Revolutionising Offshore Wind Energy: The 20MW Drivetrain Concept Study

Jack Robson

17th January 2024

Credit: Equinor Hywind Floating Offshore Wind Farm

Agenda

- Reference wind turbines
- Joule 20MW Turbine
- Chosen drivetrain configuration
- Gearbox and Generator Design
- Bearing Selection
- Hydrodynamic fluid film bearing feasibility
- Future work

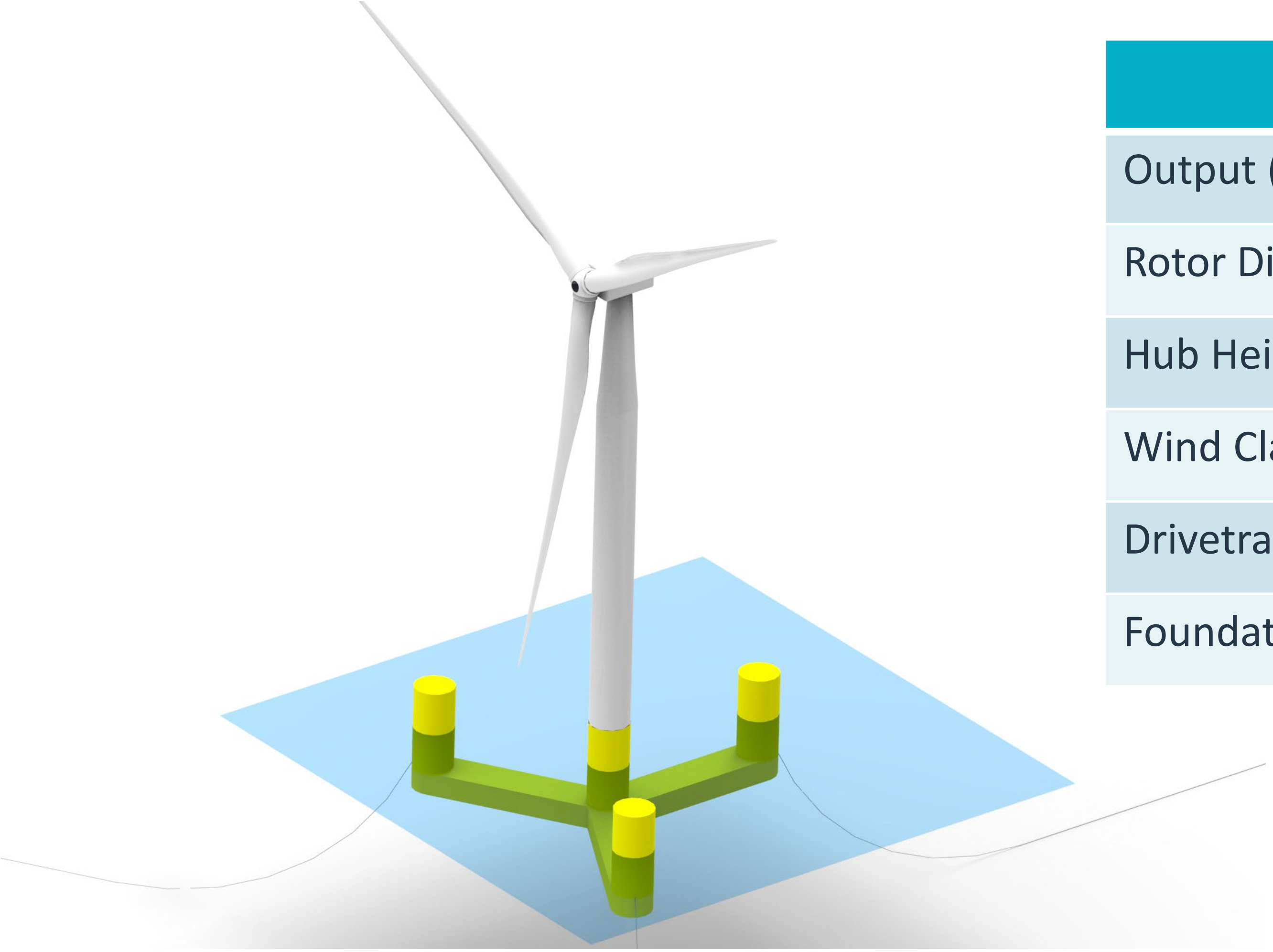
Reference Wind Turbines

Various scales of reference wind turbines have been developed through collaborative research projects, undertaken by multiple research organisations.

Model Name	Size	Foundation
IEA 3.4MW	3.4MW	Onshore
NREL 5MW	5.0 MW	Fixed Monopile
LEANWIND 8MW	8.0 MW	
DTU 10MW	10.0 MW	
IEA 10MW	10.0 MW	Fixed Monopile
INNWIND	10.0 MW	Triple Spar
IEA 15MW	15.0MW	Multiple Variations
Joule 20MW	**20.0 MW**	**Semi Submersible**
IEA 22MW	22.0MW	Fixed Monopile

- Reference wind turbines act as benchmarks for the industry
- Aid the evaluation of new designs
- Form the foundation for research for academic organisations
- Aim to produce a reference wind turbine at the 20MW scale with drivetrain components designed in great detail

Joule 20MW Reference Wind Turbine



Joule 20MW	
Output (MW)	20
Rotor Diameter (m)	270.7
Hub Height (m)	165.0
Wind Class	IC
Drivetrain	Medium Speed Geared
Foundation	Semi Submersible

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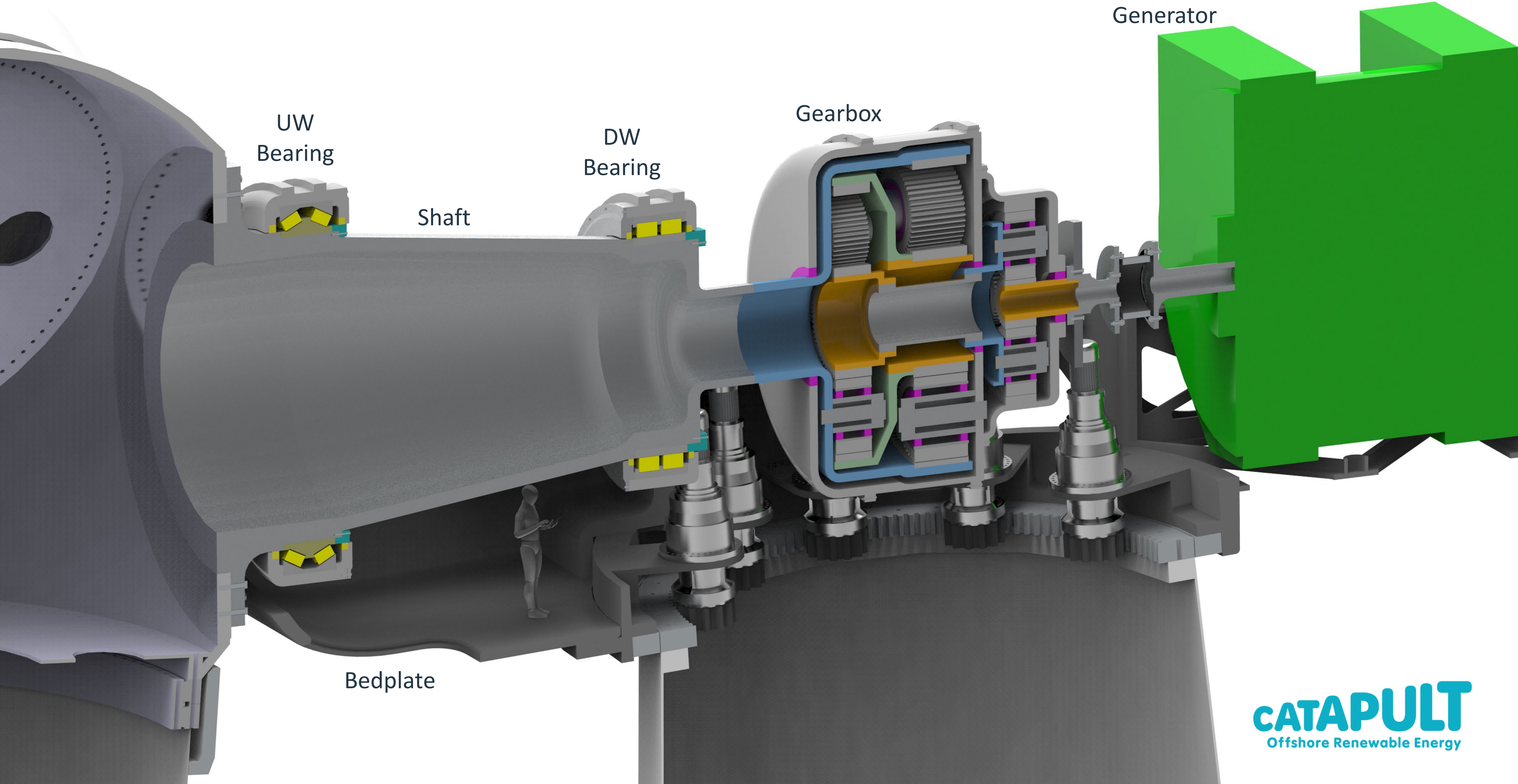

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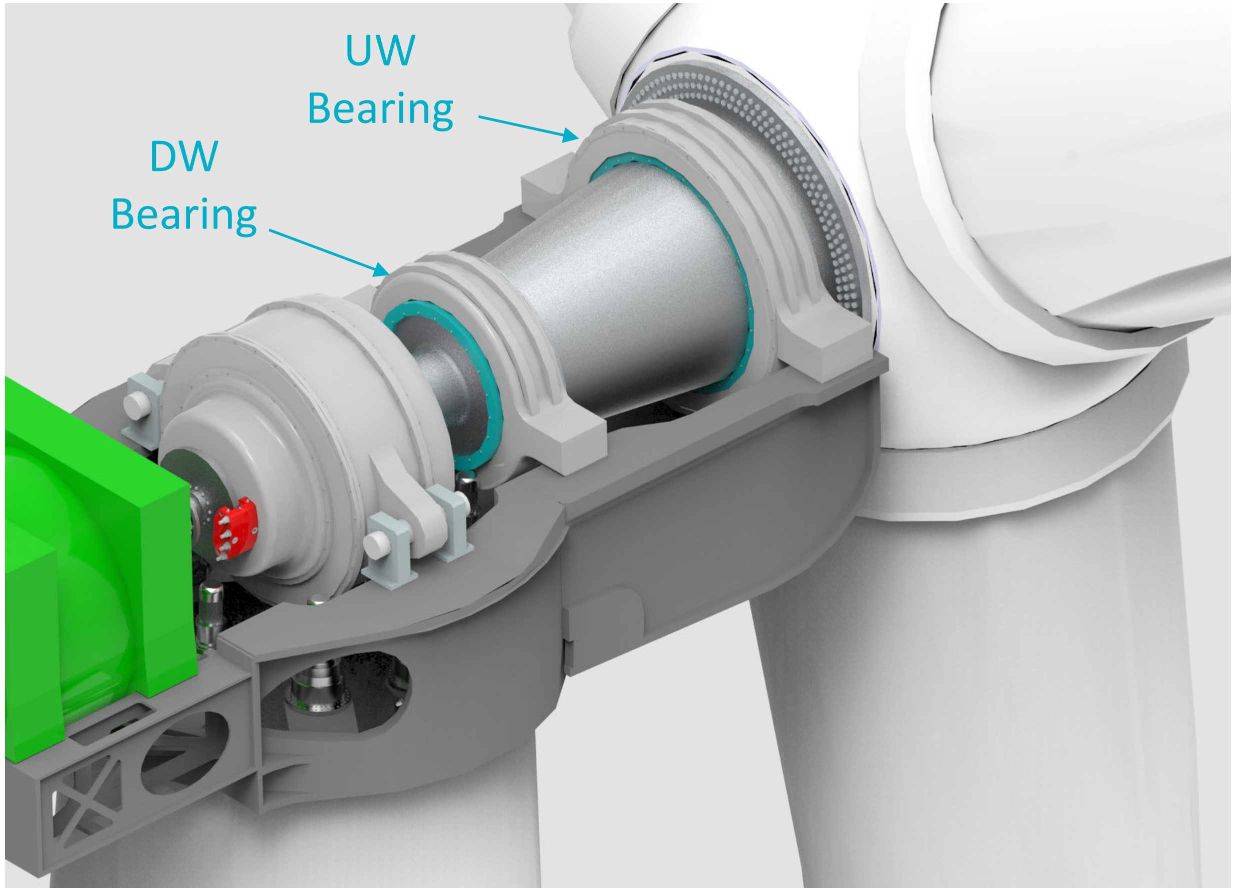
Main Bearing Configurations for 20MW and Beyond

Four-Point Configuration

Four-point suspension drivetrain (double rotor) suspension arrangements have a main shaft that is supported by two main bearings. This system type is commonly employed in large multi-megawatt turbines, hence its selection in the Joule Phase 2 project.



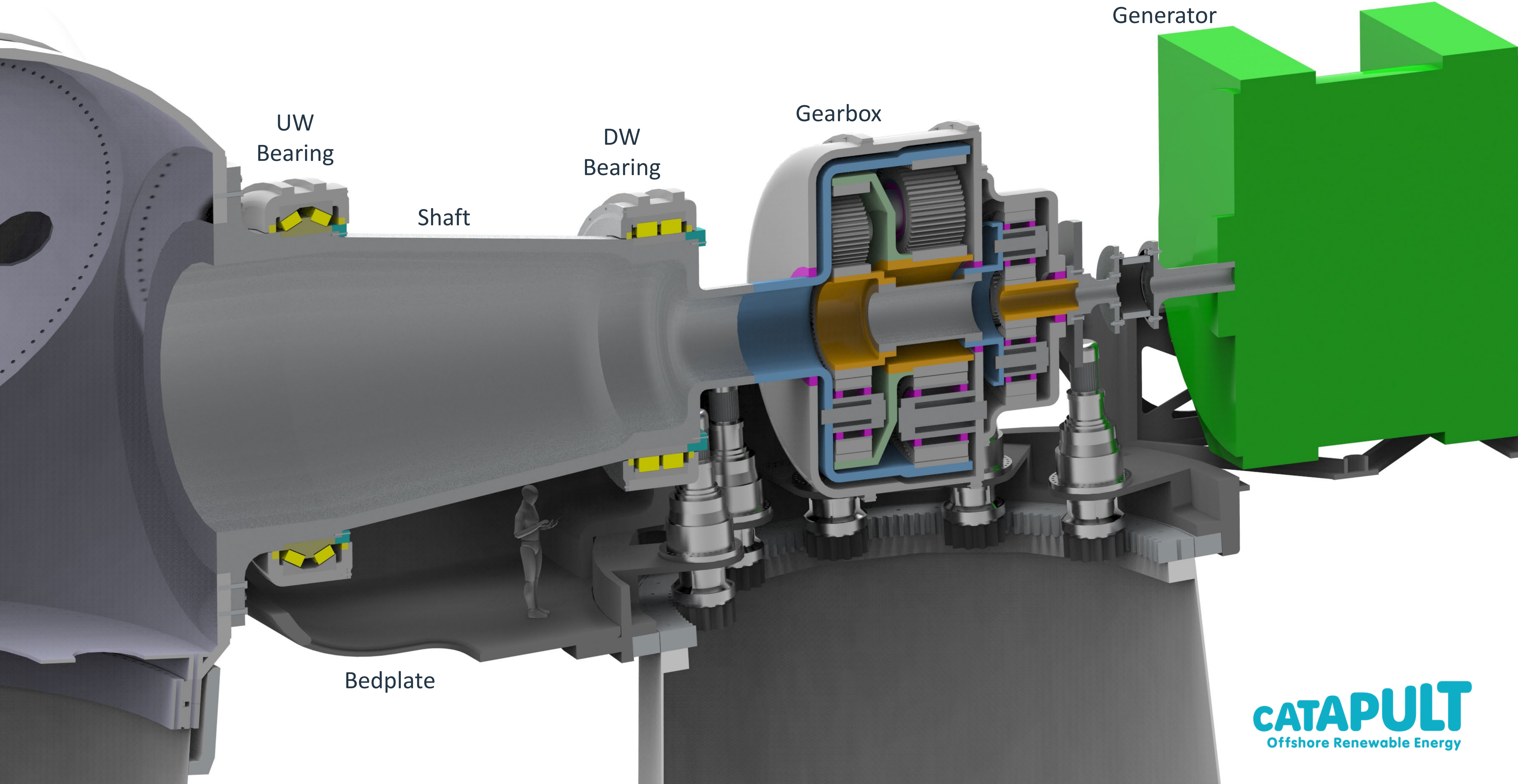
Advantages

- All non-torque loads transmitted from rotor to main frame
- No non-torque loads transferred to gearbox
- Gearbox replacement is simpler in this configuration

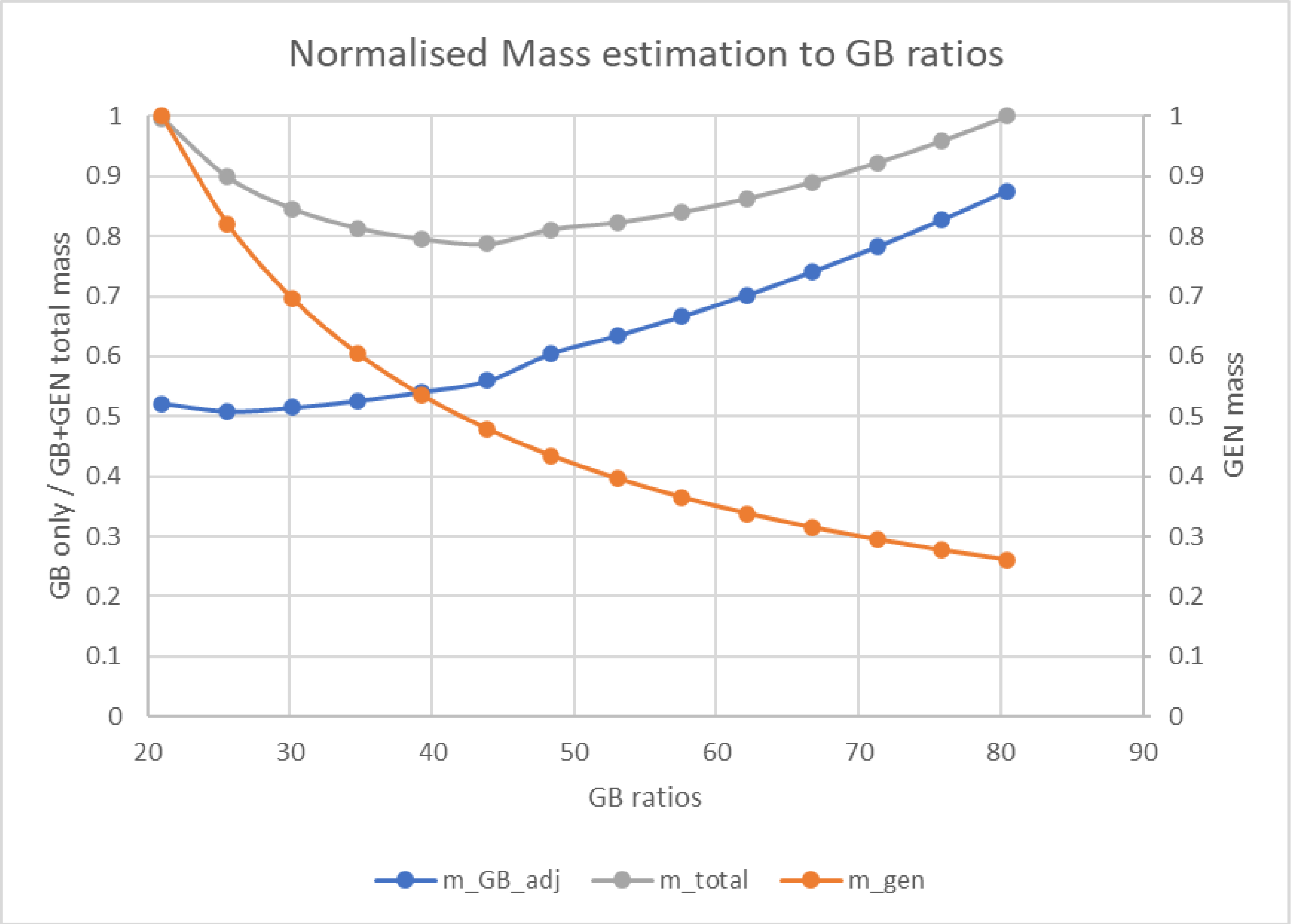
Disadvantages

- Additional complexity added to drivetrain design
- Increased weight and space requirements
- Overdetermination leads to constraint forces in the gearbox

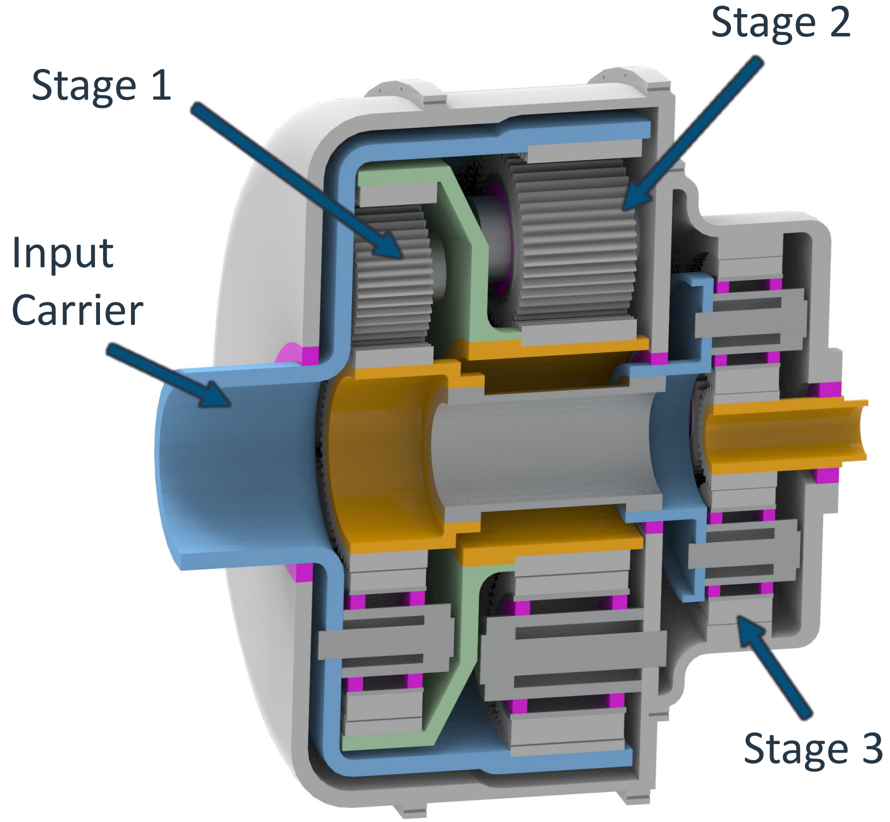
Joule 20MW Reference Wind Turbine



Gearbox & Generator Design

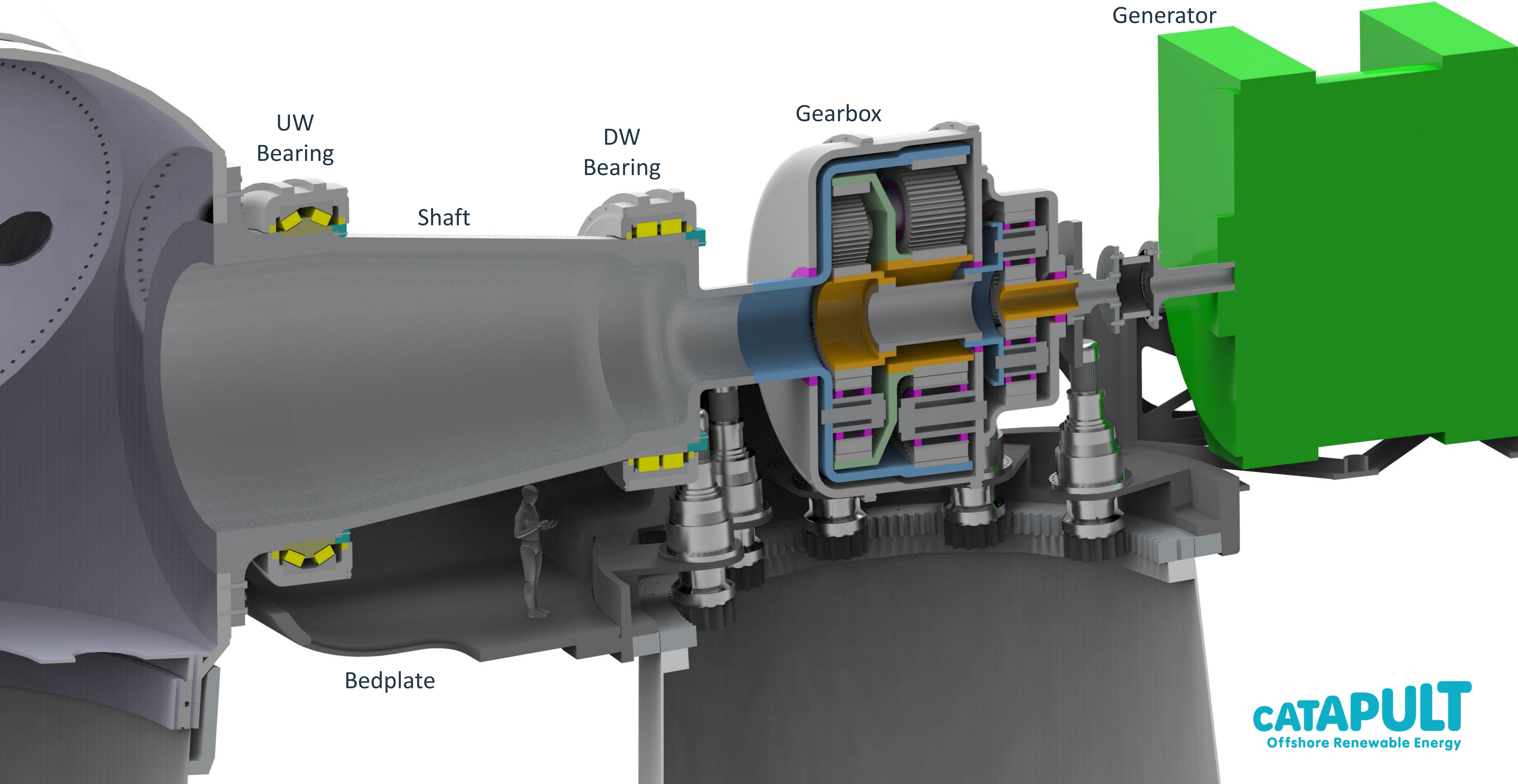


The gearbox chosen is a three-stage differential power flow planetary gearbox with a medium speed gear ratio



Baseline Generator = Permanent Magnet Generator

Joule 20MW Reference Wind Turbine



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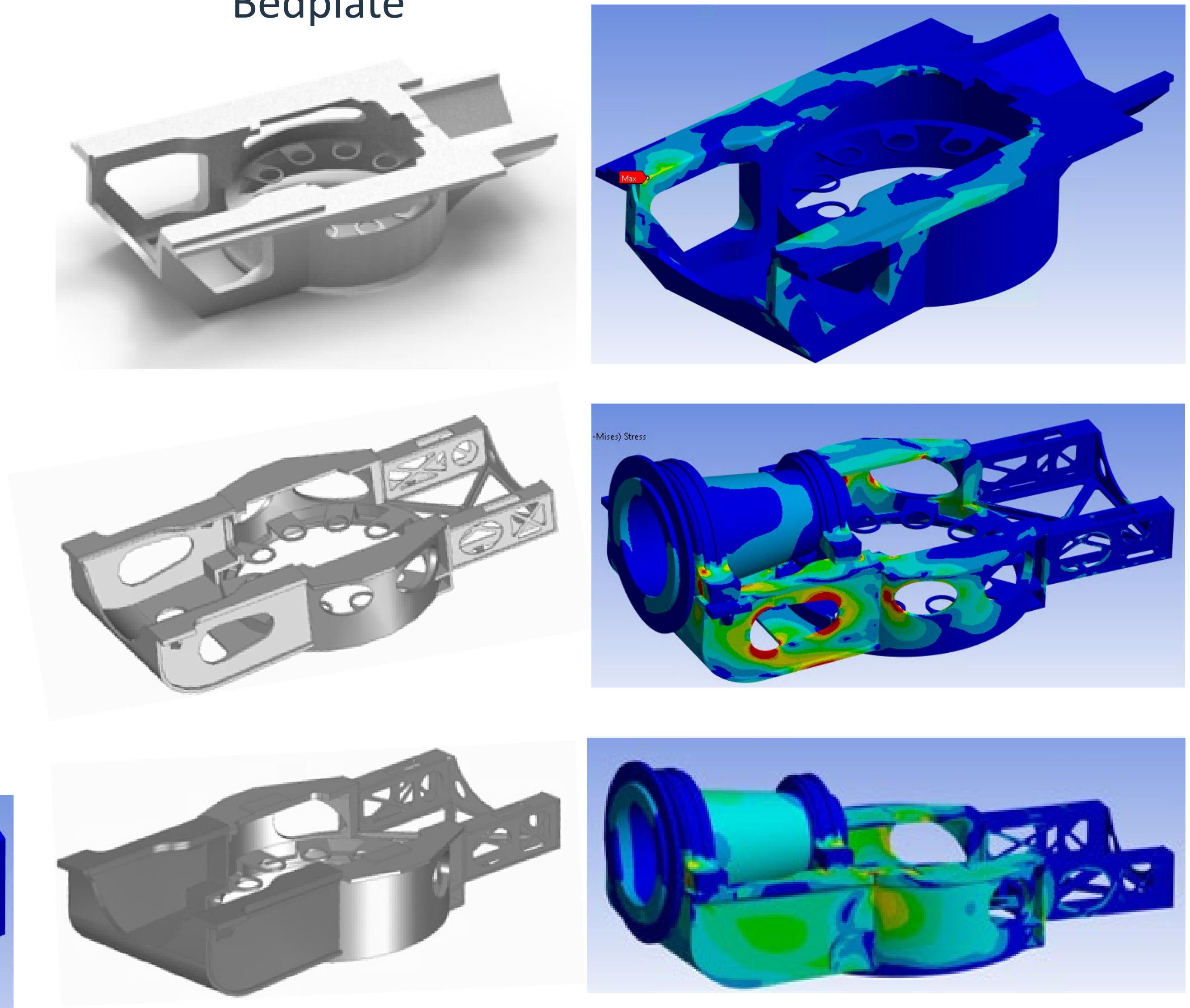
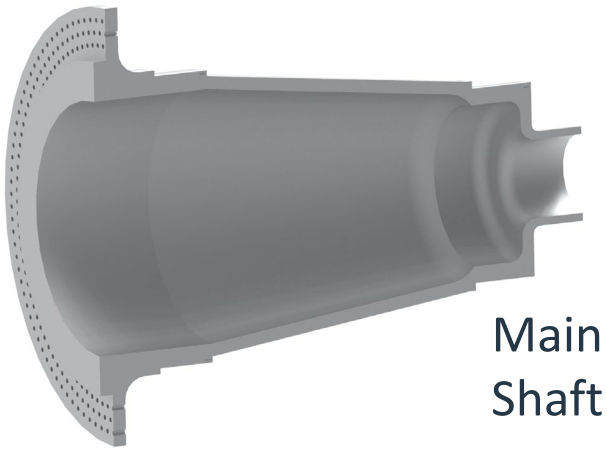
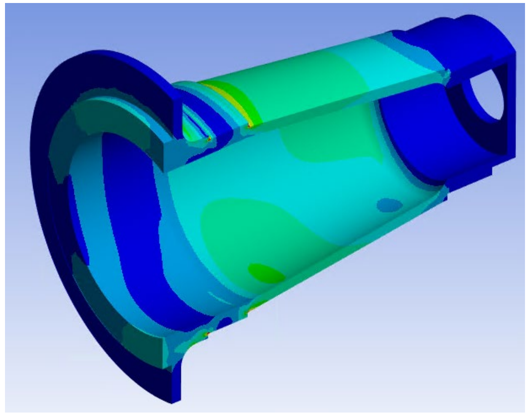
Structural Optimisation

Bedplate

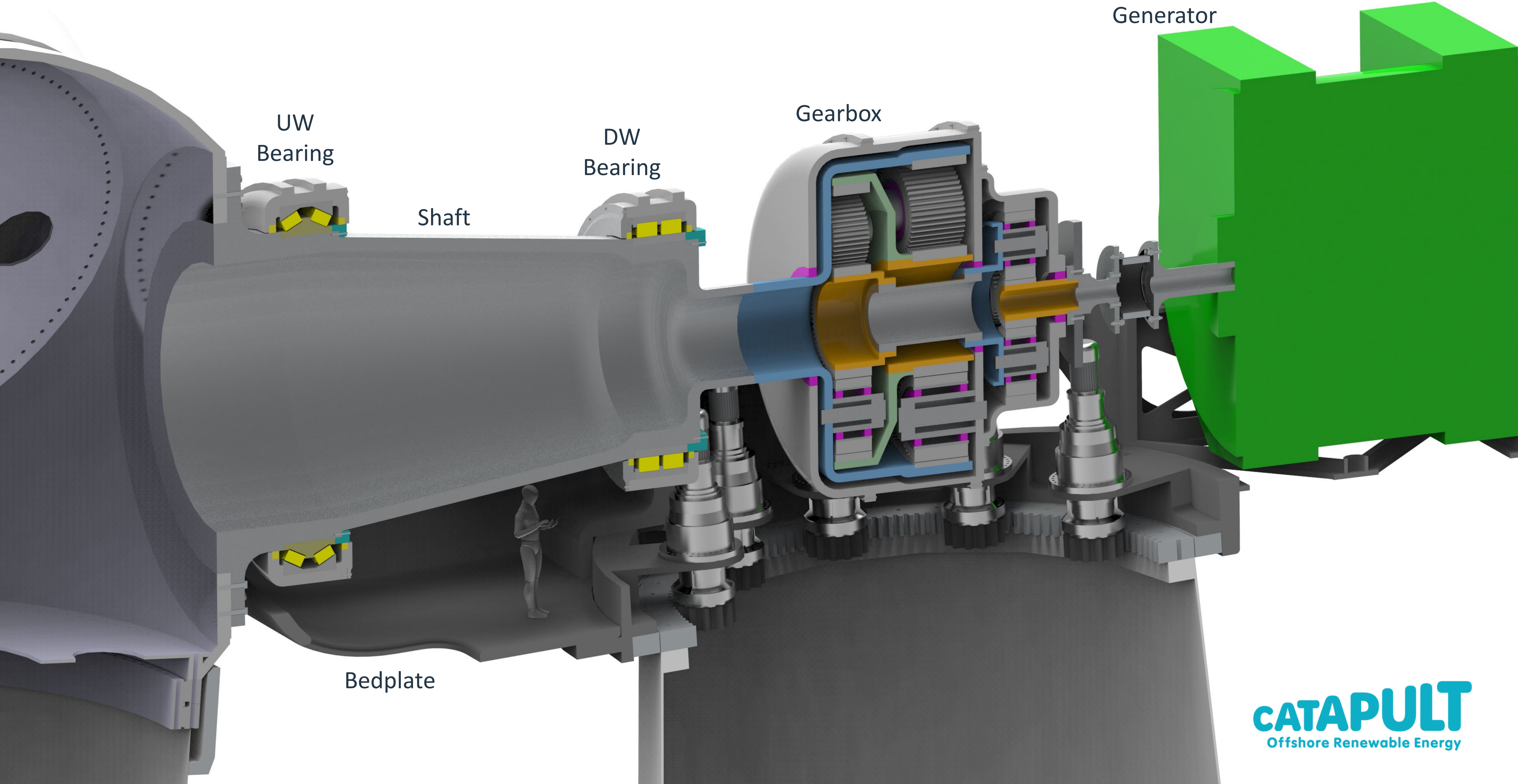






Main
Shaft

Joule 20MW Reference Wind Turbine



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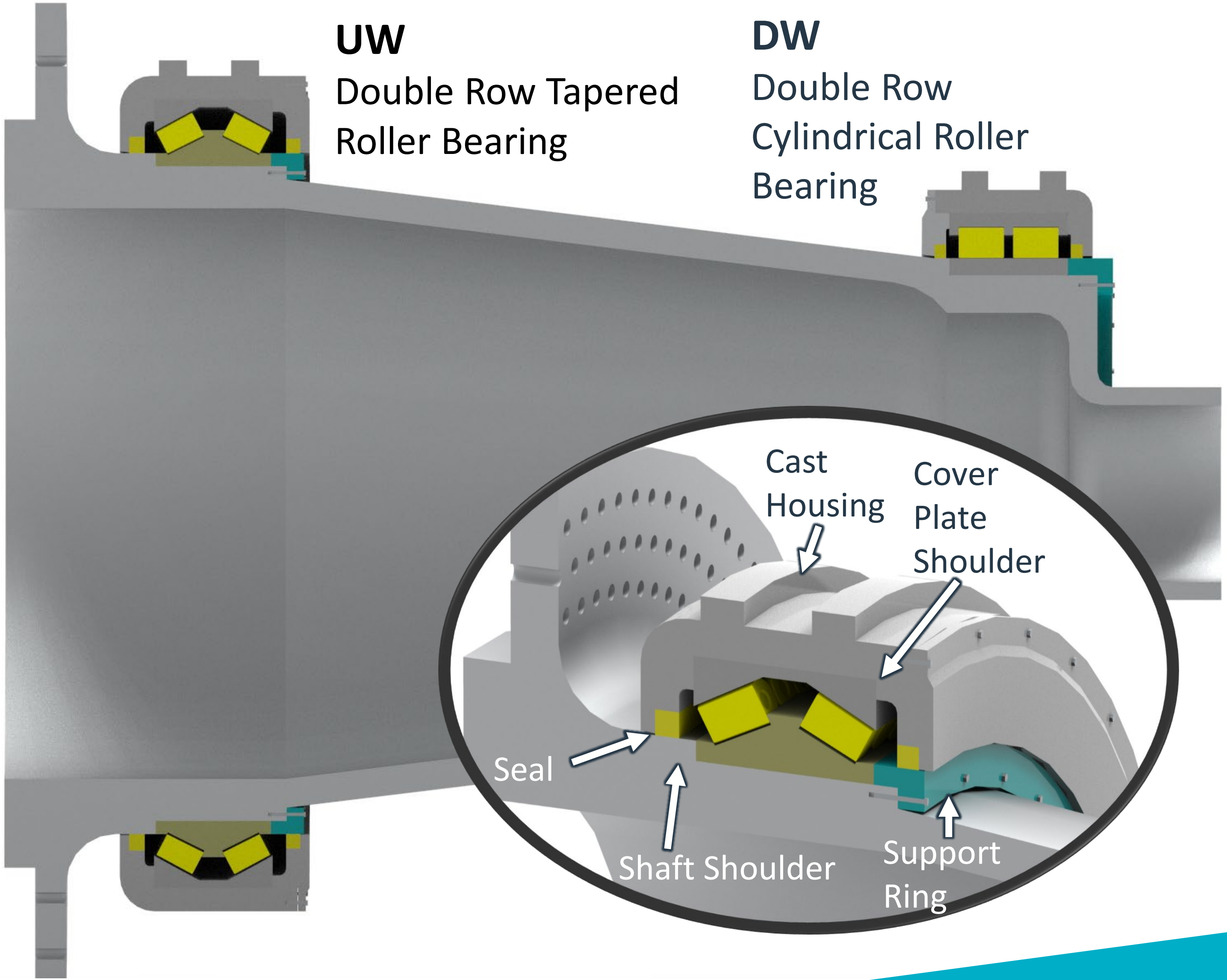
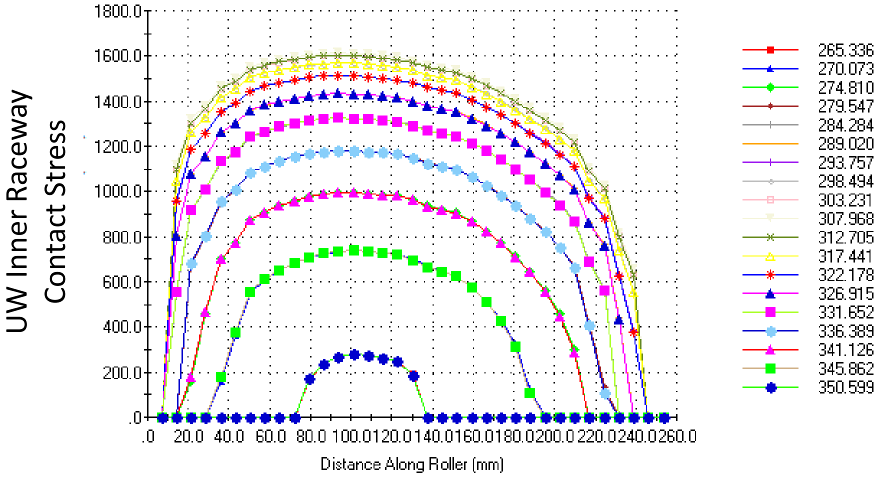
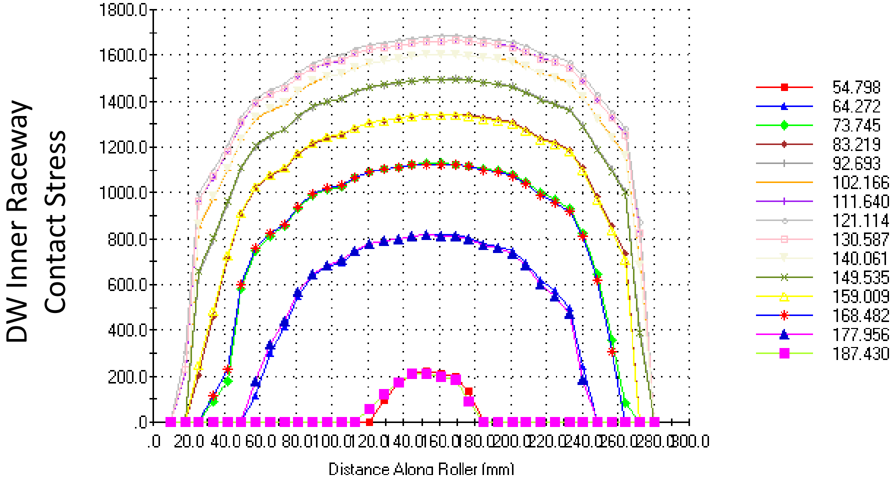
Main Bearing Configurations for 20MW and Beyond

Steel Baseline Shaft with Rolling Element Bearings







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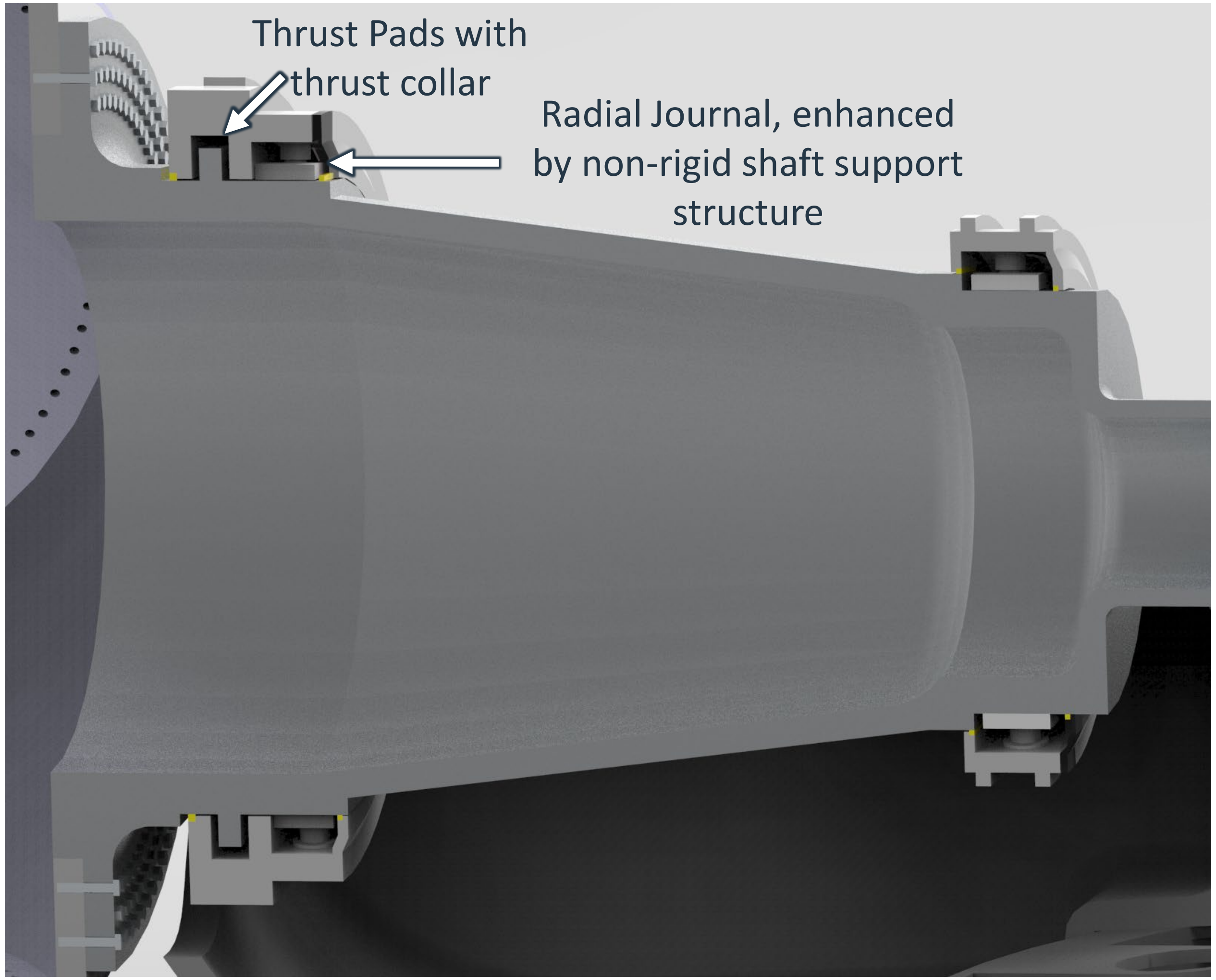
Main Bearing Configurations for 20MW and Beyond

Steel Shaft with Fluid Film Bearings



UW

Upwind bearing is comprised of both a hydrodynamic journal bearing (radial) and a thrust bearing (axial)

DW

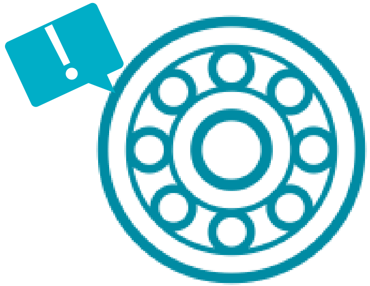
The downwind bearing features only a radial journal bearing

Comparison at 20MW Scale – Hydrodynamic Journal Bearings vs Rolling Element Bearings

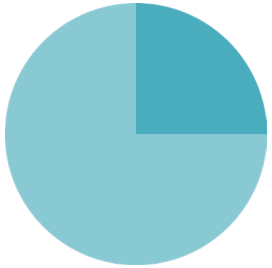
	Rolling Element Bearings	Hydrodynamic Journal Bearings
Target Benefit	•Design and manufacturing well proven in the wind industry with proven experience of application at a reduced scale •Provides a benchmark for the project •Widely available and established industry standards	•Good manufacturing scalability •Reduced complexity and cost to assembly and maintenance procedure •Extended bearing life •Pads replaced in situ upon component failure
Expected Demerit	•Poor manufacturing scalability at 20MW scale due to current limitations •Relatively complex assembly process •Whole bearing unit replaced upon failure •Expensive O&M cost upon failure	•Relatively low technology readiness level for turbine main shaft at scale •Rapid localised heating upon failure of lubricant cooling system

Hydrodynamic Journal Bearings – Potential O&M Savings

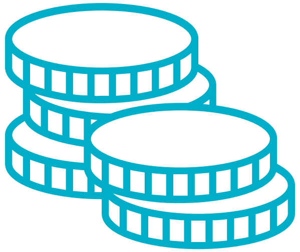
Joule Project Main Bearing LCoE Study – OPEX Related to Main Bearing Issues



Replacement of main bearing following major failure is the most significant lifetime cost

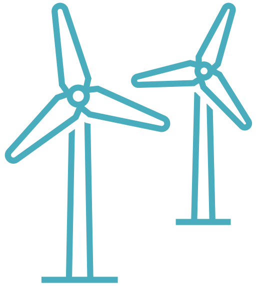


25% of bearings will fail within turbine lifetime

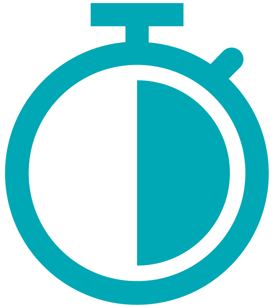


Main Bearing replacement cost for 20MW REB ≈ £3.25m

More readily available vessels for HDJ reduces downtime



Wind farm earns £46.40/MWh



Net capacity factor 50%

Modular HDJ design reduces replacement time

Cheaper vessels used for HDJ

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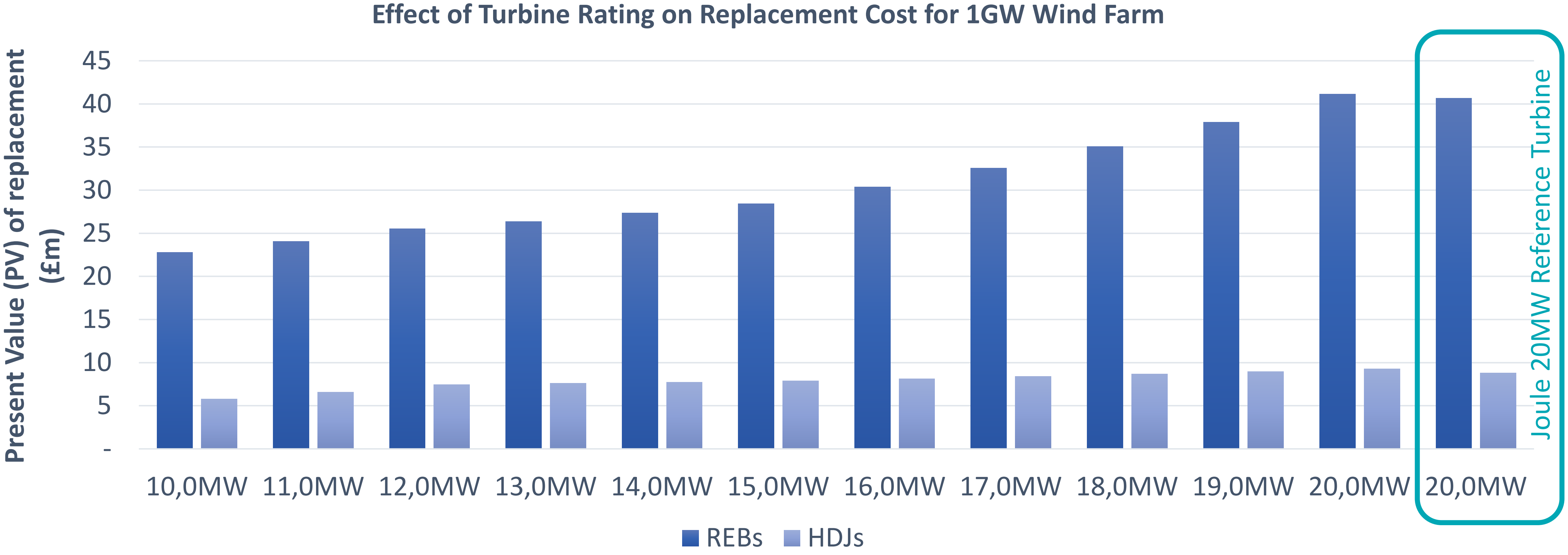
Hydrodynamic Journal Bearings – Potential O&M Savings

Joule Project Main Bearing LCoE Study – Case Study HDJ vs REB on 1GW Wind Farm



As turbine rating increases, rate of saving increases

These OPEX savings equate to an approximate 1.0-1.5% LCoE reduction

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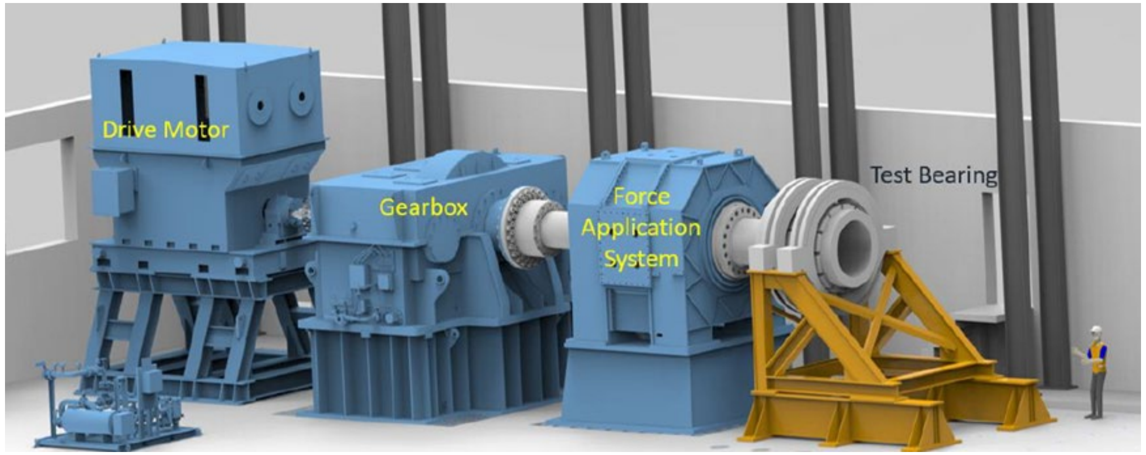
Future Work

- Testing of fluid film main bearings at OREC test facilities
- Collaboration with Greenspur to incorporate an axial flux generator that eliminates the requirements for rare earth metals
- Working alongside magnomatics to assess the suitability of a magnetically geared wind turbine gearbox at the 20MW scale
- Once the 20MW reference wind turbine design is complete, we will explore designing a reference wind turbine beyond the 20MW scale, and explore alternative drivetrain arrangements



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