Introduction to Wind Power

After reading this chapter, you will be able to…

- Explain the fundamentals of troubleshooting, and the difference between a symptom & a problem.
- Develop a procedure for locating a loss of voltage in an electrical circuit.
- Explain the wind turbines troubleshooting process.
- Troubleshoot the electrical, hydraulic, and mechanical systems of a wind turbine.
- Perform periodic maintenance on the electrical, hydraulic, and mechanical systems of a wind turbine.
- Explain the steps in installing a wind turbine.
- Explain the start-up procedures for a wind turbine.

Introduction to Wind Power

STEPS IN THE INSTALLATION OF A WIND TURBINE

- Wind turbine installation is a sequence of several steps:
  - The process begins when a is interested in determining what is involved in putting a wind turbine on his site
    - He/she may want basic information about how the wind turbine operates and functions
  - He/she will be interested in costs—initial, and ongoing.
    - Also in grants or write-offs available from federal, state or local governments.

Introduction to Wind Power

STEPS IN THE INSTALLATION OF A WIND TURBINE

- To determine the size of the turbine needed, and an estimate of how much electricity the turbine will provide:
  - You will need to know what the customer intends:
    - Home or industry supply, or as a grid-tied system.
  - Identify the amount of wind available at the location where the turbine is to be located—daily and yearly.
- After this information is identified you will be able to:
  - Show the customer wind turbines that meet the specs.
  - Provide a cost for the complete system.
  - Develop a tentative schedule of when installation can be completed and the generator can begin production.
  - Write & sign contracts, and order the wind turbine system.

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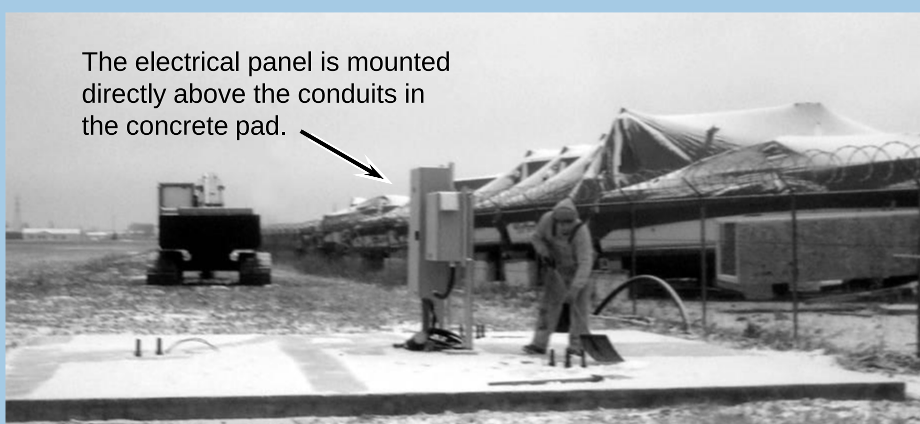
STEPS IN THE INSTALLATION OF A WIND TURBINE

- Site preparation includes:
  - Preparation of the pad and mounting for the wind turbine.
  - Providing access for service vehicles and cranes.
  - Determining the closest point to tie into the grid.
- In some cases, soil samples may be needed to be taken to determine if the soil can handle a highway surface.
  - Also to determine how large and how deep the foundation for the concrete pad must be.
- The depth of the concrete base is determined by the wind turbine size and designed maximum speed.
  - Care must also be taken to ensure water drainage is able to move excess water away from the concrete pad.

STEPS IN THE INSTALLATION OF A WIND TURBINE

Typical concrete pad for a medium-sized 50-kW wind turbine



STEPS IN THE INSTALLATION OF A WIND TURBINE

A much smaller concrete pad for a monopole tower.

The conduits and electrical panels are not mounted on the concrete pad

Introduction to Wind Power

STEPS IN THE INSTALLATION OF A WIND TURBINE

- Another step involves permits and other permissions.
  - Federal, state & local agencies or zoning boards, as well as safety & environmental conditions must be met.
  - Some locations have created a process to entice the maximum number of wind turbines to their areas.
- In some cases, permits & other documents must be obtained prior to completing the deal.
  - In others, permits, etc., are applied for and obtained during the planning process.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

- The size and weight of the turbine blades determine whether are mounted to the wind turbine while it is on the ground or after it is in the air.

Blades ready to ship.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Nacelles waiting for blades to be attached.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Nacelle being placed on the pole by a large crane.

Wind turbine blades ready to be mounted on the rotor of a wind turbine.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Wind turbine blade/rotor assembly lifted into position to be connected to the low-speed shaft.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Technician connecting the nacelle of a mid-size wind turbine to its tower.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Tightening the nuts and bolts that hold the nacelle to the tower.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Turbine blades and the rotor assembly are being connected to the nacelle.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Larger turbine blades supported by blocks while being mounted to the rotor.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Electrical cables routed through the tower.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

The cables have molded plugs to prevent them from being connected incorrectly.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

A technician connects the electrical cable to the cable connected to the generator.

A lifting sling from the crane is placed around the nacelle so the tower can be lifted into place.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Technicians secure turbine blades to the tower so they cannot rotate when the tower is lifted into place.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

After the tower is erected and secured, a technician climbs the tower to remove cables used to secure the blades to the tower during the lift.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

- The crane used must be able to lift a load larger than the actual weight of the wind turbine.
  - Actual weight of the components will be listed in the technical data for the tower, rotor, and drive train.
- Once the technicians are sure that the sling and cables are secure and operating correctly, the tower is lifted into place by the crane.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

The crane takes up the tension in its cable & sling, and begins to lift the tower.

Turbine and tower lifted well off the ground.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Technicians place nuts on the mounting bolts after the tower is set vertical

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Cable molded plug ends connected, with a strain relief loop in the cable.

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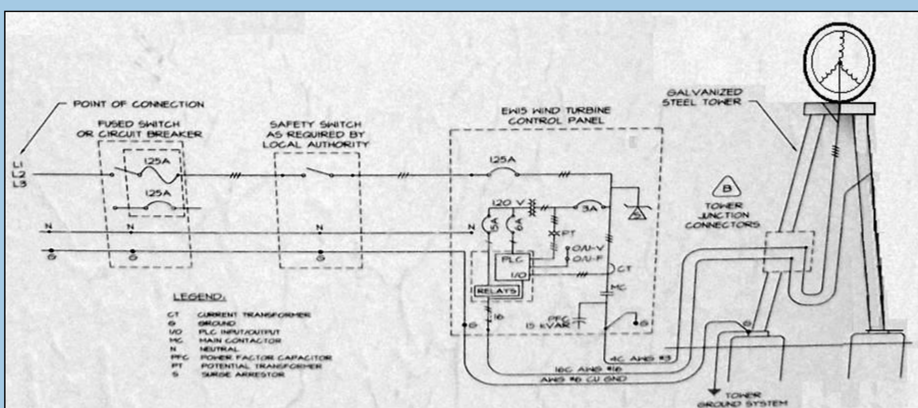
STEPS IN THE INSTALLATION OF A WIND TURBINE

A diagram mounted on the front door of the electrical cabinet.



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STEPS IN THE INSTALLATION OF A WIND TURBINE

Electrical panel, cable from the wind turbine and the wires that will connect the wind turbine to the grid.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Electrical service entrance for the property where the wind turbine is installed.

The overhead cables are 240 V from the utility power company.

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STEPS IN THE INSTALLATION OF A WIND TURBINE

Disconnect switch mounted on the wind turbine transformer.

The switch can be manually operated any time voltage from the wind turbine needs to be turned off or isolated.

Called the *tie point* for the system, the wiring from the wind turbine transformer for is connected to the wiring at the meter.

Introduction to Wind Power

STEPS IN THE INSTALLATION OF A WIND TURBINE

In a safety harness and tied off to the tower, a technician climbs to remove the ropes used to tie the blades off to the tower when the tower and wind turbine were erected.

Introduction to Wind Power

STEPS IN THE INSTALLATION OF A WIND TURBINE

- When wind speed reaches the start-up threshold, the turbine blades are released & allowed to begin turning.
  - Blade speed and voltage generated is closely monitored.
- Mechanical parts—blades, rotor, low-speed shaft, gear-box, high-speed shaft, and generator—are monitored for vibration, misalignment, or other problems.
- After the turbine has produced voltage for several hours, technicians stop it, and go over all the nuts, bolts, and other mechanical systems that might become loose.
  - They also look for signs of wear or excess heat.

Introduction to Wind Power

TROUBLESHOOTING

- The best way to find a problem is to determine what parts of the system are working correctly, and then eliminate them from the process.
- Developing a series of questions & tests to eliminate the most possibilities will help find problems more quickly.
  - By eliminating parts of the system that work correctly.
- The key to this process is to properly identify the subsections of the wind turbine system.
  - It is actually easier to identify what is working correctly, and, through elimination, focus only what is faulty.

TROUBLESHOOTING

- Use a consistent procedure each time you troubleshoot.
  - Go through a methodical system to test components.
- Some technicians fail at troubleshooting because they try to remember what was broken the last time.
  - And work as though the problem is simply repeating itself.
- Others fail because they randomly test different parts or sections of the system—with no concept of what they are testing or why.
- The first step in troubleshooting a wind turbine system is to determine what the system was doing before it had the problem.

Introduction to Wind Power

TROUBLESHOOTING

- After you check out all the wind turbine systems, you may try & operate different parts of the wind system.
  - Sometimes you will find the system can operate partially.
    - Or one part can operate, whereas another part cannot.
- An important part of the process is to identify what types, and how many subsystems the wind turbine system has.
  - Experienced may spend a few minutes just looking at the system to determine what is running, or turned on.

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TROUBLESHOOTING

- Determine the type of wind turbine you're working on:
  - *Is it an upwind or a downwind system?*
  - *Does it use an electric motor or hydraulics to change yaw direction or blade pitch?*
    - *Are these changed by the wind or centrifugal force?*
  - *Does the system have a gearbox or transmission, or is it a direct-drive system?*
  - *What type of generator & controls are used in the system?*
  - *Does the wind turbine system use regular hard-wired controls or a computer or PLC?*
    - *If a computer or PLC, is there data, or fault codes or status lights indicating problems?*

Introduction to Wind Power

TROUBLESHOOTING

- A second step involves your senses beyond vision:
  - *Is there noise from the rotor, shafts, and gearboxes?*
    - To indicate if they are under an extreme load.
  - *Are there gears, bearings, or other mechanical parts squeaking or groaning?*
    - Indicating they are running improperly, creating friction?
  - *Are there motors that hum but do not run?*
    - Such as yaw motors.
  - *Can you smell a generator, electrical component, or bearing that is overheating?*

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TROUBLESHOOTING

- Most wind turbine manufacturers have websites or call centers to provide you with additional information regarding problems that may occur with their systems.
- The manufacturer may also want you to report problems found in the field, to add them to its database.
- You can use the Internet to search for the problem you are encountering, or join an online group or forum for wind turbine technicians who will respond to questions.

Introduction to Wind Power

TROUBLESHOOTING

- Another way of troubleshooting is to look for things most likely to occur and check them out first.
  - Then move on to things that are less likely to occur.
- As you become familiar with wind turbine systems, you will learn which components are prone to failure and what their failure mode is.
  - Certain problems may occur with specific brands/models.

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TROUBLESHOOTING

- When you have identified a faulty component, you may want to swap it out to ensure the part is actually bad.
- An advantage of swapping is that if the part is expensive or has a long shipping time, you can ensure the part is faulty before you order a new one and wait for shipping.
- A problem is that some technicians use the component swap before thoroughly testing the part.
  - They guess which part is bad and may waste a lot of time changing parts that are *not* bad.
- Completely test the part in its natural operating state, and complete an alternative power-off test.

Introduction to Wind Power

TROUBLESHOOTING

- At times, you will be requested to work on a new wind turbine installation that may be under warranty.
  - If the system is new & in warranty, you will need to verify some things you propose to do, such as changing parts.
- You may have to contact the manufacturer or installer to locate the proper repair part—and send the faulty part back for testing.
- When you are changing warranty parts, the company will ask for detailed information about the system:
  - Installation date & number of hours the system has run.
  - What caused the problem you are working on.
  - Model/serial numbers of parts you are replacing.

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TROUBLESHOOTING

- You may be called to work on a system with the same problem more than once within the warranty period.
  - The company may want proof that the second failure was not due to parts installed improperly or service not carried out correctly.

Introduction to Wind Power

TROUBLESHOOTING

- It is important that each system has its own maintenance logbook—to record all maintenance on the system.
  - From periodic maintenance to failures & parts replaced.
- Accurate dates, times & number of hours the system has run are important data to enter into the logbook.
  - Some systems create a logbook record electronically through the PLC or computer system.

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DIFFERENCE BETWEEN A SYMPTOM & A PROBLEM

- You may find conditions that make the wind turbine inoperable and make the repair—only to find the condition reoccurs.
  - You have found a **symptom** rather than the **problem**.
- When you find the actual problem, it is called finding the *root cause* of the problem.
- When you find something causing a condition that makes the wind turbine inoperable, you need to ask yourself if you have found a symptom or the problem.

Introduction to Wind Power

TROUBLEHSOOTING TABLES AND MATRIX

- Larger wind turbines provide one or more operating, maintenance and troubleshooting manuals.
  - These may provide a troubleshooting matrix or table with sequences of operation & step-by-step procedures.

Troubleshooting Chart for Small Wind Turbine Electrical Problems

Symptoms	Possible Cause	Corrective Action
1. Propeller turns too slowly even in strong wind, will not start.	a. Brakes on (Run Switch on turned on). b. Battery dead or low voltage. c. Shorted diode in controller rectifier. d. Bad generator brushes. e. If new installation, generator wired incorrectly.	a. Turn Run Switch to on position. b. Charge battery or replace if defective. c. Check diodes and replace bad ones. d. Check brushes and replace worn brushes. e. Check generator wiring and change as needed.
2. Propeller runs too fast, no mechanical noise, no output.	a. Controller disconnected generator	a. Check controller fault for disconnect

See the entire table on page 228 of your textbook.

Introduction to Wind Power

TROUBLESHOOTING GENERATION/TRANSMISSION

- Some problems will involve blades, rotor, low-speed shaft, transmission, high-speed shaft, or the generator.
  - Involving transmission of power from the blades through all the shafts and transmission on to the generator.
- Alignments of all of the shafts and gearbox must be checked any time there is any suspicion of vibration.
  - Misalignment can cause vibrations through the shafts.
- A complete vibration analysis is important to ensure power transfers smoothly all the way to the generator.
  - Vibration will be amplified at each point in the system and eventually severe damage will occur.

Introduction to Wind Power

TROUBLESHOOTING GENERATION/TRANSMISSION

- The blade pitch and nacelle yaw control systems must be periodically tested, and may need troubleshooting.
- This system has two parts for the control.
  - Sensors that tell the PLC or computer what the blade pitch and yaw position should be.
  - The output control of the hydraulics or mechanical system that actually moves the nacelle and blades.
- When these parts of the system is tested, it is important that the turbine is *not* under a full wind load.
  - Test them through their full range in manual control.
  - Allow the sensors to dictate the pitch and yaw under automatic control.

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TROUBLESHOOTING GENERATION/TRANSMISSION

- You may need to troubleshoot the gearbox to determine if the ratio of the input & output speed is as rated.
  - Also test for excessive vibration and problems in creating excess heat due to the gearbox failing.
- If the gears begin to wear, are overloaded, or suffer from a lack of lubrication, the gearbox will begin to overheat and cause damage.
- The system may have a universal joint on the low- and high-speed shafts to help even out misalignment and vibration that may work its way into the shafts.
  - If there are any problems with the universal joint, it generally must be replaced rather than repaired.

Introduction to Wind Power

MECHANICAL AND TOWER PROBLEMS

- Generally, the tower and nacelle do not create problems that need troubleshooting.
  - They simply periodic inspections to ensure they remain intact, and as they were on the day of installation.
- Ensure the tower remains securely anchored and is not showing signs of corrosion or other damage.
  - Guy wires must be checked for wear and correct tension.
- The nacelle needs to be inspected where it is attached to the tower to ensure the connections remain secure.
  - Seals checked for wear & access doors for secure fit.

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TROUBLESHOOTING ELECTRICAL PROBLEMS

- To troubleshoot electrical problems, you will need to:
  - Be able to read electrical schematics & wiring diagrams.
    - As well as electronic diagrams.
  - Know how to make proper measurements with a voltmeter, ohmmeter, ammeter, or Megger.
    - And when it is appropriate to use each type of meter.
- The schematic (ladder) diagram indicates the *sequence of operations* of the wind turbine electrical system.
  - The wiring diagram indicates *locations of terminals on components*—like a picture of the electrical cabinet.

TROUBLESHOOTING ELECTRICAL PROBLEMS

- A wind turbine system that has stopped generating voltage completely likely has an open circuit.
  - By determining where voltage is interrupted, you can identify where the electrical problem has occurred.
- You will need to use the electrical diagram for the wind turbine system and measure voltage throughout the circuit wherever you suspect the voltage has stopped.
  - Most electrical diagrams indicate the amount of voltage that you should measure at different points in the circuit.

TROUBLESHOOTING ELECTRICAL PROBLEMS

- The voltmeter allows technicians to test many electrical circuits with power applied.
  – Measuring voltage on a live circuit allows many tests to be made without disconnecting any wiring or components.
- You should always set the voltmeter to the highest voltage range until you have determined *actual* voltage.
- If you the meter is set for AC voltage, and you actually measure DC, indicated voltage will not be correct.
  – Also true if the meter is set to DC but measures AC.
- A good solution is a scope meter—a digital oscilloscope
  – Which shows waveform as well amount of voltage.

Introduction to Wind Power

TROUBLESHOOTING ELECTRICAL PROBLEMS

- Ensure the voltmeter is able to measure a test voltage correctly before you use it to measure live voltage.
  – Measure a known voltage from a small battery or a known 110-V AC power source.
- Some technicians carry a secondary meter that simply detects the presence of voltage—an audible tone or ticking noise that indicates voltage is present.
- A good rule to use when working on an electrical circuit is to assume that every circuit has voltage applied and is live, and treat it that way.

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TROUBLESHOOTING ELECTRICAL PROBLEMS

- In most cases, an ohmmeter is used for a continuity test after you have used a voltmeter to locate an open fuse, faulty switch, open motor winding, or open wire.
  - The continuity test measures the amount of resistance.
- An ohmmeter presents very low impedance (resistance) and will create a short-circuit path if you place the meter leads across terminals that have voltage present.
  - This will create sparks, possibly cause molten metal from copper wire, or allow the meter to explode in your face.

All power to a circuit *must be turned off* before you use an ohmmeter to take measurements.

TROUBLESHOOTING ELECTRICAL PROBLEMS

- When making the continuity test with an analog motor, zero the meter by touching the meter leads together, use the lowest ohm setting.
- The lowest resistance setting will detect the slightest amount of resistance in the switch or wire.
  - Resistance that is very high is called infinite, and indicates an open circuit present in the contacts or the wire.
- If using a digital voltmeter, determine what the meter uses to indicate an infinite resistance measurement.
  - Such as a blinking display, or very high number (9999).

TROUBLESHOOTING ELECTRICAL PROBLEMS

- Another ohmmeter use is to measure the actual number of ohms in the windings of a motor, transformer, or coil.
  – In a three-phase motor, each of the windings should have the same value of resistance.
- When troubleshooting electronic circuits, you will also need to measure the amount of resistance accurately.
  – The ohmmeter may have a specific setting used for measuring electronic components.

Introduction to Wind Power

TROUBLESHOOTING ELECTRICAL PROBLEMS

- A **Megger** is a specialized ohmmeter for checking cables, transformer windings, and motor windings for leaking current through their insulation.
  – Using approximately 600–2500 V, displayed in megohms.
- To use a Megger, voltage to the circuit must be turned off, and the wires & components isolated during testing.
- The Megger puts the voltage into the motor winding or cable for a short time, and tests for leaking current.
- A low reading (less than 100 megohms) indicates a breakdown of resistance in the winding/cable.
  – A high resistance indicates insulation is in good condition.

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TROUBLESHOOTING ELECTRICAL PROBLEMS

- A clamp-on ammeter can indicate the presence of current, or the current load of any circuit.
  – Especially useful in determining how close the circuit wire is to overloading, which will cause a fuse to blow.
- You can also determine if a motor is beginning to wear out and has bad bearings or lack of lubrication.
  – If motor current is higher than rated, it may be overloaded.
- Many wind turbine systems have dedicated current meters mounted in their electrical panels.
  – These use a current transformer that looks like a circle and has the main wire from the generator running through its open center.

Introduction to Wind Power

TROUBLESHOOTING ELECTRICAL PROBLEMS

Shown here, each of the three main power lines from the turbine generator passes through a current transformer.

The system measures the amount of current for each line and sends it to the SCADA system.

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TROUBLESHOOTING HYDRAULIC PROBLEMS

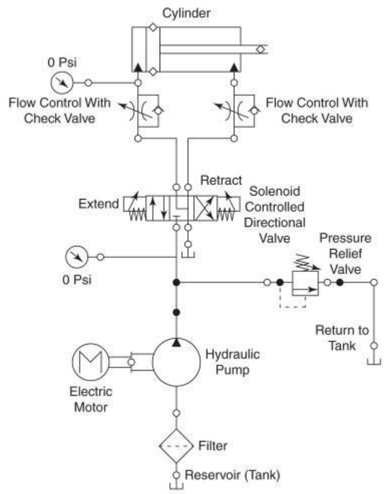
The hydraulic system consists of:

A hydraulic pump turned by an electric motor.

A reservoir that holds the fluid.

Pressure-relief, directional & flow control valves.

Actuators such as cylinders or hydraulic motors.



TROUBLESHOOTING HYDRAULIC PROBLEMS

- A hydraulic system problem is usually expressed as a condition in which an actuator does not properly function
  - Such as a cylinder rod that does not extend or retract, or is not moving fast enough.
- The hydraulic system will have gauges to indicate the pressure at various points in each hydraulic circuit.
  - These may include readouts displayed by the PLC or computer to the SCADA system,.
- You can use the pressure readings and the hydraulic diagram to determine what is causing the problem.
  - Pressure will exist in a system only when flow has filled the volume of the hoses, piping, valves, and actuators.

Introduction to Wind Power

PERIODIC MAINTENANCE

- Periodic maintenance on a wind turbine consists of a series of visual inspections, small tests, and checks.
  - Carried out on a schedule defined by a number of operating hours, or by a calendar date.
- You can find the date of the previous inspection or the number of hours the wind turbine has operated by checking the maintenance log.
  - Some turbines provide this data through SCADA.
- Most wind turbine manufacturers provide a complete procedure that includes a checklist of points that should be inspected and tests that should be completed.
  - A table of hours & dates may trigger maintenance.

Introduction to Wind Power

PERIODIC MAINTENANCE

- Properly maintained, inspected & lubricated mechanical systems, shafts, and gearboxes may last 5 or 10 years.
- It is less expensive to take a wind turbine out of service for periodic inspection before it has a major failure.
  - Manufacturers of basic parts have a history of when these parts may fail, and types of wear & tear they will receive
- It is much less expensive to provide proper lubrication of mechanical parts, bearings, and gears on a scheduled basis than to allow them to run dry and fail completely.
  - Manufacturers know the number of hours that lubricants can be used before they begin to deteriorate.
    - Some larger turbines have automatic lubrication systems/

Introduction to Wind Power

PERIODIC MAINTENANCE

- Maintenance on the tower consists of visually inspecting hardware used to hold the parts of the tower together.
  - Ensuring there are no cracks or corrosion in integral parts.
- If the tower is embedded in, or attached to concrete pad, it must be inspected for deterioration, and that the bolts that hold the tower in place are not coming loose.
- If the wind turbine is installed over water, additional inspections may be required to look for corrosion that occurs in these environments.
- Visual inspection of the turbine blades may be outlined in the periodic maintenance inspection.

Introduction to Wind Power

PERIODIC MAINTENANCE

- Some periodic maintenance on the electrical system must be performed on the system when power is turned off, locked out, and tagged out.
  - Other procedures may require the power to be on, with voltage or current measurements taken.
- Maintenance on the hydraulic system may include checking the hydraulic oil level, checking the condition of the hydraulic oil, and replacing hydraulic oil filters.
  - You may be asked to take an oil sample to be sent to a lab for analysis to determine whether metal is showing up.

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PERIODIC MAINTENANCE

- Periodic maintenance, when it is scheduled properly and performed on schedule, will save wear and tear on the system and help keep downtime to a minimum.
  - When not performed on schedule, cost and downtime will be considerably more.

MAJOR OVERHAUL OF A WIND TURBINE

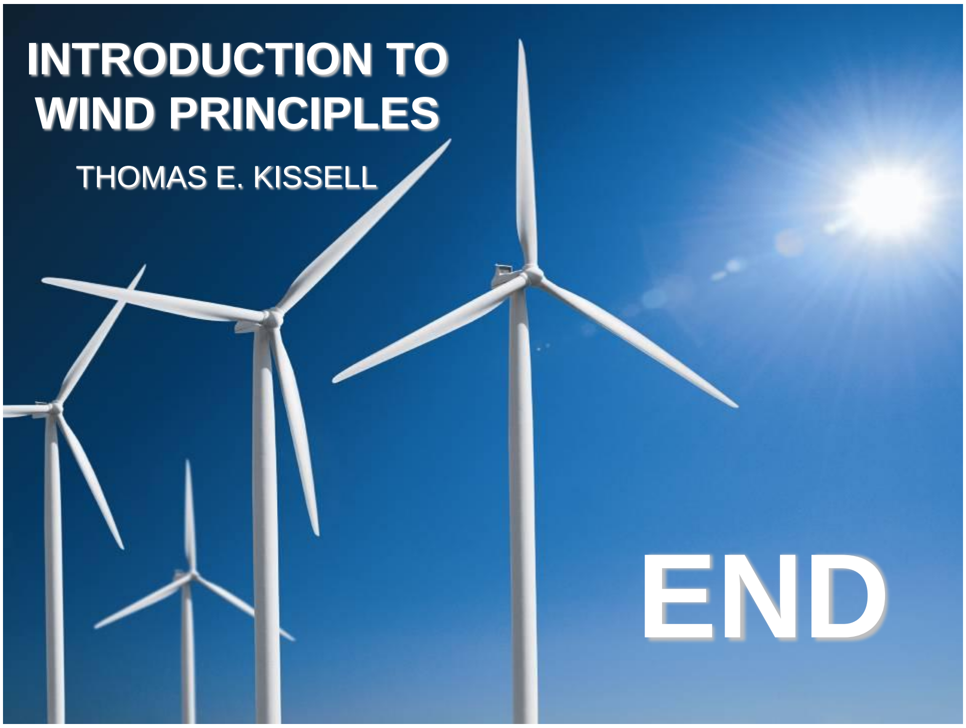
- At times a wind turbine may sustain a major failure, which requires a major overhaul of the system.
- As the wind turbine nears the end of its operating life span, certain parts may need to be changed out in what is called a major overhaul.
- It may be less expensive to change major parts than to allow the wind turbine to fail completely.
  - And so require replacement.

MAJOR OVERHAUL OF A WIND TURBINE

- The tower does not receive the amount of wear & tear, and may have a life span double that the moving parts.
  – It may be cost-effective to change drive train & generator rather than take the wind turbine down and start over.
- A major overhaul can be certified or warranted, which gives the owner basically a new system.
  – A cost-effective means to keep the wind turbine in service for a longer period of time.
- In some cases the complete nacelle for a wind turbine can be removed, overhauled and refurbished.
  – A new nacelle or refurbished nacelle can be put on the pole immediately—called swapping.

MAJOR OVERHAUL OF A WIND TURBINE

- Many overhaul facilities have a test system to turn the main shaft in the nacelle without blades connected.
  – If the technicians detect any problem, they can fix them more easily while the nacelle is on the ground in the shop.
- It is possible to load the generator with an electrical load bank or by connecting it to the grid to check the drive train, gearbox, and generator under full load.
  – If not completed in a controlled environment, an overhaul could take much longer and not be as effective.


INTRODUCTION TO
WIND PRINCIPLES
THOMAS E. KISSELL
END