10.Gearbox, Brake, Coupling

Hochschule Flensburg
University of Applied Sciences

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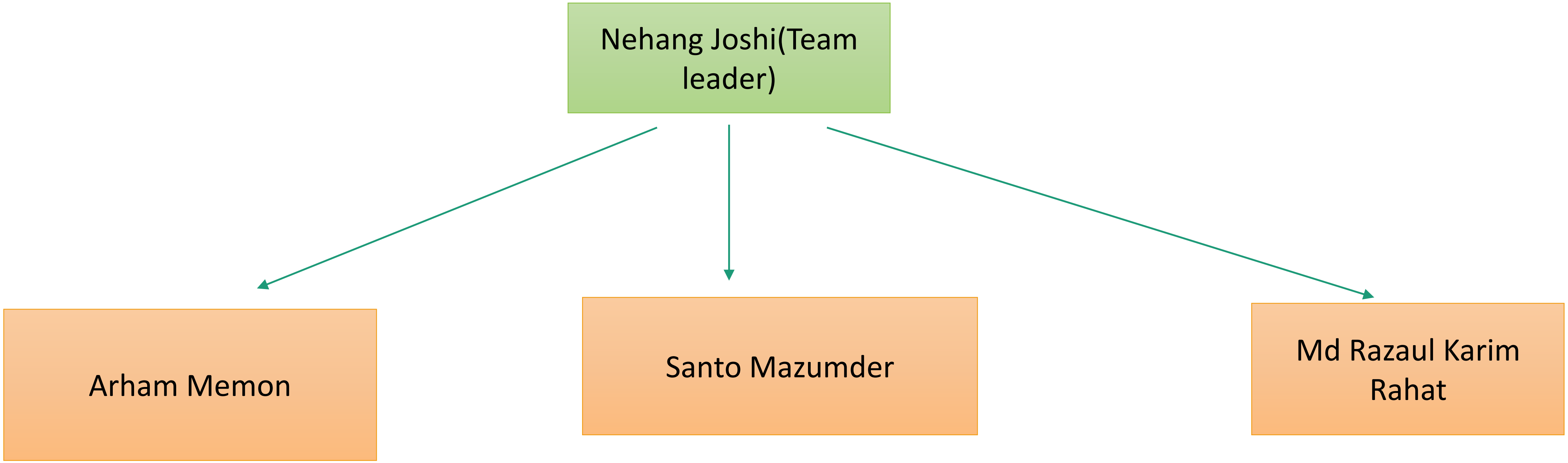
Agenda of the 4th week (11th August to 16th august)

- Study of last years documentation (in detail ………….)
- Research for appropriate mechanical drive train system and gearbox layout
- Research on relevant standards and guidelines
- Research on gearbox variants, mechanical brake systems and couplings (high speed side)
- Benchmark and definition of gearbox, brakes and coupling

- ***Research on possible suppliers suitable for delivering to Syria***

Study of last years documentation

- So basically we did research on previous year documentation and we came up with short ideas that how it should be work and how it could be done for this year as well for Syria project 2025-26.
- There are three parts for components we have to divided into three with four members as of now we all are working on same line like all the members including team leader are doing only research on this topic.



Update- Study of last years documentation (for 2nd week)

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- **So we noticed that many student did project in last many year for optimus which is describe below.**

✓ Optimus 200XL

✓ Optimus 295

✓ Optimus 60E

✓ Optimus oceanus

✓ Optimus shakti

Optimus 200XL

- As part of the masters’ course “Wind Engineering” of the HS Flensburg, a wind turbine was designed with the aim to create the highest power output on the market. This turbine is called Optimus 200XL and has a nominal power of 12.5MW. The project is an upgrade of the Optimus 200 project, which was conducted by the students of the previous semester and created a turbine of 10MW.
- The contents of this report are the outcomes of the group that was responsible for parts of the mechanical drivetrain. These parts were the gearbox, gearbox housing, coupling, coupling housing, rotor brake and lock. All these components were designed by calculations and 3DCAD drawings, which is shown in the following chapters. Also, the learned lessons of each member of the team are stated. In the end, an outlook on still open tasks is given, as well as an evaluation of the team work within the group.
- Each whole chapter was written by the person that is stated in the name of the chapter independently from the other group members.

Gearbox

- Design work 3.1.1 Description of process, issues, final solution and interfaces The process of designing the gearbox will be explained in this part. For the first step, different companies at the wind expo “WindEnergy Hamburg 2018” which produce gearboxes, have been analysed to see which concept is produced more than others by companies, which also shows the level of market friendliness of a product.
- After spending time and effort, it was decided to have a two-stage planetary gearbox with fixed ring gears to have the biggest ratio and to save money, because it was possible to use the ring gears as part of the gearbox housing. This concept doesn’t have a helical gear at the end and a hollow shaft goes directly to the generator.
- Two-stage planetary gearboxes also have some technical advantages compared to three stage ones, e.g. higher efficiencies even at partial loads because oil plunging occurs only in two stages instead of three.
- The material which has been chosen for the gearbox was 18 CrNiMo 6-7 which has 206000 N/mm2 of module of elasticity and a Poisson´s ratio of 0.3.
- One of the issues which have been recognized was the spreading of the forces and moments inside the gearbox because of the high ratio of the stages. The first idea was to have five planets in the first stage. However, there was a problem with the dimensions of the gearbox. It had to be very compact and there was not enough space for five planets with the desired ratio. Therefore, it was decided to have four planets in the first stage and three planets in the second stage

Rotor Brake

- The brake is not normally used to stop the plant in full operation. It is only used in order to achieve complete stoppage of the drive train after the plant has been stopped largely by the pitch of the blades. In small wind turbines, a mechanical rotor brake, which in cases of emergency prevents rotor runaway, has proved to be extraordinarily successful and widely used today [16]. With increasing turbine size as in Optimus 200XL with a rotor diameter of 200 m the rotor brake takes on almost unreasonable dimensions if it is to brake the rotor torque and power during full-load operation. For this reason, the task of the rotor brake in Optimus is restricted to the function of pure parking brake. The brake is designed and calculated according to the DNVGL [12] guideline, based on lecture notes by Prof. Quell and with the aid of SolidWorks software for 3D and 2D Design.

Coupling

- There are many different concepts concerning couplings in wind turbines available. The drivetrain concept of Optimus 200XL was a rather unusual one, seen from the design itself and the amount of forces it experiences. This meant, that not all coupling concepts could be used in it. Research has been done online and on the WindEnergy fair 2018 in Hamburg, where many major suppliers were exhibiting their technology.
- Because the drivetrain concept of Optimus 200XL was inspired by the designs of the Adwen AD 8-180 and the Vestas V164, it was also tried to gather information about the couplings used in these turbines. Furthermore, other promising concepts were investigated, like the Geislinger Compowind

Calculation

Certification requirements and guidelines In this part, some of the relevant guidelines which are helpful for designing a gearbox are explained. There are different guidelines like Germanischer Lloyd 2010, ISO 6336, DIN 3990 and AGMA 2001.

All of these guidelines have some limitations, but since engineers use ISO 6336 more than others, it will be evaluated here. ISO 6336 is not applicable when:

• Spur or helical gears with transvers contact ratios less than 1.0 or greater than 2.5 • Interfaces between tooth tips and root fillets • Teeth are pointed • Backlash is zero • Teeth finished by forging of sintering • Gear show poor contact patterns • Plastic yielding, scuffing, case crushing, welding and wear occurs • Vibration conditions exist with risk of an unpredictable profile breakdown

“ISO 6336 bending strength formulas are applicable to fractures at the tooth, but not applicable to tooth working surfaces features, failure of gear rim, of the gear blank through web and hub.”

Calculation methods

Different calculation methods have been used for designing the gearbox which will be described in detail. Also, Willis formula is used for finding the teeth number of each gear.

Bearings Several bearings have been used in this concept. Two of them are for the first and second stage, two of them for planets of first and second stages and one of them is placed at the end of the gearbox on the second stage sun gear, where the connection to the generator is.

Bearing of stages Double row tapered roller bearings were used in this concept which were selected from SKF bearing products. The model name for the first stage is “BT2B 332496/HA4” and for the second stage it’s “LM 283649/610/HA1”. In the first stage, the bearing has been cut and used because the other ones had smaller inner diameter than needed diameter, but for the second stage, 2 of them are used.

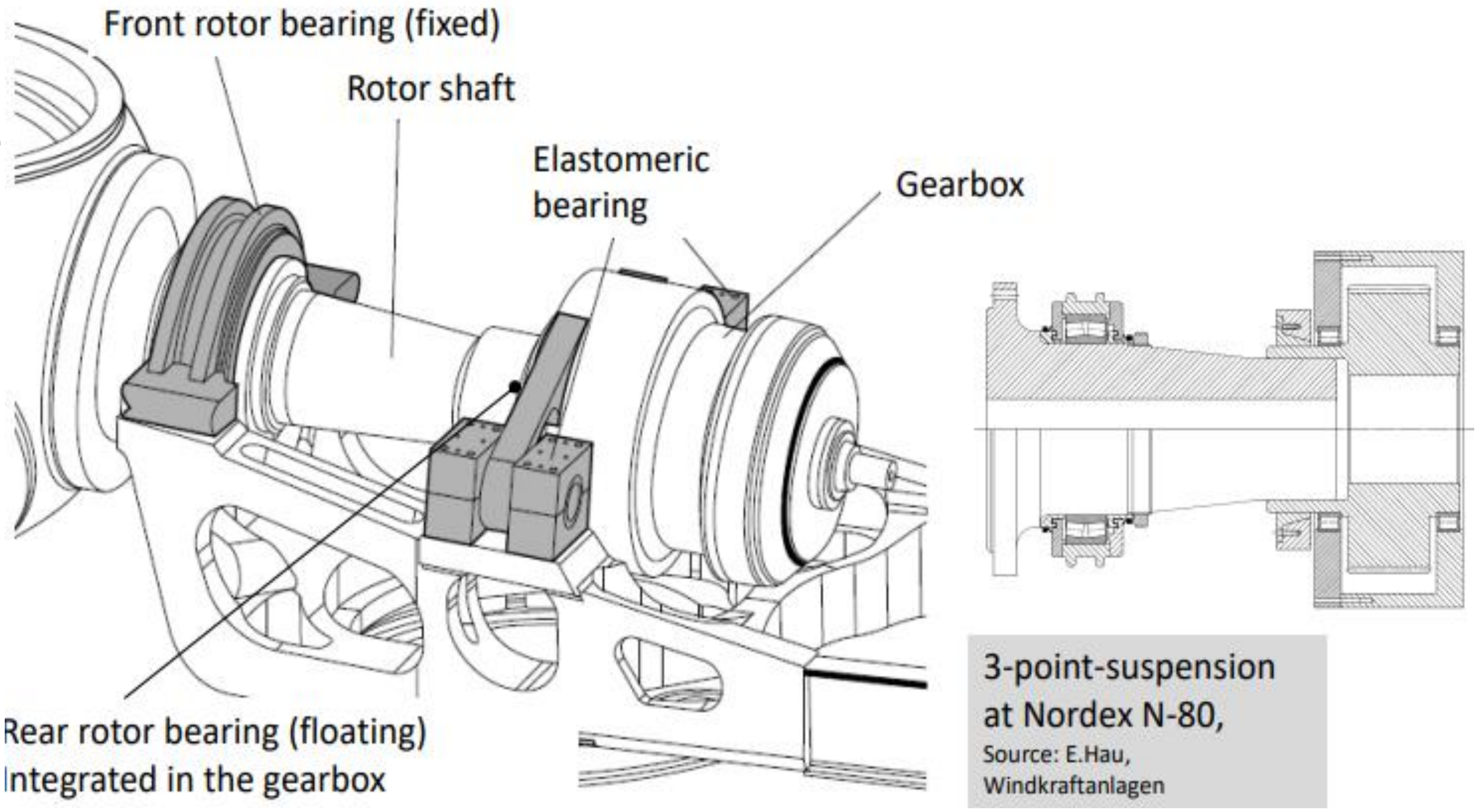
Rotor Lock

In the operation of a wind turbine, the rotor lock has no direct functions, and is only used for servicing or repairs at the drive train to protect the workers in the nacelle from any movement during standstill conditions [11]. According to the design load case (DLC) 8.1 in the standard DNVGL-ST-0437 chapter 4.5.8 “Transport, installation, maintenance and repair (DLC 8.1 to 8.5)” [12]. The rotor lock must be installed and has to be capable of standing all other DLC cases up to DLC 8.5 in which the turbine is not under operation and there are no workers inside the nacelle. The conditions used for the load calculations are DLC 8.1 and DLC 8.2 in which the maximum load moment is achieved at a wind speed of $Vwind = 12\ m\ s/$and wind direction angle of WD = +30. The rotor lock system is designed with the aid of SolidWorks 3D-CAD software.

Optimus 295

Gearbox Data

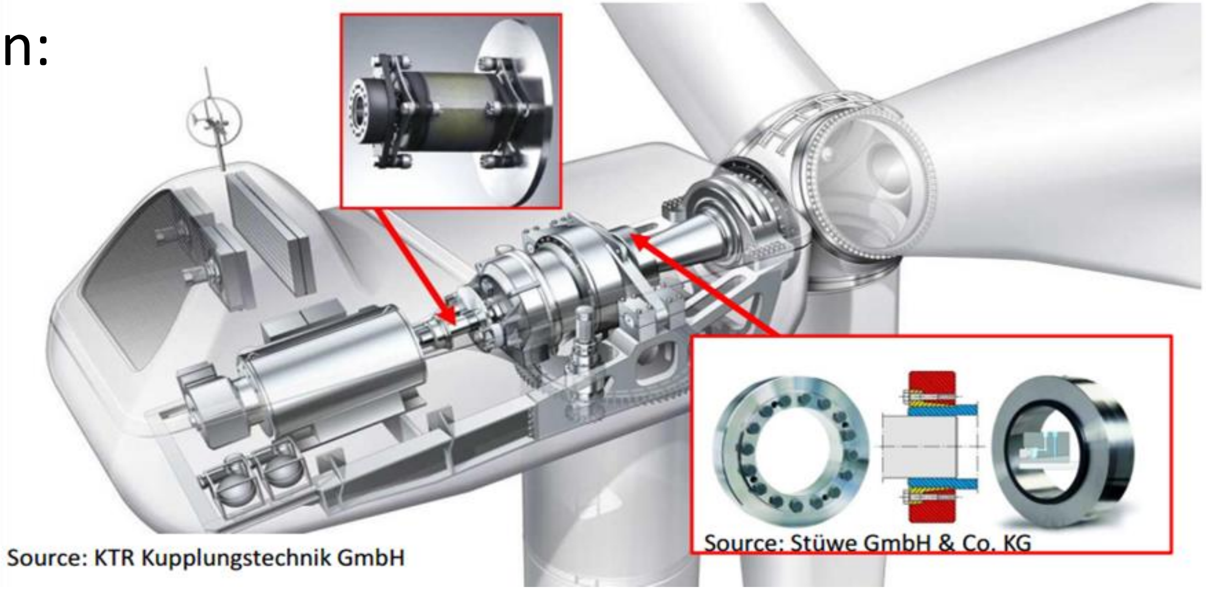
- Target ratio of 70 - 80
- 3 stages of planetary gears
- 18CrNiMo 6-7, cast Iron for the housing
- Fixed ring



Couplings

In general, the coupling is the connection between:

- Rotor shaft and gearbox (LSS)
- Gearbox and generator (HSS)



Main Objectives:

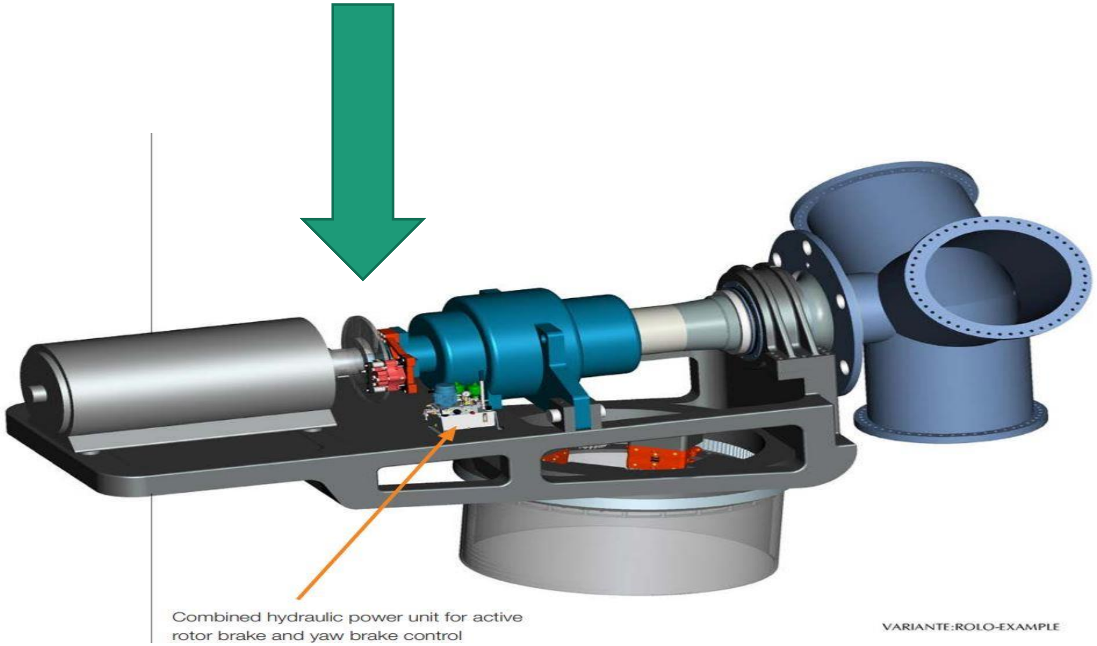
- To handle high torque, Minimize shock loads, and compensate misalignments between the rotor shaft and the gear box

Installation methods

Before the generator

Pros
- Control and Safety
- Reduced Gearbox Stress

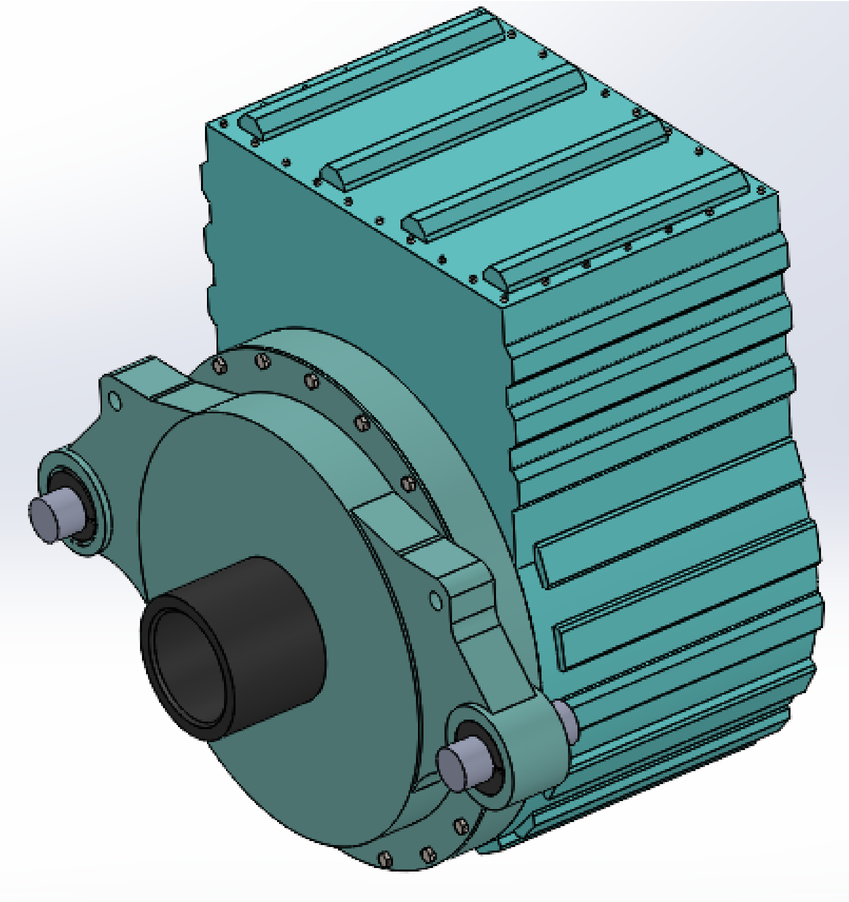
Cons
- Energy Loss
- High Cost



Source: https://www.svendborg-brakes.com/

Optimus 60E

Gearbox



Specifications	
Total Ratio	58.91
Type	1- Planetary 2- Spur
Input Speed (min^{-1})	25.46 rpm
Output Speed (min^{-1})	1500 rpm
Length (mm)	1564 mm
Width (mm)	1980 mm
Weight (Kg)	7354 kg
CO_2 Footprint (Kg CO_2)	7338.91 kg

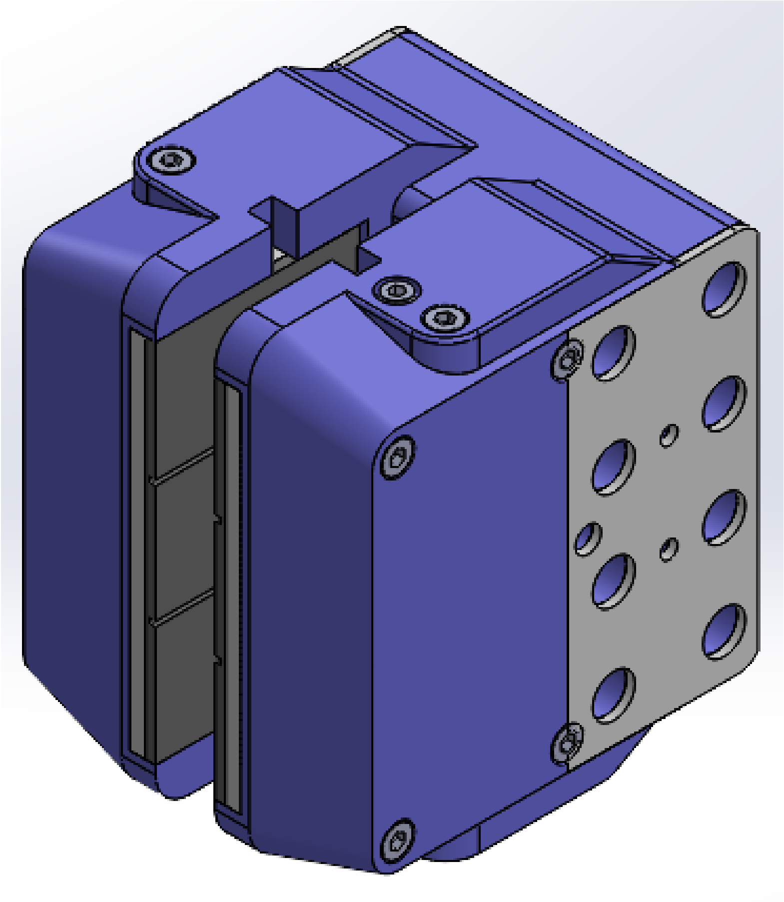
Market Analysis

Since Nepal's small country and not many wind turbines are installed, we looked at his very close neighbour for analysing, which wind turbine OEMs are available in our rated power category. This will not only ensure the availability of suppliers but also would help us know which OEMs would be preferred to produce a wind turbine with our rated power of 800KW.

The results from the wind turbine manufacturers in India provided by the Ministry of New and Renewable Energy, Government of India [1] in the preferred rated power shows all turbines larger than 1000 kW with a rating in the range of 180-289 W/m2.WEC smaller than 1000 kW are in the range of 294-395 W/m2Based on this, our Wind turbine has a rotor rating of 300 W/m2. With a rotor diameter of rotor 60 m, this leads to a rated electrical power on the grid side of is 800 KW. Hence, it was decided to have a rated power of 800 KW for Optimus 60E.

Optimus 60E

Brake Caliper



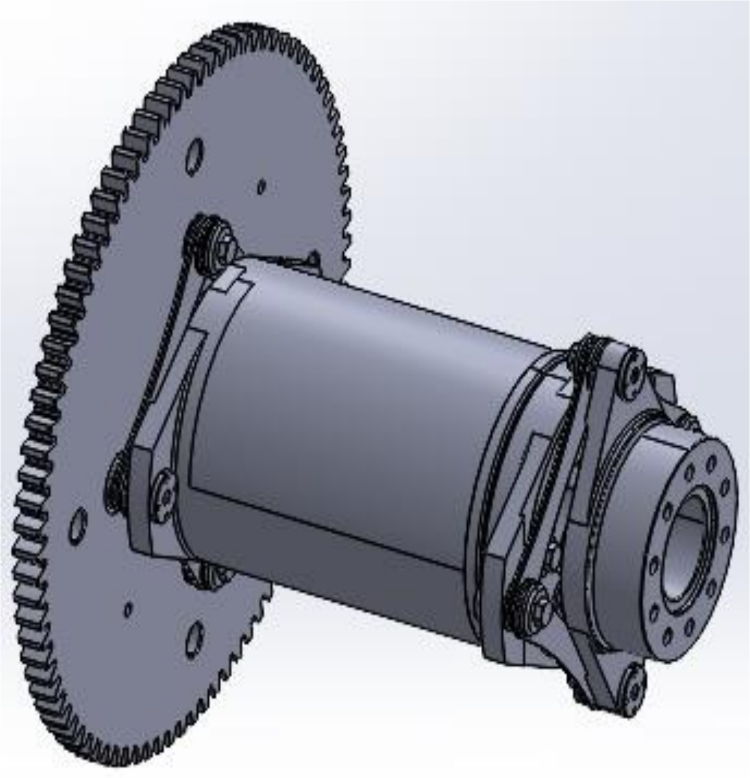
Brake Specification	
Type - Svendborg	45-X-104
Length (mm)	220
Width (mm)	167
Height (mm)	175
Weight (kg)	40
CO_2 Footprint (Kg CO_2)	30.4

Relevant standards and guidelines

The following are the standards and guidelines that were followed while designing the gearbox: • GL 2010: Guideline for the Certification of Wind Turbines • ISO 6336-1:2019: Calculation of load capacity of spur and helical gears • DIN 3990: Load capacity calculation of spur gears • ANSI/AGMA 2001-D04: Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth

Optimus 60E

Coupling



Specification	
Type - KTR	Radex-N NANA 4
Length (mm)	679
Brake disc(mm)	∅700 x 30
Weight (kg)	164.29
CO_2 Footprint (Kg CO_2)	124.83
$M_{N,LSS}$ (KNm)	5.50
$n_{N,LSS}$ (min^{-1})	25.46
$n_{N,HSS}$ (min^{-1})	1500

Design work
interfaces

This section will go over the design process for the gearbox. Initially, numerous firms' gearboxes were studied, and different gearbox models were analysed to determine which would be the most fit for the purpose based on market availability and cost.

After doing market research and weighing the cost and limitations of wind turbine transportation, a one-stage planetary two-stage spur gearbox with a fixed ring gear was selected. A connection was employed in the Low-speed shaft is also to stabilise the sun gear for this design. Since spur gears are less expensive than helical gears, they were employed for this gearbox.

Initially, 1 planetary and 2 spur gear stages were configured according to Layout 1 (see figure 3), however it was subsequently discovered that this arrangement is unstable and will not offer proper load distribution inside the planetary stage. As a result, a modification in layout is required for improved load distribution

Dimensioning of Gears

The module, teeth number, and stage ratio are the most crucial aspects when dimensioning a gear. It was important to experiment with these three factors to get the optimum result. The size of the gearbox, which is proportional to the gear dimensions, is usually the key concern for designers.

An excel sheet was prepared for having an ideal gear with different tooth numbers examined and in parallel ratios of stages modified, and the item that needed to be verified was the gaps between the planets. The gears were spur to determine the largest feasible dimension, but the planet carrier components were a difficulty. The planet carrier's front and rear components must be linked, and this connection must be made between the planets.

The aim for the gearbox's overall ratio was 58.91, and the total ratio of 58.91 was accomplished in the end, which was satisfactory. The final gear dimensions will be detailed in later chapters; however, the table 3 demonstrate the result of final dimension of each stage from the excel sheets that were prepared.

Drawings

The following are a set of drawings for an 800KW gearbox with an initial torque of 330 KNm and 25.46 RPM input to the first stage of planetary gear with three planets, a 116 RPM output from the sun gear is generated. This 116 RPM enters the second stage of spur gear, resulting in a 438 RPM output at the end of the second stage. Finally, using the 3rd stage of spur gear, the output torque of 1500 RPM is generated.

Certification requirements

In this part, some of the relevant guidelines which are helpful for designing a gearbox are explained. There are different guidelines like Germanischer Lloyd 2010, ISO 6336, DIN 3990 and AGMA 2001. All these guidelines have some limitations, but since engineers use ISO 6336 more than others it will be evaluated here. ISO 6336 is not applicable when: • Spur or helical gears with transvers contact ratios less than 1.0 or greater than 2.5 • Interfaces between tooth tips and root fillets • Teeth are pointed • Backlash is zero • Teeth finished by forging of sintering • Gear shows poor contact patterns • Plastic yielding, scuffing, case crushing, welding and wear occurs • Vibration conditions exist with risk of an unpredictable profile breakdown

“ISO 6336 bending strength formulas are applicable to fractures at the tooth, but not applicable to tooth working surfaces features, failure of gear rim, of the gear blank through web and hub.”

Calculation methods

The gearbox was designed using a variety of calculation approaches, which will be discussed in depth. The Willis formula is used to determine the number of teeth in each planetary stage gear, and the strength of the gear teeth is then defined using the Lewis equation.

Elastomeric Bearings

From the main bearing, the main shaft gearbox that transmits energy to the generator though the gearbox, the final target point, is collectively called a drive train. The gearbox has a long shutdown period, which is a major factor that increases the maintenance cost of a wind turbine. Therefore, the design of a gearbox that satisfies the required lifespan is a very important factor in determining the unit cost of a wind turbine generator. Among them, the effect of the actual main bearing stiffness and the drivetrain support stiffness considering the design operating temperature considering the load capacity for the applied load on the input load of the gearbox.

Effect of non-torque on the lifespan of the gearbox There are many international standards and related studies on gear design, and by using them, a gear that satisfies the required lifespan can be designed. However, in the 3-point support gearbox most used in generators, the torque arm supporting the gearbox as well as the gearbox The design loads for the torque arm were derived by considering the effects of the transmitted torque and self-weight of the gearbox. Based on the design loads, design methods for the torque arm pin and elastomeric bushings were introduced in the terms of material and size selection.

The guidance for elastomeric bushings design was taken from ESM Gmbh. In the following chapter we have calculated the loads of elastomeric bearing according to according to the dimensions provided by ESM.

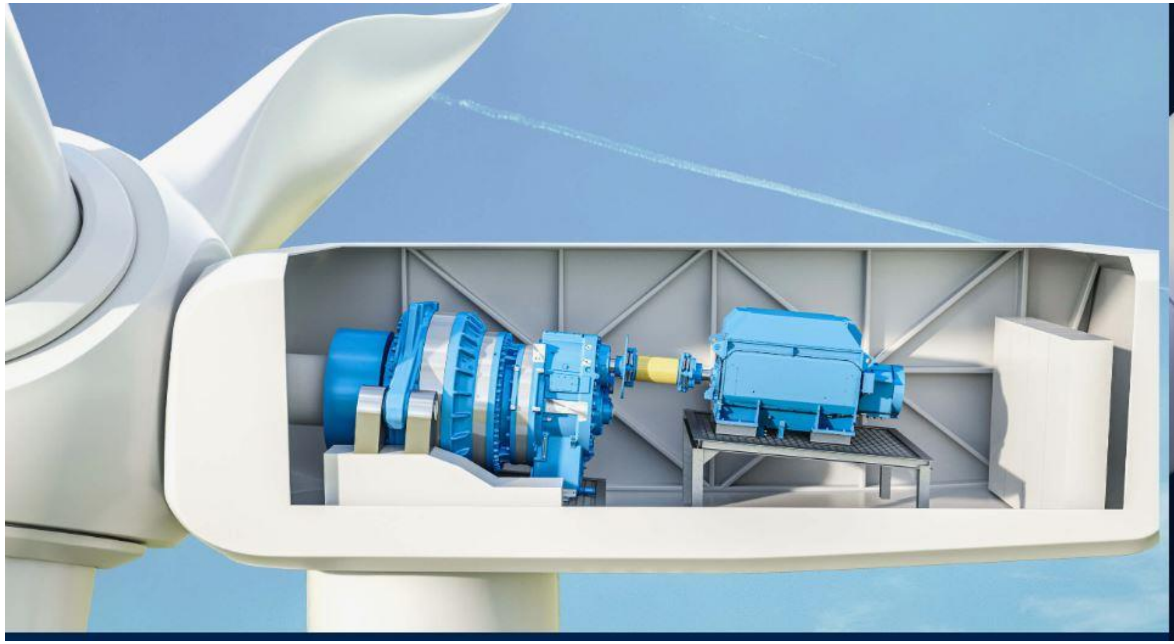
ESM provided us with the following two options according to our loads:

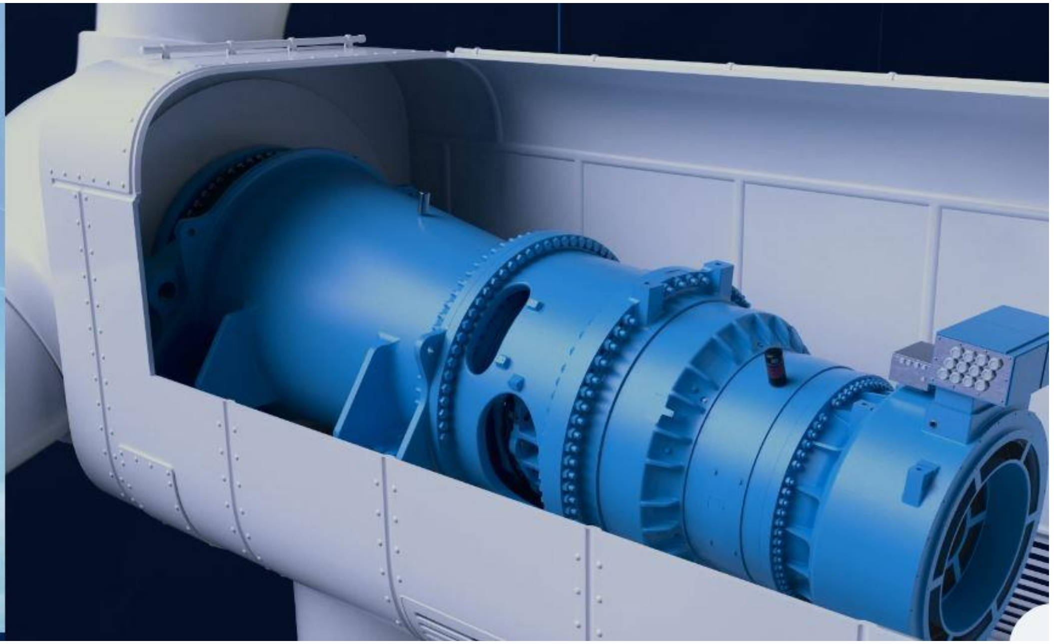
Rotor Brake

Design Basics

A wind turbine rotor brake is a brake placed next to the gearbox that reduces the rotational speed of the blade assembly, fixes the blade so that it does not rotate in the case of power transmission maintenance or power generator rest, and in an emergency, has the emergency function of stopping power transmission in the event of an aerodynamic brake failure due to a problem with blade pitch control. In addition to a rotor brake, the brake system of a wind turbine includes a rotor lock that prevents the rotation of a stopped rotor, and a yaw brake that controls the yawing of the nacelle of the wind power generator. Relating to this report the designing is executed strictly close to the DNV-GL standards and the calculations were obtained by the lecture notes of the “Mechanical Drive Train” course. Normally there are choices to make about the position of the brake. In this project, the gearbox output is held very close to the commercial turbine “Enercon E-48” with similar specifications. In arrangement with Mr. Quell the brake is acquired and delivered by the original equipment manufacturer. As it can be assumed, a proper actual design work did not take place. Nevertheless, the calculations were made to have existing values when contacting the suppliers.

Optimus Oceanus





Research on relevant standards and guidelines (AS per pervious year)

IEC 61400-1:2019, Wind energy generation systems —Part 1: Design requirements

• IEC 61400-4:2012, Wind turbines —Part 4: Design requirements for wind turbine gearboxes

• ISO 6336-2:2019, Calculation of load capacity of spur and helical gears —Part 2: Calculation of surface durability (pitting)

• ISO 6336-3:2019, Calculation of load capacity of spur and helical gears —Part 3: Calculation of tooth bending strength

• ISO/TS 6336-4:2019, Calculation of load capacity of spur and helical gears —Part 4: Calculation of tooth flank fracture load capacity

• VDMA Specification 23903, Basic design requirements for plain bearings in main gearboxes of wind turbines

• VDMA Specification 23904, Reliability assessment for wind energy gearboxes

Research on possible suppliers suitable for delivering to Syria

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- Got some idea about from the internet and some website that is **Winenergy** group of company which origin of the German possible to provide in Syria because they have large production of gearbox which can gives good amount of work output and higher generation rates.
- Enercon company is also leading for supplies in Syrian region.
- ZF wind power Antwerpen also who is responsible to provide in this country
- ZF wind power and giants company like Siemens and flander 40-50% stockholder for this project for suppliers.

(Above companies are located **in European region** mostly are capable enough)

- Goldwind and Dongfang is also could become leading for suppliers of gearbox,brake,coupling (**Asian region** and these companies located in china)

- **Remarks-** possibility for some other companies can do still research and proof required for supply chain

Semi-integrated design (so-called 3-point-suspension)

- Company in Germany which is using this kind of concept.

a. Senvion

b. Vestas

c. Siemens

d. Nordex

e. GE

(Task and aim is to do research that is they are also provider in Syria)?.................................

Manufacturer

coupling	Gearbox
• Geislinger • Flender • ESM	• ZF • DVS • Eickhoff • Winergy • NGC • Brauer • Multigear • Convent • Eno • SKF

Gearbox

Suppliers in the market:

Suppliers

GEISLINGER®
COUPLINGS AND DAMPERS. BUILT TO LAST.

FLENDER
winergy

JAURE®

VOITH

Geislinger

COMPOWIND Coupling

An innovative concept of fatigue-resistant and maintenance-free fiber composite membranes. With more than 90% reduction of rotor non-torque loads.

- Fatigue-resistant
- Maintenance-free
- No aging, no wear, resistant to heat, frost, and saltwater
- Diameters up to 3.5 m
- Weight-saving design
- Long life cycle

Source: https://www.geislinger.com/en/products/product/compowind-coupling/

Flender

ARPEX GIGA wind coupling

- This coupling can transmit torques of up to 12 MNm.
    - maintenance-free
    - compensate for axial, angular and radial misalignments.
    - A lot of Mechanical components

Source: https://www.flender.com/Produkte/Kupplungen/ARPEX-Windkupplungen/p/ATN09001

Jaure

JHC couplings

- Jaure hydraulic shrink coupling
    - Easier installation
    - Can withstand high shock loads
    - Leakage risk
    - High pressure oil pump system is needed

Source: https://www.regalrexnord.com/brands/jaure/wind-power-drives

COMPOWIND Coupling General View

Source: https://www.geislinger.com/en/products/product/compowind-coupling/

Brake system

Suppliers in the market:

- **ICP WIND**
- **Svendborg Brakes**
- **KTR**
- **Stuwe**

Summary work of our group this week 11th August to 16th august

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- Research on previous year documents and got information about gearbox,brake,coupling
- **Remarks**- Fully research is still pending due to taking decision for appropriate because in every project they used different drive train concept as per area of the country
- Research on appropriate drive train concept and gearbox
- **Remarks-** Got mostly idea about which is most relevant concept for wind turbine in Syria region but still need conformation about the variants of the drive train and gearbox just because of Syrian region is located in middle east and its very different location than western European countries so it would like to more critical than previous year project to choose drive train and its needs to required mentor guidance.
- Research on brake system and coupling for wind turbine
- **Remarks-** Got idea about various kind of brake system and coupling which is use for most advance developments and which is most suitable for turbine but still needs to be use other medium to get more information about it (like research paper, YouTube, company documentation.
- We are able to find that which kind of company can still provide in the Syria region and it should be cost effective as per aim of the project so we are still trying to find and try from next week would be possible to find for new or cost cutting design.

Research on standards and guild line and benchmarks for gearbox,brake,coupling

Remarks- Mostly aware and filmier with standards but still required to few

- Research on Syrian market and know about suppliers

Remarks- Research on possible suppliers suitable for delivering to Syria is still remain just because lack of knowledge and new country for project which is quite far from wind turbine market.

Work load and media used for this week.

- **10 hours / This week**

- **<u>Media used</u>**

(Google chrome , YouTube , WhatsApp, research paper, companies pdf and documents)

- **<u>Medium of compunction with team mates</u>**

(WhatsApp group) **Remarks- will try to improve for offline as well as online meeting (zoom, WebEx)**

Next week plan in advance description (18th August to 23th august) 5th week

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- Research previous year documentation in detail
- Software installation (Solidworks, Anysys,Dlubal).
- Get some idea about calculation……………..
- Get more information or gathering from companies website , articles and generals………….
- Familiar with wind turbine data trough research paper…………
- **Practice and try to improve data and information about topic.**

In sum up we are still trying to improve our method for work balance sure that we will do before 20th August…………

- **10 hours / This week**
- **Media used**

(Google chrome, YouTube, WhatsApp, research paper, company's pdf and documents)

- **Medium of compunction with team mates**

(WhatsApp group) **Remarks- will try to improve for offline as well as online meeting (zoom, WebEx)**