

# Troubleshooting Small Wind-Electric Systems



# Noise & Heat

by Hugh Piggott

Courtesy Jytte Piggott

The author inspects a time-worn turbine.

## What's That Noise?

Although manufacturers may claim that their wind turbines are virtually silent, the reality is that wind turbines make a variety of sounds. Blades swish, and an electrical hum is audible in most conditions. If you do not know what to expect, listen to a few wind turbines before you buy one. You will get to know the sounds that a productive turbine typically makes.

Noise is subjective and may be a problem in its own right, especially if your neighbors object to it. Sometimes you can do something about wind turbine noises, but often they are inherent in the design. The only solution may be to shut down the turbine in certain conditions, such as high winds or at night, if the noise causes complaints. It's a pity that not everyone enjoys the music of wind energy, but if you respect your neighbors, it's more likely that they will honor your request not to cut firewood with their chainsaws on Sunday mornings.

When a new sound arises, it may be a symptom of a problem that is worth investigating or it may be "normal" for this make of turbine in a particular wind. For example, one manufacturer produced a turbine without any furling system. Rather than protecting them from overspeed, the design allowed the blades to flutter (oscillate)—with a very

loud noise. Thousands of these turbines were sold before the problem was fixed with an electronic braking system.

This is a case of "buyer beware." Make sure you know what sort of noises the turbine is expected to produce because some of them are quite loud in strong winds. You can listen to some examples of rather loud turbines at Mike Klemen's Web page (see Access).

## Swishing & Chopping Noises

Whooshing, chopping, and whistling noises are fairly normal, but can be objectionable. Some turbines have special blade



Early models of this turbine had severe noise issues in high winds.

Hugh Piggott



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**High speeds and long hours of operation will erode the blade material, literally digging holes in the leading edge. This damage can cause imbalance, noise, and reduced efficiency.**

shapes that are intended to reduce noise, but the most important factor is the speed at which the blades run. If the turbine has a high cut-in rpm, then its blades will run unloaded in low winds and make a whistling sound. Loud noises in high winds may be due to a control system that disconnects the turbine when the battery is fully charged. In both cases, it helps to put a load on the turbine to slow the blades.

Defects in the blade profile can cause whistling noises that sound more like squeaking bearings. A small hole or notch in the blade tip will often make a squeak. This is easy to fix with some car body filler. Balance the blades after making such repairs.

### Rattling & Tapping Noises

Out-of-balance blades will shake the turbine such that it rattles audibly. Imbalance may be due to blade damage—maybe from a bird strike or from wind erosion. Or water may have gotten into a blade. The main symptom of this (low-frequency) vibration is a shaking tail. The solution is to repair and balance the blade assembly (see sidebar on blade balancing).

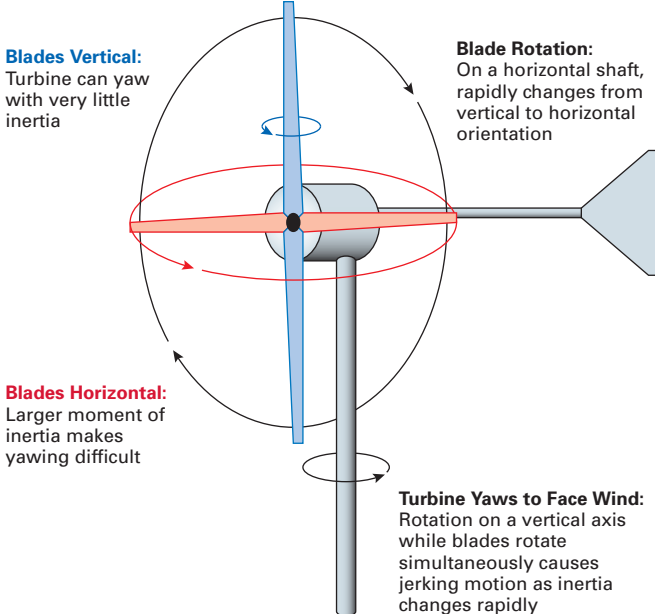
Two-bladed turbines have inherent vibration issues. In turbulent conditions, the wind shifts from side to side, and a wind turbine will yaw around to follow it. When a two-bladed turbine yaws, it shakes. The best things you can do to mitigate this problem are to avoid turbulent sites and make sure that the tower does not resonate at the same frequency as the turbine. For instance, the natural frequency of a guyed tower can be increased by adding guys at more levels. Keep everything bolted down tight and you will have no accidents.

Persistent, violent shaking due to imbalance and resonance can result in fatigue failure of the tail, or can possibly even bring down the whole machine with or without its tower.

Although rattling sounds usually mean imbalance, they may also indicate that something is working loose, like blade or alternator mounts. If your turbine makes a rattling sound without shaking, you need to stop the turbine and investigate the cause. Loose fastenings can lead to parts falling off. Check all nuts and bolts, and check for slack bearings.

Another very similar noise is the sound of internal parts touching. For example, magnets can come loose inside the alternator, or the stator may shift on its mounts so that these parts scuff each other once per revolution. You can best verify this by listening as you turn the shaft by hand. If this is the cause of the noise, the alternator needs to be dismantled and repaired.

## Vibration of Two-Bladed Turbines



**The tail is usually the first casualty from an out-of-balance rotor. Here, the upper boom has cracked.**



# Blade Balancing

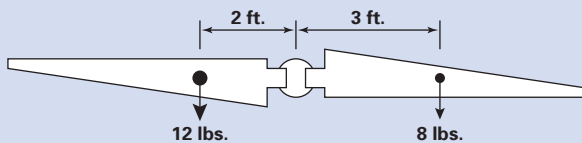
Balancing is a procedure for adjusting the center of gravity of the blade and hub assembly to the exact center of its rotation. There are several good methods for balancing the blades. This one consists of two stages:

- 1) Check that each blade has the same moment of weight, and
- 2) mount the three blades symmetrically on the turbine.

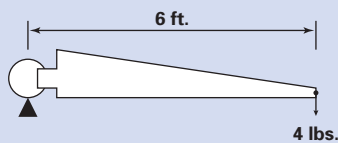
It is not sufficient to simply check that each blade weighs the same since the centers of gravity might be in different places. The final test is to compare the “moment of weight” of one blade with another—the turning effect produced by the blade’s weight. The moment of weight depends on how far this weight is from the center of the shaft. Multiply the weight by the distance.

Make a balancing jig that allows a blade to pivot on an axis passing through its center of rotation. The blade tip must be the same distance from this axis as it would be from the center of the wind

## Determining Moment of Weight



Although one blade is heavier than the other, these two blades balance because they both have a moment of weight of 24 foot-pounds.



If the fulcrum is set at the shaft center, and the scale at 6 ft., then both blades will weigh 4 lbs.

**A balancing jig allows the fulcrum to be at a point equivalent to the center of rotor rotation.**

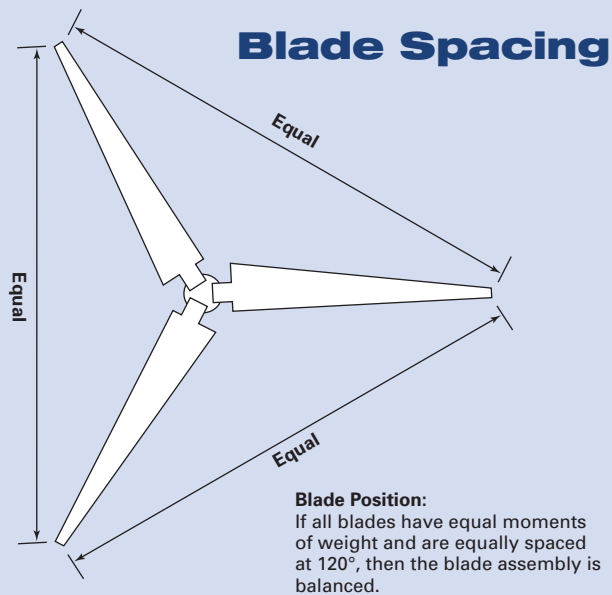


turbine. You can then measure the moment of weight by weighing the tip of the blade or by comparing two blades teetering on the same pivot axis. Take care to measure the weight of each blade at the same distance from the pivot so that you obtain an accurate comparison. The actual weight does not matter, but it is important that they all weigh the same when measured at that point and, therefore, have the same moment of weight. It is equally accurate to compare two blades by mounting them on the same pivot axis but projecting them in opposite directions—if they balance, then their moments are effectively the same.

**The point of contact with the scale must always be the same distance from the fulcrum. If the weights that the blades exert are different, then add weight to the lighter ones until they all read the same.**



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To adjust a blade's weight, add some mass somewhere. In the case of hollow blades, you can inject some filler paste inside the tip. Drill one or two holes into the interior, very close to the tip. Then find out how much body filler is needed by trial and error, placing the paste on a scrap of paper or plastic on the blade tip. When you have discovered the desired weight, mix the paste with hardener and force it all through the holes, smoothing and sanding the surface.

If the blade is solid, you will need to add weights to the root. Much heavier weights will be needed here because they work at a much smaller radius from the axis. Often, blade-fixing bolts are used to attach these balancing weights. Longer bolts may be needed if the weights are thick.

When the blades are identical, mount them symmetrically on the rotor hub and check the distances between the three tips. Each pair of tips must be the same distance apart ( $\pm 0.5\%$ ). Try to pull the blades in the direction of their rotation as you tighten the bolts, so that they will not move thereafter when they are cranking out power.

Verify that the tips of the rotating blades track each other precisely in the same plane, neither upwind nor behind the others, and have the same angle or "pitch."

**Adding the same amount of weight to a blade tip has more effect than adding it to the base. The discolored patch on this blade shows where resin paste has been used to fill a hole and then smoothed.**



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**Worn bearings can produce noise. They also can produce heat, which can lead to catastrophic failure.**

### Grinding & Growling Noises

A failed bearing in the alternator will produce a steady grinding noise that grows slowly louder over a period of weeks. It is a scratchy growl, akin to the low-pitched white noise of static on the radio. If you hear this, plan to dismantle the machine and replace the bearing before it fails completely and damages the alternator.

Humming or growling vibrations are usually electrical in origin. A clearly tonal vibration suggests an electrical imbalance. Alternating current consists of a series of pulses. Current in the wires equates to torque in the alternator. Pulses of torque produce noise. Most turbines have a three-phase arrangement of coils in the alternator that shifts the timing of these pulses until they blend into an almost smooth torque (with a slight whine due to "ripple"). But if a single wire or a diode fails, the current in the wires become unbalanced and the alternator will vibrate or growl. This vibration is much higher in frequency than the vibrations caused by unbalanced blades. It's closer to a hum than a shake, but it can make the turbine rattle and buzz. Acute vibration can produce dangerous cracks in the structure of the turbine if it is allowed to persist for long periods.

If you begin to hear a new growl in the turbine and its tower, check the wiring with a multimeter. Compare the voltages and the currents. Investigate any asymmetries. Check the rectifier (see "Troubleshooting Small Wind Systems" in *HP134*).

Sudden, loud roaring noises are most likely due to "flutter" of the blades. This is an oscillation caused by torsional instability of the blades when overspeeding. The best solution is to shut down the turbine and/or adjust its control systems so that it protects itself from such conditions.

### Whines & Whistles.

Most small wind turbines will produce a slight whine as they generate electricity. This is due to the ripple current in the rectifier. In most cases the sound is very muted, but it may occasionally be loud enough to be bothersome to some listeners. The bearings also can affect the machine's resonance. Tapered roller bearings can be adjusted with a nut. This may reduce the sound level, but take care to stay within the correct range of adjustment.



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**An insulation failure in these high-voltage windings led to arcing between wires.**

Pulse-width-modulated (PWM) load controllers also produce noise. These controllers divert a precisely controlled current into the dump load by switching it on and off rapidly. Diverting some current away from the battery helps prevent overcharging and holds the battery voltage at its optimum level. Pulse-width modulation does create a high-pitched whistling sound, both in the controller and in the dump load resistance/heater. If this sound is a nuisance, there are options for fixing it.

The crude solution is to manually consume more energy from the system so that the controller no longer needs to divert it. A better fix is to install a relay-based charge control device that switches heaters on and off for seconds or minutes. This will not keep the battery voltage under precise control, but, besides silent operation, this strategy has the added advantage of working with standard AC heating elements, which can be energized via the inverter.

Alternatively, it may be possible to find a heater that makes less noise. "Wire-wound" resistors and heaters are the most common, but also the noisiest dump loads. Heaters surrounded by bricks or in a tank of water are much quieter because the mass deadens the noise. Underfloor heating wires are also silent. Why not make your dump loads both useful and peaceful?

**PWM controllers switch heating loads on and off very abruptly to avoid dissipating heat in their transistors. This creates a sharp-edged current wave form containing audible high-frequency harmonics.**



## Overheating & Burned-Out Parts

All electrical circuits and devices lose some energy as heat. Overloaded systems will overheat, and this can lead to failure or even fire. It's a good idea to keep an eye on the instruments from time to time, and check that the turbine is working within its design limits in high wind speeds. It is difficult for wind turbine designers to anticipate what a particular machine will do in every condition. Very high and sustained winds may produce overheating from excessive current, sometimes resulting in electronics failure. It is wise to install the electronic and electrical parts on incombustible surfaces.

Even small turbine design "improvements" can produce overheating. For example, a new blade design can behave differently and defeat the overspeed controls, overheating a turbine that previously limited its output at a safer level.

Electrical overload can burn out the alternator on the turbine, but so can mechanical failures. Worn alternator bearings can overheat or allow the moving magnet-rotor of the alternator to rub on the stator, producing more heat and resulting in burnout of the stator windings.

### Wiring & Connections

If the installer uses an undersized wire in the system, it can overheat dangerously when the turbine has high output in strong winds. Fitting a fuse or breaker to the wire will make it safer, but if it blows or trips you will have a runaway turbine. Disconnected from its load, it will run alarmingly faster and may produce dangerously high voltages in the wires. Be aware that the current in three-phase wiring will be about 80% of the current in the DC side of the rectifier (and not 33% of it, as some people assume). Check the ampacity of the wiring. Thicker wires are both safer and more efficient, so make sure there is a generous safety factor in the wiring design.

Current in wires and connections produces heat in proportion to their resistance. A loose connection becomes warm and corrodes over time. Corrosion is accelerated by the heat, and increases the resistance, in a cycle that ends up with failure and/or scorch marks. Experienced electricians will tighten all electrical connections to their rated torque. Antioxidant paste helps to prevent corrosion of connections. If a connection feels warm or looks tarnished, clean and tighten it, or better yet, replace it.

### Electronic Overloads

Rectifiers are a place where overheating can cause persistent problems in a hard-working wind system. High temperatures shorten the life of the diodes. Make sure that the connections are clean and tight. If the heat sink is getting too hot to touch, keep it clear of obstructions and dust, upgrade its size, or fit a fan.

### Hot Batteries

If the charge controller fails to divert surplus energy into a dump load, the battery will overcharge and get hot. For a short while, this may not harm the battery (and may even be therapeutic for it), but it will gas vigorously and may spatter the surroundings with acid. If this situation persists and the



A burned diode can imbalance turbine load and produce electrical noise.

battery loses much of its electrolyte, it may explode. The *National Electrical Code (NEC)* Article 690.72(B)(1) requires solar-electric systems that use a diversion charge controller as the primary means of regulating battery charging be fitted with a second, independent means to prevent overcharging the batteries, and this is also good practice (although rare) in wind systems.

### Tune In to Your Turbine

It's very satisfying to produce your own electricity from the wind. The sound of the turbine gently converting the free wind into useful electricity is part of that experience. It's well worth listening to that sound and paying attention to any warning signals. And if the sound becomes a nuisance or the warnings become too worrying, it is good to be ready to stop the turbine.

High power output impresses some people, but what actually matters is the total energy production, and that comes from sustained, useful power in normal winds. High peaks of power in exceptional weather conditions will not add much to the energy total, but they may well overheat things and lead to damage or even danger. Keep an eye out for overloaded parts in the system and stay one step ahead of failures.

### Access

Hugh Piggott builds, installs, and troubleshoots wind generators at his home in northwest Scotland and beyond. He has written several hands-on books about small wind turbines and RE systems.

[www.ndsu.nodak.edu/ndsu/klemen/Audio\\_and\\_Video.htm](http://www.ndsu.nodak.edu/ndsu/klemen/Audio_and_Video.htm) • Audio files of small-wind turbine sounds





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