wind-electric
SYSTEM MAINTENANCE

by Roy Butler & Ian Woofenden


Courtesy Roy Butler

If it's human-made and has moving parts, it needs maintenance. It doesn't matter if it's a spinning engine, a spinning wheel, or a spinning wind generator. You can't run a car for years—or even months—without maintenance and expect it to last long. And it's no different with a wind generator.

Veteran wind energy expert Mick Sagrillo says that the "average home-sized wind turbine will put on as many 'miles' in four months as the average car does in 100,000 miles." And regular maintenance is crucial for the survival, safety, and energy production of a wind-electric system. Once a year is a minimum for inspection and maintenance, and twice a year is usually better, especially if you have a good wind resource or experience frequent high winds or turbulence. Although some wind generator manufacturers say you can do a turbine and tower inspection with binoculars, we strongly recommend a more up-close approach: a hands-on, bottom-to-top, comprehensive annual inspection.

"If it's human-made and has moving parts, it needs maintenance."

Most modern wind generators do not have parts that need to be routinely replaced, like the brushes or bearings of older machines. So routine maintenance is primarily focused on inspection of the whole machine, cleaning, and tightening hardware. The spinning turbine and wind forces acting on a tower can cause vibration, which can loosen or damage hardware, turnbuckles, and other tower and turbine components. These are the types of things to watch for during an inspection.

Get ready first (see "Maintenance Gear" sidebar), and prepare all the climbing gear, tools, supplies, and spare parts you may need for the job. Use a good checklist and a digital camera to record any problems found. And have all the equipment manuals available—you'll be amazed at what you learn by reading them!

On the Ground: Electrical & Electronics

Before you climb the tower, there's a lot of work to be done on the ground. In addition to inspecting the tower (see below), we like to do maintenance and troubleshooting in the power room before we climb. Finding problems on the ground prior to climbing will help us know what to look for aloft.

Turbine to Inverter/Controller Wire Run

- Look for signs of damage on all conduit, wire runs, junction boxes, and conduit fittings, such as water intrusion, condensation, chew marks from critters, cracks, frost-heaving, and so on. Long conduit runs that were improperly installed can store several gallons of water, so be aware when opening junction boxes.
- Check wire terminals on all components (disconnects, junction boxes, inverter, controller) for proper tightness and signs of arcing or other degradation.
- Test all fuses and circuit breakers for electrical deterioration using the continuity tester on a multimeter and look

for physical deterioration. Cartridge fuses can deteriorate over time, especially in outdoor installations.

- Use a multimeter to check all surge arrestors. SOV- and MOV-type arrestors can only take so many voltage spikes before failing.
- Use a megohmmeter on wire runs to check for ground faults. Skinned or cracked wire insulation in underground conduit is one of the most common causes of ground faults. At the very least, system performance will suffer. Some older inverters can be damaged by ground faults. Worse yet, if the equipment grounding system is compromised as well, a shock hazard can result.
- While the turbine is operating, check for balanced three-phase output (when applicable). Allow for the fact that there will be variations in the wind speed and thus the voltage while you are moving the meter probes—you're looking for variations of 10% or more between phases. Test two or three times to rule out variations caused by changing wind speed.
- Perform other turbine-specific electrical tests per the manufacturer's recommendations. A good owner's manual will include testing protocols for the turbine electronics.

Electronics

- For grid-tied inverters, test the ability to disconnect when the grid goes down by turning off the inverter breaker and verifying "0 voltage" at the inverter output. After turning the grid breaker on, verify the 5-minute delay before the inverter reconnects to the grid.
- For battery-charging controllers, confirm that the charging set point programming is appropriate for the batteries. Verify the controller's ability to perform this function—by checking a voltmeter to make sure power is diverted when the high battery voltage set point is reached.
- When applicable, test the electrical integrity and operation of the turbine diversion loads.
- Make sure there is no flammable material near the diversion loads. Inspect any heat shields for physical damage and signs of overheating.

Inspecting junction and pull boxes, including all connections, is part of the routine maintenance needed on wind-electric systems. Note the water damage found in this junction box.

Courtesy Roy Butler

MAINTENANCE GEAR

Here are the primary things you may need for a maintenance check on a wind-electric system. For more information, see "Tools of the Wind-Electric Trade" in *HP124*.

- An assistant on the ground while you're climbing
- Climbing harness, lanyards, and fall-arrest device
- Two radios (be sure they're on the same channel!)
- Service line and pulleys
- Closeable tool bags
- Water bottle
- Lanyards and rope pieces for securing turbine and rotor
- Spotters and assistants for tilting a tower
- Electric, hydraulic, or Tirfor-type winch
- Various load-rated pulleys, cable, and shackles
- Digital camera
- Spud adjustable wrench with belt-mounted holster
- Insulated screwdrivers and pliers
- Sockets and wrenches (check manuals for appropriate sizes)
- Torque wrench (250 foot-pounds)
- Multimeter with probe leads and current clamp
- Megohmmeter
- Penetrating oil
- Grease gun and grease
- Spare hardware for turbine, tower, and guy cables
- Rags for blade cleaning
- Epoxy for blade repair
- Spare leading-edge tape, if appropriate
- Spare fuses
- Battery safety gear (goggles, rubber gloves, and baking soda)
- Anticorrosion paste for battery terminals and cable ends
- Distilled water
- Hydrometer
- Wire brushes
- Spare ground wire and clamps

- Clean dust or other obstructions from any cooling fans and vents. Heat dissipation is essential for proper electronics operation and has a direct effect on the equipment's life expectancy.

Batteries

Battery maintenance could be the subject of a complete article (see "Flooded Lead-Acid Battery Maintenance" in *HP98* for more information). Owners of battery-based systems will need to follow a basic maintenance procedure:

- Check all battery connections for tightness and clean corrosion from them; then grease or coat connections with an anticorrosion coating.
- Clean battery tops with water and a rag.
- Check electrolyte level and fill as needed with distilled water.
- Check settings on battery monitor.
- Check settings on charge controller(s).

On-the-Ground Tower Inspection

Safety First

Before climbing or lowering a tower, fully inspect all components accessible from the ground. Any serious problems must be corrected before climbing the tower.

Most home-scale wind installation companies receive several calls each year from system owners with turbines that have been orphaned by their original installer but still need inspection or repair. Although we apply the following procedures on all inspections, we always take a much harder look at an unknown installation.

Before You Climb

- Foundations: Check for excessive anchor movement. This may be the only indication of a failed or failing foundation system. Look for deterioration of the anchor rods or other attaching points, especially where they contact the concrete or the ground.
- All towers: Examine the overall appearance of the tower. Check that it is straight and plumb. Small discrepancies are OK, but a seriously out-of-plumb tower can be an indication of a more significant problem. At the very least, it could be dangerous to climb or tilt. Also check it for rust, since deep-rooted rust can affect the tower's structural integrity. Minor surface rust is to be expected. Probe the rusted area with a sturdy screwdriver or similar tool. Look for broken welds or structural components that are bent or missing. Bent or missing tower parts may be easy to spot, but cracked welds are not. Rust streaking around galvanized welded joints may be an indication of a cracked weld. If a safety-climb system such as a Lad-Saf is installed, check the cable and tensioner integrity. Fall-arrest systems should not be used for support at all until the entire fall arrest assembly is checked.
- Guyed towers: Inspect all hardware: turnbuckles, equalizer plates (which equalize the tension on each set of guy wires), cable clamps, etc., for deterioration, excessive movement, and tightness. Look for loose or missing lock nuts, Palnuts, and turnbuckle safety loops—these things can bring down a tower. Check guy wires for rust and broken or frayed strands. Pay close attention to the area where the cable passes around the thimble at the guy ends. This is a high-stress area, subject to vibration, susceptible to corrosion, and perhaps very difficult to see. Minor surface rust or the occasional missing guy cable strand may not present a major issue now, but bears watching. Once corrosion starts, it can accelerate quickly, especially in salt-air environments. Some tower grounding conductors are connected directly to the guy wires. Galvanic reaction from dissimilar metals may be causing corrosion inside the attaching hardware. Remove, inspect, and replace if needed.

Inspect the tower base and all guy anchors—make sure there are no issues before climbing to inspect the tower and turbine.

Courtesy Roy Butler

The turnbuckle safety loops should never be allowed to rub against the guy cables. This photo shows an example of a rub point on the top of the lower turnbuckle. Friction and vibration will eventually damage this guy cable.

Courtesy Ian Woofenden

Courtesy Roy Butler

A broken furling cable on a Bergey Excel means that there is no means of shutting it down. Regular inspections of braking and furling systems are crucial to safety.

Check for proper guy tension and adjust as needed. This varies between tower manufacturers, so follow the proper procedure for your tower. The tangential intercept method (using a bit of geometry and the sag of the cable) is often used for tilt-up towers; the oscillation method (using some math and a controlled shaking of the cable) is routinely used for fixed guyed lattice towers. Wind turbine installation manuals are great sources for this type of information.

- Freestanding towers: Inspect the hardware that secures the tower to the foundation. Look for signs of unusual movement around the hardware and leg flanges, such as misalignment, weathering patterns, or cocked bolts. If grout was used under the tower legs, check the drain-holes for blockage and clean as necessary. Moisture buildup inside hollow tower legs can lead to freeze damage and eventual tower collapse.
- Grounding: Never climb an ungrounded tower—look for proper grounding of the tower and guy wires. There are many different tower grounding methods, but they are beyond the scope of this article (for more information, see "Get Grounded: Renewable Energy System Grounding Basics" in *HP118*.) Again, review the tower manuals! Inspect the grounding wire and hardware. The most common problems found are loose and missing ground-rod clamps.
- Brake: Inspect and test the tower-mounted turbine disconnect and shorting brake. If applicable, check the furling or brake mechanism for proper operation. (This should not be done in a high wind.) Brake, short, or otherwise secure the turbine before ascending the tower.

On the Tower

Safety on towers requires knowing how to climb safely, and having the right equipment. There is no substitute for tower climbing experience, so if you're new at it, find a mentor and get some practice. Climb the fixed tower, lower a tilt-up tower or use a lift (see Access for articles on tower styles and tower safety).

Tower Mechanical

- Look for missing or loose bolts, nuts, and lock nuts. Carry several sizes and types of spare hardware with you so you can inspect and repair or replace hardware in the same visit.
- Check for proper torque. A good manual will have the manufacturer's recommended torque specifications and hardware sizes so you can throw the appropriate sockets and wrenches in your climber's tool bag. While the majority of tower hardware can be tightened with a torque wrench that goes up to 250 foot-pounds, some tower hardware may require 350 foot-pounds or higher—plan accordingly.
- Down-tower wiring. Check cable and conduit integrity and verify that it's properly secured. This will range from a Kellums-type hanger for jacketed multiconductor cable to various types of clamps for conduit, and even wire ties for flexible metallic-sheathed cable assemblies.
- Inspect tower-mounted data equipment, such as the boom, anemometer, and wind vane mounting hardware. Also check their wire integrity and tie-downs. The anemometer is another manufactured item that has moving parts. They do not last forever and may need to be replaced.
- On the way down, wire-brush rusted tower parts and apply cold-galvanizing spray or paint.

Wind Generator

- Turbine mechanical: Bearing problems may be difficult to spot, so learning to read the telltale signs of bearing failure—such as rust streaks—is essential. This is caused by moisture entering then exiting the bearing, which usually leaves a very distinctive, rust-colored residue behind. This is especially true for rotor bearings, where the streaks may be seen artfully arranged on one side of the blades.
- Where moisture has not been a factor, a fine black powder may be seen around the bearing race or on nearby surfaces. This is most often found in protected areas, such as the rear rotor and the yaw bearings inside the turbine nacelle. Grease/oil where it shouldn't be is a sure sign that sealed bearings are no longer sealed.
- Loose hardware can leave similar signs, where vibration and movement have worn away protective coatings and allowed oxidation to occur.

Courtesy Roy Butler (2)

Blade cracks and wear may call for repair, or they may be warnings of imminent blade failure, which can be catastrophic for machine and tower.

- Inspect turbine-to-tower mounting hardware and check for proper torque. Look for cracking or other signs of stress on the mainframe welds.
- Verify blade mounting integrity, including loose blades and loose or missing hardware.
- Check the blades for structural integrity: cracks, pits, erosion, leading edge wear, or damaged/missing leading edge tape. If excessive movement is found, egging of mounting holes or other damage may be present.
- Slowly spin the rotor, listening for unusual noise or feeling for resistance to turning, which can be caused by grit on the magnets, dry bearings, too much play, or magnets rubbing on the stator. Check for bearing slop by lifting upward on the rotor.
- Inspect all bearing and pivot points, which typically include rotor and yaw bearings, furling bearings or pivot, furling or brake assembly, and friction areas. On furling turbines, the tail pivot bushings are a high wear point, especially at turbulent wind sites. If the upper pivot bushing lets go, the tail can swing downward into the blades, destroying both.
- Inspect the governor assembly if applicable (for example, with Jacobs and Kestrel turbines). There are lots of moving parts in there that need loving attention!
- On turbines such as the Endurance S-250, check the brake pads for wear. Inspect the condition of the flexible hoses in the air brake system and check the color of the desiccant. The color changes as moisture is absorbed to indicate when replacement is needed.
- Check out the slip-ring and brush assembly. Look for pitting or roughness (signs of arcing), and uneven wear on slip rings. Brushes can jump track or track unevenly, causing excessive slip-ring and brush wear, arcing, and premature failure of the assembly. Inside this assembly is another place to look for black dust, metal shavings, or excessive grease from bearing failure, which can cause electrical problems by interfering with brush contact with the slip rings.

Telltale signs of damaged bearings—oil and rust streaks on the blades—call for immediate action.

Courtesy Ian Woofenden

- Inspect the turbine wire connections. Look for wear and loose terminals from vibration, evidence of arcing, and conductor insulation breakdown. Corrosion from moisture may be present yet unseen inside terminal blocks or other connectors.

Lubrication

- Some sealed bearings can be greased with a needle-type grease gun attachment. Any grease seal openings created during this process should be carefully and thoroughly sealed to keep out moisture. Small, handheld tubes of RTV sealant serve this purpose well.
- Where applicable, grease all fittings, and change gearbox oil (i.e., on Endurance and Jacobs turbines) according to manufacturer's recommendations.
- Watch where the oil goes when performing an oil change. An unplanned coating of oil on the tower will not make for a pleasant tower descent!

Maintain It—or Bury It

Don't believe anyone who says wind-electric systems can be maintenance free! The only time that holds true is if you leave all the components in their original boxes, and store them in a cool, dry place. Once you install and operate the system, it will need maintenance. In most cases, it will need periodic repair. And if you go light on maintenance, it'll need even more repair more often.

The results of poor maintenance are held up for public observation on tower tops across the country. Some stay aloft as tributes to the difficulty of keeping wind-electric systems going. With others, neglect and abuse becomes catastrophic, as turbines and towers fail and give their owners gray hair.

Slip rings can be misaligned and not conduct the turbine output to the down-tower wiring.

Courtesy of Ian Woofenden

Slip ring or brush failure and shorting can make sparks and fire, putting your wind generator out of commission.

Grease from a bearing failure caused this slip ring assembly failure.

Courtesy of Roy Butler (2)

Furling bushings wear out after years of operation, and need to be replaced.

Courtesy Roy Butler

The advice of two long-time wind-energy users? Take maintenance very seriously, and do it on a regular basis. Heed the message your wind-electric system is trying to send you—"Take care of me and I'll try to take care of you."

Access

Roy Butler (roy.butler@homepower.com) lives off-grid on a windy hilltop in the Finger Lakes region of New York state. Because he's frequently away, installing wind turbines and teaching installation workshops, his own turbine suffers from "mechanic's car syndrome."

Ian Woofenden (ian.woofenden@homepower.com) lives a "do as I say, not as I do" existence as a wind-electric system owner, author, tower jockey, and consultant in Washington's San Juan Islands—and can tell you from experience why you should maintain your wind generators.

Recommended Reading:

"Wind Generator Tower Basics" by Ian Woofenden in *HP105*

"A Beginner's Guide to Tower Climbing Safety" by Ian Woofenden in *HP128*