Gadget Freak Case #168

Wind Generates Useful Power at Home

Bo Andersson built a wind-powered generator just because he wanted one to use as a foundation for more experiments. When people said his idea to use a truck "rear end," or differential, to transmit wind power to a generator on the ground wouldn't work, he went ahead and put it on top of a 30-foot tower. Now Bo puts power back into the grid. And he can truly reap the wild wind.

Figure 1. The completed wind generator. Note the anemometer and wind vane near the top of the tower and the narrow shaft inside the right section of the tower that turns the turbine section into or out of the wind.

> Editor's Note: Design News presents this Gadget Freak design more as a proof-of-concept and experimental testbed than as directions to build a home wind-powered electricity generator. We assume any builder will design a system that meets their needs and suits their environment. Before you install a tower, consult with local building, zoning, and planning departments and uncover any conveyances, covenants, and restrictions (CC&Rs) placed upon your property. You might need a building permit, variance, or special-use-permit. If you install a tower, always use the recommended safety equipment such as a harness, safety belt, protective helmet, proper footwear, and so on.
>
> We strongly recommend you seek advise from professional tower-installation companies and a Professional Engineer who can help design your setup. Before you attach any experimental apparatus to the power grid, always consult with a licensed electrician and always follow applicable state and local electrical codes, and the National Electrical Code (US). Outside the US, follow your country's electrical codes.

For a file of Dynamic C code, mechanical drawings and a complete schematic diagram for this project, go to: www.gfreak.com/GF168/GF168.zip.

The Wind-Power Generator

The windmill equipment comprises a 33-foot (10 meter) self-supporting metal tower attached to a concrete base that measures 13 x 13 x 2 feet (4 x 4 x 0.6 meters). Andersson used a local Professional Engineer to specify the dimensions of the base given the height, local conditions, and wind load of the tower. Three hundred and thirty eight cubic feet of concrete is nothing to sneeze at!

Figure 2. Pouring concrete for the engineered base.

Instead of mounting a generator near the windmill blades, or turbine, at the top of the tower, Andersson used a truck "rear end," or differential gear set to convert the rotary motion of the moving blades on a horizontal axis to vertical rotary motion. The blades attach to a mounting plate where a vehicle wheel would normally attach to the rear end. The other wheel shaft was locked in a fixed position. Thus, the rotating blades transfer all their energy into what was the drive shaft. (Andersson used a crane to lift the entire tower assembly with the rear-end already mounted on the top.) For a helpful video about differential-gear operations, visit: www.youtube.com/watch?v=K4JhruinbWc. (Stay with it through the motorcycle rides.)

Figure 3. A wheel hub on this truck rear end, or differential, connected to the the rotating blades. The usual drive-shaft connection (upper center) connected to the long shaft that turns the motor/generator at the tower base.

The mounting plate holds in place six blades--imported from China--to form a fixed-pitch turbine, 13 feet (4 meters) in diameter. The drive-shaft on the differential connects to a 22-foot (6.7 meter) vertical, segmented automotive drive shaft that powers a generator close to the bottom of the tower. This configuration simplifies testing and substituting motors or generators near ground level

Andersson mounted the differential so it could rotate at the top of the tower under control of a motor, or under manual control, to position the turbine perpendicular to the wind direction. In some cases, though, Andersson wanted to turn the propeller parallel to the wind direction, as explained later. A Rabbit BL5S220 single-board computer automatically compared the rotor position to the wind direction. A combination electronic anemometer and wind vane mounted near the top of the tower provided the needed wind-direction and wind-speed data. A continuous-rotation potentiometer indicates the position of the differential and wind-blade assembly.

Figure 4. A close-up view of the tower top. Norte the mounting of the truck differential. A large gear mounted underneath the U-shaped bracket will turn the turbine into or out of the wind.

For information about the BL5S220 and BL4S100 computers, go to: www.rabbit.com/products/bl4S200/. You will find information on this Web page for both computer boards.

At the bottom of the tower, a 1/3 hp bi-directional single-phase motor (1800 rpm) provides the power to rotate the differential and wind-blade assembly. This motor connects to a 60-to-1 gearbox and drives another vertical shaft that runs to the top of the tower. Here, the positioning shaft connects to an automotive starter gear that drives a larger gear for a 16-to-1 drive ratio that rotates--at about 1.8 RPM--the differential and thus the turbine assembly. If the BL5S220 computer decides it must change the position of the differential and wind-blade assembly, it operates two of three relays simultaneously to control motor direction.

Figure 5. The tower top ready for mounting to the tower frame.

The vertical shaft from the wind turbine drives a 3-phase, non-synchronous motor that acts like a generator when the rotational speed of the motor/generator drive shaft becomes high enough for it to produce net electrical power. At that time, a Rabbit BL4S100 computer electrically connects the motor/generator to the electrical grid.

At lower speeds the motor/generator would act like a motor and draw power from the grid, so the BL4S100 computer prevents this condition from occurring. To measure the rotational speed of the wind-turbine vertical shaft, Andersson mechanically linked it with a small stepper motor, one coil of which serves as a speed transducer. The BL4S100 computer counts pulses from the stepper motor and converts them into an revolutions-per-minute value. When the turbine shaft--and thus the motor/generator--rotates too slowly, the computer turns off the grid connection. The grid connection is direct--the system requires no intermediate converters or inverters.

Figure 6. A "backwards" speed reducer (top, gray) provides power at 1800 rpm for the above the motor/generator (middle, black). The red rubber "boot" below the motor/generator shields the stepper motor used as a speed sensor.

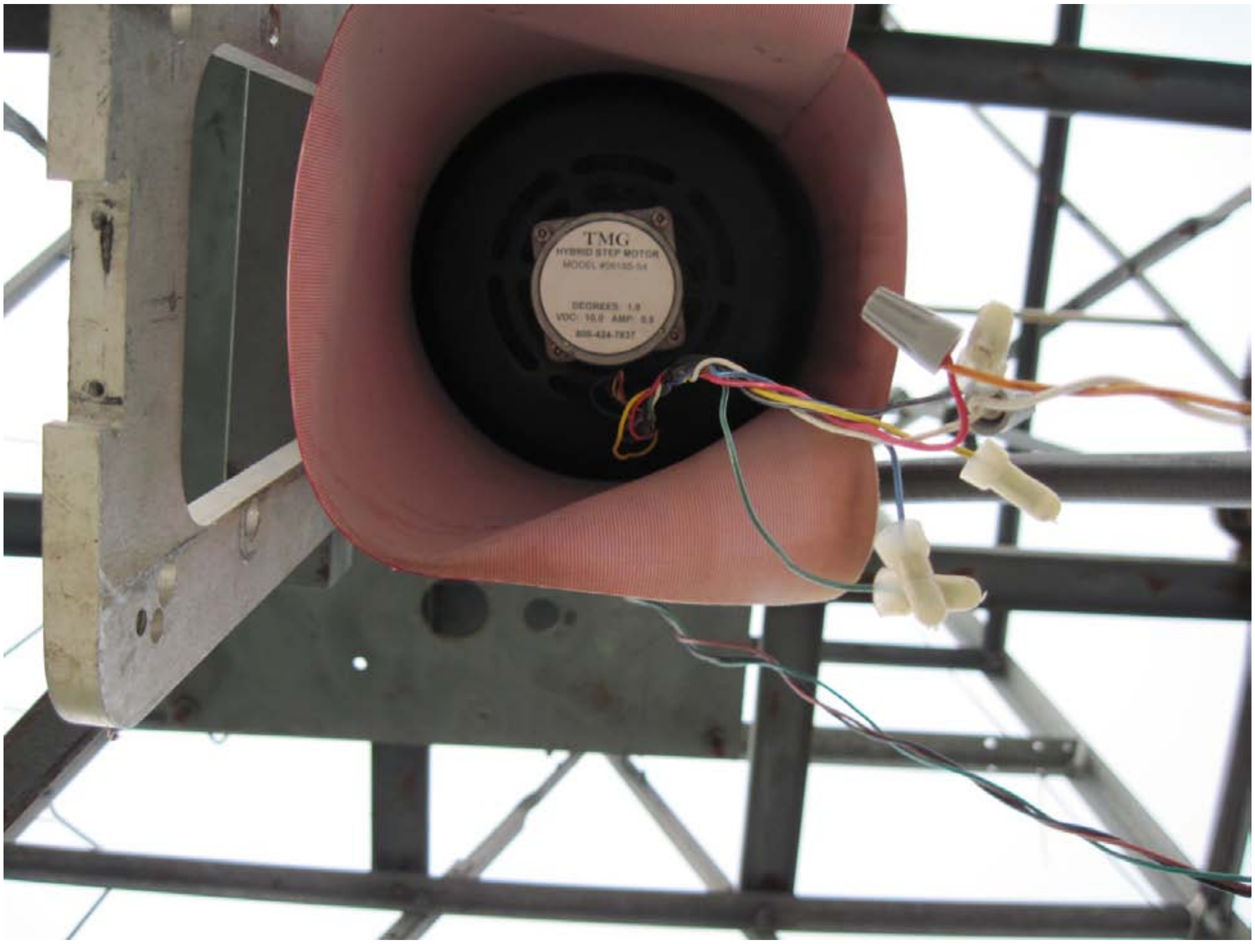

Figure 7. A view looking up into the rubber "boot" at the bottom of the motor/generator shows the stepper motor used to measure rotational speed.

A protective relay senses the loss of grid voltage and controls a contactor--a high-power relay--that disconnects the motor/generator from the grid. In high winds without the electrical load of the grid, the motor would experience no force to oppose shaft rotation. Thus, the wind turbine and motor/generator could "run away" in an uncontrolled fashion. At present Andersson's wind-powered generator has no mechanical brake to stop the turbine from over-spinning.

> Editor's Note: Andersson used ferrite or iron-powder cores to create a transformer that let him measure AC current. Unfortunately, he no longer had specifications for the core materials. As an alternative, you can use a ready-made current-sense transformer such as the Triad Magnetics CST-1020 that can produce an AC low-voltage signal based on the intensity of AC current flow on a conductor that passes through the center hole. You should use a rectifier circuit to convert the AC signal to a DC signal before you feed it to the ADC input on the single-board computer.
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> Andersson noted, the problems are non-linearity and variations of the output.

> The variations, or noise, can be filtered out, but that affects the response time. Some of that can be taken care of by software. Any sensing device of this kind requires calibrated to create a correction curve that the software can use to provide accurate current measurements. Andersson used an "old fashioned" kilowatt-hour house meter to monitor generated power, but for statistical data picked up by the computer he used the transformer described above to log output current for statistical purposes.
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> The Triad transformer has a maximum sensing range of 20A for 50- or 60-Hz power. For information about how to use this type of transformer, see "Self Powered AC Current Indicator," http://www.discovercircuits.com/DJ-Circuits/self-powered-AC.htm. Find a data sheet for the CST-1020 transformer on the Triad Magnetics Web site at: www.triadmagnetics.com. The Bill of Materials list the CST-1020 transformer.

As further protection from high winds and a run-away condition, the BL5S220 computer also detects the loss of grid power and will turn the turbine head ninety degrees out of the wind to stop the rotor. The BL5S220 computer also collects wind speed, shaft-rotation frequency, grid-voltage and generated-current data from sensors and transmits this information by WiFi to an office PC computer for further processing. The programs for both computers used the Rabbit Dynamic C language and co-statements.

Notes

Andersson started with a permanent-magnet generator and controller bought from a company in China. That equipment might have provided a more efficient generator, but the inverters that connected to the grid had problems. "The generator would produce a high voltage, normally about 400V DC," said Andersson. "But if the rotor over spins, which it did at the start of the project, it could produce over 1000V. That's hard to handle, so for the time being I decided to use a 3-phase non-synchronous motor. It was cheaper than a permanent-magnet motor and easier to connect to the grid because if it is not up to the proper speed, it will not produce any power. When it gets above the grid frequency, it will automatically synchronize to the grid--and that's it. It's very safe because if the grid drops out, there is no power generated. It is self synchronizing. The computer measures the rotation speed of the motor and when the output signal exceeds 60 Hz the contactor connects the generator to the grid."

"There is a need for making wind generators that work with low wind velocities and this one does," added Andersson. "I found that you need a lot of open space to get wind to drive a wind generator. This one sits in an area close to buildings and it could be higher. That would be better. At low altitudes we get a lot of gusty wind. I wanted to also see if I could control the effect of the wind."

So far, Andersson doesn't generate enough power to require a special utility meter. Instead, he continues to use his standard electric meter and just plugs his generator into a mains-power outlet.

"This type of project tends to get expensive because you have to do a lot of experimenting," noted Andersson. "As my next step, I plan to use a larger motor/generator because the turbine can produce about 3.5 kw, or 5 horsepower, so I'll use a 5 HP, 3-phase motor on it. That doesn't necessarily mean I will get much more power because the wind determines the output. But when we have a windy day, we will get more power."

Bo Andersson provided the photographs used in this document.

Bill of Materials

Heavy Mechanical Components			
Amt.	Description	Part #	Source
1	Windmill Tower, 30-foot		Topper Co.
6	Windmax Blades, 13’ Diameter	WINDMAX-131WH	Applied Magnets
1	Chevrolet Suburban Truck Rear End, Modified		
2	2-inch Heavy-Duty Bearing		
3	Automotive 8-foot Drive Shafts with Bearing		
4	1-inch Universal Joint		
2	3-Piece Flexible Coupling		
1	3-Phase, 240V Motor	10-2385	Surplus Center
2	25μF Run-Time Capacitor, 370V	22-1106	Surplus Center
5	5-foot, 1-inch Diameter Steel Rod		
5	Bearing blocks with 1-inch Bearings		
5	1-inch Universal Joint		
2	Automotive Starter Flywheel with Drive		
1	1/3-hp Motor	OMT13-18-56CB	Omega Engineering
1	60:1 RA Gear Reducer		Surplus Center
Generator-to-Grid Components			
1	Contactor, Solid State, RN1A48D50	251-2002	Allied Electronics
1	20V Transformer, Center Tapped, 0.3A, 110/220V AC	967-7195	Allied Electronics

1	Ammeter, 0-10A AC	229-4332	Allied Electronics
1	6V 2A, 12V 1A Transformer, 110/220V AC	967-1105	Allied Electronics
1	DPST Relay, 25A, Normally Open, 240V AC Coil	886-2268	Allied Electronics
2	Current-measuring Transformer, 20A, CST-1020	967-0119	Allied Electronics
2	1N4007 Diode	266-0007	Allied Electronics
1	82Ω Resistor, 3W	296-5485	Allied Electronics
1	100Ω Resistor, 1W	296-2247	Allied Electronics
2	6800 μF Capacitor, 16V DC	613-0103	Allied Electronics
1	Stepper Motor, 1.8-degrees, NEMA 23 Frame		
Rotor Direction-Control Components			
1	10KΩ Potentiometer, 3W Continous Rotation, ETI Systems	522-0132	Allied Electronics
3	DPDT Relay, 10A, 24V Coil, IDEC	814-3032	Allied Electronics
2	DPDT Switch, on-off-on	683-0064	Allied Electronics
Computers and Sensors			
1	BL4S100 Single-Board Computer	BL4S100	Rabbit
1	BL5S220 Single-Board Computer	BL5S220	Rabbit
1	Anemometer Transmitter Kit	6332	Davis Instruments
1	Anemometer Sensor	6410	Davis Instruments
Web URLs for Sources:			
Applied Magnets: http://www.magnet4less.com/index.php?cPath=8_19			
Topper Company: http://www.4kllamas.com/wind.htm			

Surplus Center Burden Sales Co.: https://www.surpluscenter.com/home.asp			
Omega Engineering: http://www.omega.com/Auto/pdf/OMT_SERIES.pdf			
Rabbit, Digi International: http://www.rabbit.com/			
Davis Instruments: http://www.davisnet.com/			
Allied Electronics: http://www.alliedelec.com			

Diagrams, Drawings, and Code

For a file of Dynamic C code, mechanical drawings and a complete schematic diagram for this project, go to: www.gfreak.com/GF168/GF168.zip.

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