Maine-Built Windmills From Scratch

Everett Russell

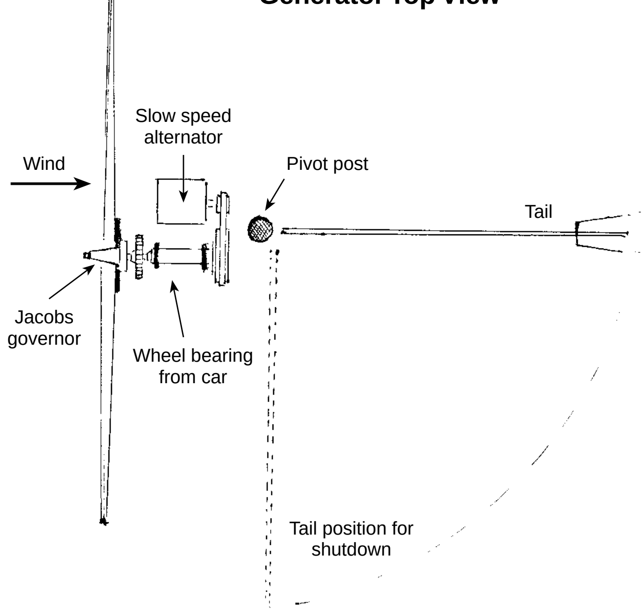
One of Everett Russell's two home-built wind generators with a 14 foot rotor diameter.

I have been building windmills since 1937. These windmills are strong and practical. Unlike many others, mine are built from scratch. Some people say building windmills from scratch is not practical. I disagree. I believe my machines are not only practical, they're rugged, they continue to serve me well, and they have passed the test of time.

Right now I have two working windmills—both 14 feet (4.3 m) in diameter and about 500 pounds (225 kg) each. They both generate at 120 volts. One puts out 10 amps, and the other generates 20 amps, at about 225 rpm in a 20 mph (9 m/s) wind. The alternator that puts out the 20 amps is a larger alternator; its rotor is 4-1/2 inches (11 cm) long. The 10 amp alternator rotor is 3-1/2 inches (9 cm) long and it has a smaller diameter as well. The total cost of each machine is less than US$500.

The windmills power the machine shop where my approach to windpower continues to evolve. They also run a variety of yard and garden equipment such as an electric lawnmower, chainsaw, and power tools. My wind power system is separate from the utility grid. I use standard utility service in my house.

Generator Top View



The system is 120 volts DC. I have several strings of ten 12 volt batteries, salvaged from a junkyard. Many shop tools will run on 120 volts DC as well as AC, like drills, lawnmowers, light bulbs, grinders, electric saws, etc. My lathe, however, has two 40 V shunt-wound DC motors in series. I can drill holes all day in the shop without wind, using the energy in the batteries. But to work on the lathe, it is best to wait for a windy day. I can't use this system directly in my home because many of the appliances run only on AC—refrigerators, VCRs, TVs, and other things. But no inverter is needed for my shop tools.

Looking up from below: the genny's tail structure is folded to the side.

My system for working on my windmills is a bit unusual. I climb to my 46 foot (14 m) windmill platform by a series of very secure stairways and ladders. Once I reach the top platform, there is one final ladder to climb. This last ladder is mounted on the main frame of the windmill itself. When the windmill turns into the wind, the top ladder pivots right along with it.

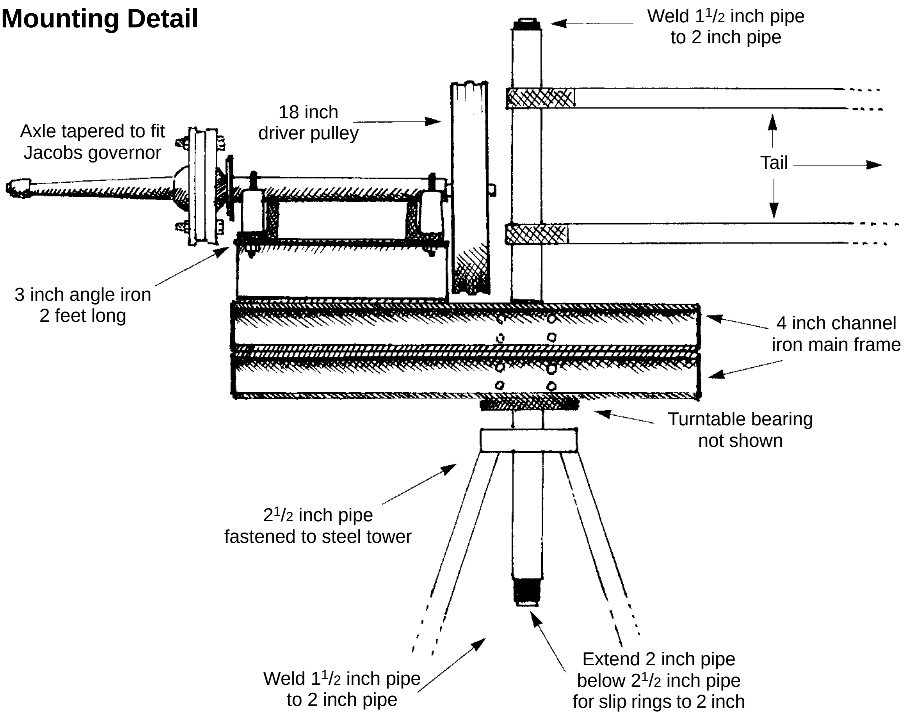
Built From Scratch

When I say my windmills are built from scratch, I mean it. They can be put together with material found in most any junkyard. Among the scrap metal parts that I've recycled to fabricate my present system are 4 inch (10 cm) channel iron, angle iron, pipe, and about 15 inches (38 cm) of the rear axle housing of a car. I use my 16 inch (40 cm) lathe to machine the taper into the extra 10 inches (25 cm) of axle (propeller shaft) to fit a Jacobs governor. I also thread the end of this shaft so the governor can be bolted in place.

The Jacobs governor governs at a certain speed whether it is loaded or not. If the alternator stops working, the machine is still protected from overspeed. This governor system is similar to a flyball governor, but the blades take the place of the flyballs. They move outward against three strong springs, and at the same time they turn, giving more pitch and slowing the prop. The prop can't turn faster than 225 rpm. Tom Hill has Jacobs governor and blade plans that he sells for US$12.50.

I manufactured my own slow-speed alternator from plans I found in *Alternative Sources of Energy* magazine, volume #38. The alternator is made from a large three-phase induction motor (10 to 15 hp). A lot of machine work is involved. The stator has to be rewound for the voltage and speed you want. It has a wound

Mounting Detail



The top ladder section is affixed to the genny and yaws with it.

field, so it has sliprings and brushes. The brushes and sliprings are where I have had the most trouble.

I use a Jacobs-type shutoff. Pulling on a rope from the ground pulls the tail perpendicular to the blades so the prop faces into the wind. The rope is fastened to a cleat at the bottom of the tower. When the rope is unfastened from the cleat, a spring pulls the tail back 90 degrees so it is parallel with the blades. The blades are then edgewise to the wind, and the machine is shut down. There has to be tension on the rope to keep the machine running. If the rope breaks, the tail will swing back to the off position.

The cut end of the axle is bearing mounted and attached to an 18 inch drive pulley. The bearing housing is mounted with U-bolts to the bird's frame.

I use an 18 inch (46 cm) driver V-pulley on the propeller shaft. On the machine with the larger alternator, there's a 4 inch (10 cm) V-pulley on the alternator, which speeds the alternator up 4-1/2 times. The machine with the smaller alternator has a 3-3/8 inch pulley because of the machine's higher cut-in speed. I also manufacture the Jacobs governor and blades, but they could be bought, or a fixed blade, side-facing prop could be used.

Machining the Parts

The main frame is made of materials from a salvage yard, such as channel iron, pipe, and angle iron. I don't have a steel tower. I have a 45 foot (14 m) center wood post with a 2-1/2 inch pipe bolted to the side with U-bolts. I am not happy with it, since more pipe is needed and it's difficult to use sliprings. But I couldn't afford an all-steel tower.

Inside the 2-1/2 inch pipe, I use a length of 2 inch with 1-1/2 inch pipe inside that, cut longer than the 2 inch pipe and welded together at the ends. These two pipes are the yaw pipes. Then two lengths of 4 inch channel iron are welded to a 4 inch length of 2-1/2 inch pipe. By using four bolts, the channel iron is clamped to the 2 inch pipe with 1-1/2 inch pipe inside of the 2 inch pipe. Then another pair of pieces of 4 inch channel iron above the first two are also clamped to the 2 inch yaw pipe.

The other end of the axle is also bearing mounted and U-bolted. A short section of axle is machined to a taper that will accept a Jacobs governor.

Detail of the underside of the drive shaft mounting. The furled tail is visible in the background.

Two more 4 inch (10 cm) pieces of channel iron are cut shorter, with two pieces of 3 inch (7.6 cm) angle iron bolted across them for the pillow blocks to sit on. These hold up about 15 inches (38 cm) or longer of the rear axle housing from a rear wheel drive car. It has to be the ball bearing type. This gives me a very rugged thrust bearing (wheel bearing), since it often goes the life of a car—like 150,000 miles. The housing is soft and can be cut off 15 inches or longer with a pipe cutter.

That end of the housing has to have a bearing, which has to be fitted, and the axle must be cut off at least 4 inches (10 cm) beyond the bearing. This is where the driver pulley goes. On the other end (where the wheel of the car used to go), fasten an extra length of axle cut about 10 inches (25 cm) long, which can be tapered for the Jacobs governor. To make the taper for the Jacobs governor, machine 1-1/4 inches to the foot (3 cm per 30 cm) about 3 degrees on each side of the lathe center line.

To fasten the extra length of the axle (10 inches long or longer) to the length of the axle in the housing, you will need to drive out the studs in both flanges and use 1/2 inch (13 mm) plate in between. Drill the same number of holes in the plate as in the flanges, and bore out the center of the 1/2 inch plate to just fit the little hubs where the car wheel went. Then bolt the two flanges together. This is simplified, but a machinist should be able to understand this description.

With the housing bolted down with U-bolts (9/16 inch (14 mm) diam.) to 3 inch (7.6 cm) angle iron with pillow blocks between, you have a very solid machine. If you don't want a flyball governor and want to use a side-facing governor, you wouldn't need the short 10 inch axle. You could bolt the fixed blades directly to a plate which could be bolted on the long axle, the same as in a car. By the way, the backing plate is not needed, so cut it off, but leave the part between the end of the housing and the bearing retainer.

Jacobs Prop Speed vs. Alternator Speed

	Alternator rpm	
Prop rpm	*For 4 inch Pulley (1 to 4.5 ratio)*	*For 3-3/8 inch Pulley (1 to 5.3 ratio)*
100 *	450	533
120	540	640
150	585	800
200	900	1,067
225 **	1,013	1,200

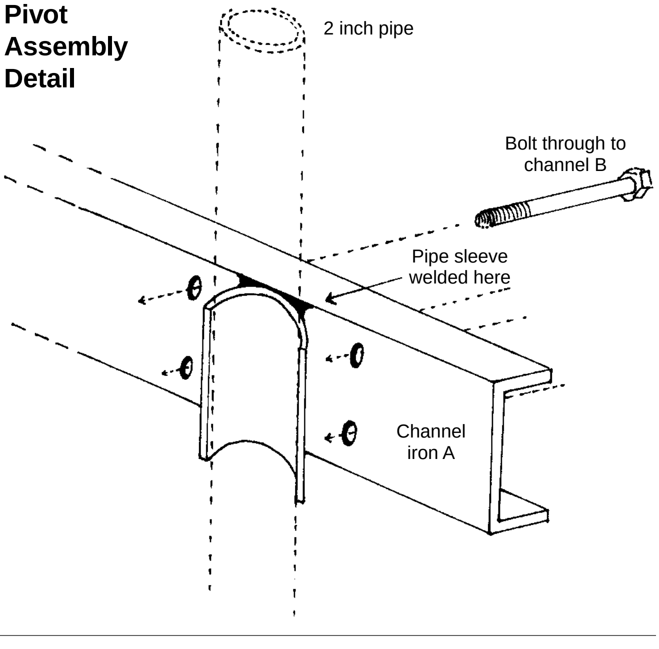
**10 mph wind*
***20 mph wind*

Bearings

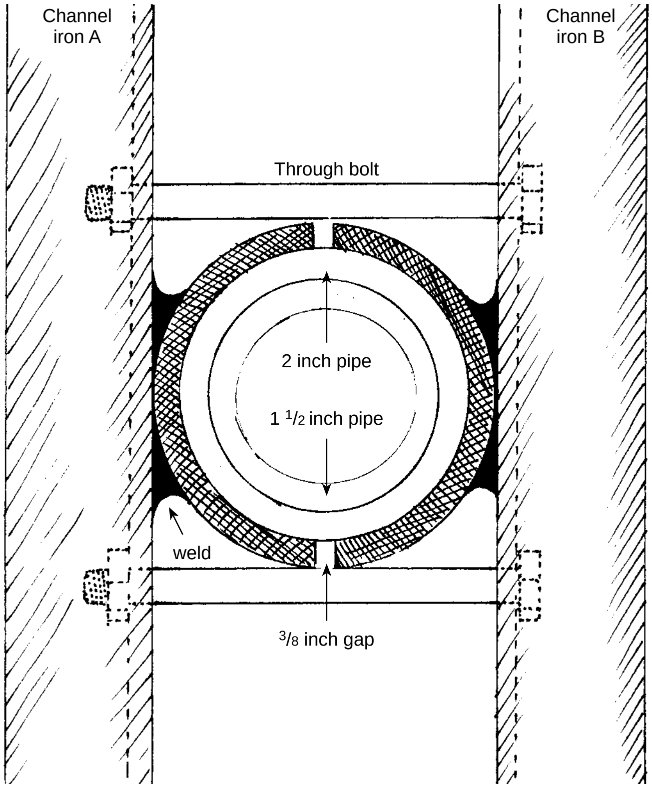
A wheel bearing from a car is now a propeller shaft bearing. When about 15 inches (38 cm) of the housing is cut off, you have a bearing fitted in the housing already. This bearing has to be a ball bearing type—roller bearings won't do. A ball bearing is needed to take the thrust. On the other end of the housing, a ball bearing has to be fitted. Also, the axle has to extend out from the housing about 4 inches (10 cm) for the driver pulley to be mounted.

For the yaw bearing, I fitted a tapered roller bearing from a 1-1/2 ton truck at the top end of the 2-1/2 inch pipe (which is fixed in the tower).

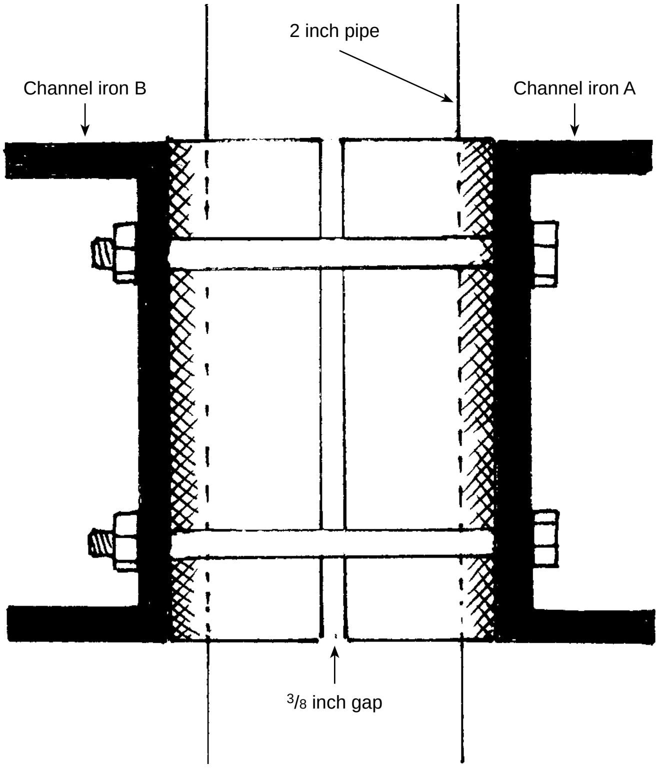
Pivot Assembly Detail



Main Frame Assembly: Top View



Main Frame Assembly: Side View



Lifelong Passion

Back in the '30s when I first got interested in wind power, my father was not very happy about it. I was just a teenager at the time, and wanted to buy some windmill plans. The price of the plans had been marked down from $2.50 to $1. My father insisted that it was still way too much money to spend on such a thing.

But I went ahead and ordered the plans from J. Leo Ahart in Dow City, Iowa. Ahart was a contemporary of Duncan, editor of the classic *Autopower.* I have the original 1937 copy of *Practical Electric Magazine* in which I found the ad for the windmill plans.

My father was quite angry with me for spending a dollar that way. But the wind power bug had caught me. It wasn't long after this that I had a windmill down by the shore generating electricity to light a small cottage we had there. Over sixty years later, I'm still excited about tapping the power of the wind.

Author Everett Russell: designer and builder.

Access

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FUNKY WINDMILL

Peter Jones

What started off as an interest in wind energy several years ago turned into an obsession that has never left me. And like many obsessions, by its very nature it tends to be evangelical. So whenever possible I try to spread the word!

The Funky Windmill is a kinetic sculpture made of recycled parts. It uses wind energy to light up the LEDs on the windmill—a good demonstration of recycling and renewable energy. In itself, it serves no useful purpose other than as a garden ornament that looks really good in the dark. But I hope that it will act as a catalyst for youngsters, and kindle an interest in renewable energy and recycling.

The project I describe here is made of recycled parts, with the exception of the blue and white LEDs, which I was unable to source from old equipment, and (sadly) had to buy new!

Details of the construction are kept to a minimum, since actual building will depend upon what materials are available. The windmill is built around a stepper motor from a computer disk drive attached to an automotive cooling fan. There must be tens of thousands of old hard disk drives and 5-1/4 inch floppy disk drives knocking about. These contain beautifully engineered stepper motors that are ideal for use as small AC generators. (The steppers used in 3-1/2 inch drive units are too small to be of any use.)

Cooling fans from automobiles are readily available from car breakers' yards (junkyards). Most European cars built in the last ten to fifteen years use electric cooling fans, so I guess the same must go for North American vehicles. These are ideal for the job.

Theory of Operation

Stepper motors are built to a very high degree of precision, and are generally overengineered. Many have shaft bearings of the size used on skateboard wheels! They generally consist of a series of radial coils wound on formers with metal or ferrite cores, and have a multi-pole magnet fitted to the rotating shaft. Impulses fed to the coils will cause the magnet to rotate in steps of anything from 1.8 to about 8 degrees, depending upon the design.

When the shaft is turned, the rotating magnet induces an electric current in the coils, and it behaves like an AC generator. Coil configuration varies from type to type, but the most common ones have four wires coming from two sets of coils. Some have six wires where the two sets of coils are centre tapped. The windings can be identified by using a continuity tester. If you don't have a tester, you can identify them by trial and error using an LED and twisting the shaft of the motor back and forth.

Motors with small steps will give the best type of display on the windmill. Being AC generators, they will cause the LEDs to strobe, giving the effect of a series of coloured dots as the blades rotate. The smaller the steps on the motor, the closer together the dots will be.

In a conventional windmill, the generator would be fixed, and the rotating blades fitted to the shaft. But in this design, the stepper motor is fixed to the rotating fan, and the shaft fitted to the body of the windmill. This is done so that the electricity generated can be fed directly to the coloured LEDs on the blades of the fan.

Fan Selection

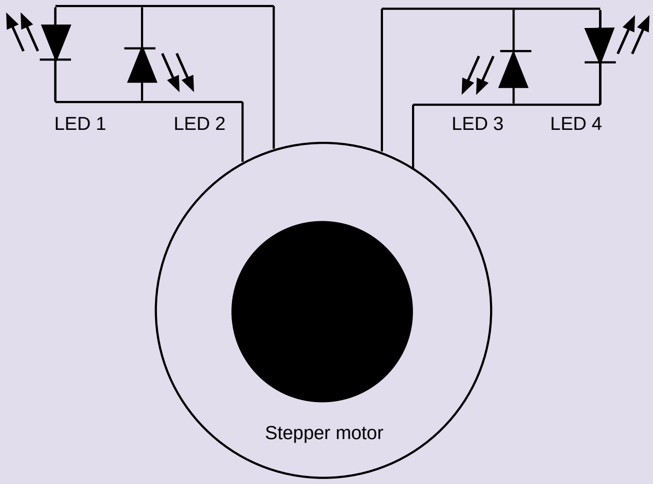
Vehicle cooling fans come in a multitude of sizes and designs, with as few as four or as many as fifteen blades. The blade design will generally be that of an aerofoil, so it is important that the flat or concave side of the blades face the wind. However, because the fans are designed to be driven by a motor, you'll find that when they're blown, the direction of rotation is wrong for the aerofoil, and the thin edge of the blade leads.

In a proper wind generator, this would be very inefficient, but it presents no great problem here. In fact, it tends to limit the upper rotational speed, protecting the LEDs. I have constructed several units using different types of fans and stepper motors, and they all rotate happily in a gentle breeze.

Electronic Connections

The construction shown in this article uses a stepper motor with two independent sets of coils. The motor generates AC when it's spun, and the output from each coil set is constantly changing in polarity. LEDs have an anode and cathode, so when used on direct current (DC), it is important that they are connected the correct way 'round. When connected to an alternating current (AC) source, they will strobe at the frequency of the generator, no matter which way they are connected.

Left: Funky Windmill at dusk.
Below: Schematic.






From left to right: Testing the stepper motor with LEDs. Fitting the windmill's shaft onto the motor. Installing the stepper motor inside the fan. Shaft attached to the fan, and facing the right direction.

If two LEDs are connected back-to-back to an alternating current source, one will be on when the other is off, and vice versa. So with a stepper motor having two coil sets (four wires), it's possible to use four LEDs (see diagram). If a six-wire (effectively a four-coil set) stepper is used, eight LEDs can be driven.

I used no current limiting resistances or reverse polarity protection diodes, and I was a little worried at first that at high wind speeds the LEDs would blow. But despite some pretty strong winds, all's been well so far!

Construction

Very few parts are needed for construction. They are:

- Fan
- Stepper motor
- Metal rod or tube for main body
- Yaw bearing
- Tail
- LEDs

The windmill is built from recycled materials, so the exact construction will of course depend upon which bits and pieces are available, and what type of tools are to be used. The sort of person who would be interested in making one of these things will probably have a shed or basement full of junk just ready to be utilised.

No specialized tools are required, though a hot melt glue gun will make life a lot easier when it comes to sticking down wires and fixing the stepper to the fan. But two part epoxy will do the job just as well, if not perhaps as quickly. Access to a small electric welder is always useful when it comes to fabricating metalwork, but again it is by no means essential.

The simplest way to attach the stepper to the fan is just to glue or bolt it to the reverse side (facing away from the wind). This will depend upon the design of the fan. Some have a flat disk at their centre, while others have a convex moulding at one side with a recess at the other. Gluing the motor to the reverse side leaves the motor exposed to the weather, requiring regular greasing to prevent water getting at the innards.

My preferred method is to install the stepper inside the centre boss of the fan (see photo), with the shaft poking out of the back. If this method is used, check that the fan will be facing in the correct direction. Some vehicle cooling fans blow through the radiator from the outside, while others suck air into the engine compartment, so the recess can face in either direction.

Whichever way the stepper is fitted, try to get it as central as possible to reduce any vibration, which will be inevitable if it's eccentric. The shaft of the motor has to be fixed to the body of the windmill. Motor shafts vary in size, and there is usually a stainless steel cylinder about half an inch (13 mm) in diameter fitted to the shaft. I've found that a length of steel tube about eighteen inches (46 cm) long is the easiest thing to attach to the shaft, either by welding, or as a sleeve that can be drilled and held with a set screw.

A tail is needed at the back of the metal tube to ensure that the fan faces into the wind. A piece of aluminium, mild steel, or plastic can be screwed, welded, or fitted with brackets. I used a piece of steel from an old external hard disk case from an Apple computer. The shape is not important, but the tail should be about six inches (15 cm) high.

Once the tail has been fitted, find the balance point along the body. This will be the best point to support the windmill, and some sort of yaw bearing will be needed. An old bicycle wheel hub makes an excellent bearing. The spindle can be fixed directly onto the body of the windmill, and the hub clamped onto the supporting pole. Grease the bearings well before fitting. It's also worthwhile to put a plastic cover at the top of the hub to keep rain out of the bearings.

Light It Up!

To fit the LEDs onto the fan, drill holes through the blades and push the LEDs through from the back. Most fans are made from a flexible type of plastic, so a good tight push fit can be achieved. It's better to avoid imbalance by distributing the LEDs around the fan, rather than fitting them all to one blade. The wires on the stepper will not be long enough to feed out to the blades, so they will have to be extended. Wires can be run down the back of the blades and taken to the stepper through small holes, which can be sealed with glue.

All connections should be soldered, and care must be taken while soldering the LEDs not to overheat them. Holding the leads with a small pair of pliers to act as a heat sink will prevent this. I used red, green, blue, and white LEDs. The red and green ones came from old bike lights. The blue and white ones are hard to find in old equipment, since they've not been available for too long and are still relatively expensive compared to the red ones. Hyper-bright types will give a much better effect than those of low-intensity LEDs.

I finished off the front of the fan by gluing on a slice of plastic cut from an old, floating ball valve. A plastic lid from a container would have been just as good. Paint all the metalwork to prevent rusting, and the job's finished. Now whatever the weather forecast may say, whenever you build a windmill, you can guarantee that you're in for a week of still weather, staring at it while waiting for something to happen!

The effect is certainly worth waiting for, and it makes a great kinetic sculpture for the garden, doubles up as a weather vane, and can be built for next to nothing out of junk!

Access

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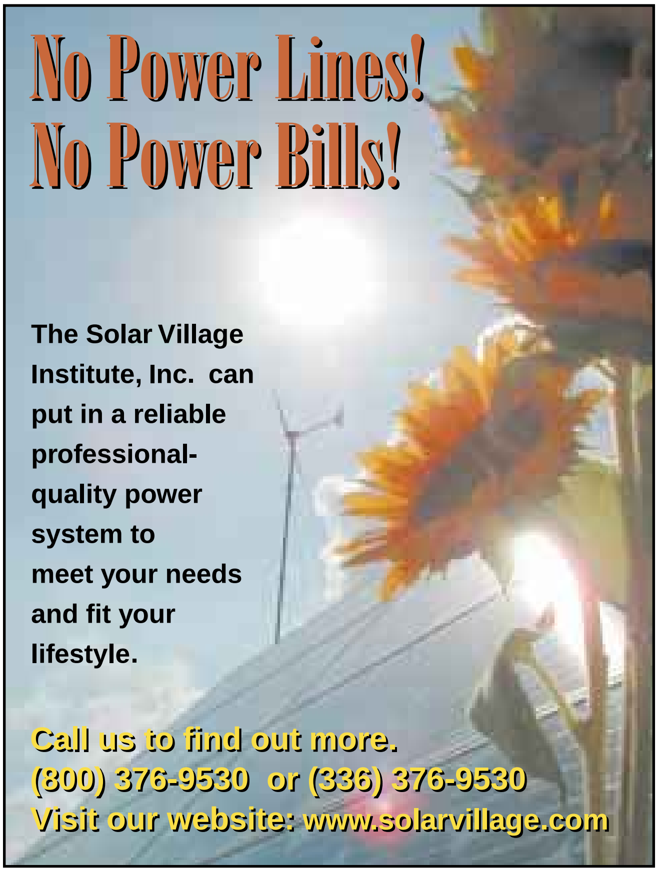
The Funky Windmill—built with (mostly) recycled parts—assembled, painted, and awaiting action.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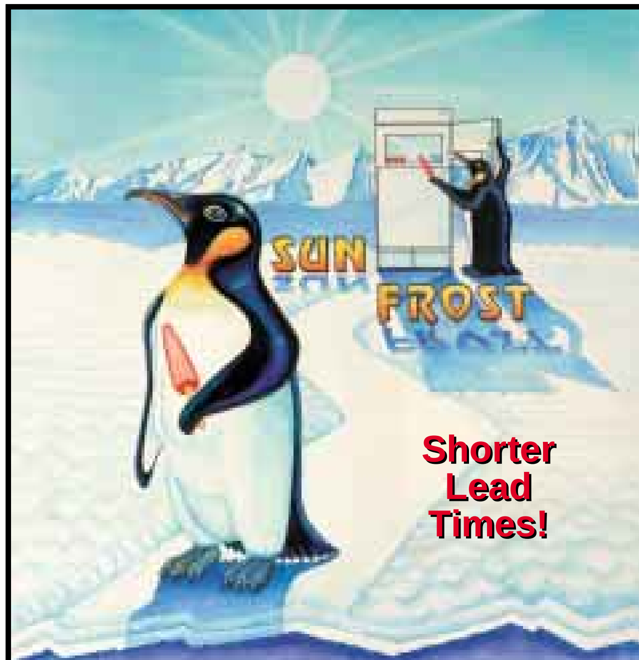
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Shorter Lead Times!