone	Accessibility for inspection and repair	SN - curve	DFF for WTG	DFF for OHVS
Atmospheric	Yes / No	Air – for coated surfaces Free – for CA only	2.0	2.0
Splash	Yes	Air (+ Free)	2.0	3.3
	No		3.0	10.0
Submerged	Yes	Seawater – where CP Free – for CA only	2.0	3.3
	No		3.0	10.0
Scour	No		3.0	10.0
Burried	No	Seawater	3.0	10.0

CORROSION PROTECTION

Legend: CA = Corrosion Allowance; CP = Cathodic Protection; *Optional*

Zone	Internal (MP/TP)	External
Atmospheric zone	*Coating* + CA	Coating + CA
Splash zone – above MSL	*Coating* + CA	Coating + CA
Splash zone – below MSL	*Coating (+ CP)* + CA	Coating (+ CP) + *CA*
Submerged zone	*Coating and/or CP*	Coating and/or CP
Burried MIC zone	*Coating and/or CP* + CA	Coating and/or CP + CA
Burried zone – below MIC	-	-

Remarks:

- ~ Applicable SN-curves to be defined ifo air/water and design life/coating life
- ~ Specific corrosion rates may be applied for upper, middle and lower splash zone.
- ~ In case of internal cathodic protection water and air refreshment shall be facilitated.
- ~ Metallized coating is recommended in MIC zone, flanges, etc to protect from damage.
- ~ Higher resistant coating or allowance usually applied on boat landing bumpers.

DESIGN DRIVERS for Substations

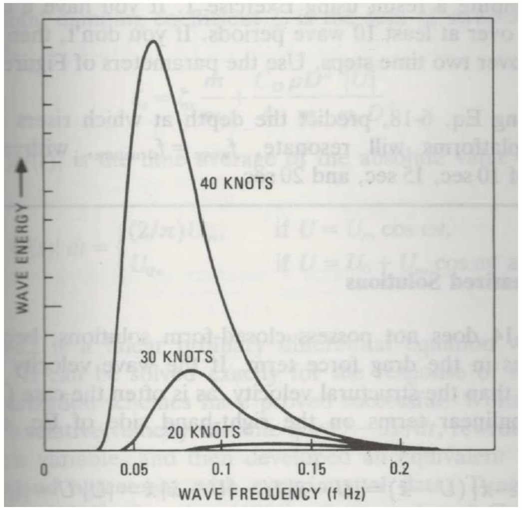
- ~ Stabbing point geometry
- ~ Topside weight and envelope of CoG

- ~ Topside box dimensions
- ~ Environmental (wind) loading

- ~ GIS level
- ~ Platform levels
- ~ Limiting accelerations

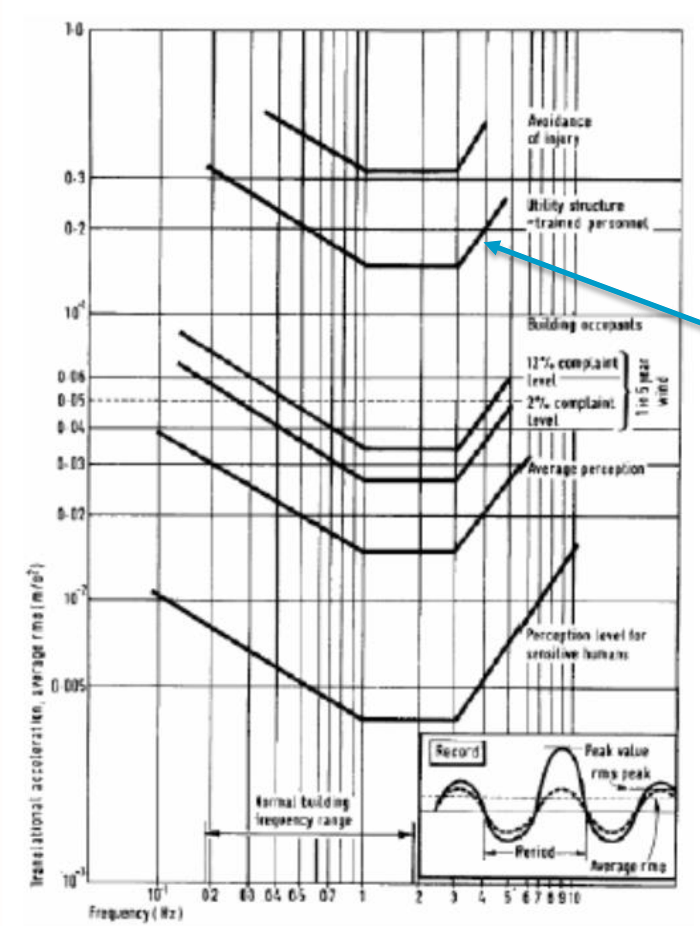
EIGEN FREQUENCY

- WTG natural frequency within the permitted soft-stiff range between 1P and 3P
- WTG jacket support structures are more stiff and benefit from frequency relaxation in the stiff of the permitted range
- Substation support structures are designed in the stiff end



Source: Blevins

ACCELERATIONS



Source: Irwin, A. W. (1984) Design of Shear Wall Buildings. CIRIA – Construction. Industry Research and Information Association, 1984

- ~ check of rms accelerations for human comfort at different platform levels (e.g. utility structure – trained personnel)
- ~ check of peak accelerations at elevation of sensible equipment (e.g. max 0.2g at GIS elevation)

CONCLUSION

~ The WTG and OHVS support structure design require a specific design approach, but many synergies are possible throughout the design, fabrication and installation process.

~ OHVS support structure design is mainly ULS driven, whereas WTG support structures are ULS + FLS driven

~ Due to the specific design approach, a dedicated lead for the design of the OHVS support structure is recommended but there is benefit in sharing cross-competences within the team.

THANKS FOR YOUR ATTENTION

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