Electricity and New Energy

Electrical Pitch Hub
Wind Turbine Learning System

Course Sample
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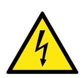
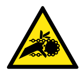
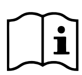
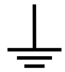
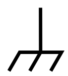
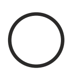
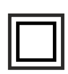
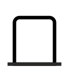
Safety and Common Symbols

The following safety and common symbols may be used in this course and on the equipment:

Symbol	Description
DANGER	DANGER indicates a hazard with a high level of risk, which, if not avoided, will result in death or serious injury.
WARNING	WARNING indicates a hazard with a medium level of risk, which, if not avoided, could result in death or serious injury.
CAUTION	CAUTION indicates a hazard with a low level of risk, which, if not avoided, could result in minor or moderate injury.
CAUTION	CAUTION used without the "Caution, risk of danger" sign, indicates a hazard with a potentially hazardous situation, which, if not avoided, may result in property damage.
	Caution, risk of danger. Consult the relevant user documentation.
	Caution, risk of electric shock.
	Caution, lifting hazard.
	Caution, hot surface.
	Caution, risk of fire.
	Caution, risk of explosion.

Symbol	Description
	Caution, belt drive entanglement hazard.
	Caution, chain drive entanglement hazard.
	Caution, gear entanglement hazard.
	Caution, hand crushing hazard.
	Static sensitive contents. Observe precautions for handling electrostatic discharge sensitive devices.
	Notice, non-ionizing radiation.
	Consult the relevant user documentation.
	Radio Equipment Directive (RED) geographical restrictions – consult the relevant user documentation.
	Direct current.
	Alternating current.
	Both direct and alternating current.

Symbol	Description
	Three-phase alternating current.
	Earth (ground) terminal.
	Protective conductor terminal.
	Frame or chassis terminal.
	Equipotentiality.
	On (supply).
	Off (supply).
	Equipment protected throughout by double insulation or reinforced insulation.
	In position of a bi-stable push control.
	Out position of a bi-stable push control.

Preface

Wind power has been used for centuries for tasks such as grinding grain, pumping liquids, and driving machinery. In the 1890s, the first wind machines used to produce electricity were built in Denmark, Scotland, and the United States. This type of clean and renewable energy has since then evolved to such an extent that it now meets a significant portion of the electricity demand in several countries, and its use continues to expand.

Wind turbines are the machines most used to produce electricity from wind power. One important component of such machines is the blade pitch control system. This system maximizes the energy production by setting the turbine's blades at an optimum angle for best output and prevents the equipment from being damaged during extreme wind conditions. Several technologies have been developed over the years to pitch the blades on wind turbines. Electrical pitch control systems are among these technologies, and their use is widely spread throughout wind farms all over the world.

The Electrical Pitch Hub Learning System is designed to introduce students to the fundamentals of electrical pitch control systems, with emphasis on operation and control of the equipment. Basic electrical knowledge is recommended before starting the course. The course presents the different components of an electrical pitch control system and provides useful information for future wind turbine technicians and operators.

We invite readers to send us their tips, feedback, and suggestions for improving the course.

Please send these to:

services.didactic@festo.com

The authors and Festo Didactic look forward to your comments.

About This Course

Course objectives

When you have completed this course, you will be familiar with electrical pitch control of wind turbines as well as with the advantages and disadvantages of this technology. You will be able to identify the main components of an electrical pitch control system and to explain how it works. You will also be familiar with a systematic approach to troubleshoot electrical pitch hubs in wind turbines.

The following video presents the Electrical Pitch Hub Learning System in operation.

Electrical Pitch Hub Learning System in operation

The following video presents the Electrical Pitch Hub Learning System connected to the Wind Turbine Learning System.

Electrical Pitch Hub Learning System connected to the Wind Turbine Learning System

Safety considerations

Safety symbols that may be used in this course and on the equipment are listed in the Safety and Common Symbols table at the beginning of this document.

Safety procedures related to the tasks that you will be asked to perform are indicated in each exercise.

Make sure that you are wearing appropriate protective equipment when performing the tasks. You should never perform a task if you have any reason to think that a manipulation could be dangerous for you or your teammates.

Before performing manipulations with the equipment, you should read all sections regarding safety in the Safety Instructions and Commissioning document accompanying the equipment.

System of units

Units are expressed using the International System of Units (SI) followed by units expressed in the U.S. customary system of units (between parentheses).

To the Instructor

You will find in this instructor version of the course all the elements included in the student version together with the answers to all questions, results of measurements, graphs, explanations, suggestions, and, in some cases, instructions to help you guide the students through their learning process. All the information that applies to the instructor is placed between markers and appears in red.

Accuracy of measurements

The numerical results of the hands-on exercises may differ from one student to another. For this reason, the results and answers given in this course should be considered as a guide. Students who correctly perform the exercises should expect to demonstrate the principles involved and to make observations and measurements similar to those given as answers.

Time requirements

At the beginning of each section in this course, you will find an indication of the time required by an average student to perform the section. This time indication is for reference purposes only. The actual time required by students may vary significantly from one class to another, and from one student to another.

To prevent inconsistencies in the times required to complete sections, it is recommended that the instructor perform the tasks in the section beforehand to obtain a general idea of the time required to complete the section. The instructor can then better estimate the time required for his or her class to perform the tasks.

Sample

Extracted from

Instructor Guide

Rotor

Rotor

1 min.

Competency

- Explain the function of a wind turbine rotor.

The rotor is the most important part of a wind turbine. The rotor allows the transformation of wind energy into mechanical energy, as well as the rotation of the main shaft and electrical generator. The two main components of the rotor are the blades and the hub. The blades catch the wind, while the hub secures the blades to the main shaft and encloses the blade control system. The three-bladed rotor is the most common configuration in larger wind turbines. There are also configurations of two or even one blade, but they are less common.

Hub

9 min.

Competencies

- Explain the function of the pitch control system on a wind turbine.
- Describe the most common types of hubs used on wind turbines.
- Identify the aerodynamic forces acting on a wind turbine blade.
- Explain the angle of attack and the pitch angle in the context of wind turbine blades.
- Describe how a pitch control system can control the blade speed of a wind turbine.
- Describe the stall phenomenon and explain its influence on the performance and operation of a wind turbine.

The hub is the part of a wind turbine where the blades and the rotor shaft connect. Small wind turbines may have fixed blades, but in most wind turbines, it is possible to vary the angle of the blades. This feature is called “blade pitch control” and requires a pitch hub system that moves the blades. Pitch control allows to control the rotor speed. This prevents the rotor from turning while winds are too high or too low to produce electricity.

Hub types

Electrical and hydraulic hubs are the two main types of pitch hub systems. The type of hub depends on the actuator that performs the pitch control. Regardless of the hub type, a bearing connects each blade to the hub. The design of the blade pitch bearing allows the blade to pitch around a pitching axis. The hub encloses the hydraulic actuator or electric gear-driven motor and controller.

Rotor blade aerodynamics

Wind machines can utilize two types of aerodynamic force to extract power: drag and lift. Drag is the most obvious form, as it is the one against which you fight when you are facing the wind (see the following figure). It can be defined as the sum of forces acting on an object parallel to the relative fluid flow direction.

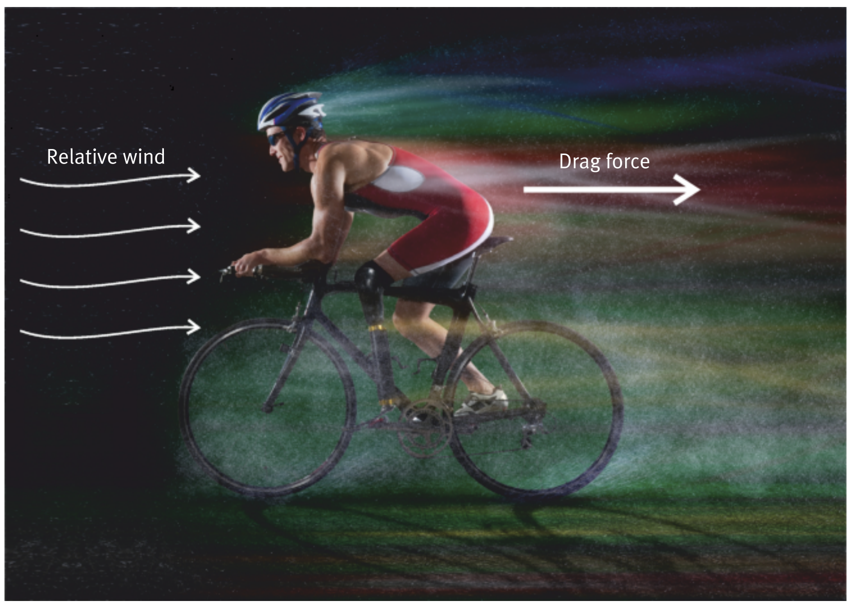


Figure 42. Drag force.

Lift, on the other hand, is perpendicular to the relative flow direction. It is caused by deflection of the flow on the surface of an object. Airplanes are remarkable applications of this principle, considering that the lift force exerted on the wings suffices to maintain the aircraft in the air.

The key in creating lift force lies in the shape of the deflecting object. One way to understand lift intuitively is to imagine the flow path and the pressure created on the upper and lower surfaces of a wing (see the following figure). In short, the stretching of the air along the top path thins the air and produces a lower air pressure, creating a net upward force.

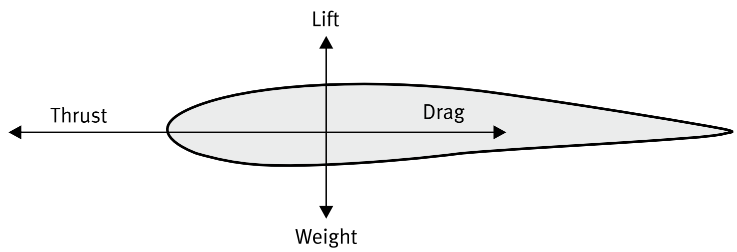


Figure 43. Forces acting on the cross-section of an airplane wing (airfoil).

The following figure depicts a wind turbine in operation. Viewed from the front of this nacelle, the blades turn in a clockwise direction.

Figure 44. Moving blades on a wind turbine.

If we look at a single blade (see the following figure), we can observe that it has two long edges, known as the leading and trailing edges. The blade tip refers to the end farthest from the hub. The blade root is the end bolted to the hub.

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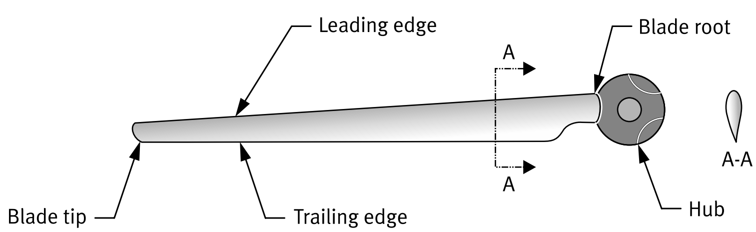

Figure 45. Rotor blade attached to the hub.

Notice the similarity between the cross-sectional view of the blade and the airplane wing shown previously in this section.

The leading edge is thicker and tapers down to the thinner trailing edge (see the A-A cross-section in the previous figure). This is the blade's aerodynamic profile.

Variations in this profile can affect the blade's performance at different wind speeds.

Pitch angle and angle of attack

The angle of attack refers to the blade angle relative to the wind direction. It describes the angle between the apparent wind direction (current wind direction adjusted for the wind forces that the rotating blades create) and a hypothetical blade centerline running from a blade's leading edge to its trailing edge (see the following figure). On the other hand, the pitch angle is the blade angle from the same hypothetical blade centerline to the hub's plane of rotation (see the following figure). While the pitch angle is a fixed number based on a mechanical setting, the blade's angle of attack to the wind can vary based on changes in wind direction and the speed of rotation.

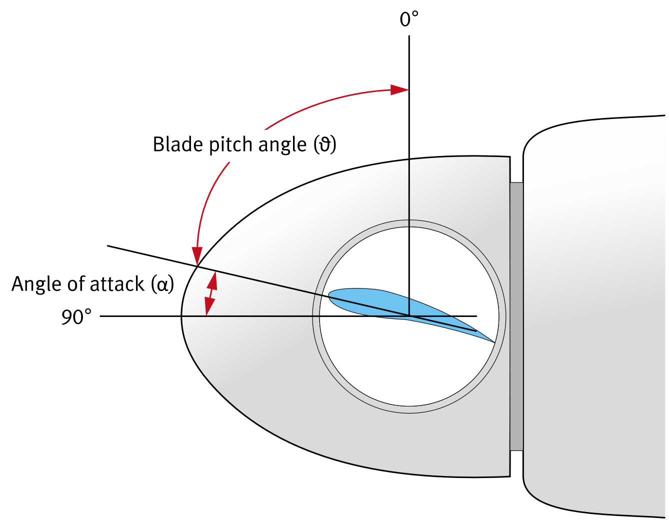

Figure 46. Pitch angle (looking through the hub).

Speed control on a wind turbine

Speed control on a wind turbine can be accomplished using a pitch control system. As the blade's angle of attack to the wind increases, the blade surface area exposed to the wind also increases. The force on a turbine blade is the result of the wind pressure multiplied by the exposed blade area. As the angle of attack increases, the resulting force on the blade also increases. This change in the angle of attack increases the blade's lifting force, which results in an increase in hub rotational speed. A reduction in the angle of attack has the opposite effect of reducing the lifting force and force angle slowing the turbine. The following figure shows what happens when air flows around a stationary blade in a feathered position. In this situation, air flow exerts an equal and opposite force on either side of the blade.

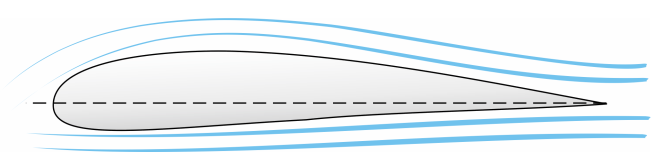

Figure 47. Airflow around the blade in a feathered position.

Slightly tilting the blade has an important effect on the blade. As shown in the following figure (for a blade at such a point in its course that it is parallel to the ground), a small angle of attack is enough to create lift and start blade rotation.

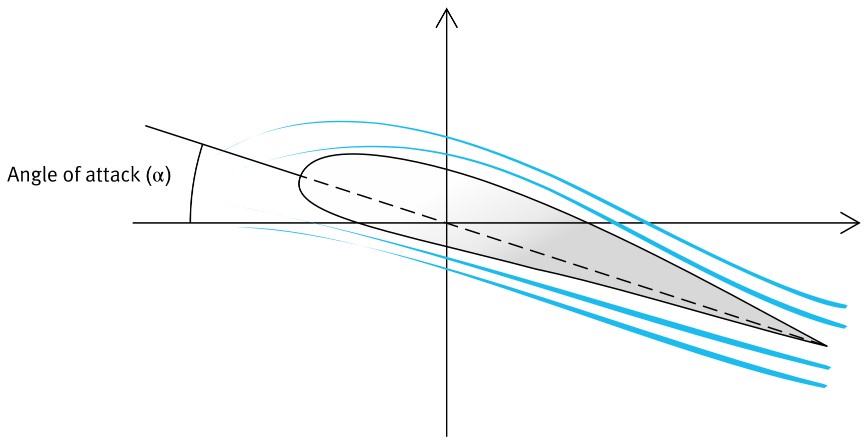

Figure 48. Blade just out of the feathered position.

As the rotor and blades gain rotational speed, the wind component of the airflow hitting the blade becomes relatively less important. Therefore, the blade is slowly pitched to the vertical so that it remains as aerodynamic as possible yet still generates lift that is converted in driving torque by the drive train system.

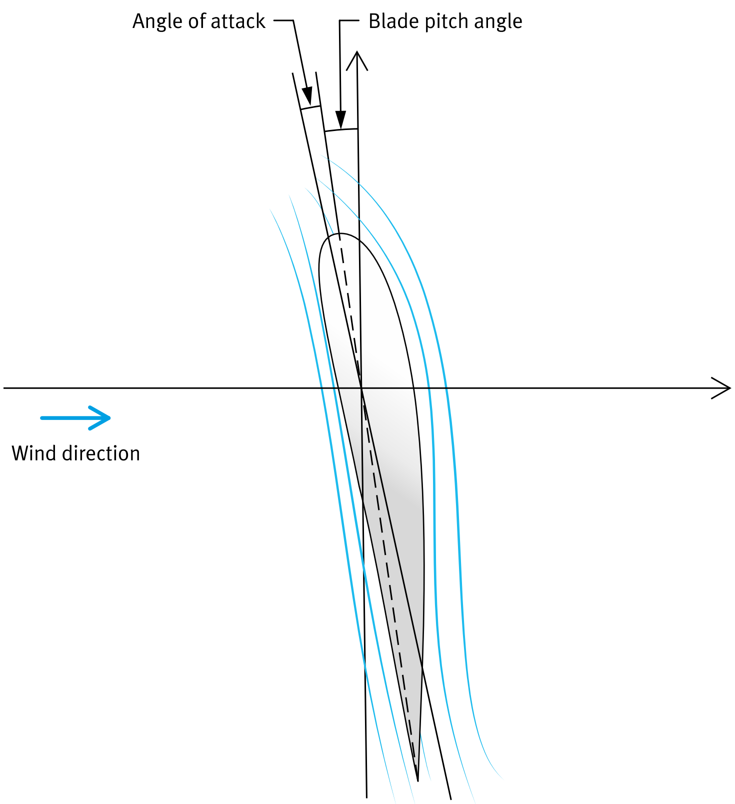

Figure 49. Blade operational position (almost vertical).

During power generation, blades are pitched slightly in or out of the wind to maintain a constant rotational speed. When the wind turbine is stopped, blades are pitched toward the feathered position, which slows down the rotor aerodynamically.

Stall

In nature, wind tends to move or blow in either laminar or turbulent flow patterns. Laminar flow means that all the air molecules align into parallel paths. In turbulent flow, there is some discourse to the direction in which the air molecules move. When wind blows, it is generally laminar in flow until a surface disrupts that flow and causes turbulence. As the wind contacts the turbine blade, it splits into two laminar flow sections. As the blade's angle of attack is increased relative to the wind, the blade further divides and redirects flow as long as the air sticks to the surface of the blade. When air separates from the backside of the blade due to an additional increased angle of attack, the result is known as positive stalling (see the following figure).

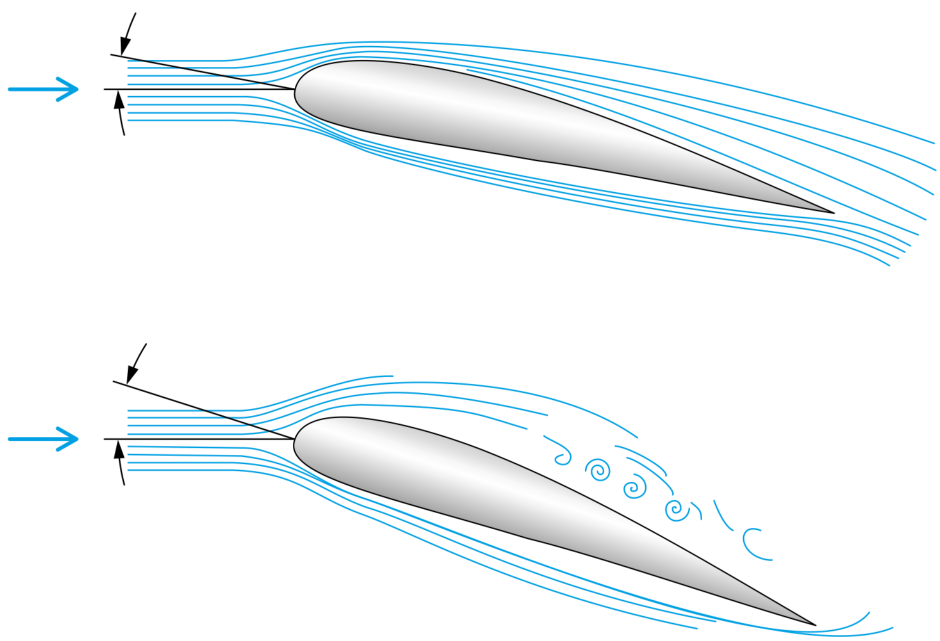

Figure 50. Positive stall.

When the angle of attack is negative, air can separate from the front side of the blade. This is known as negative stall. In both negative and positive stalling, the flow of air through the turbine is disrupted. This can adversely affect the performance and operation of the wind turbine. Some stall effects might include increased drag or vibration, which can damage blades, gears, or bearing systems.

Blade inspection and maintenance

3 min.

Competency

- List the elements of a blade maintenance program.

Blades are often made from composites of epoxy resins, foam or balsa, and electrical-grade glass (E-glass). E-glass is formed into fiber and is a primary component of common fiberglass. The use of composites on such a large scale is a relatively new practice. Therefore, it is important that turbine owners and operators ensure blade quality. Failure to do so could reduce the profitability of a turbine or even destroy the turbine.

A proper wind turbine blade inspection and maintenance program can be broken down into three main categories: on-site arrival inspection, installation inspection, and routine maintenance inspection. On-site arrival inspections start with an exterior inspection to determine if any transportation damage has occurred.

Installation inspections begin with a review of the lifting equipment and installation procedure. This ensures they conform to the manufacturer's defined procedures and recommended hardware. Two additional inspections must then be performed: dynamic balance and aerodynamic alignment, which focuses on cone angle, partition angle, blade contour and twist, and pitch angle.

Cone angle refers to the angle of the blades relative to the plane of rotation (see the following figure). This places the blades in a V shape and helps to reduce stresses on the rotor blades. Partition angle refers to the space of blade angles on the rotor hub. The blade contour and twist refer to the shape of the blade and the changes in blade pitch along its length. Pitch angle refers to the angle between the blade chord line and the rotor's plane of rotation.

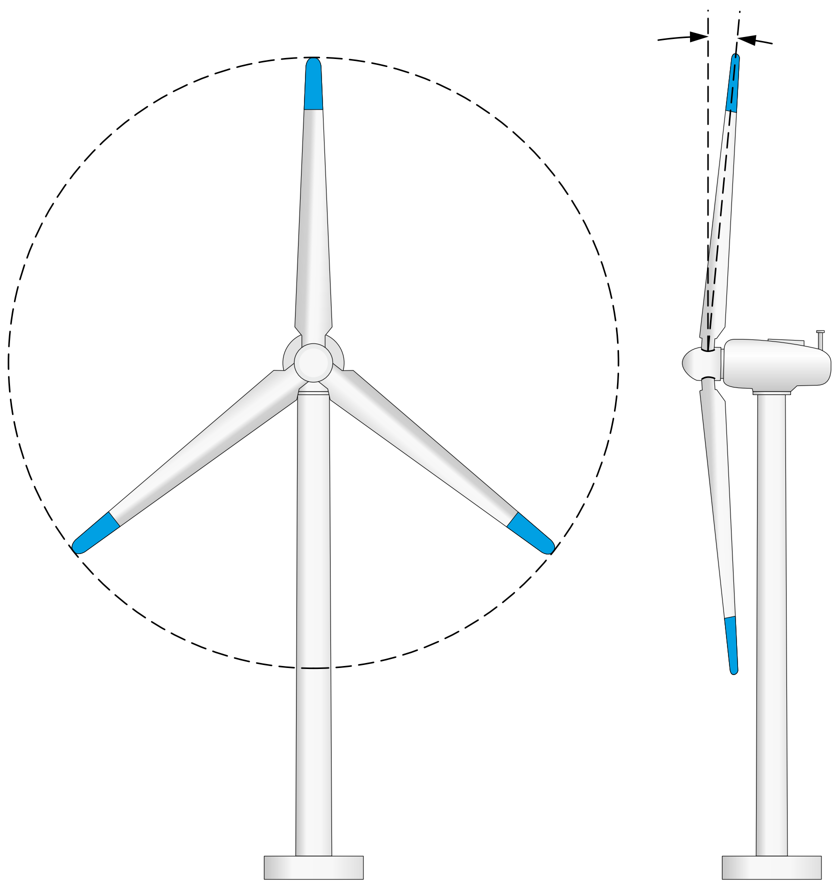

Figure 51. Cone angle.

The last element of a blade maintenance program is the routine inspection. Rotor blades are subject to extreme weather conditions, constant vibration, and rotational stress. For this reason, it is important to set periodical inspections. This ensures a long operational life.

Examples of common maintenance procedures include the following:

- Inspection of root-securing bolts for corrosion. Bolts are re-tightened to proper torque specifications.
- Measurement of vibration levels, and installation of counterweights to reduce vibration.
- Pressure washing of blades to eliminate dirt and other contaminants. Qualified personnel can apply coatings such as Teflon paint to help reduce the accumulation of both dirt and ice. Cosmetic repairs are also possible.
- Visual inspections for impact damage, lightning damage, edge erosion, fatigue cracks, stress-induced de-lamination of the blade layers, and freeze and thaw damage. Leading edge tape can be applied to protect and extend the life of the blades by reducing edge erosion.

There are other more sophisticated testing methods available. They are non-destructive and include tests such as ultrasonic, tap, or infrared thermography. These have the advantage of identifying a suspected damaged area and provide measured data points, which is not possible with visual inspection. This is useful when determining and maintaining a permanent record of any damage.

Power control

6 min.

Competencies

- Explain power control in the context of wind turbines.
- Explain passive power control.
- Explain active power control.
- Explain active stall control.

Power control is an important feature of a wind turbine. It regulates the rotation speed of the rotor assembly when wind is present. For stand-alone or off-grid direct current (dc) systems, power controls can improve safety and efficiency, and prevent damage caused by excessive wind speed. For on-grid or alternate current (ca) grid-tie systems, power control can aid in maintaining a constant sinusoidal output to match the phase of the ac distribution network to which the turbine is coupled. Grid-tie turbines can also overspeed if there is a loss of load on the generator (i.e., if the connectivity to the grid is broken). The reduction in generator load reduces the resistance on the turbine hub. This, in turn, can cause a rapid acceleration of the rotor. Power controls can be used to prevent or control this acceleration to avoid turbine damage.

The need for reliability is common to all control system designs. Many forms of power generation require significant monitoring and control; however, wind turbines operate somewhat independently and with very little oversight. Maintenance visits are scheduled approximately every six months; therefore, reliable control systems that can self-monitor and require no servicing are preferred.

Wind turbine power control is accomplished through a system of passive control, active control, or a combination of both.

Passive power control

Passive control systems that are often found in smaller wind turbines utilize methods such as centrifugal force-controlled tip braking or unique blade designs to reduce the risk of turbine overspeed. They do not require monitoring or a control system to enable power regulation.

Tip brakes can be metal plates that extend off the tip of the blade. They can also be a short blade tip length, which can be rotated to act as an airflow damper when excessive blade speed occurs. These are often mechanically or electromechanically controlled. They automatically deploy and retract as the blade speed increases and decreases. Often, a sophisticated control system is not required for these systems to operate.

An alternate method of passive braking is utilized in passive stall-control turbines. The wind turbine rotor blade profile is aerodynamically designed to ensure stall is introduced the moment the wind speed becomes too high. This stall prevents the lifting force of the rotor blade from acting on the rotor. It is the result of turbulence on the side of the rotor blade that is not facing the wind (see the following figure).

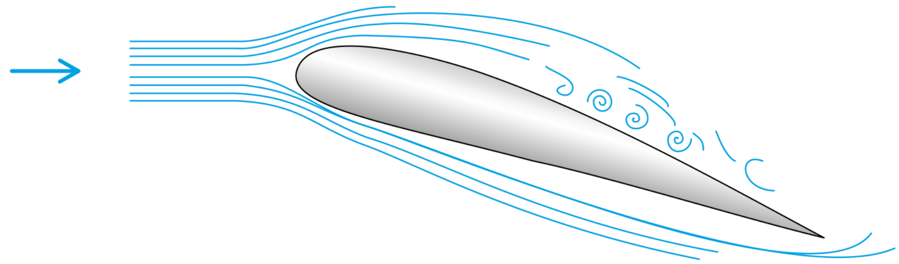

Figure 52. Blade stall.

The rotor blades of stall-control wind turbines are coupled to the rotor hub at a fixed angle. Each blade is twisted slightly along its longitudinal axis to ensure the rotor blade stalls gradually rather than abruptly when the wind speed reaches its critical value. The benefits of passive stall control include the lack of moving parts in the rotor itself and the absence of a complex control system that could be unreliable. However, the design of stall-control systems is a very complex aerodynamic process, and it can create unique challenges in the structural dynamics of the turbine, leading to stall-induced vibrations.

Active power control

Active power control systems are commonly found in larger turbines and are employed in the Electrical Pitch Hub Learning System. Active power control systems monitor the wind through instrumentation, and then mechanically adjust the entire blade pitch or tip pitch to respond to variations in wind speed.

In a full blade pitch system, the blades are mounted on rotating bearings that are fixed to the rotor hub (see the following figure). This allows the blades to pivot into and away from the wind, adjusting the angle of attack. In nearly all large-scale commercial wind turbines, mechanical control systems that employ either hydraulic pistons or electrical servomotors drive the blade pitch to adjust to wind and operational conditions specified by an automatic controller.

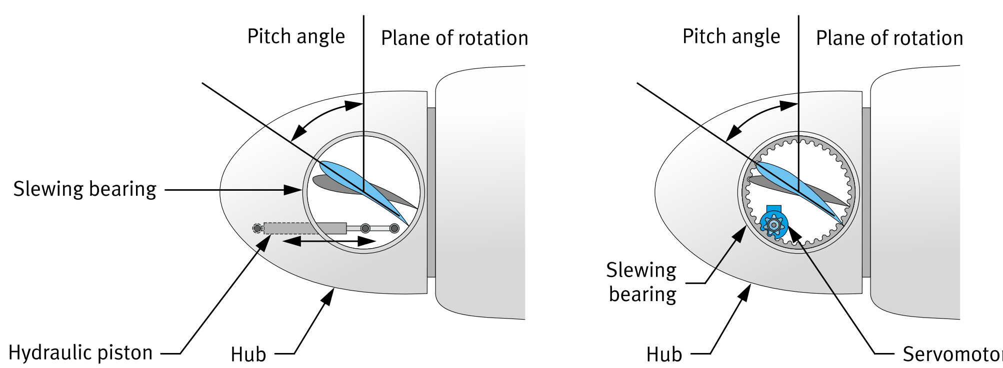

Figure 53. Pitch control system.

During normal grid-tie in-service operation, the electronic controller checks the power output of the turbine many times per second. This includes the monitoring of shaft speed, pitch angle, wind velocity, and generator output. When the power output becomes too high, the controller signals the blade pitch drive mechanism to turn the rotor blades slightly out of the wind (see the following figure). Conversely, the blades are turned back into the wind whenever the wind drops.

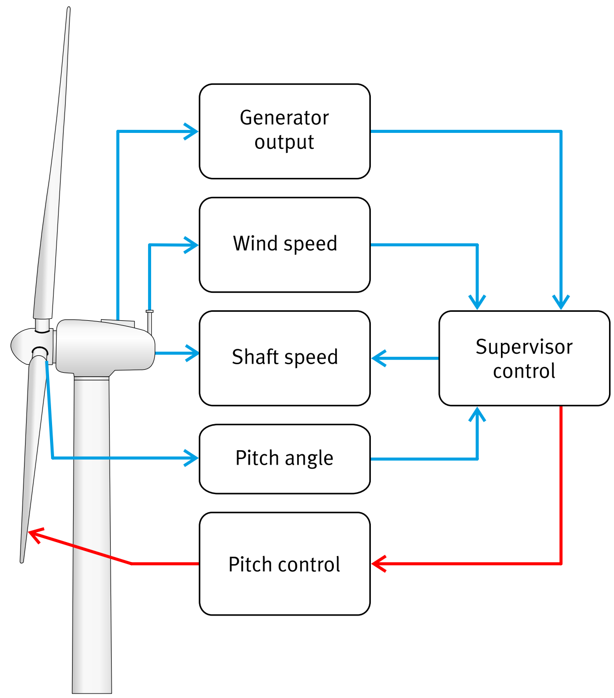

Figure 54. Pitch control block diagram.

Active stall control

An increasing number of larger wind turbines use a combination of pitch and stall-control systems called active stall control. Unlike the standard pitch control that reduces pitch angle to slow the turbine, an active stall-control turbine increases the angle of attack of the rotor blades to make the blades go into a deeper stall. This wastes the excess energy in the wind and keeps the rotor speed closer to constant. Active stall controls the output power of a turbine more accurately than passive stall, specifically because it avoids overshooting the turbine's rated power at the beginning of a gust of wind. Active stall-control turbines can be run almost exactly at rated power at high wind speeds. Passive stall-control wind turbines, on the other hand, experience a drop in electrical power output for higher wind speeds as the rotor blades go into their designed deeper stall.

Common types of pitch control

Hydraulic pitch control

4 min.

Competencies

- Recognize the main components of a hydraulic pitch control.
- Recognize the main components of an electrical pitch control.
- Explain the differences between hydraulic and electrical pitch hubs.

Hydraulic pitch control systems feature a hydraulic piston to pitch the wind turbine blades. The system includes a hydraulic pump, control valves, and pressure distribution blocks to control the pitch angle of the blades. The extendable piston is fixed to a pivot on the slewing bearing, thus allowing to pitch the blade. As the hydraulic piston extends or retracts, the blade pitch varies to match the controller's demands. The following figure shows the main components of a hydraulic pitch control system used for training purposes.

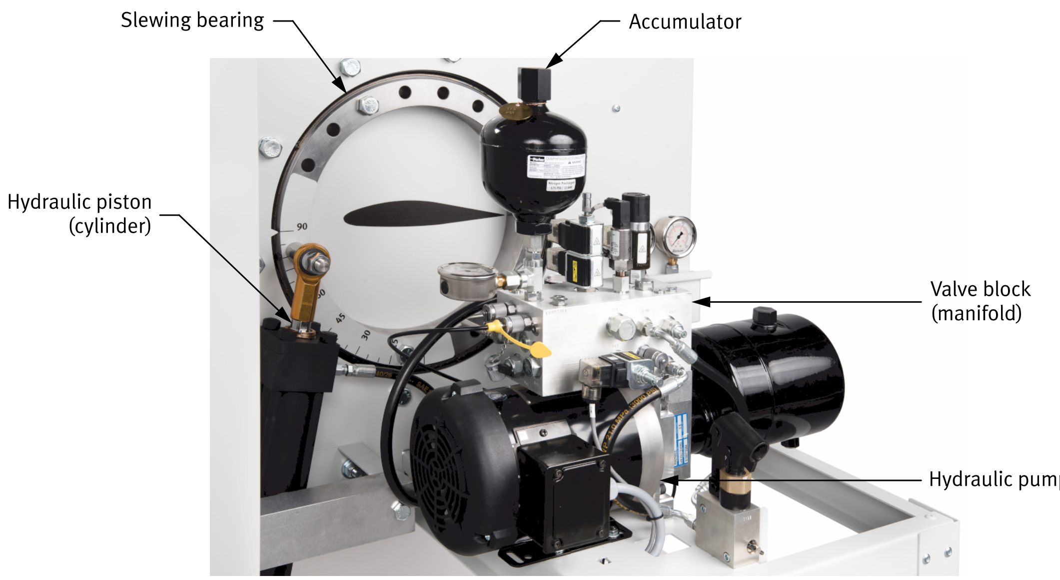

Figure 55. Hydraulic pitch control.

Electrical pitch control

The electrical pitch system features an electronic programmable logic controller (PLC). This PLC controls the servomotor drives, which operate the stepper motors. For each blade, a gearbox couples a stepper motor to a slewing bearing. The gearbox often features a planetary speed reduction assembly. This allows converting the fast-rotational speed of the electric motor into a slower rotation of higher torque.

Sometimes, each motor has its own controller that operates in unison with the others, and it can assume full control of all blades if one or more of the additional control units fail (see the following figure).

Figure 56. Electrical pitch system using servomotors.

Difference between hydraulic and electrical pitch hubs

The table below presents a comparison between electrical and hydraulic pitch hubs, emphasizing the advantages and disadvantages of each system.

Table 2. Comparison between electrical and hydraulic blade pitch systems.

Variable	Hydraulic	Electrical
Design/ composition	• One power unit • Three actuators, control valves, and accumulators	• Three sets of motors/gears, drives, controllers, and energy storage units • Three to eight switchgear cabinets depending on what functions are assembled in one cabinet
Strengths	• High forces • Gearless/no backlash Fail-safe powered by accumulator	• Low energy consumption • Quiet operation

Variable	Hydraulic	Electrical
Weaknesses	• Possibility of oil leakage • Higher energy consumption	• Backlash • Increased probability of failure (higher number of components)
Cost	• Lower initial cost • Higher running cost (higher maintenance)	• Higher initial cost • Lower running cost (less maintenance)
Maintenance	• Cylinder seals need to be replaced every few years • Repetitive oil and filter replacement	• Largely maintenance-free except battery change
Working environment	• Noisy • Risk of oil leakage	• Little room for movement in hub
Best known as	• Highly reliable, proven fail-safe functionality	• Environmentally friendly system

Slewing bearings

8 min.

Competencies

- Explain the function of a slewing bearing in an active pitch control system.
- Realize the importance of bold tightening in slewing bearing maintenance.
- Be able to use a torque wrench to tighten the mounting bolts of a slewing bearing.
- List the NLGI grades for grease classification.

A primary component in an active pitch control system is the bearing that secures the blade to the hub and allows the system to change the pitch angle. This component is the slewing bearing. It is a large rolling bearing that can accommodate axial, radial, and moment loads in any direction. Common bearings for pitch control systems are four-point contact ball slewing bearings. The following figure shows a slewing bearing and identifies its location on a hub.

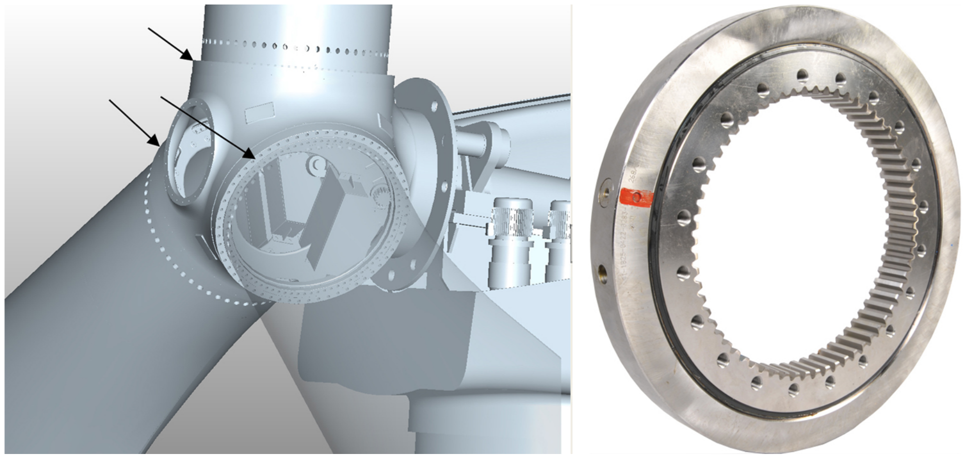

Figure 57. Slewing bearing.

Slewing bearings can perform slewing, oscillating, and rotational movements. A typical slewing bearing consists of an inner ring with a toothed gear, an outer ring, and rolling elements. The rolling elements can be balls or cylindrical rollers. They are separated by polyamide spacers, as shown in the following figure. Each ring of the bearing has threaded holes to accommodate attachment bolts to the turbine hub and turbine blade.

(a) (b)

Figure 58. Ball (a) and roller (b) slewing bearings.

The Electrical Pitch Hub Learning System includes a slewing bearing and its drive components. This helps to understand the functional characteristics of a slewing bearing in operation on an actual wind turbine. To facilitate classroom usage, the blade itself is not present. Rather, it is represented by an outline sketch on the front of the system. The following figure shows the slewing bearing and blade of the system.

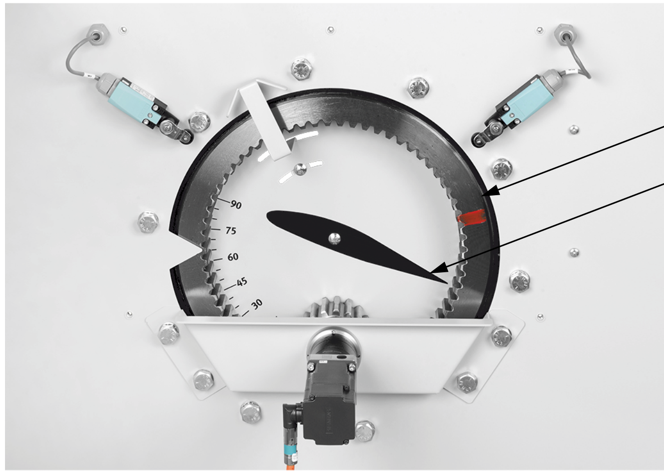

Figure 59. Slewing bearing and blade of the Electrical Pitch Hub Learning System.

Tightening bolts

The initial stage in slewing bearing maintenance is the inspection of the mounting bolts. Missing bolts and nuts should be replaced only with those recommended by the wind turbine manufacturer. Due to their small cross section, slewing bearings cannot bear much direct load. This means that the mounting that holds the slewing bearing must bear the load. It is thus essential to tighten the bearing firmly. During the first installation of a slewing bearing, it is important not to apply protective coatings or oils in the bearing mounting mating surface. Failure to do so could impair the integrity of the coupling between these elements.

All bolts and nuts should be tightened with an accurate torque wrench (see the following figure) in a minimum of two stages: tightening all bolts up to approximately 50% of the final torque specification followed by tightening to the finish specification. Depending on the bearing make and type, each manufacturer may have its own unique tightening specification that must be followed.

Figure 60. Common torque wrench.

Indications on how to use a torque wrench

- To adjust the wrench, pull down on the collar and rotate the handle until you obtain the desired torque value (indicated on the Metric or SAE scale), then release the collar.

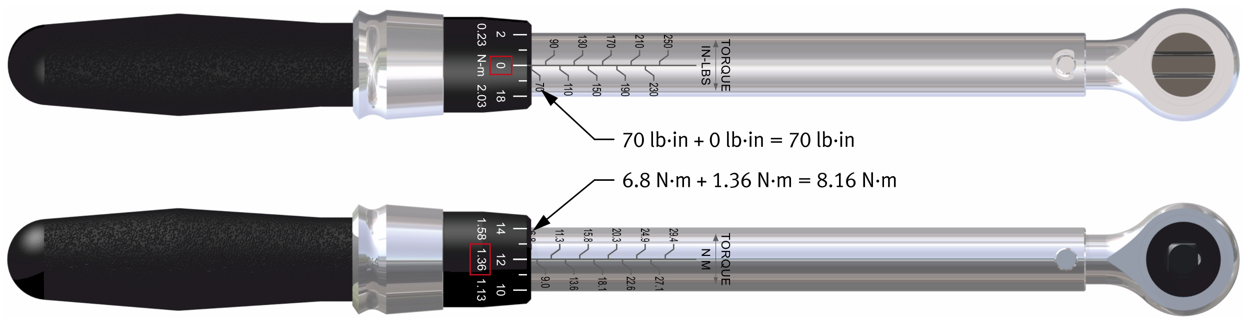

Figure 61. Examples of wrench adjustments (Metric and SAE).

Using the torque wrench in reverse direction is also possible. This is because in the field some bolts are threaded in reverse direction (although not on the learning system).

- To apply torque,
    - Attach the proper socket.
    - Set the direction of operation properly.
    - Follow the recommendations of the component manufacturer as to how to torque the fasteners. Hold the handle by the grip and apply a slow and steady force.

Usually, you will follow a pattern (criss-cross, clockwise, etc.) and apply only a small torque to the fasteners the first time. You will increase the torque during subsequent rounds until you hear and/or feel a little “click” for all bolts during a single round.

- You should always return a torque wrench adjustment to zero after use to maintain the tool calibration.
- To tighten a fastener to a lesser torque value, loosen the fastener first before you retighten it.
- Do not use a torque wrench with excessive force (more than the rated capacity). Always use a different tool (e.g., a ratchet) for disassembly.

Lubrication of slewing bearings

The National Lubricating Grease Institute (NLGI) classifies lubricating greases into nine numerical grades based on consistency. The following table shows that grades range from NLGI000 (fluid) to NLGI 6 (very hard grease).

Table 3. Table of NLGI grades ranked according to consistency.

NLGI Grade	Tag(s) on the manifold	Appearance	Food consistency analog
000	445-475	Fluid	Cooking oil
00	400-430	Semi-fluid	Applesauce
0	355-385	Very soft	Brown mustard
1	310-340	Soft	Tomato paste
2	265-295	"Normal" grease	Peanut butter
3	220-250	Firm	Vegetable shortening
4	175-205	Very firm	Frozen yogurt
5	130-160	Hard	Smooth pate
6	85-115	Very hard	Cheddar cheese

NLGI Grades 000 to 1 are used in applications such as enclosed and open gearings, and gear drives operating at low speeds. Grades 0, 1, and 2 are used in highly loaded gearing. Grades 1 through 4 are often used in rolling contact bearings, where grade 2 is the most common.

Manufacturers often fill slewing bearings with mineral oil-based grease at a NLGI 2 consistency rating, mixed with a lithium soap thickener and extreme pressure additives. Re-lubrication of a customized slewing bearing depends on the needs of the application.

Lubrication of the Electrical Pitch Hub Learning System

6 min.

Competencies

- Identify the key lubrication points of the learning system.
- Describe the automatic lubricator of the learning system.
- Describe the lubricator status based on the lubricator LEDs behavior.
- Select lubricator switch settings according with the dispensing time and amount of lubricant required.

The Electrical Pitch Hub Learning System can be lubricated using either a grease gun or an automatic filler. The following figure shows the system's automatic lubricator.

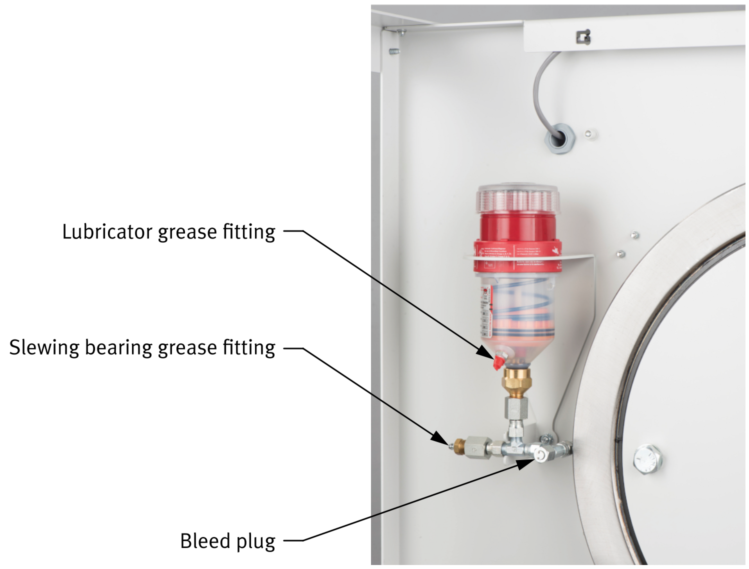

Figure 62. Automatic lubricator of the learning system.

The above figure shows three key lubrication points on the system: the grease fitting that allows filling the lubricator, the grease fitting to manually grease the slewing bearing, and a bleed plug to purge the grease contained in the lubricator. For training purposes, the bleed plug should be removed during trial filling to avoid over-lubricating the slewing bearing.

Using the automatic lubricator

The automatic lubricator of the learning system is a self-contained unit powered by a battery pack and driven by a dc motor. It includes a block of DIP switches that allow users to set the amount of grease and lubrication interval. At each interval, the lubricator feeds approximately 1.25 grams of grease to the bearings. The DIP switches are shown in the following figure.

Figure 63. DIP switches on the automatic lubricator .

Operating the automatic lubricator

The automatic lubricator allows changing the lubricant dispensing rate during operation. To do so, set all switches in use to OFF. Then, select the new switch setting according to the dispensing rate you desire to use. To turn off the lubricator, set all switches to OFF.

Switch 7 is the purge switch. Setting it to ON causes the lubricator to provide an immediate shot of grease.

The lubricator features a set of LEDs to indicate the status of the unit. The following table indicates the lubricator status corresponding to the behavior of each LED.

Table 4. Lubricator status corresponding to the behavior of each LED.

Indication	LED	Behavior
Operation OK.	Green	One flash every 20 seconds
Currently pumping grease.	Green	One flash every 1 second
If the internal limit switch counter is faulty, the unit goes into an operational timed failsafe mode.	Red	One flash every 20 seconds
Low battery. Replace it as soon as possible.	Red	Two flashes every 20 seconds

Indication	LED	Behavior
Unit paused via remote control option (if used here).	Blue	Two flashes every 20 seconds
Unit paused due to low ambient temperature. Unit will resume operation when temperature increases above -15°C (5°F).	Blue	Four flashes every 20 seconds

When empty, the automatic lubricator can be refilled using a manual, pneumatic, or electrical grease gun.

NOTICE

Do not overfill the automatic lubricator, as this could damage the unit. Fill it until the piston O-rings reach the marks on the grease container, and no further. Excess grease may be expelled through the pressure relief valve.

Refer to the manufacturer's manual for more recommendations on the use of the automatic lubricator.

Lubricator switch settings

Operating conditions such as loads, temperatures, speeds, and vibrations determine the dispensing time and amount of lubricant required for an application. The user can then associate the determined dispensing time and amount of lubricant to the corresponding switch setting. The following table presents a guide to select the dispensing rate on the automatic lubricator. This table compares the output rate of the automatic lubricator with several manual lubrication schedules. It indicates the switch settings that provide comparable lubrication to that of the manual lubrication schedules.

Table 5. Switch settings.

Manual lubrication schedule	Automatic lubricator	
	Unit life	Switch setting
Once per day 3 – 4 strokes	1 month (30 days)	Switch 2 set to ON, all other switches set to OFF.
Once per 2 or 3 days 3 – 4 strokes	2 months (60 days)	Switch 3 set to ON, all other switches set to OFF.
Once per week 8 – 10 strokes	3 months (90 days)	Switches 2 and 3 set to ON, all other switches set to OFF.

Manual lubrication schedule	Automatic lubricator	
	Unit life	Switch setting
Once per two weeks 8 – 10 strokes	6 months (180 days)	Switches 3 and 4 set to ON, all other switches set to OFF.
Once per month 8 – 10 strokes	12 months (360 days)	Switches 4 and 5 set to ON, all other switches set to OFF.
Once per two months 8 – 10 strokes	24 months (720 days)	Switches 5 and 6 set to ON, all other switches set to OFF.

Refer to the lubricator manufacturer's manual for more information on switch settings and lubrication schedules.

Greasing the slewing bearing

16 min.

Competencies

- Load a manual grease gun.
- Be able to perform lubrication tasks using a manual grease gun.
- Be able to perform lubrication tasks using an automatic lubricator.

A grease gun and a grease cartridge are provided to maintain good lubrication of the slewing bearing. The grease selected is an NLGI grade 2 lithium multipurpose grease. Grease specifications can be found in the table of NLGI grades presented before.

The grease gun model can vary. If you are using a different model, refer to the manufacturer's directions.

Loading the grease gun

1. Take the grease gun. Pull back the rod handle and lock it as shown in the following figure.

   Unscrewing the barrel while the rod is not pulled and locked can cause a mess.

Figure 64. Locking the rod handle.

2. Unscrew the gun head from the barrel as shown in the following figure.

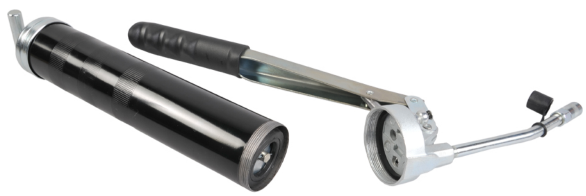

Figure 65. Opening the grease gun.

3. The cartridge can be removed to verify that the grease meets the bearing requirements. If you need to add a new cartridge:

a. Remove the plastic cap (see the following figure).

Figure 66. Removing the plastic cap.

b. Insert the new cartridge, open end first, into the barrel. Push the cartridge until the pull-tab seal is level with the barrel rim, as shown in the following figure.

Figure 67. Inserting a new grease cartridge.

c. Remove the seal (see the following figure).

Figure 68. Removing the seal.

d. Screw the gun head back into place.

e. Unlock the rod handle and push it back to exert pressure on the grease and depress the air bleeder valve to expel air.

f. Pump the lever until grease flows out (see the following figure).

The first time you pump the grease, it can come out faster than expected. Before you start pumping, be careful not to point the gun in the direction of other people or unwanted areas.

Figure 69. Grease flowing out of the gun.

Using the grease gun

4. Remove the bleed plug, as shown in the following figure.

Figure 70. Removing the bleed plug.

Removing the bleed plug allows to observe the grease flowing through the tubing and prevents the over-lubrication of the slewing bearing.

5. Wipe the slewing bearing grease fitting with a clean rag to prevent contaminants from entering the slewing bearing.

Figure 71. Cleaning the slewing bearing grease fitting.

6. Insert the grease gun nozzle in the grease fitting of the slewing bearing, as shown in the following figure. Make sure to place the nozzle at a suitable angle so it's inserted tightly into fitting.

Figure 72. Inserting the grease gun into the slewing bearing grease fitting.

Make sure to have a clean cloth to wipe off the grease coming out of the bleed plug.

7. Slowly pump grease until an amount like the one shown in the following figure comes out of the bleed plug.

Figure 73. Pumping grease into the slewing bearing grease fitting.

8. Wipe off the grease from the bleed plug.

9. Replace the bleed plug.

Using the automatic lubricator

10. Wipe the lubricator grease fitting with a clean rag to prevent contaminants from entering the lubricator (refer to the following figure).

Figure 74. Cleaning the lubricator grease fitting.

11. Insert the grease gun nozzle into the lubricator grease fitting, as shown in the following figure.

Figure 75. Inserting the grease gun into the lubricator grease fitting.

12. Pump a small amount of grease inside the automatic lubricator. Since this is only to show the filling of an automatic lubricator, there is no need to fill it completely.

NOTICE
Do not overfill the automatic lubricator, as this could damage the unit. Fill it until the piston O-rings reach the marks on the grease container, and no further. Excess grease may be expelled through the pressure relief valve.

Figure 76. Pumping a small amount of grease inside the automatic lubricator .

13. Remove the bleed plug.

14. Remove the top cap of the lubricator, as shown in the following figure.

Figure 77. Removing the top cap of the lubricator .

15. Ensure that all DIP switches are set to OFF, as shown in the following figure.

16. Plug the battery pack connector to the connector inside the lubricator's unit, as shown in the following figure. The three LEDs flash, one after the other.

Figure 78. Plugging the battery pack to the connector inside the lubricator ’s unit.

17. Set DIP switch 7 (purge) to ON.

    Make sure to have a piece of cloth to wipe off the grease coming out of the bleed plug.

18. Once the lubricator starts to dispense grease (this takes approximately 1 minute or less), set DIP switch 7 to OFF.

19. The lubricator dispenses grease for approximately 1 minute and then stops (refer to the following figure).

Figure 79. Lubricator dispensing grease.

20. Unplug the battery pack connector from the connector inside the lubricator's unit, and replace the top cap.

21. Wipe the lubricator grease fitting with a clean rag and replace the bleed plug.

Review questions

1. What is the angle of attack?

   a. It is the blade angle from the blade centerline to the hub's plane of rotation.

   b. It is the angle between the apparent wind direction and a hypothetical blade centerline running from a blade's leading edge to its trailing edge.

   c. It is another term to describe the twist angle of a blade.

   d. It is the arithmetic sum of the twist angle and the pitch angle.

b

2. What are the two main types of pitch hub?

   a. Electro-hydraulic
   b. Electrical
   c. Pneumatic
   d. Hydraulic

b and d

3. What are the two types of aerodynamic force that wind machines can use to extract power?

   a. Weight
   b. Lift
   c. Thrust
   d. Axial
   e. Drag

b and e

4. Which of the following forces is perpendicular to the relative flow direction?

   a. Resulting force between lift and drag
   b. Drag
   c. Both lift and drag
   d. Lift

d

5. Which items do you need to manually lubricate the slewing bearing of the learning system?

   a. Grease gun and oiler
   b. Oiler, grease gun and grease (cartridge)
   c. Grease gun and grease (cartridge)
   d. A clean rag and water

c

6. Which tool is used to measure the force applied while fastening bolts?

   a. Pipe wrench
   b. Monkey wrench
   c. Adjustable wrench
   d. Torque wrench

d

7. The resulting force on a wind turbine blade increases when

   a. the exposed area of the blade decreases.
   b. the angle of attack decreases.
   c. the angle of attack increases.
   d. the pressure decreases.

c

8. A reduction in the angle of attack

   a. always increases the lift.
   b. increases the blade speed.
   c. does not have any effect on the wind turbine speed.
   d. helps to slow down the wind turbine.

d

9. What is the pitch angle?

   a. It is the blade angle from the blade centerline to the hub's plane of rotation.
   b. It is the angle between the apparent wind direction and a hypothetical blade centerline running from a blade's leading edge to its trailing edge.
   c. It is another term to describe the twist angle of a blade.
   d. It is the arithmetic sum of the twist angle and the pitch angle.

a

10. What system controls the speed on a wind turbine by varying the pitch angle?

    a. The power control system
    b. The yaw system
    c. The manual speed control system
    d. The pitch control system

d

11. The Electrical Pitch control system is an example of which type of power control?

    a. Passive control when feathered, active control at high speed
    b. Active control
    c. Passive control
    d. Passive control, but only at low speed

b

12. The main categories of a proper wind turbine blade inspection and maintenance program are

    a. on-site arrival inspection, installation inspection, and routine maintenance inspection.
    b. videoscope inspection and installation inspection.
    c. vibration analysis and videoscope inspection.
    d. thermographic inspection and maintenance inspection.

a

13. The company where you work decided to replace the manual lubrication system of an application by an automatic system like that of the Electrical Pitch Hub Learning System. An employee currently uses a manual grease gun to feed 3 to 4 strokes per day. What DIP switch setting would you recommend on the automatic lubricator?

    a. Switch 3 set to ON, all other switches set to OFF
    b. Switch 2 set to ON, all other switches set to OFF
    c. Switches 2 and 3 set to ON, all other switches set to OFF
    d. Switches 5 and 6 set to ON, all other switches set to OFF

b

14. When using the automatic lubricator of the learning system, which DIP switch purges grease from the lubricator?

    a. All DIP switches, depending on the configuration.

    b. It depends on the lubrication rate.

    c. DIP switch 7.

    d. It is impossible to purge the system using the DIP switches.

c

15. Which component of the learning system secures the blade to the hub and allows changing the pitch angle?

    a. PLC

    b. Slewing bearing

    c. Pinion gear

    d. Planetary gearbox

b

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