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On design and modelling of a 10 MW medium speed drivetrain for bottom fixed offshore wind turbines

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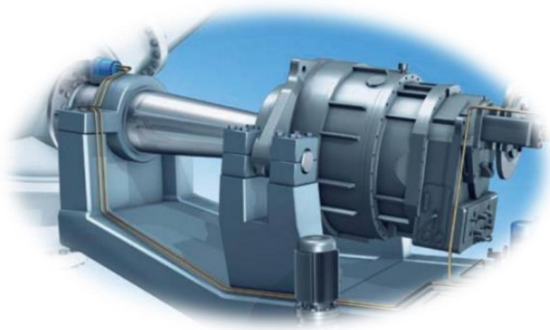
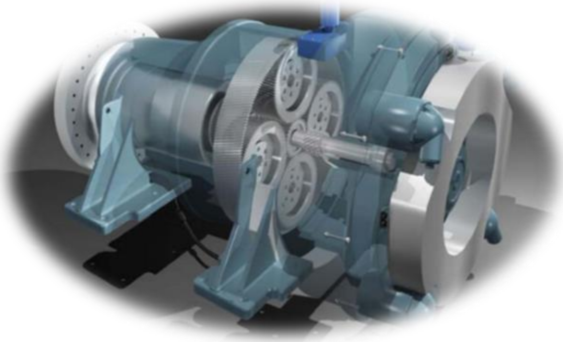
Outline

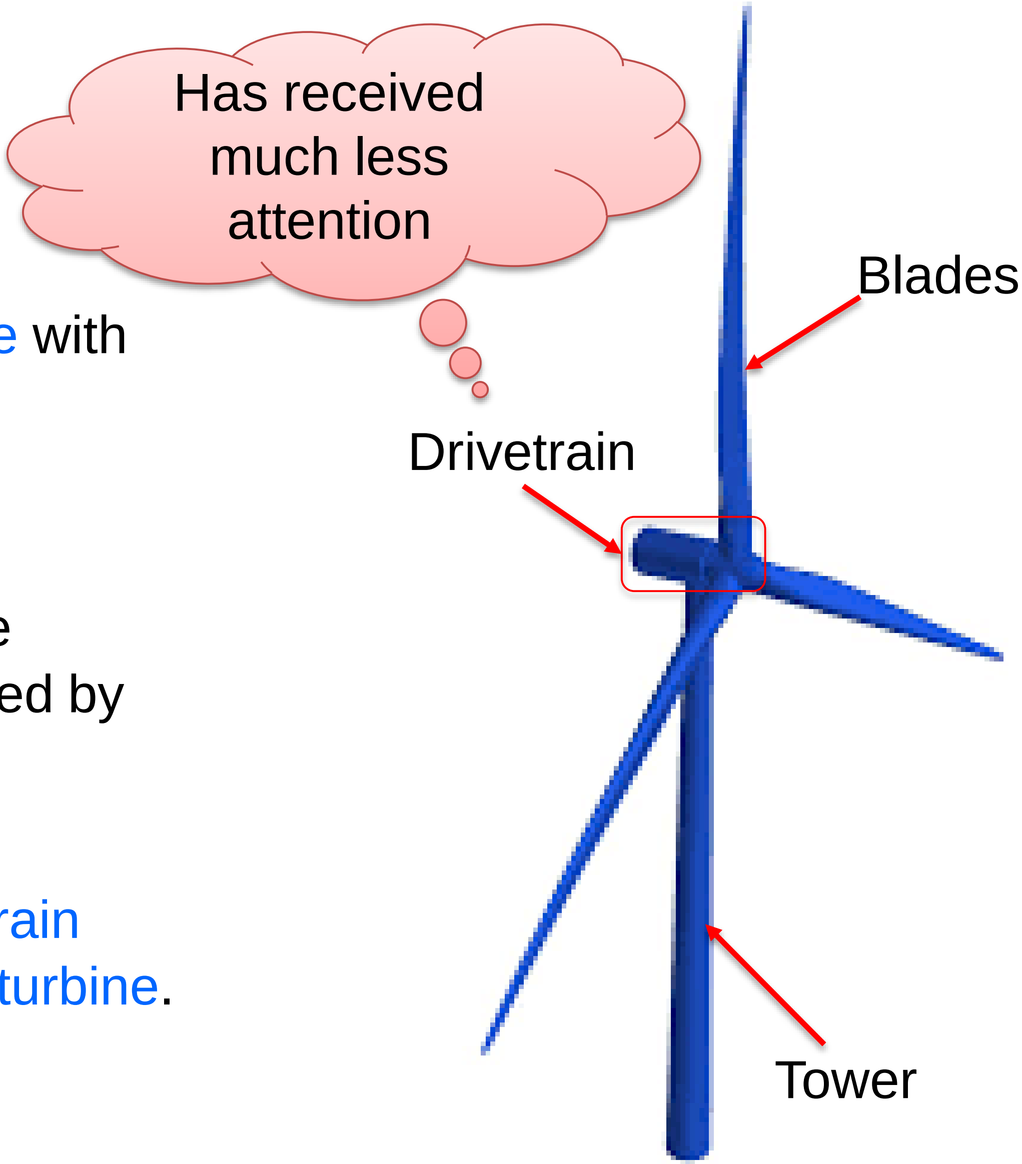
- Introduction
- Methodology
- Drivetrain design
- Drivetrain modelling
- Model comparison
- Concluding remarks





Background

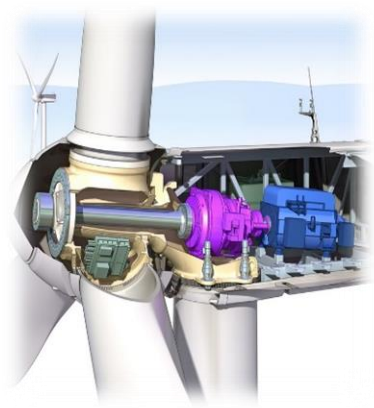
- There is no industrial experience with 10 MW wind turbine design and manufactuing.
- The earliest 10 MW wind turbine concept description was proposed by DTU in 2013.
- No attension was paid on drivetrain design and study of the 10 MW turbine.



DTU 10 MW wind turbine

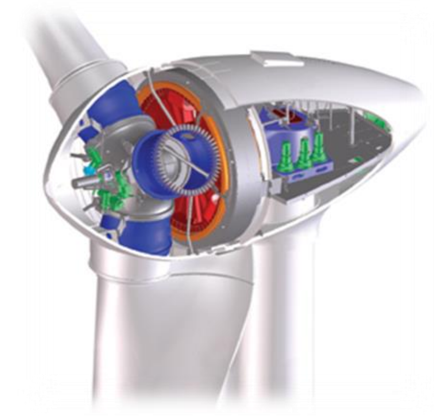
Background

The most common drivetrain concepts



High Speed

Medium Speed



Direct Drive

- One medium speed drivetrain configuration was proposed by DTU.
- **Advantageous** of medium speed drivetrain?
- Applications: AREVA 5 MW, Winergy 8 MW and Vestas 9.5 MW, etc.
- No reference medium speed drivetrain for public study and analysis today.

Motivation

- To provide a baseline medium speed drivetrain for DTU 10 MW RWT.
- The baseline model could be used as a reference model for multi-megawatt scale offshore wind turbines.

Objective

- To establish a detailed drivetrain numerical model for dynamic and reliability analysis.
- To provide all modelling parameters to support public researh studies.

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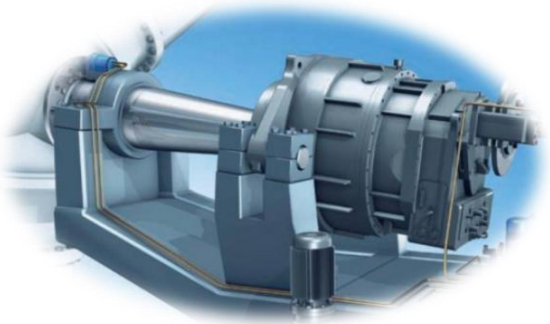
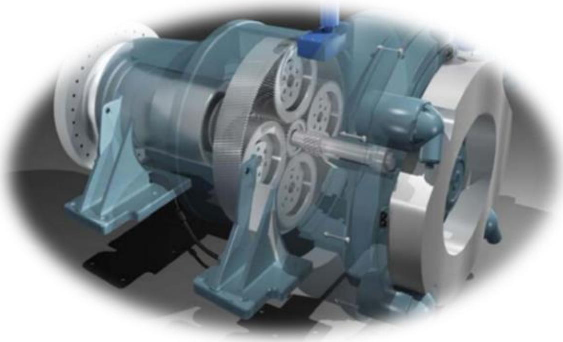
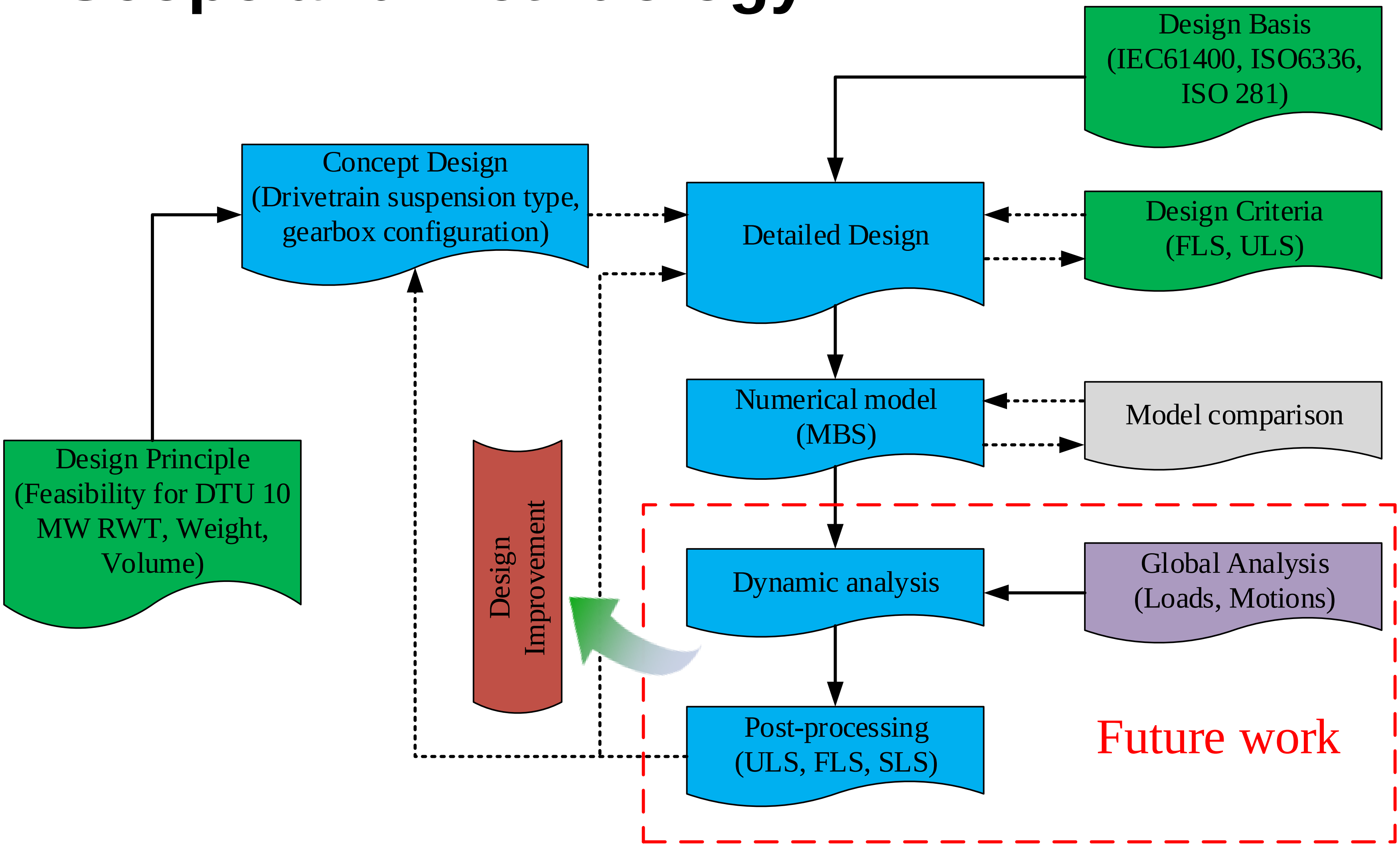




Scope and Methdology



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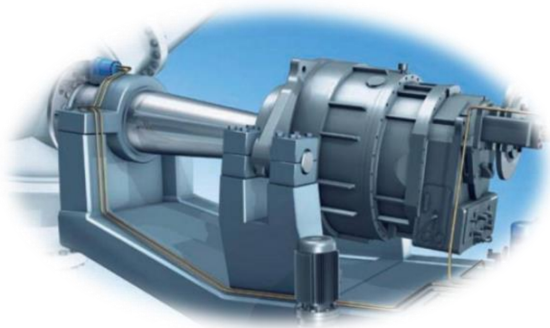
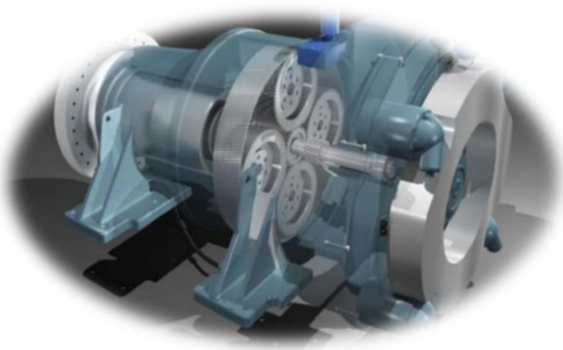




Drivetrain design

Design basis: IEC 61400-4

Gear design: ISO 6336-2, 3, 6

Bearing design: ISO 76, 281

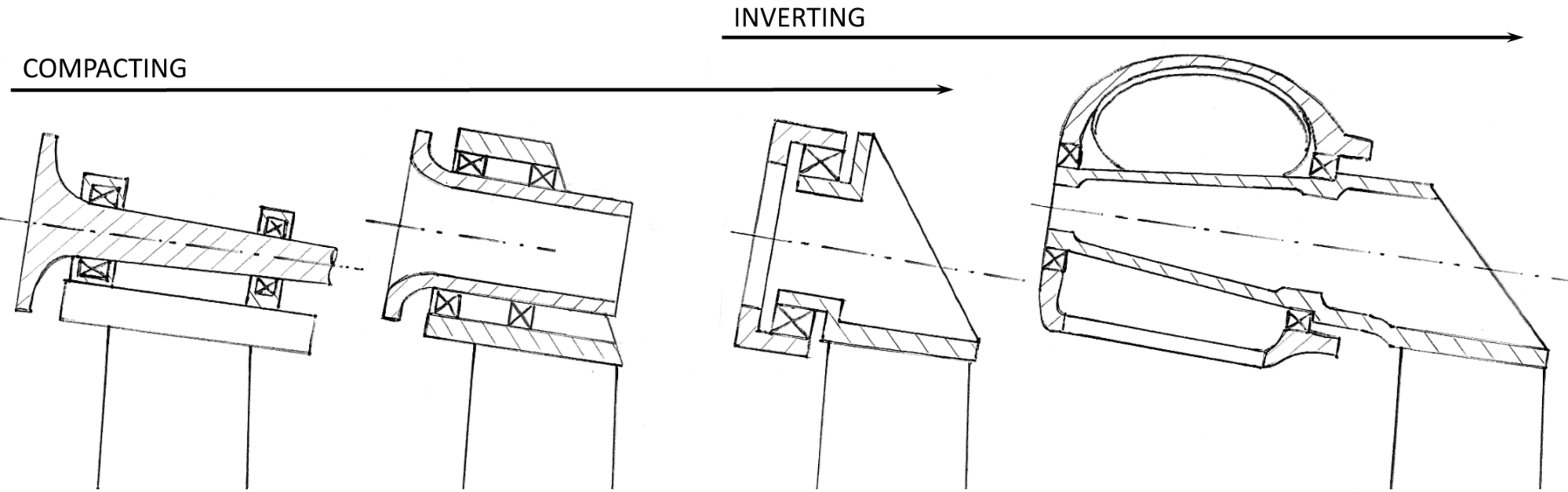
Shaft design: DIN 743

Design loads: IEC 61400-1, DNVGL-ST-0361

Design criteria:

- ✓ All components-gears, bearings and shafts-are designed to withstand fatigue loads and ultimate loads during normal oprating conditions.
- ✓ All components are designed to satisfy the relevant safety requiremnts of wind turbine drivetrain design codes.

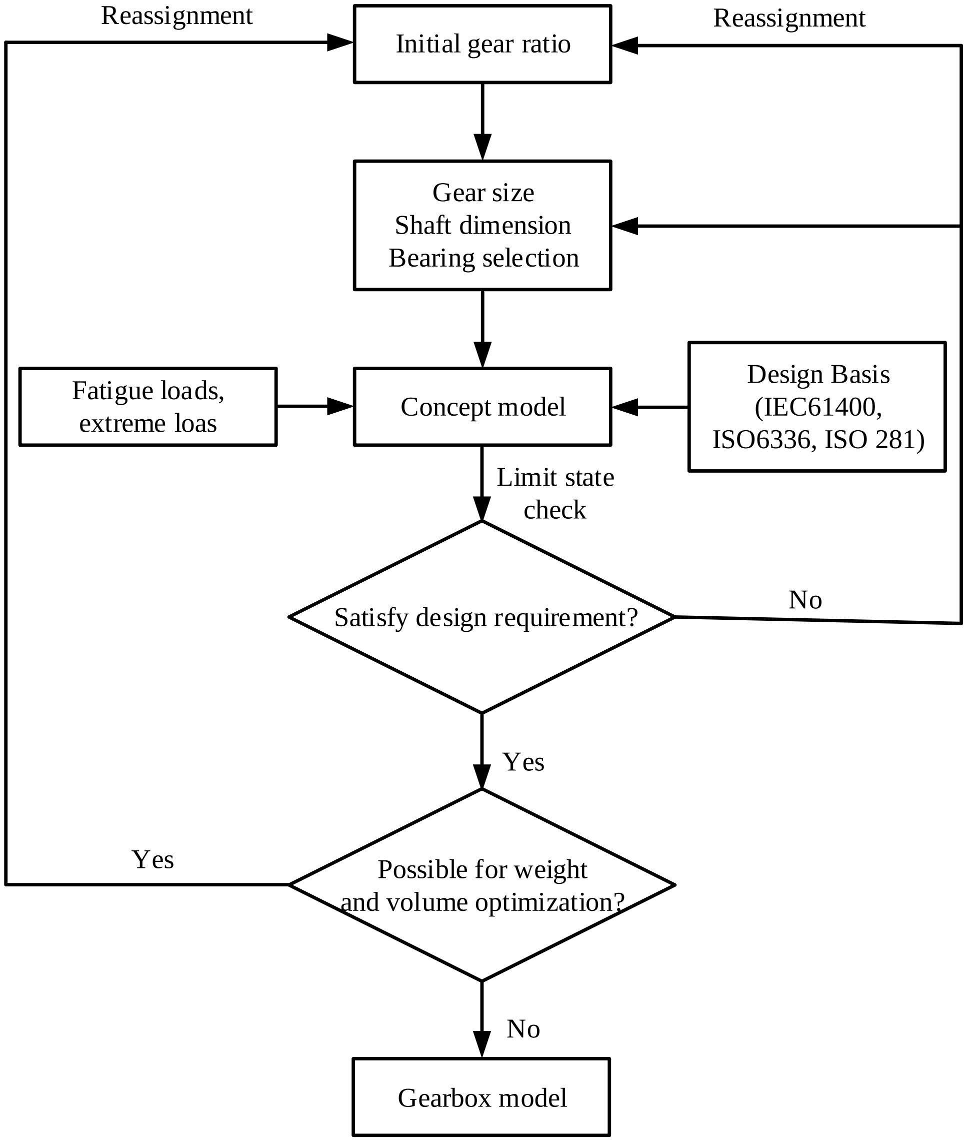
Drivetrain design - Drivetrain configuration



Main bearing arrangements (Torsvik et al. (2018))

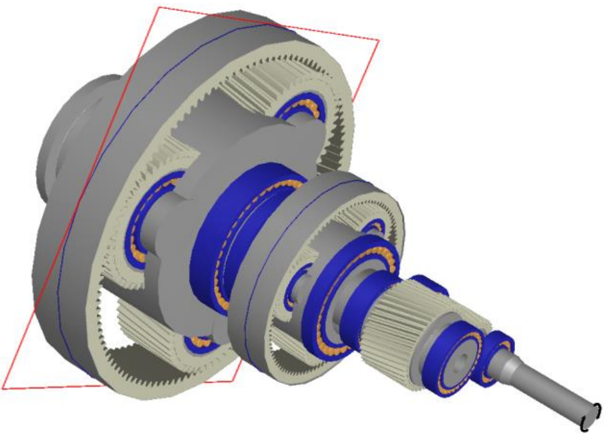
A four-point supports, two main bearings and two torque arms, drivetrain configuration is selected in this study.

Drivetrain design – Gearbox design flow

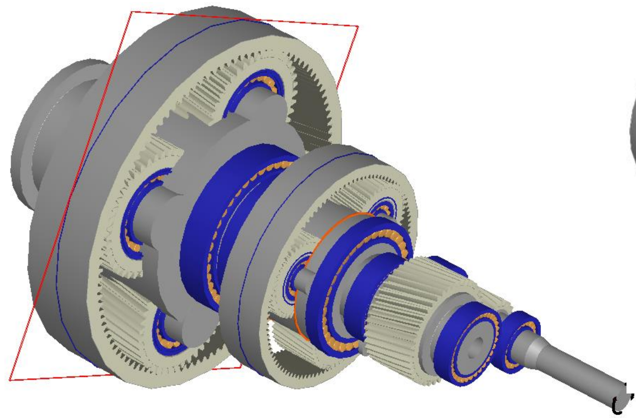


Flowchart of gearbox design

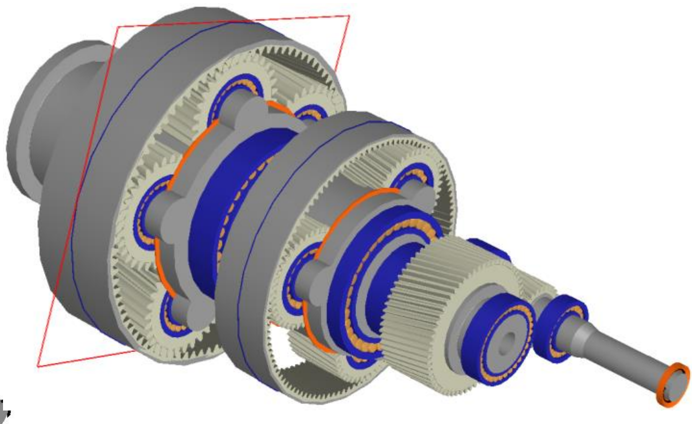
Drivetrain design – Gearbox layout options



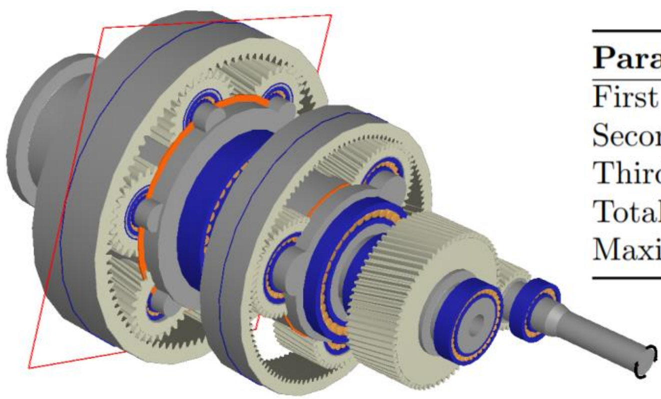
A



B



C



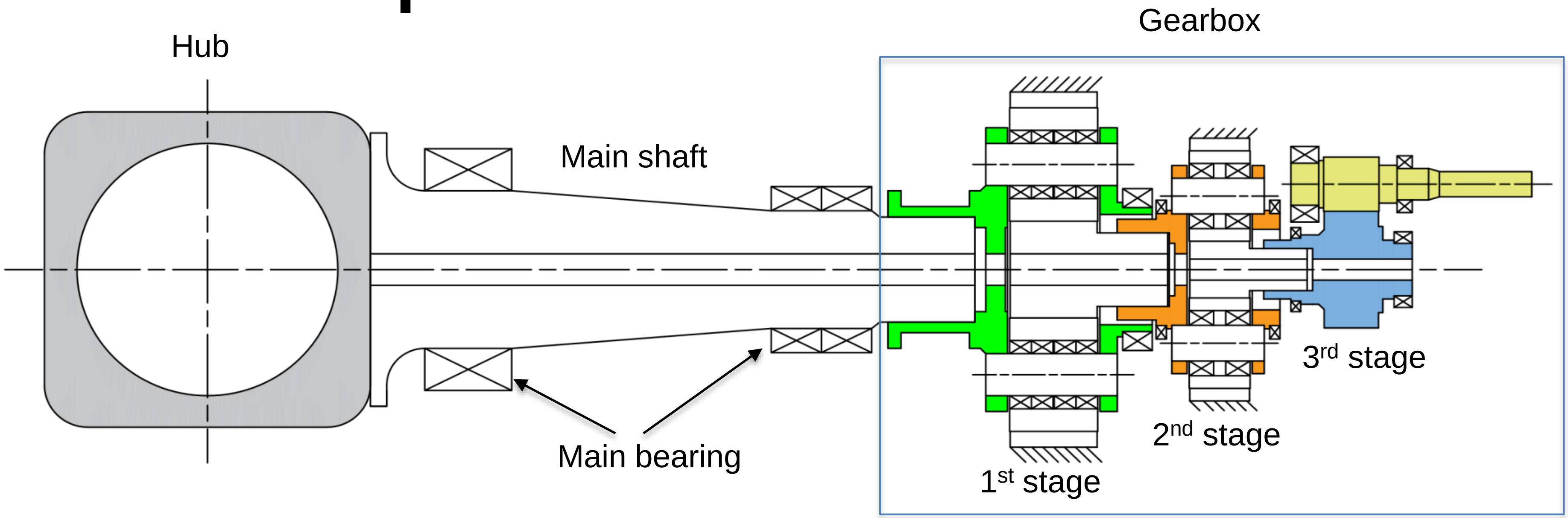
D

Comparison of 4 gearbox layout options

Parameter	A	B	C	D
First stage	1:6000 (3p)	1:5.280 (4p)	1:4.423 (5p)	1:3.316 (6p)
Second stage	1:5.348 (3p)	1:5.160 (3p)	1:5.192 (3p)	1:5.625 (3p)
Third stage	1:1.556	1:1.826	1:2.179	1:2.680
Total dry weight ($\times 1000kg$)	65.66	60.59	60.43	57.16
Maximum outer diameter (m)	3.878	3.396	3.098	3.068

- Principle: minimize drivetrain weight and volume
- Priority consideration: maximum outer diameter

Drivetrain specifications



10 MW wind turbine drivetrain schematic layout

10 MW wind turbine drivetrain specifications

Parameter	Value
Drivetrain type	4-point supports
Gearbox type	Two planetary + one parallel
First stage gear ratio	1:4.423
Second stage gear ratio	1:5.192
Third stage gear ratio	1:2.179
Total gear ratio	1:50.039
Designed power (kw)	10000
Rated input shaft speed (rpm)	9.6
Rated generator shaft speed (rpm)	480.374
Total gearbox dry weight ($\times 1000kg$)	60.43
Maximum gearbox outer diameter (m)	3.098
Service life (year)	20

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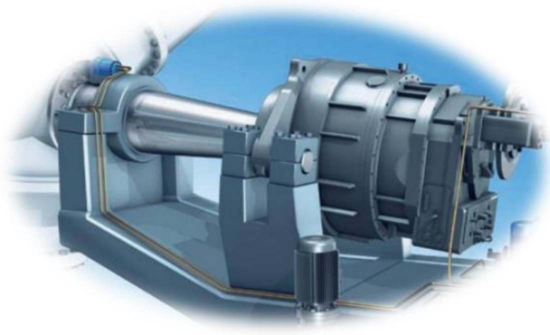
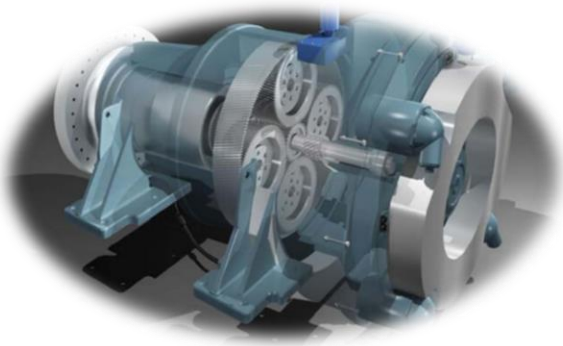
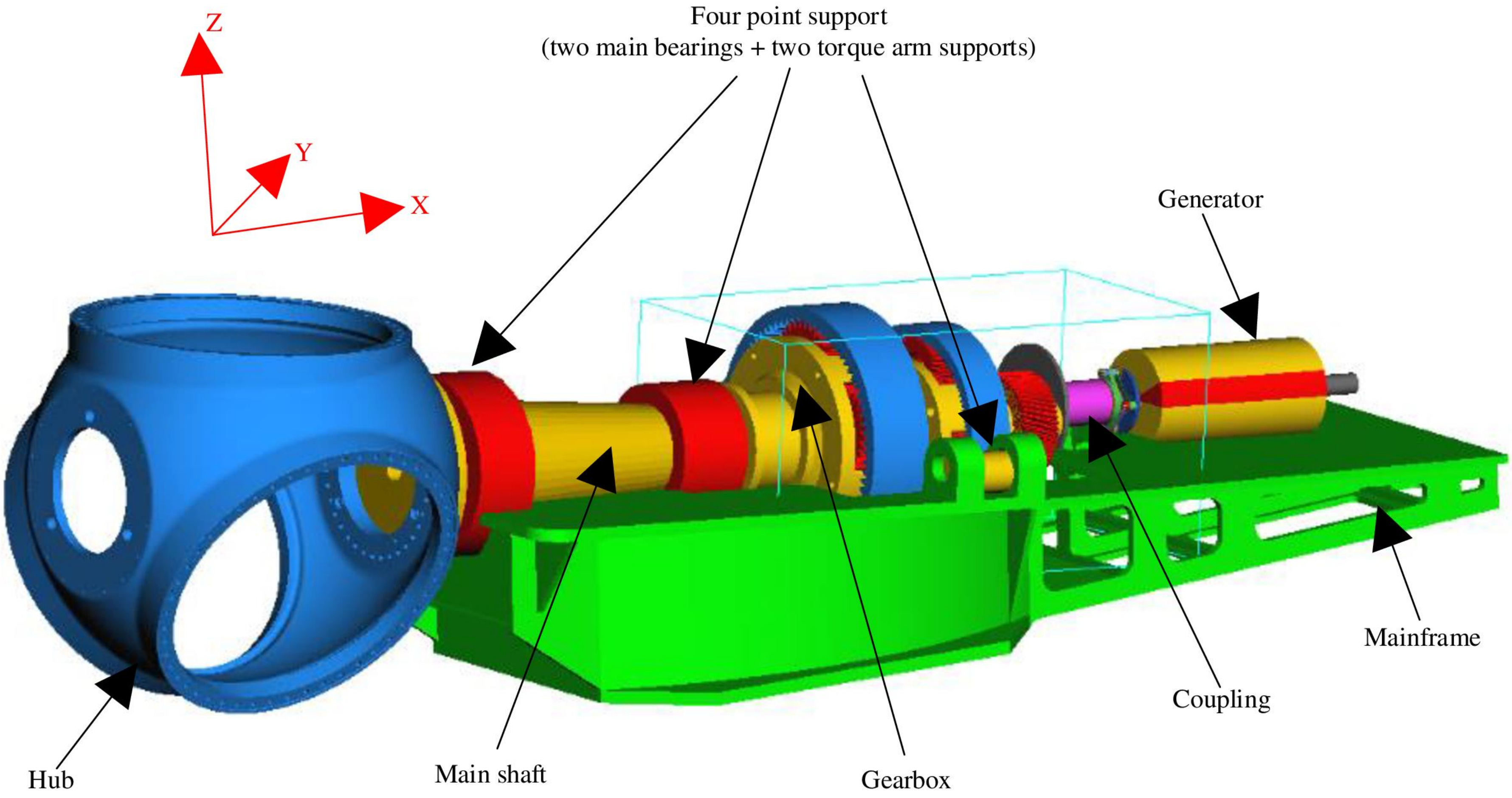


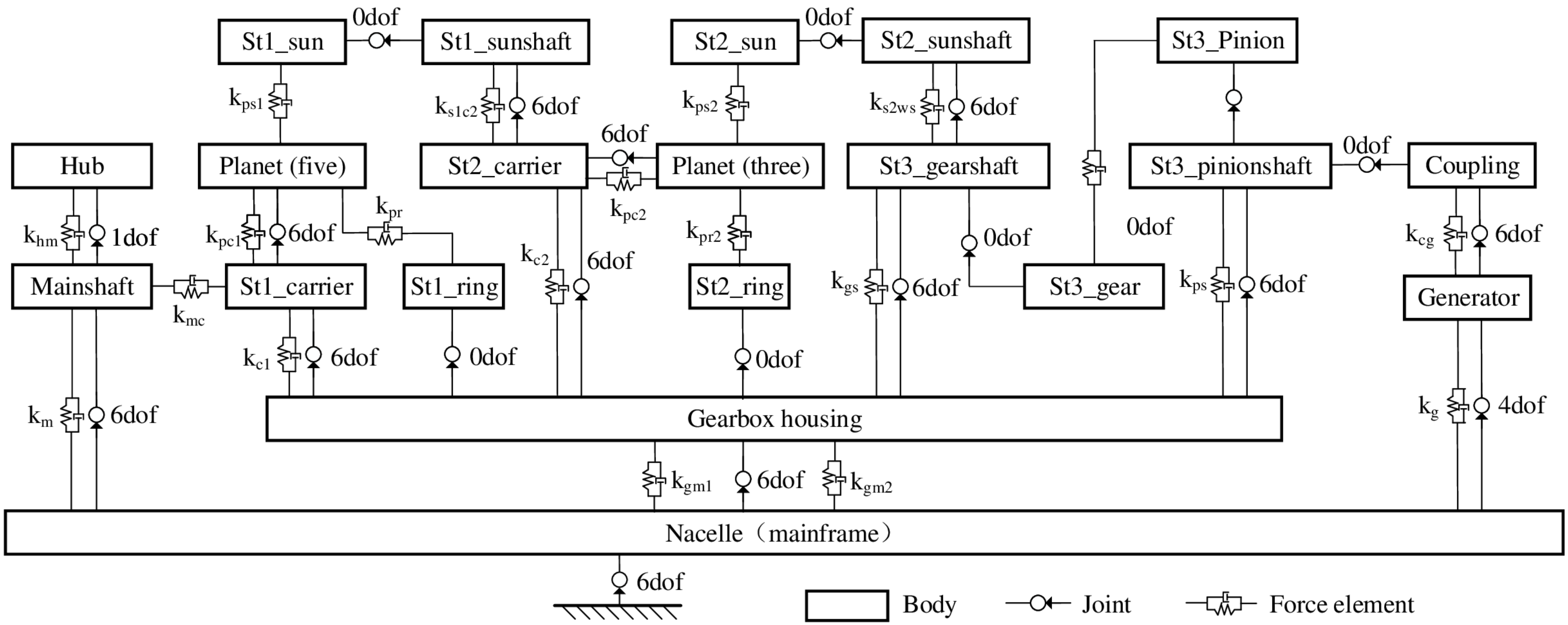


Drivetrain modelling – MBS model



10 MW wind turbine drivetrain MBS model

Drivetrain modelling – Topography diagram



Topography diagram of the 10 MW wind turbine drivetrain MBS model

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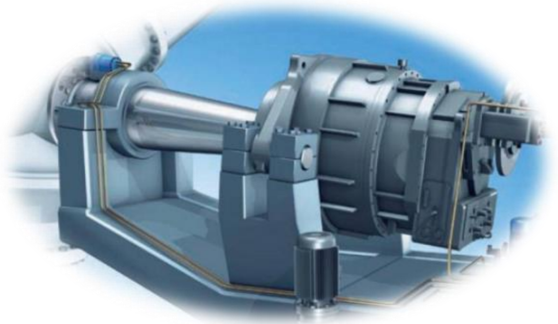
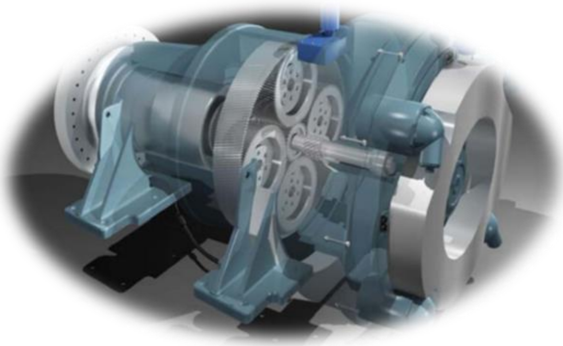
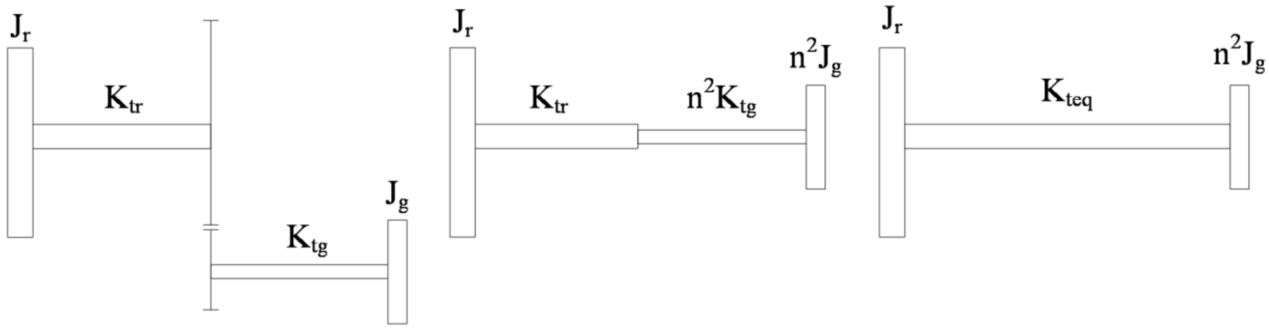




Model comparison

Simplified drivetain model provided by DTU:



Two mass model of the wind turbine drivetrain

First egienfrequency

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k_{teq}(J_r + n^2 J_g)}{J_r n^2 J_g}} \qquad f_n = \frac{1}{2\pi}\sqrt{\frac{k_{teq}}{J_r}} \qquad k_{teq} = \frac{k_{tr} n^2 k_{tg}}{k_{tr} + n^2 k_{tg}}$$

Natural frequency for the shaft torsion mode.

Shaft torsion mode	Simulation frequnecy [Hz]	Reference frequency [Hz]
$F_{\text{free-free}}$	4.003	3.889
$F_{\text{free-fixed}}$	0.612	0.6116

The first egienfrequency obtained from detailed drivetrain model match well with the corresponding value derived from simplified model.

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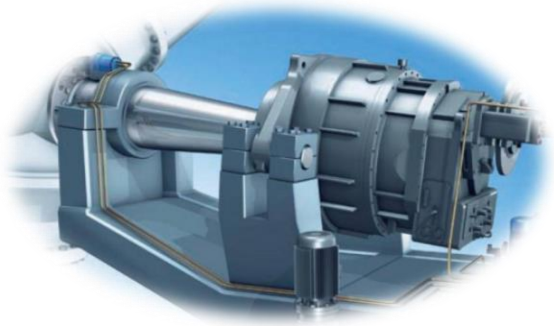

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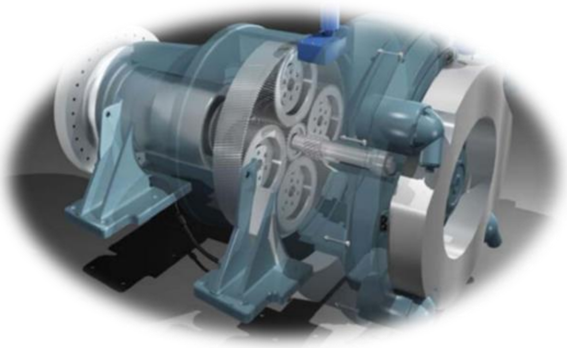
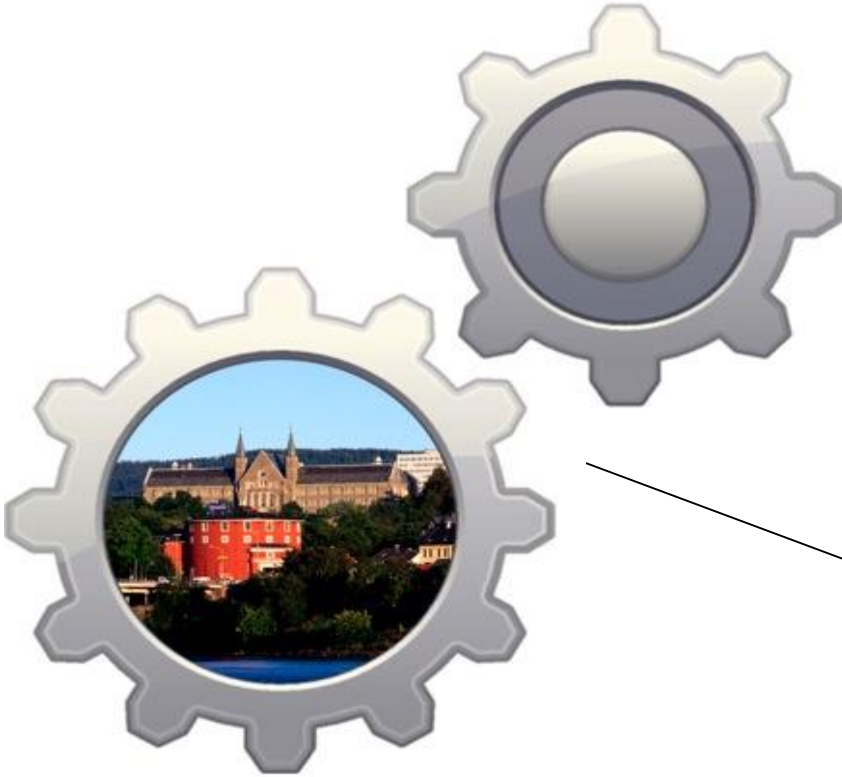


Concluding remarks

- A four-point supports drivetrain configuration and a two planetary stages + one parallel stage gearbox strucutre is designed for DTU 10 MW wind turbine.
- Four gearbox layout options are provided and compared and one optimized option is finally selected with compromised consideration of volume, weight and load sharing performance principles.
- A high fidelity numerical drivetain model is developed using MBS method.
- Model comparison is conducted, and the rationality of the developed drivetrain model is initially verified.



Thanks