WEC Development Project

Winter Semester 2025/2026

Final Design Report

Optimus Syria

LOAD AND DYNAMICS

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Date : 27.01.2026

TABLE OF CONTENTS

ABSTRACT

The increasing deployment of large-scale wind turbines has intensified the need for detailed load dynamics analysis to ensure structural integrity, operational safety, and long-term reliability. This project investigates the load dynamics of a 5 MW horizontal-axis wind turbine, with a focus on the origin, transmission, and interaction of dynamic loads acting on the main turbine components. Aerodynamic, gravitational, inertial, and operational loads are examined, along with their influence on the rotor, drivetrain, nacelle, tower, and support structure.

The study considers both normal and transient operating conditions, including rated power operation, start-up, shutdown, and emergency braking events. Particular attention is given to the effects of wind turbulence, wind shear, yaw misalignment, and rotor–tower interaction, as these factors significantly contribute to load variability and fatigue damage in large wind turbines. Furthermore, the role of turbine control strategies, such as collective pitch control and generator torque regulation, is analyzed with respect to their effectiveness in mitigating dynamic loads and stabilizing system response.

The results underline the load dynamics, highlighting the importance of accurate load modelling in accordance with international design standards. A comprehensive understanding of load behavior in a 5 MW turbine provides essential insights for the optimization of structural design and operational strategies. This project supports the development of reliable and efficient utility-scale wind turbines and contributes to the advancement of sustainable wind energy systems.

LIST OF ABBREVIATIONS

ABBREVIATION	*DESCRIPTION*
FAST	Fatigue, Aerodynamics, Structure and Turbulence
lFract	Blade fractions
AeroCent	Aerodynamic centre of airfoil
StrcTwst	Blade structural twist
BMassDen	Blade mass density
FlpStff	Flapwise stiffness
EdgStff	Edgewise stiffness
HtFract	Tower height fractions
MassDen	Mass density
TwFAStif	Tower fore-aft stiffness
TwSSStif	Tower side-side stiffness
VS_RtGnSp	Rated generator speed
VS_RtTq	Rated generator torque
VS_Rgn2K	Generator torque constant
VS_SlPc	Generator slip percentage
WD	Wind direction
DLC	Design Load Case

LIST OF FIGURES

LIST OF TABLES

SUB-TEAM PROJECT ORDER CONTRACT

Project Name: Optimus Syria
Sub-Team: Load and Dynamics
Client: Bakhtyar Karim (Head of Project)
Date: 13.07.2025
Project Number: 01.2025
Team Leader: Md Aman

Problem Description

The Load and Dynamics sub-team is responsible for analyzing and evaluating the structural and aerodynamic loads acting on the wind turbine system. This includes developing and validating load cases, simulating dynamic behavior using aeroelastic models (e.g., OpenFAST, TurbSIM), and supporting other teams (such as Lidar, Rotor Blade, Hub & Shaft, Yaw Bearing & Tower) by providing accurate load information.

Goals

• Define relevant load cases based on IEC standards
• Build and validate dynamic models using OpenFAST or equivalent
• Analyze mechanical and aerodynamic loads across components
• Support interface teams with necessary dynamic data
• Optimize load responses through design iterations

Deliverables

• Load case definitions and documentation
• Simulation results for each critical load case
• Input data for other teams (tower, rotor, drivetrain, etc.)
• Final load summary tables and plots
• Contributions to the final report and final presentation

Milestones & Deadlines

Milestone: Initial preparations
Deadline: 24th Aug – 7th Sep 2025
Comments: Define modeling tools, assign team roles, prepare load case plan

Milestone: Concept freeze
Deadline: 13th Sep 2025
Comments: Confirm load case list and simulation approach

Milestone: Load principal measurements
Deadline: 7th Oct 2025
Comments: Perform preliminary simulations and system dynamic checks

Milestone: Interface freeze
Deadline: 28th Oct 2025
Comments: Share load data with Lidar, Tower, and Blade teams

Milestone: Input freeze for simulation
Deadline: 18th Nov 2025
Comments: Provide validated load profiles for component optimization

Milestone: Design freeze
Deadline: 9th Dec 2025
Comments: Submit final load calculations for structural review

Milestone: Final Report
Deadline: Week 3/2026 (13–17 Jan)
Comments: Submit complete load analysis and method documentation

Milestone: Final Presentation
Deadline: Week 4/2026 (20–24 Jan)
Comments: Present load strategy, challenges, and optimization methods

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Team Leader Duties

- Assign tasks for load simulation, validation, and reporting
- Ensure correct usage of modeling tools (OpenFAST, etc.)
- Collaborate with teams relying on load input (Tower, Lidar, Blade)
- Maintain organized results and simulation files
- Communicate regularly with Head of Project
- Ensure weekly reporting and adherence to milestones

Restrictions

No restrictions have been identified so far. If any arises during the project, they will be
addressed accordingly.

Risk Management

Risk: Inaccurate or unstable simulation results
Action: Perform convergence checks and validate with test cases

Risk: Interface data not compatible with other teams
Action: Standardize input/output format and communicate early

Risk: Time delay in simulation runs
Action: Distribute simulation work and parallelized tasks

Signatures

Role: Head of Project
Name: Bakhtyar Karim

Signature: Bakhtyar Karim

Role: Sub-Team Leader
Name: Md Aman
Signature: Md Aman

1. INTRODUCTION

The present report documents the load analysis carried out for the wind turbine "Optimus Syria 5MW" developed with in the scope of the project. Which is is widely understood across Mashahde regions of Syria. The "5.0" represents the turbine's power rating of 5 MW. The main objective of this work is to determine and evaluate the structural loads acting on the turbine components under operational and extreme conditions in accordance with relevant international standards. The load analysis represents a key step in the overall turbine design process, as it forms the basis for the structural dimensioning of blades, drivetrain, tower, and supporting components.

The report is structured to first describe the turbine model definition used for the load analysis. The turbine model data consist of inputs collected from the different groups involved in the development of the Syria 5.0 project. Parameters that were not available from these sources were either retained as default values from FAST or defined based on engineering assumptions guided by the supervisor's experience.

The analysis modes and the defined Design Load Cases (DLCs) are also presented in this report. The load assumptions adopted for the study are based on the requirements of the DNVGL-ST-0437 standard (Edition 2016) for the certification of wind turbines (DNV-ST-0437 Loads and site conditions for wind turbines n.d.). The selected DLCs, relevant turbine data, and the resulting load analysis outcomes are documented and discussed in detail.

Due to plausibility issues identified in some of the load values, selected values were replaced with statistically representative data based on DNV GL load statistics. The documentation of the overall work process is provided in the associated Load Handbook.

This report presents a comprehensive load analysis of the Syria 5.0 wind turbine. The study begins with a detailed description of the turbine model specifications employed for the load analysis, incorporating data obtained from the various project development teams involved in the Syria 5.0 project. In cases where specific input data were unavailable, default parameters from the FAST software were applied, or engineering assumptions were introduced based on the supervisor's professional experience. The analysis of the defined Design Load Cases (DLCs) is carried out in accordance with the DNVGL-ST-0437 standard (Edition 2016), which provides the basis for wind turbine certification.

The key sections of this report include the definition of the Design Load Cases (DLCs), the turbine input data, and the results of the load analysis. The load calculations were performed

using the MExtreme toolbox, which integrates the open-source wind turbine simulation software FAST developed by the National Renewable Energy Laboratory (NREL) (Jonkman and Buhl 2005).

OpenFAST UPDATION

OpenFAST is a powerful and flexible simulation tool used to analyze the complex dynamic interactions within wind turbines. It accounts for a wide range of physical processes and modeling fidelities, making it a crucial framework for wind energy research and development. At its core, OpenFAST acts as an integrative "glue code" that combines various computational modules to model aerodynamics, control and electrical system dynamics and structural dynamics.

This integration enables detailed simulations of coupled nonlinear aero-hydro-servo-elastic behavior in the time domain, offering insights into the performance and structural integrity of wind turbines under diverse operational conditions. OpenFAST supports the analysis of multiple wind turbine configurations, including two- or three-bladed horizontal-axis rotors, pitch- or stall-regulated systems, rigid or teetering hubs, and upwind or downwind rotors and it can simulate turbines with either lattice or tubular towers, catering to scenarios onshore or offshore, with fixed-bottom or floating substructures.

For this Optimus project we are working with OpenFAST v3.0. But previously in other optimus project they have used Openfast version 3.5 3. We are using OpenFast version 3.0 because this version is LiDAR simulation enabled version so for the Optimus Syria turbine we are developing turbine with a LiDAR Feedforward controller (OpenFAST n.d.).

2. PROJECT ORDER

Project Name:	Optimus Syria	Project Number:	1.0
Sub-Project	Load & Dynamics	Project Manager:	Bakhtyar Karimzade
Customer:	Andreas Manjock	Deputy / SI:	Federico De Mita
Date:	27.01.2026	Team Leader:	Md Aman
Problem Description (Reasons for the project, Strategic Purposes):			
Loads team represents the interface between the designer teams and provides the designer teams with tailored component loads. This requires active communication between load engineers and designers in order to implement latest design modification into the simulation model.			
Project Objectives:			
Load calculation and analysis for the Syrian site turbine			
Build up a new simulation model of the turbine in the aero-elastic tool / Software FAST from NREL 5.0			
Configuration of the operational controller			
Running several loops to establish extreme loads			
Summarizing the final loads in a load report fulfilling certification requirements according to DNVGL-ST-0437 / IEC 61400-1			
Compilation of a manual about Software			
Organization (Committees, People, Responsibilities):			
Steering Committee:	Andreas Manjock, Bakhtyar Karimzade, Federico De Mita		
Project Team:	3rd Semester 'Masters Wind Engineering' 2025/26		
Team Leaders:	Md Aman		
Sub-Project Team:	Md Aman, Arham Memon, Paresh Dulabhai Nakum		
Dates, Milestones			
Start of Project:	23.09.2025		
First Load estimation based on statistics	05.10.2025		
Turbsim and OpenFAST Introduction	10.10.2025		
First load simulation and Design load cases implementation	21.10.2025		
Optimization and further loops	22.10.2025 - 15.12.2025		
MExtremes Imtroduction	19.12.2025		
Last design loop	04.01.2026		
Report submission	27.01.2026		
Final Presentation / End of Project	02.02.2026		
Reporting			
Timeline of the semester			
Team Leader: Md Aman	Head of Project: Bakhtyar Karimzada		
Date: 27.01.2026	Date: 27.01.2026		
Signature: Md Aman	Signature: Bakhtyar Karimzada		

Figure 1 Project Order

3. ENVIRONMENTAL CONDITIONS

The wind turbine is proposed to be installed in the Mashahde region of Syria, an area characterized by a prevailing north–northwest wind direction that defines the dominant wind behavior of the region.

3.1 LOCATION

The wind turbine is proposed to be installed at **34°40′22″ N, 36°35′59″ E** in the Mashahde region of Syria. The site is characterized by open agricultural land with limited surrounding infrastructure, thereby reducing environmental and social constraints. Wind resource evaluations have identified the area as having sufficient wind potential for effective power generation.
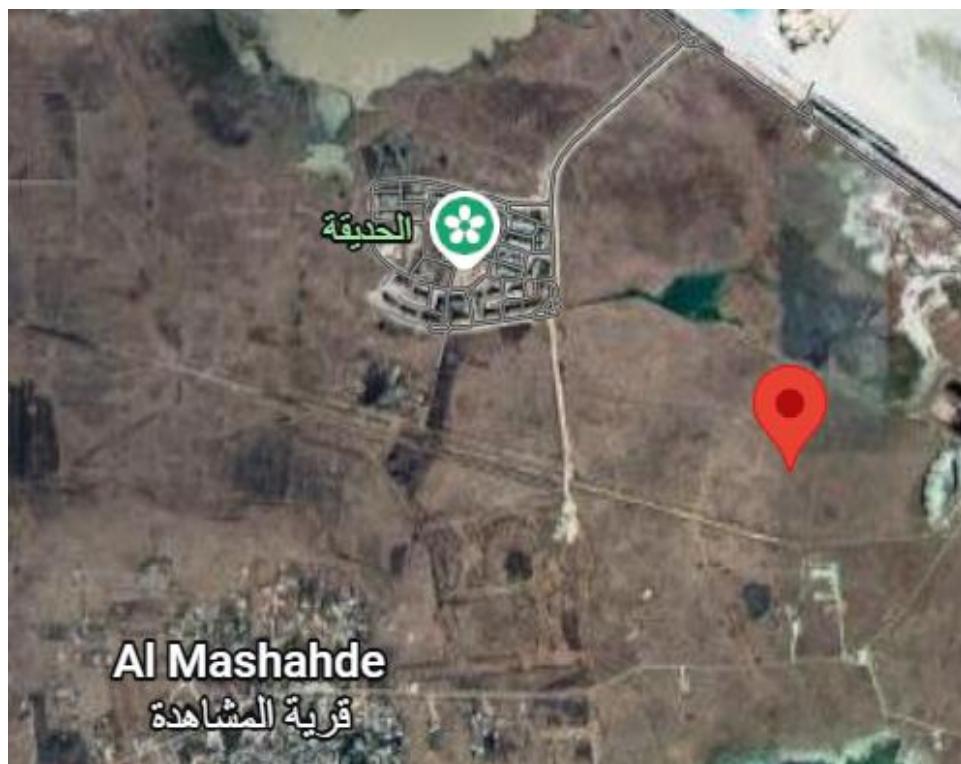
Figure 2Wind Turbine Location

Figure 2 Wind Turibne Location (Google Maps n.d.)

3.2 WIND CONDITIONS

Here in this section, you can find the environmental values for our specific site data. These values at a hup height of

Characteristics turbulence intensity	0.16 (reference value)
Average wind speed	8.49 m/s
Reference wind speed	34 m/s
Mean flow inclination	0
50-year extreme wind speed (10 minutes)	42.5 m/s
Annual extreme wind speed	34 m/s

Table 1 Other Environmental Conditions

Average temperature range	24 °C
Temperature range	-2 to 38 °C
Relative humidity of the air (Average)	66 %
Air density	1.017 kg/m^3
Solar radiation / UV index max	7

Table 2 Wind Conditions at Our Location

4. REQUIREMENTS AND DEFINITIONS OF THE GUIDELINES
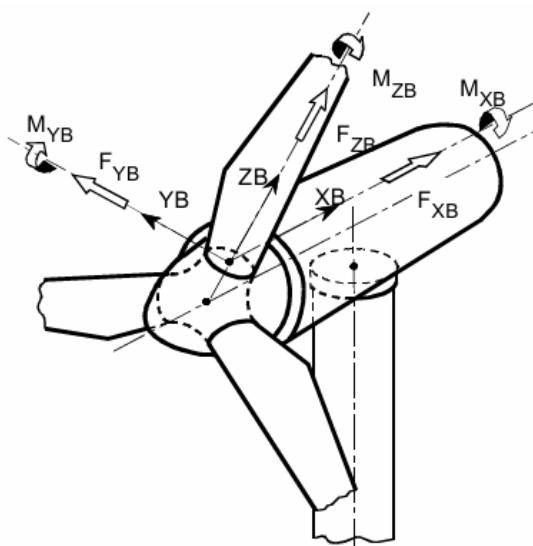
To advance the Optimus Syria 5.0 project toward B-Certification, the **DNV GL Guideline (Version 2016)** was adopted as the primary reference framework. As the world's leading certification body for wind turbines, DNV GL has established comprehensive guidelines for the certification of wind turbine systems, including standardized definitions of coordinate systems, which were followed throughout this project.

4.1 DNV GL COORDINATE SYSTEMS

To avoid mistakes during the project regarding forces and moments we defined the DNV GL coordinate systems as the determining ones (DNV-ST-0437 Loads and site conditions for wind turbines n.d.). Therefore, we have calculated all loads corresponding to these coordinate systems and communicated these to the other groups, so that they can transfer these loads int their needed coordinate systems if it is needed.

BLADE COORDINATE SYSTEM

The blade coordinate system has its origin at the blade root and rotates with the rotor. Its orientation to the rotor hub is fixed.
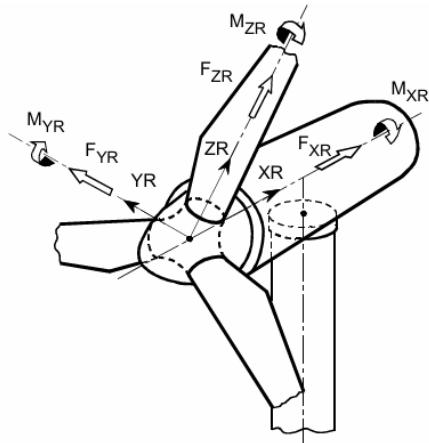
XB   in direction of the rotor axis
ZB   radially
YB   so that XB, YB, ZB rotate clockwise

Figure 3 Blade coordinate system

ROTOR COORDINATE SYSTEM

The rotor coordinate system has its origin at the rotor centre (or any other position on the rotor axis, e.g. hub flange or main bearing) and rotates with the rotor.
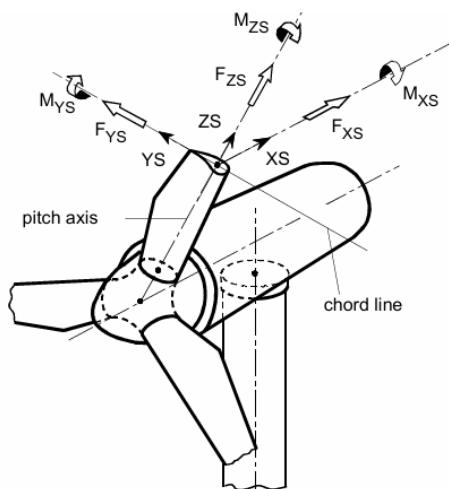
XR in direction of the rotor axis
ZR radially, orientated to rotor blade 1
    and perpendicular to XR
YR perpendicular to XR,
    so that XR, YR, ZR rotate clockwise

Figure 4 Rotor coordinate system

CHORD COORDINATE SYSTEM

The chord coordinate system has its origin at the intersection of the corresponding chord line and the blade pitch axis. It rotates with the rotor and the local pitch angle adjustment.

YS in direction of the chord, orientated to
    blade trailing edge
ZS in direction of the blade pitch axis
XS perpendicular to the chord, so that
    XS, YS, ZS rotate clockwise

Figure 5 Chord Coordinate System

HUB COORDINATE SYSTEM

The hub coordinate system has its origin at the rotor centre (or any other position on the rotor axis, e.g. hub flange or main bearing) and does not rotate with the rotor.

XN in direction of the rotor axis
ZN upwards perpendicular to XN
YN horizontally sideways, so that XN, YN, ZN
      rotate clockwise
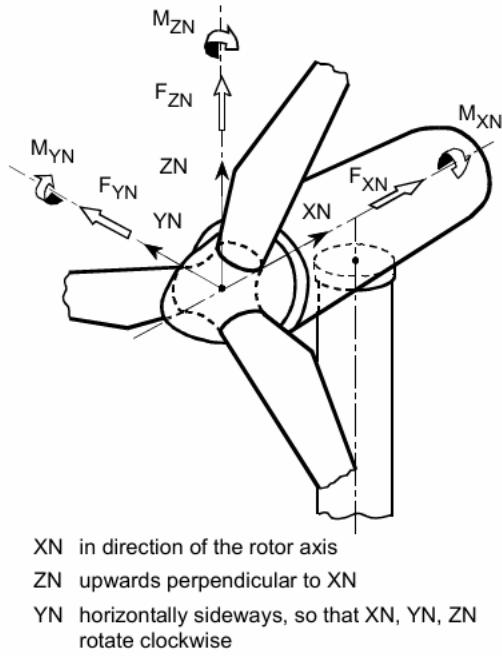
Figure 6 Hub Coordinate System

YAW BEARING COORDINATE SYSTEM

The yaw bearing coordinate system has its origin at the intersection of the tower axis and the upper edge of the yaw bearing and rotates with the nacelle.

XK horizontal in direction of the rotor axis,
      fixed to nacelle
ZK vertically upwards
YK horizontally sideways, so that XK, YK, ZK
      rotate clockwise
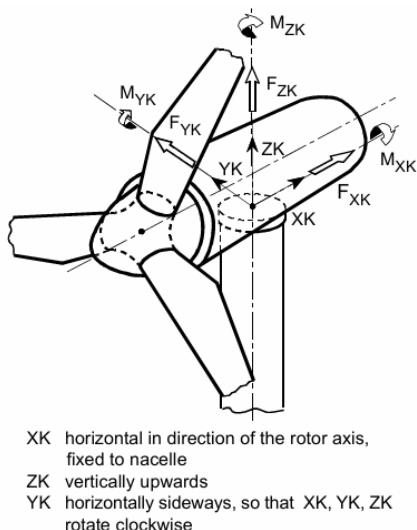
Figure 7 Yaw Bearing Cordinate System

TOWER COORDINATE SYSTEM

This coordinate system has its origin between mudline/respective upper edge of foundation for onshore wind turbines and tower top at the intersection with the support system axis and does not rotate with the nacelle. The orientation corresponds with the tower top coordinate system. In addition, other locations on the support system axis are also possible.

XF horizontal
ZF vertically upwards in direction of the tower axis
YF horizontally sideways, so that XF, YF, ZF
      rotate clockwise
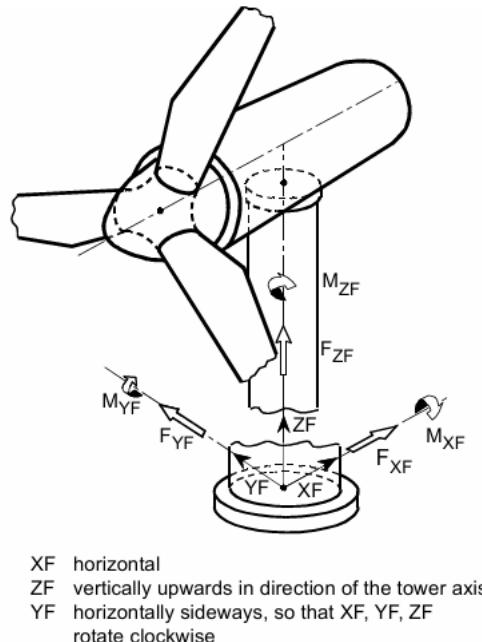
Figure 8 Tower Coordinate System

4.2 STANDARDS

The load calculation is based on the Det Norske Veritas (DNV) Standard DNVGL-ST-0437 "Loads and site conditions for wind turbines" version 2016 (DNV-ST-0437 Loads and site conditions for wind turbines n.d.). Unlike the International Electrotechnical Commission (IEC) standard, the DNV GL standard was used because it is available as an open source.

4.3 DESIGN LOAD CASE DESCRIPTION

Beneath the design load cases (DLC's) will be described. They are given and defined by the DNV GL Guideline (DNV-ST-0437 Loads and site conditions for wind turbines n.d.) and just to point out in our project Syria5.0 we did work only on the Ultimate loads.

Design Situation	DLC	Wind Conditions	Other Conditions	Type of Analysis	Partial Safety Factors
1) Power Production	1.1	NTM Vin < Vhub < Vout	For extrapolation of extreme loads (offshore – only RNA)	U	N (1.25)
	1.2	NTM Vin < Vhub < Vout		F/U	F/N
	1.3	ETM Vin < Vhub < Vout		U	N
	1.4	ECD Vhub = Vr – 2 m/s, Vr, Vr + 2 m/s		U	N
	1.5	EWS Vin < Vhub < Vout		U	N
	1.6	NTM Vin < Vhub < Vout		-	N
	1.7	NTM Vin < Vhub < Vout	Ice formation	F/U	F/N
2) Power production + occurance of fault	2.1	NTM Vin < Vhub < Vout	Normal control system fault or primary layer control function fault	U	N
	2.2	NTM Vin < Vhub < Vout	Abnormal control system fault or secondary layer protection function fault	U	A
3) Start up	3.1	NWP Vin < Vhub < Vout		F/U	F/N
	3.2	EOG Vhub = Vin, Vr ± 2 m/s, and Vout or ETM Vin < Vhub < Vout	The timing of the gust and the start-up event chosen for minimum 4 distinct points	U	N
4) Normal shutdown	4.1	NWP Vin < Vhub < Vout		F/U	F/N
	4.2	EOG Vhub = Vr ± 2 m/s and Vout or ETM Vin < Vhub < Vout	The timing of the gust and the shutdown event chosen for minimum 6 distinct points	U	N
5) Emergency stop	5.1	NTM Vhub = Vr ± 2 m/s and Vout	Azimuth position at the time of the emergency stop shall be randomly selected	U	N
6) Parked (standing still or idling)	6.1	EWM Vhub = Vref	Yaw misalignment of ±8 deg Possible yaw slippage	U	N
	6.2	EWM Vhub = Vref	Loss of electrical network Yaw misalignment of ±180°	U	A
	6.3	EWM Vhub = V1	Extreme yaw misalignment Yaw misalignment of ±20 deg	U	N
	6.4	NTM Vhub < Vin and Vout < Vhub < 0,7 Vref	Investigation of natural frequencies during idling	F/U	F/N
7) Parked and fault conditions:	7.1	EWM Vhub = V1	Fault that produces deviations from the normal turbine behaviour while parked; including loss of electrical network	U	A

Figure 9 Design Load Cases

Detailed DLC's

Load Case:		DLC 1.2	
Operating Condition:		Power Production	
External condition:		Normal turbulence model	
Limit state:		Ultimate limit state	
Description of Simulation			
Load Case	**Wind speeds**	**Description**	**Wind direction**
1.2	3:2:25	Normal Power Production	0
Comments			
Wind Power Law Shear Exponent:	0.2		
Wind Slope:	0	°	
Duration of simulation:	600	S	

Table 3 DLC 1.2

Load Case:		DLC 4.2	
Operating Condition:		Normal Shutdown	
External condition:		Normal turbulence model	
Limit state:		Ultimate limit state	
Description of Simulation			
Load Case	**Wind speeds**	**Description**	**Wind direction**
4.2	3:2:25	Normal Shutdown	0
Comments			
Wind Power Law Shear Exponent:	0.2		
Wind Slope:	0	°	
Duration of simulation:	400	Seconds	

Table 4 DLC 4.2

Load Case:		DLC 5.1	
Operating Condition:		Emergency Stop	
External condition:		Normal turbulent model	
Limit state:		Ultimate limit state	
Description of Simulation			
Load Case	**Wind speeds**	**Description**	**Wind direction**
5.1	Vr ± 2 m/s , 25m/s	Emergency Stop	0
Comments			
Wind Power Law Shear Exponent:	0.2		
Wind Slope:	0	°	
Duration of simulation:	400	Seconds	

Table 5 DLC 5.1

Load Case:		DLC 6.1	
Operating Condition:		Parked (standing still or idling)	
External condition:		Extreme wind model (50-years)	
Limit state:		Ultimate limit state	
Description of Simulation			
Load Case	**Wind speeds**	**Description**	**Wind direction**
6.1	42.5 m/s	Idling / Parked	0
Comments			
Wind Power Law Shear Exponent:	0.2		
Wind Slope:	0	°	
Duration of simulation:	600	Seconds	

Table 6 DLC 6.1

Load Case:		DLC 7.1	
Operating Condition:		Parked and fault conditions	
External condition:		Extreme wind model (01-year)	
Limit state:		Ultimate limit state	
Description of Simulation			
Load Case	**Wind speeds**	**Description**	**Wind direction**
7.1	34 m/s	Parked + fault	0
Comments			
Wind Power Law Shear Exponent:	0.2		
Wind Slope:	0	°	
Duration of simulation:	600	Seconds	

Table 7DLC 7.1

5. MAIN FACTS ABOUT SYRIA 5.0MW WT

The following are the main facts about the configuration of the student project Optimus Syria 5.0.

Description	Value
Rated power	5.0 MW
Rotor diameter	160
Hub height	100
Turbine class	II-A
Environmental temperature range	-2 to 38° C
Design lifetime	20 years
Rated wind speed, Vrated	10.86 m/s
Cut-in wind speed, Vcut-in	3 m/s
Cut-out wind speed, Vcut-out	25 m/s

Table 8 Optimus Shakti Main Facts

6. TURBINE MODEL PARAMETERS

In the following sections the different groups of components of the Optimus Syria 5.0 are described.

6.1 ROTOR BLADES AND AERODYNAMICS
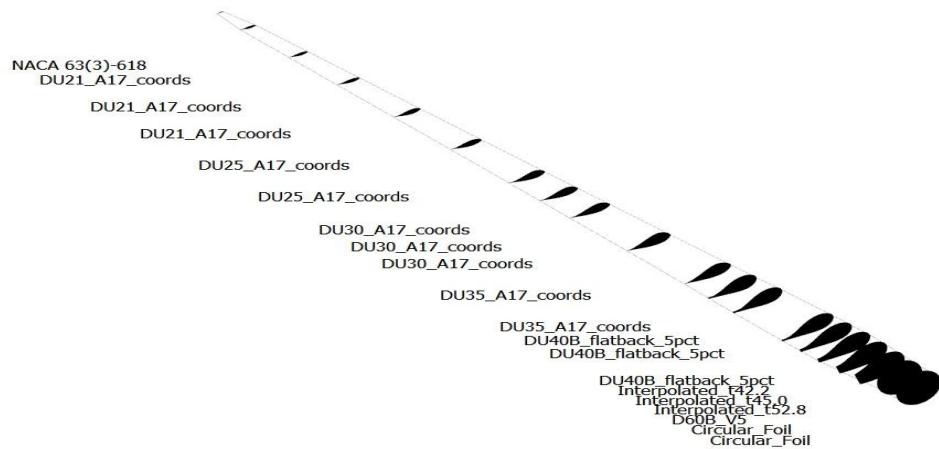
Figure 10 Aero-Foils Distribution Among Blades

A total of 11 Aerofoils is being used in this project for designing the blade all airfoils data is available in Aero data folder. In the structure data fold the structural property of blade is available. Three identical rotor blades, each with a length of 87 meters and an approximate mass of 25 tons, are attached to the hub. The blades are manufactured from a combination of advanced materials, including glass fiber–reinforced polymer (GFRP), carbon fiber–reinforced polymer (CFRP), and lightweight core materials such as balsa wood and foam. The structural integrity and stability of the blades are primarily ensured by key components such as the spar caps and shear webs.

Parameter	Value
Blade Length in m	80 m
Cone Angle in degree	4°
Single Blade mass in kg	48869 kg
Material	N/A
Rated tip Speed in m/s	85 m/s

Table 9 Blades Properties
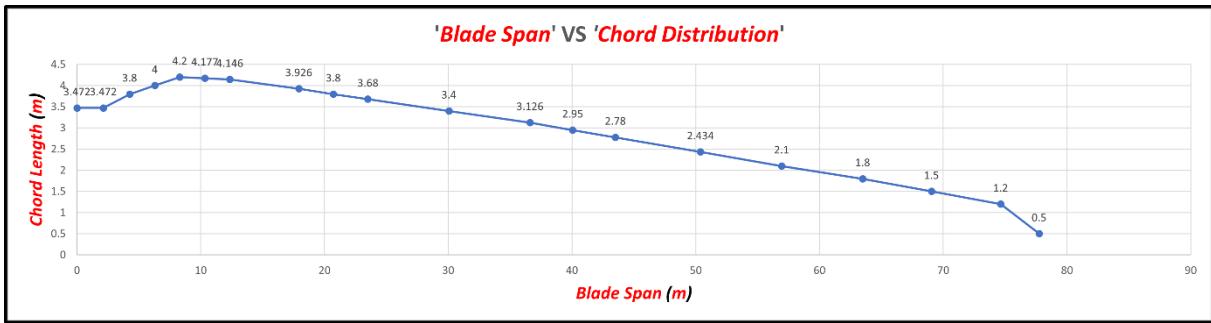
Figure 11 Blade Span & Chord Distribution

6.2 DRIVETRAIN

The gearbox is supported using a three-point suspension arrangement incorporating main shaft bearings, which represents one of the most reliable and commonly adopted drivetrain configurations in modern wind turbine systems.

Parameter	Value	Unit
Gearbox efficiency	97.5	%
Gearbox ratio	120	-
Drivetrain torsional spring	867637000	N-m/rad
Drivetrain torsional damper	6215000	N-m/(rad/s)

Table 10 Main Properties of the Drive Train

6.3 TOWER
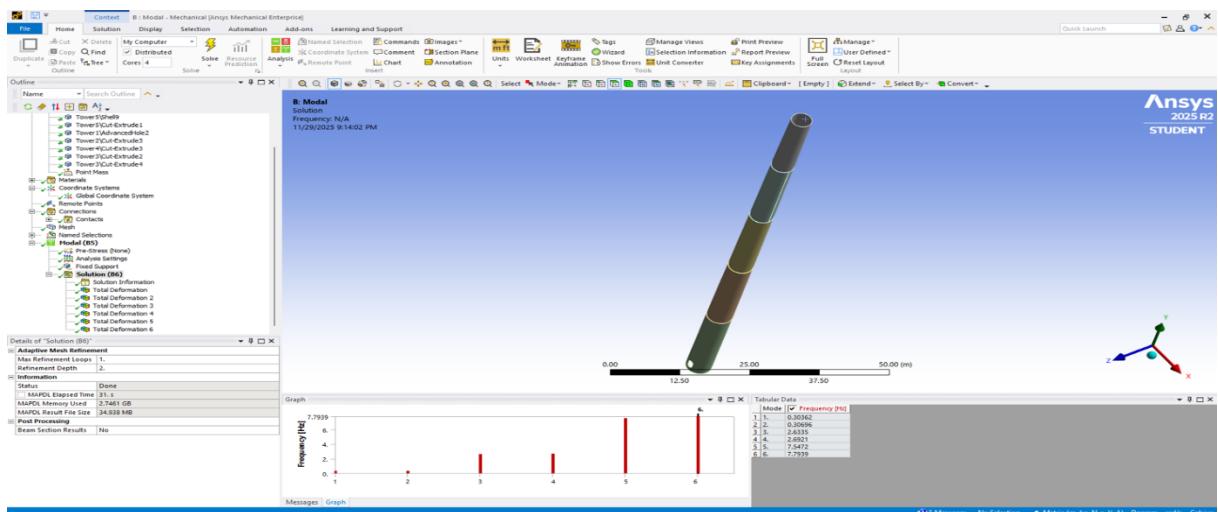
Figure 12 Calculation of the Eigen Frequency using Ansys of Tower

An own tower design exists for the load calculations. The structural properties and the outer diameter needed for the tower drag model with a cD = The tower height is htower= m. The structural properties of tower is available in the below table.

A foundation model was not considered in the load calculation. The tower is fixed rigidly at the ground.

Parameter	Value
Tower height in m	100 m
Sectional Geometry	Conical
Base Outer Diameter in m	4.8 m
Tower Top Outer Diameter in m	3.8 m
Base Thickness in m	0.8 m
Top Thickness in m	0.4 m

Table 11 Tower Parameters

HtFract	TMassDen	TwFAStif	TwSSStif
(-)	(kg/m)	(Nm^2)	(Nm^2)
0.000000000	6436.03557075	4.85E+11	4.85E+11
0.204081633	4695.55004376	3.56E+11	3.56E+11
0.408163265	3940.29153488	2.75E+11	2.75E+11
0.612244898	2697.35181742	1.73E+11	1.73E+11
0.816326531	2266.78664823	1.32E+11	1.32E+11
1.000000000	2049.76542772	9.78E+10	9.78E+10

Table 12 Distributed Tower Properties

6.4 MASS AND INERTIA

The values for the mass and inertia are based on the final design for the Optimus Syria turbine. The masses of the nacelle have a considerable influence on resulting eigenfrequencies and therefore on the final loads. These values are given in the ElastoDyn file.

Description	Value	
Hub mass	72434.28	kg
Nacelle mass	129790.8	kg
Hub inertia about rotor axis	115926.0	kg.m2
Generator Inertia about High-Speed Shaft	2977.0	kg.m2
Nacelle inertia about yaw axis	2.60789E+06	kg.m2

Table 13 Masses & Inertias

CONTROLLER

For this Optimus Syria project we have a three loop of controller, first one was NREL DISCON controller which was applicable for OpenFAST version 3.5 3, after that for second loop ROSCO feedback controller for OpenFAST version 3.0 and in the last loop for this project have LiDAR WRAPPER as a controller. It is a feedforward controller, which works with ROSCO controller. Which shows an estimate of 6-9% optimization.

We have made a comparison at the normal turbulent model DLC 1.2 wind speed of 25 m/s between those three controllers regarding the pitch behaviour and the corresponding power output. We found that LiDAR WRAPPER controller is more optimized in comparison with other two, which is demonstrated in the below figure.
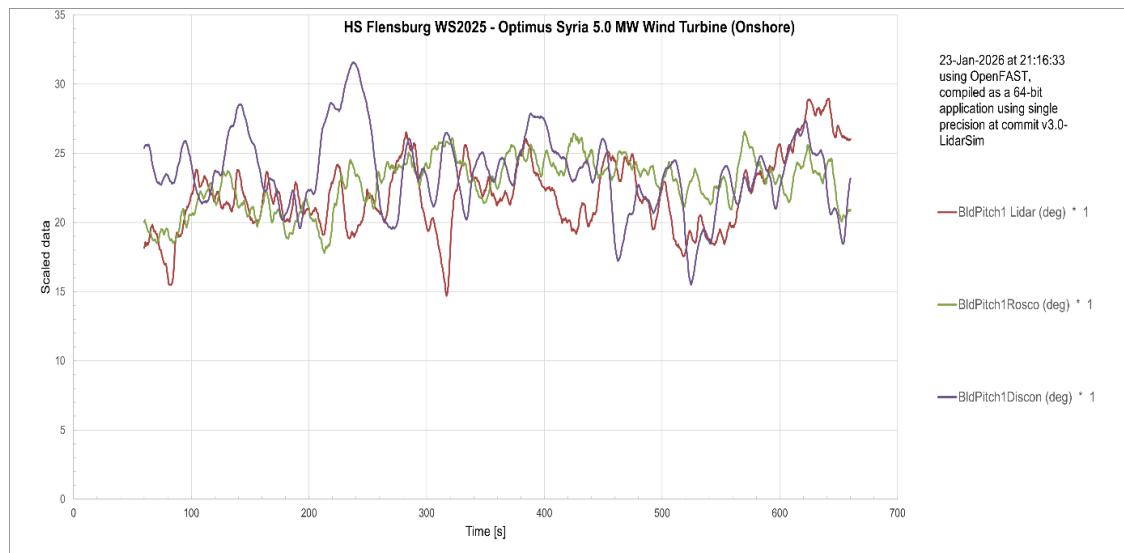
Figure 13 Comparisons among Blade Pitching
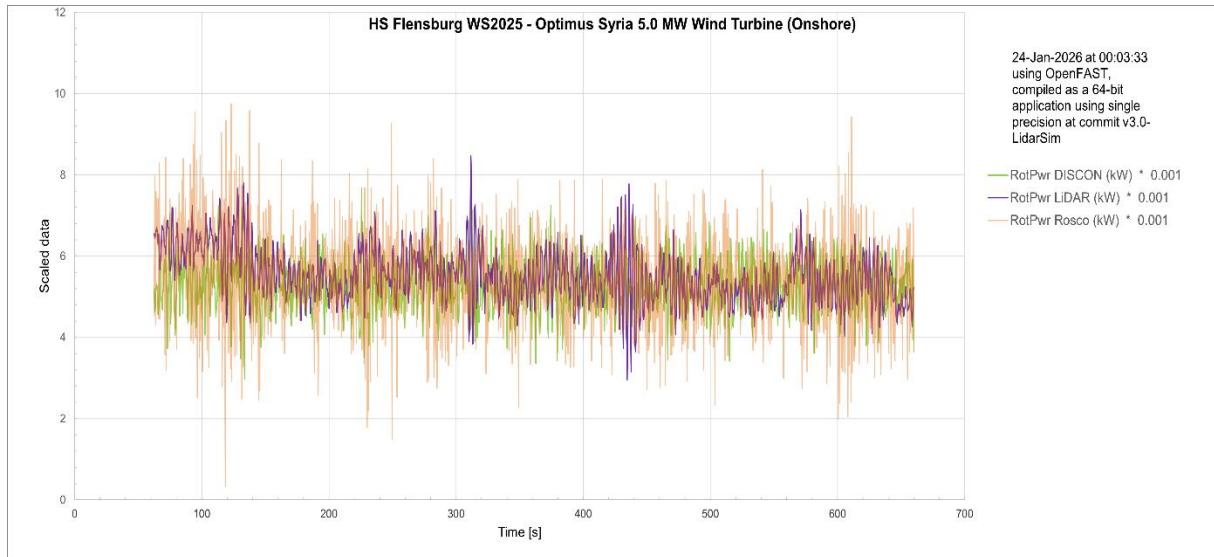
Figure 14 Comparisons among Rotor Power in KW

7. SIMULATIONS

For the load calculations detailed in this document, multiple software tools were utilized. The core of the aero-servo-elastic analysis was conducted using OpenFAST, version 3.5.3, developed by the National Renewable Energy Laboratory (NREL) (Jonkman and Buhl 2005). The turbine components and their associated parameters, discussed later in this document, were modeled using a set of OpenFAST reference input files. OpenFAST, along with its modules, served as the backbone for the simulation processes. The workflow for the load calculation includes three key steps: pre-processing, processing, and post processing, all of which are explained in detail in the Optimus Syria5.0 manual. This year's approach relied on a comprehensive suite of open-source tools provided by NREL, complemented by widely used applications like MS Excel, MATLAB, and Python. Specifically:

- Pre-and post-processing: NREL's tools, along with MExtremes, were used for analyzing and generating extreme-event tables across various output regions.
- Processing: OpenFAST handled the core simulations and computations.
- Post-processing: Additional analysis was carried out using Excel files to process and interpret primary and output data. This integrated toolset provides a robust and systematic framework for accurate and detailed load calculations.

The single steps, pre-processing, processing, and post-processing, are described in detail in the Optimus Syria Manual as a standard simulation approach. Nonetheless, it depicts a consolidated overview of the steps, as well as the tools and modules associated with them. This year all the software used is an extensive open-source software toolbox provided by NREL in conjunction with Excel. In general, the tools used can be divided into NREL Tools for pre- and post-processing, OpenFAST and its modules for processing, additional Excel files for post-processing the files, primarily ASCII files, and output files and To keep this report short and clear, the steps of the simulation with FAST and Mextreme (MathWorks - Maker of MATLAB and Simulink n.d.) are documented in the handbook of the Loads and Dynamics Team of the Syria5.0.

8. RESULTS OF SIMULATIONS

To present the simulation results, which is only the Extreme Loads, we mainly focused on four regions:

- Blade root i.e. flapwise & Edgewise
- Hub center
- Tower top
- Tower Base

8.1 EXTREME LOADS

The maximum and minimum value of each load along with its contemporaneous value associated with the load case is reported based on recommended presentation of the calculation results of extreme loads written in the GL guidelines. As described in guidelines for our calculation we have to conclude safety factor for ultimate loads to analyze of ultimate strength if the load of different causes can be determined independently of each other The parcel safety factor for the load cell have the minimum values given as per guidelines of DNV.

Summary of the most important extreme load values:

Extreme Load	Optimus Syria (kN-m)
Blade Edge Moment	40,411
Blade Flap Moment	32,168
Rotor Shaft	33,980
Yaw Bearing / Tower Top	40,001
Tower Bottom	299,660

Table 14 Extreme Load Values

Parameter	Type	File Name	DLC Name	Calculated Extreme	TipClrnc1 (m)	TipClrnc2 (m)	TipClrnc3 (m)	TTDspFA (m)	TTDspSS (m)	Time (sec)	Wind1VelX (m/sec)
TipClrnc1	Minimum	.\Data\DLC4.2\DLC4.2_11_4.out	DLC_4.2	2.442E+000	2.442E+000	8.021E+001	8.002E+001	4.435E-001	-7.696E-002	7.585E+001	5.253E+000
TipClrnc1	Maximum	.\Data\DLC4.2\DLC4.2_15_5.out	DLC_4.2	8.283E+001	8.283E+001	7.084E+001	6.899E+001	-7.801E-001	7.539E-002	2.096E+002	1.514E+001
TipClrnc2	Minimum	.\Data\DLC5.1\DLC5.1_8_2.out	DLC_5.1	2.714E+000	7.978E+001	2.714E+000	7.995E+001	7.682E-001	-1.198E-001	1.048E+002	7.840E+000
TipClrnc2	Maximum	.\Data\DLC4.2\DLC4.2_8_6.out	DLC_4.2	8.281E+001	6.742E+001	8.281E+001	7.148E+001	-6.047E-001	3.453E-002	2.194E+002	9.050E+000
TipClrnc3	Minimum	.\Data\DLC4.2\DLC4.2_10_1.out	DLC_4.2	2.111E+000	7.997E+001	8.035E+001	2.111E+000	6.517E-001	-8.610E-002	1.444E+002	1.035E+001
TipClrnc3	Maximum	.\Data\DLC4.2\DLC4.2_13_1.out	DLC_4.2	8.282E+001	6.484E+001	7.336E+001	8.282E+001	-5.739E-001	6.667E-002	2.104E+002	1.252E+001
TTDspFA	Minimum	.\Data\DLC4.2\DLC4.2_5_6.out	DLC_4.2	-1.119E+000	7.483E+001	6.498E+001	8.249E+001	-1.119E+000	1.948E-001	2.249E+002	1.107E+001
TTDspFA	Maximum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	1.417E+000	8.162E+001	1.603E+001	8.041E+001	1.417E+000	-1.485E-001	1.570E+002	4.493E+001
TTDspSS	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-2.454E+000	8.176E+001	6.990E+001	6.721E+001	5.491E-001	-2.454E+000	4.564E+002	5.030E+001
TTDspSS	Maximum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	2.110E+000	8.052E+001	5.005E+001	8.078E+001	3.919E-001	2.110E+000	6.023E+002	4.729E+001

Table 15 Tip Clearance & Deflection

Parameter	Type	File Name	DLC Name	Calculated Extreme	LSShftFxa (kN)	LSShftFya (kN)	LSShftFza (kN)	LSSTipMxa (kN-m)	LSSTipMya (kN-m)	LSSTipMza (kN-m)	LSShftFxy1 (kN)	LSShftMxy1 (kN-m)	Time (sec)	Wind1VelX (m/sec)
LSShftFxa	Minimum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	-1.258E+003	-1.258E+003	-2.630E+003	-1.396E+003	-9.470E+002	4.572E+003	-2.326E+003	2.915E+003	4.669E+003	3.320E+002	5.214E+001
LSShftFxa	Maximum	.\Data\DLC1.2\DLC1.2_9_6.out	DLC_1.2	1.613E+003	1.613E+003	-2.516E+003	-2.309E+002	6.836E+003	2.677E+003	8.937E+002	2.989E+003	7.342E+003	5.159E+002	9.102E+000
LSShftFya	Minimum	.\Data\DLC4.2\DLC4.2_17_2.out	DLC_4.2	-3.463E+003	2.275E+002	-3.463E+003	-5.030E+002	-2.726E+003	-1.528E+004	-3.389E+003	3.470E+003	1.552E+004	2.296E+002	1.587E+001
LSShftFya	Maximum	.\Data\DLC4.2\DLC4.2_15_1.out	DLC_4.2	3.627E+003	1.252E+002	3.627E+003	-4.389E+002	-3.474E+003	8.030E+003	-1.324E+004	3.630E+003	8.749E+003	2.157E+002	2.060E+001
LSShftFza	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.632E+003	3.726E+002	-4.437E+002	-3.632E+003	4.682E+003	-3.128E+004	-1.624E+004	5.794E+002	3.163E+004	2.134E+002	2.299E+001
LSShftFza	Maximum	.\Data\DLC4.2\DLC4.2_17_4.out	DLC_4.2	3.684E+003	2.527E+002	-7.529E+002	3.684E+003	-3.460E+003	-6.815E+003	2.422E+004	7.942E+002	7.643E+003	2.270E+002	1.799E+001
LSSTipMxa	Minimum	.\Data\DLC4.2\DLC4.2_21_3.out	DLC_4.2	-2.780E+004	-3.276E+002	3.514E+002	-2.406E+003	-2.780E+004	-1.598E+004	5.503E+003	4.805E+002	3.206E+004	2.134E+002	1.477E+001
LSSTipMxa	Maximum	.\Data\DLC4.2\DLC4.2_21_3.out	DLC_4.2	2.514E+004	-2.372E+002	2.202E+003	-1.292E+003	2.514E+004	1.001E+004	-1.391E+003	2.215E+003	2.706E+004	2.126E+002	1.560E+001
LSSTipMya	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.244E+004	3.872E+002	-2.759E+002	-3.561E+003	3.587E+003	-3.244E+004	-2.087E+004	4.754E+002	3.264E+004	2.134E+002	2.472E+001
LSSTipMya	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.398E+004	-1.538E+002	3.248E+003	5.994E+002	-9.844E+003	3.398E+004	7.900E+003	3.252E+003	3.538E+004	2.116E+002	2.392E+001
LSSTipMza	Minimum	.\Data\DLC4.2\DLC4.2_25_3.out	DLC_4.2	-3.254E+004	4.932E+002	2.634E+003	-3.005E+002	-4.343E+003	-1.368E+003	-3.254E+004	2.680E+003	4.553E+003	2.336E+002	2.585E+001
LSSTipMza	Maximum	.\Data\DLC4.2\DLC4.2_17_4.out	DLC_4.2	3.390E+004	2.589E+002	-2.512E+003	2.255E+003	-5.453E+003	1.135E+003	3.390E+004	2.526E+003	5.570E+003	2.257E+002	2.258E+001
LSShftFxy1	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	4.607E+000	3.758E+000	-2.665E+000	-2.639E+003	-4.729E+003	-1.428E+004	2.738E+003	4.607E+000	1.505E+004	2.690E+002	4.050E+001
LSShftFxy1	Maximum	.\Data\DLC4.2\DLC4.2_15_1.out	DLC_4.2	3.630E+003	1.252E+002	3.627E+003	-4.389E+002	-3.474E+003	8.030E+003	-1.324E+004	3.630E+003	8.749E+003	2.157E+002	2.060E+001
LSShftMxy1	Minimum	.\Data\DLC4.2\DLC4.2_3_2.out	DLC_4.2	2.723E+000	2.047E+002	-2.651E+003	-7.977E+001	-1.530E+000	-2.253E+000	2.734E+003	2.659E+003	2.723E+000	4.118E+002	3.679E+000
LSShftMxy1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.538E+004	-1.538E+002	3.248E+003	5.994E+002	-9.844E+003	3.398E+004	7.900E+003	3.252E+003	3.538E+004	2.116E+002	2.392E+001

Table 16 Rotor Shaft

Parameter	Type	File Name	DLC Name	Calculated Extreme	RootFxb1 (kN)	RootFyb1 (kN)	RootFzb1 (kN)	RootMxb1 (kN m)	RootMyb1 (kN m)	RootMzb1 (kN m)	RootFxyb1 (kN)	RootMxyb1 (kN-m)	Time (sec)	Wind1VelX (m/sec)
RootFxb1	Minimum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	-1.100E+003	-1.100E+003	-7.009E+001	-2.214E+002	1.354E+003	-3.474E+004	8.374E+002	1.102E+003	3.476E+004	2.669E+002	4.240E+001
RootFxb1	Maximum	.\Data\DLC6.1\DLC6.1_3.out	DLC_6.1	1.153E+003	1.153E+003	-4.323E+002	-1.913E+002	1.232E+004	3.505E+004	-1.041E+003	1.231E+003	3.715E+004	4.494E+002	5.098E+001
RootFyb1	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-1.238E+003	4.766E+002	-1.238E+003	1.723E+003	4.116E+004	3.587E+003	4.203E+002	1.327E+003	4.132E+004	2.086E+002	2.765E+001
RootFyb1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	1.267E+003	-3.645E+002	1.267E+003	1.254E+003	-4.577E+004	-9.474E+003	-1.558E+003	1.318E+003	4.674E+004	2.116E+002	2.244E+001
RootFzb1	Minimum	.\Data\DLC6.1\DLC6.1_3.out	DLC_6.1	-5.890E+002	-6.387E+001	-4.720E+001	-5.890E+002	2.614E+003	3.980E+003	-8.809E+001	7.941E+001	4.761E+003	2.772E+002	4.089E+001
RootFzb1	Maximum	.\Data\DLC1.2\DLC1.2_25_2.out	DLC_1.2	3.252E+003	5.399E+002	1.174E+002	3.252E+003	-4.637E+003	1.187E+004	-1.354E+002	5.525E+002	1.274E+004	1.421E+002	3.069E+001
RootMxb1	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-4.577E+004	-3.645E+002	1.267E+003	1.254E+003	-4.577E+004	-9.474E+003	-1.558E+003	1.318E+003	4.674E+004	2.116E+002	2.244E+001
RootMxb1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	4.243E+004	4.822E+002	-1.134E+003	7.926E+002	4.243E+004	6.861E+003	-1.600E+002	1.232E+003	4.298E+004	2.147E+002	2.323E+001
RootMyb1	Minimum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	-3.506E+004	-1.098E+003	-8.428E+001	-2.788E+002	2.388E+003	-3.506E+004	1.010E+003	1.102E+003	3.514E+004	2.675E+002	3.932E+001
RootMyb1	Maximum	.\Data\DLC6.1\DLC6.1_3.out	DLC_6.1	3.517E+004	1.118E+003	-2.232E+002	-2.303E+002	6.604E+003	3.517E+004	-6.845E+002	1.140E+003	3.578E+004	4.047E+002	4.835E+001
RootMzb1	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-1.665E+003	7.169E+002	-6.865E+002	-5.756E+002	2.098E+004	2.419E+004	-1.665E+003	9.925E+002	3.202E+004	4.560E+002	4.316E+001
RootMzb1	Maximum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	1.594E+003	-8.232E+002	-1.816E+002	-5.435E+002	6.998E+003	-2.835E+004	1.594E+003	8.430E+002	2.920E+004	6.167E+002	5.357E+001
RootFxyb1	Minimum	.\Data\DLC4.2\DLC4.2_15_1.out	DLC_4.2	4.935E-001	-2.782E-001	-4.076E-001	-5.690E+002	1.702E+002	7.119E+002	-5.500E+000	4.935E-001	7.319E+002	4.515E+002	1.497E+001
RootFxyb1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	1.327E+003	4.766E+002	-1.238E+003	1.723E+003	4.116E+004	3.587E+003	4.203E+002	1.327E+003	4.132E+004	2.086E+002	2.765E+001
RootMxyb1	Minimum	.\Data\DLC4.2\DLC4.2_17_3.out	DLC_4.2	1.008E+001	-4.734E-001	7.790E+000	-5.659E+002	1.006E+001	7.430E-001	-3.020E+000	7.804E+000	1.008E+001	3.515E+002	1.754E+001
RootMxyb1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	4.674E+004	-3.645E+002	1.267E+003	1.254E+003	-4.577E+004	-9.474E+003	-1.558E+003	1.318E+003	4.674E+004	2.116E+002	2.244E+001

Table 17 Blade Root

Parameter	Type	File Name	DLC Name	Calculated Extreme	YawBrFxp (kN)	YawBrFyp (kN)	YawBrFzp (kN)	YawBrMxp (kN m)	YawBrMyp (kN m)	YawBrMzp (kN m)	Time (sec)	Wind1VelX (m/sec)
YawBrFxp	Minimum	.\Data\DLC5.1\DLC5.1_8_6.out	DLC_5.1	-1.324E+003	-1.324E+003	-9.196E+001	-4.253E+003	-8.502E+003	-1.051E+004	-9.960E+003	2.081E+002	7.595E+000
YawBrFxp	Maximum	.\Data\DLC6.1\DLC6.1_6.out	DLC_6.1	1.667E+003	1.667E+003	1.147E+003	-4.203E+003	-1.708E+003	4.389E+003	6.678E-004	6.098E+002	5.370E+001
YawBrFyp	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-2.319E+003	7.958E+002	-2.319E+003	-4.543E+003	4.235E+004	-6.943E+003	-8.712E-004	4.565E+002	5.073E+001
YawBrFyp	Maximum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	2.396E+003	4.907E+002	2.396E+003	-4.278E+003	-1.022E+004	-1.997E+003	2.560E-004	6.023E+002	4.620E+001
YawBrFzp	Minimum	.\Data\DLC1.2\DLC1.2_25_4.out	DLC_1.2	-6.129E+003	4.124E+002	-2.406E+002	-6.129E+003	7.069E+003	-8.721E+003	-6.731E+003	6.492E+002	3.086E+001
YawBrFzp	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.132E+003	-4.653E+002	-1.493E+002	-3.132E+003	-5.153E+003	5.420E+003	3.089E+004	2.140E+002	2.393E+001
YawBrMxp	Minimum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	-2.836E+004	8.728E+002	-2.257E+002	-4.599E+003	-2.836E+004	1.048E+004	1.250E-004	2.396E+002	4.607E+001
YawBrMxp	Maximum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	4.236E+004	7.667E+002	-2.318E+003	-4.568E+003	4.236E+004	-7.839E+003	-9.072E-004	4.564E+002	5.030E+001
YawBrMyp	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-4.741E+004	2.655E+002	-2.082E+001	-5.029E+003	2.136E+003	-4.741E+004	-1.661E+003	2.164E+002	2.652E+001
YawBrMyp	Maximum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	4.000E+004	6.826E+002	-4.510E+002	-4.425E+003	-1.036E+004	4.000E+004	1.091E-004	3.286E+002	5.331E+001
YawBrMzp	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.919E+004	-3.310E+002	1.069E+002	-5.420E+003	-1.914E+003	-1.274E+004	-3.919E+004	2.146E+002	2.357E+001
YawBrMzp	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.376E+004	-3.287E+001	-5.358E+001	-3.584E+003	1.843E+002	-6.014E+003	3.376E+004	2.283E+002	2.255E+001

Table 18 Yaw Bearing

Parameter	Type	File Name	DLC Name	Calculated Extreme	TwrBsFxt (kN)	TwrBsFyt (kN)	TwrBsFzt (kN)	TwrBsMxt (kN m)	TwrBsMyt (kN m)	TwrBsMzt (kN m)	RootFxyc1 (kN)	RootMxyc1 (kN-m)	Time (sec)	Wind1VelX (m/sec)
TwrBsFxt	Minimum	.\Data\DLC5.1\DLC5.1_8_6.out	DLC_5.1	-1.593E+003	-1.593E+003	-8.849E+001	-8.899E+003	-1.014E+002	-1.513E+005	-8.822E+003	3.105E+002	7.514E+003	2.084E+002	7.975E+000
TwrBsFxt	Maximum	.\Data\DLC6.1\DLC6.1_6.out	DLC_6.1	2.226E+003	2.226E+003	1.228E+003	-9.091E+003	-1.289E+005	2.022E+005	-1.868E+002	4.524E+002	1.462E+004	6.096E+002	5.324E+001
TwrBsFyt	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-2.480E+003	1.136E+003	-2.480E+003	-9.434E+003	2.853E+005	8.304E+004	1.395E+002	7.703E+002	2.383E+004	4.563E+002	5.012E+001
TwrBsFyt	Maximum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	2.630E+003	7.771E+002	2.630E+003	-9.108E+003	-2.682E+005	6.143E+004	-1.078E+002	4.147E+002	8.679E+003	6.023E+002	4.729E+001
TwrBsFzt	Minimum	.\Data\DLC1.2\DLC1.2_25_4.out	DLC_1.2	-1.089E+004	6.284E+002	-2.398E+002	-1.089E+004	3.182E+004	4.624E+004	-6.723E+003	3.433E+002	9.761E+003	6.492E+002	3.086E+001
TwrBsFzt	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-7.857E+003	-4.053E+002	1.855E+002	-7.857E+003	-8.550E+003	-3.881E+004	3.089E+004	2.441E+002	1.573E+004	2.140E+002	2.393E+001
TwrBsMxt	Minimum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	-2.682E+005	7.771E+002	2.630E+003	-9.108E+003	-2.682E+005	6.143E+004	-1.078E+002	4.147E+002	8.679E+003	6.023E+002	4.729E+001
TwrBsMxt	Maximum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	2.867E+005	1.116E+003	-2.439E+003	-9.431E+003	2.867E+005	8.667E+004	1.655E+002	7.710E+002	2.328E+004	4.564E+002	4.969E+001
TwrBsMyt	Minimum	.\Data\DLC4.2\DLC4.2_5_6.out	DLC_4.2	-1.521E+005	-1.539E+003	1.813E+002	-8.936E+003	-1.775E+004	-1.521E+005	-1.097E+004	5.005E+002	1.348E+004	2.248E+002	1.077E+001
TwrBsMyt	Maximum	.\Data\DLC6.1\DLC6.1_6.out	DLC_6.1	2.022E+005	2.226E+003	1.228E+003	-9.091E+003	-1.289E+005	2.022E+005	-1.868E+002	4.524E+002	1.462E+004	6.096E+002	5.324E+001
TwrBsMzt	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.919E+004	-7.846E+001	-3.043E+002	-1.015E+004	1.234E+004	-3.239E+004	-3.919E+004	8.534E+002	2.847E+004	2.146E+002	2.357E+001
TwrBsMzt	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.376E+004	5.466E+001	-1.478E+002	-8.308E+003	9.823E+003	-4.010E+003	3.376E+004	2.177E+002	1.203E+004	2.283E+002	2.255E+001
RootFxyc1	Minimum	.\Data\DLC4.2\DLC4.2_15_1.out	DLC_4.2	3.655E-001	8.261E+001	1.535E+002	-9.064E+003	-1.774E+002	-5.914E+003	2.334E+001	3.655E-001	5.422E+002	4.515E+002	1.497E+001
RootFxyc1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	9.830E+002	1.138E+002	-9.519E-001	-9.828E+003	-3.722E+003	-1.255E+004	-3.075E+004	9.830E+002	3.061E+004	2.086E+002	2.765E+001
RootMxyc1	Minimum	.\Data\DLC4.2\DLC4.2_17_3.out	DLC_4.2	7.469E+000	6.329E+001	3.663E+001	-9.065E+003	-4.976E+003	-5.385E+003	-6.109E+001	5.781E+000	7.469E+000	3.515E+002	1.754E+001
RootMxyc1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.461E+004	-7.745E+002	-6.269E+002	-9.669E+003	2.572E+004	-7.707E+004	-3.375E+004	9.763E+002	3.461E+004	2.116E+002	2.244E+001

Table 19 Tower Base

Parameter	Type	File Name	DLC Name	Calculated Extreme	LSShftFys (kN)	LSShftFzs (kN)	LSSTipMys (kN-m)	LSSTipMzs (kN-m)	LSShftFxa (kN)	LSSTipMxa (kN-m)	Time (sec)	Wind1VelX (m/sec)
LSShftFys	Minimum	.\Data\DLC6.1\DLC6.1_5.out	DLC_6.1	-1.210E+003	-1.210E+003	-2.135E+003	-1.199E+004	-3.911E+003	1.638E+002	5.694E+003	4.094E+002	4.443E+001
LSShftFys	Maximum	.\Data\DLC6.1\DLC6.1_3.out	DLC_6.1	1.265E+003	1.265E+003	-1.830E+003	6.239E+003	5.114E+003	-6.214E+002	3.985E+003	4.106E+002	4.739E+001
LSShftFzs	Minimum	.\Data\DLC4.2\DLC4.2_17_2.out	DLC_4.2	-2.785E+003	-4.527E+001	-2.785E+003	-7.518E+003	-8.209E+003	2.365E+002	-6.604E+003	2.199E+002	1.727E+001
LSShftFzs	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-1.063E+003	-8.258E+001	-1.063E+003	6.053E+003	2.241E+004	-1.864E+002	-5.582E+003	2.139E+002	2.401E+001
LSSTipMys	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-2.710E+004	-2.838E+002	-2.461E+003	-2.710E+004	-2.831E+003	3.673E+002	2.087E+003	2.164E+002	2.652E+001
LSSTipMys	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	2.380E+004	1.897E+002	-1.564E+003	2.380E+004	3.652E+003	-3.969E+002	-1.223E+004	2.128E+002	2.153E+001
LSSTipMzs	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-2.760E+004	2.244E+002	-2.756E+003	7.669E+002	-2.760E+004	-5.306E+001	1.168E+003	2.146E+002	2.357E+001
LSSTipMzs	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	2.428E+004	-9.876E+001	-1.378E+003	-7.695E+002	2.428E+004	4.783E+001	-2.345E+003	2.283E+002	2.255E+001
LSShftFxa	Minimum	.\Data\DLC6.1\DLC6.1_2.out	DLC_6.1	-1.258E+003	8.243E+002	-2.046E+003	2.069E+003	3.188E+003	-1.258E+003	-9.470E+002	3.320E+002	5.214E+001
LSShftFxa	Maximum	.\Data\DLC1.2\DLC1.2_9_6.out	DLC_1.2	1.613E+003	-1.389E-001	-1.872E+003	-4.779E+002	2.035E+003	1.613E+003	6.836E+003	5.159E+002	9.102E+000
LSSTipMxa	Minimum	.\Data\DLC4.2\DLC4.2_21_3.out	DLC_4.2	-2.780E+004	-2.852E+002	-1.778E+003	-1.008E+004	7.434E+003	-3.276E+002	-2.780E+004	2.134E+002	1.477E+001
LSSTipMxa	Maximum	.\Data\DLC4.2\DLC4.2_21_3.out	DLC_4.2	2.514E+004	1.965E+002	-1.881E+003	3.567E+003	-6.583E+003	-2.372E+002	2.514E+004	2.126E+002	1.560E+001

Table 20 Machine Bed

Parameter	Type	File Name	DLC Name	Calculated Extreme	RootFxc1 (kN)	RootFyc1 (kN)	RootMxc1 (kN m)	RootMyc1 (kN m)	YawBrFxp (kN)	YawBrMxp (kN m)	LSShftFxy1 (kN)	LSShftMxy1 (kN-m)	Time (sec)	Wind1VelX (m/sec)
RootFxc1	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-5.779E+002	-5.779E+002	-4.088E+002	1.237E+004	-1.658E+004	7.969E+002	3.622E+004	1.693E+003	2.449E+004	4.567E+002	4.897E+001
RootFxc1	Maximum	.\Data\DLC1.2\DLC1.2_25_2.out	DLC_1.2	5.711E+002	5.711E+002	2.199E+002	-5.055E+003	1.650E+004	8.377E+002	5.615E+003	2.448E+003	1.287E+004	1.389E+002	3.155E+001
RootFyc1	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-9.660E+002	-1.821E+002	-9.660E+002	2.734E+004	-1.377E+004	-1.756E+002	-6.354E+003	3.367E+003	2.970E+004	2.086E+002	2.765E+001
RootFyc1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	9.341E+002	2.412E+002	9.341E+002	-3.137E+004	1.135E+004	-4.784E+002	-1.131E+004	3.172E+003	2.850E+004	2.117E+002	2.331E+001
RootMxc1	Minimum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	-3.184E+004	3.133E+002	9.247E+002	-3.184E+004	1.357E+004	-5.192E+002	-1.217E+004	3.213E+003	3.308E+004	2.116E+002	2.244E+001
RootMxc1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	2.799E+004	-2.066E+002	-8.906E+002	2.799E+004	-1.445E+004	-1.751E+002	3.356E+003	3.102E+003	2.792E+004	2.148E+002	2.345E+001
RootMyc1	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	-1.663E+004	-5.755E+002	-3.953E+002	1.177E+004	-1.663E+004	7.922E+002	3.472E+004	1.702E+003	2.337E+004	4.568E+002	4.865E+001
RootMyc1	Maximum	.\Data\DLC1.2\DLC1.2_9_6.out	DLC_1.2	1.888E+004	5.478E+002	-4.591E+002	1.097E+004	1.888E+004	1.403E+003	7.532E+003	2.768E+003	8.423E+003	5.163E+002	9.501E+000
YawBrFxp	Minimum	.\Data\DLC5.1\DLC5.1_8_6.out	DLC_5.1	-1.324E+003	-1.880E+002	-1.815E+002	1.922E+003	-6.411E+003	-1.324E+003	-8.502E+003	1.535E+003	9.109E+003	2.081E+002	7.595E+000
YawBrFxp	Maximum	.\Data\DLC6.1\DLC6.1_6.out	DLC_6.1	1.667E+003	-2.948E+002	-3.643E+002	1.389E+004	-7.545E+003	1.667E+003	-1.708E+003	4.450E+002	1.072E+004	6.098E+002	5.370E+001
YawBrMxp	Minimum	.\Data\DLC6.1\DLC6.1_1.out	DLC_6.1	-2.836E+004	1.716E+002	-5.831E+002	1.667E+004	7.122E+003	8.728E+002	-2.836E+004	2.900E+003	1.494E+004	2.396E+002	4.607E+001
YawBrMxp	Maximum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	4.236E+004	-5.495E+002	-5.444E+002	1.797E+004	-1.434E+004	7.667E+002	4.236E+004	1.715E+003	2.949E+004	4.564E+002	5.030E+001
LSShftFxy1	Minimum	.\Data\DLC6.1\DLC6.1_4.out	DLC_6.1	4.607E+000	-1.678E+002	1.108E+002	-2.212E+003	-7.925E+003	-1.621E+002	-2.133E+003	4.607E+000	1.505E+004	2.690E+002	4.050E+001
LSShftFxy1	Maximum	.\Data\DLC4.2\DLC4.2_15_1.out	DLC_4.2	3.630E+003	1.310E+002	8.215E+002	-2.825E+004	6.865E+003	-2.777E+002	-3.974E+003	3.630E+003	8.749E+003	2.157E+002	2.060E+001
LSShftMxy1	Minimum	.\Data\DLC4.2\DLC4.2_3_2.out	DLC_4.2	2.723E+000	3.237E+001	-4.182E+002	9.797E+003	7.697E+002	3.000E+001	-1.535E+001	2.659E+003	2.723E+000	4.118E+002	3.679E+000
LSShftMxy1	Maximum	.\Data\DLC4.2\DLC4.2_23_6.out	DLC_4.2	3.538E+004	3.549E+002	8.827E+002	-3.096E+004	1.481E+004	-5.716E+002	-1.226E+004	3.252E+003	3.538E+004	2.116E+002	2.392E+001

Table 21 Pitch Bearing

8.2 Final Representation of values

After complete simulation of result, we got extreme calculated tables, below there is a bar chart diagram which shows comparison among calculated loads with LiDAR feedforward with ROSCO feedback.
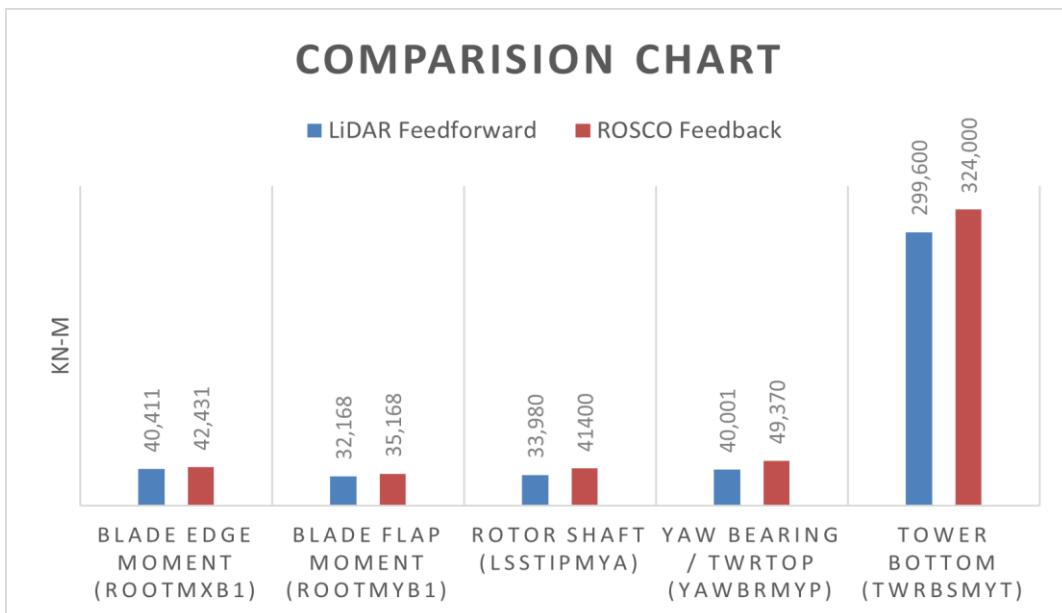

Figure 15 Comparison among with LiDAR feedforward with ROSCO feedback

9. LESSONS LEARNED

- Teamwork was a significant outcome for this project. With team members hailing from diverse countries, each bringing unique perspectives and attitudes, the group developed a strong, well-structured dynamic. Every member contributed ideas to address the challenges faced, and these contributions consistently met with mutual respect and collaboration.

- The overall vision of the project, including its objectives and individual tasks, must be clearly understood by the team leader. It is the leader's responsibility to effectively communicate this vision to all team members to ensure alignment and a shared understanding of the goals. By providing detailed guidance and clarity, the team can avoid unnecessary delays, prevent duplication of efforts, and ensure that each member's time is utilized efficiently. A well communicated vision also fosters collaboration, streamlines workflows, and keeps the project on track toward its intended outcomes.

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