Notes on Building and Testing Hugh Piggott's Axial Flux Wind Generator

Guemes Island, WA, April 2004

Truck testing the wind generator we built during the seminar.

Homebrew Wind Power guru Hugh Piggott offers frequent seminars all over the world for folks who want to learn how to build wind turbines from scratch. Otherpower.com sent 3 staffers in 2004 and 2 of us in 2003 to Hugh's spring seminars on Guemes Island, Washington. These were put on by Solar Energy International (SEI), and were excellent learning experiences for us. On this page I'm attempting to give some details, advice, and update information about the process of building and flying the wind turbines deatiled in Hugh Piggott's Axial Flux Alternator Wind Turbine Plans.

Hugh Piggott explaining to the class the finer points of how this homebuilt wind turbine operates. This one is flying at Guemes islander Win Anderson's General Store, right at the ferry dock, and is grid tied.

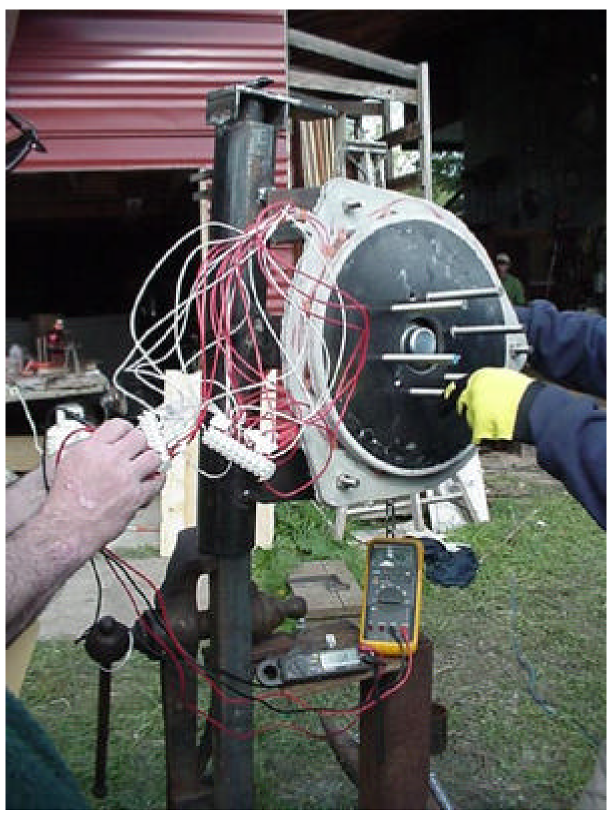
- Lowering Win's wind turbine happened on our first afternoon of the seminar -- it gave all the students a taste of what their project would look like when it was done, Hugh got to give a hand-on theory lesson, and it gave a chance for Hugh and Win to inspect the machine (it was erected on October 2003, and was built at the 2003 Seminar--the Dans helped build it). This brings up another point -- *Do regular maintenance on your wind turbine, whether it is home-built or commercial!* That way a loose bolt, cracked weld, or rubbing wire can be fixed easily, before causing an in-operation disaster.

- **If you are contemplating investing your time and money into building a wind turbine from scratch, Hugh Piggott's designs are a proven option. He's been building them, flying them, and teaching about homebuilt wind power for over 25 years. We highly recommend that you read Hugh's book Windpower Workshop to get a detailed grasp of the concepts involved in designing a functioning turbine that is sturdy and reliable. He covers many different design ideas, and explains the pros and cons of each. If you decide to embark on the project, his Axial Flux Alternator Wind Turbine Plans contain detailed CAD drawings, dimensions and materials lists for the latest version of the turbines he's building. Essential!**

- One new development at the 2004 Seminar was building a test model of Hugh's new 12-foot diameter design. We did indeed finish it and test fly it. The design is quite similiar to the 8-footers detailed in Hugh's plans, but the alternator is much more powerful and all the structural components have been re-designed and beefed up.

Hugh Piggott atop the tower for his new 12 foot dia. wind turbine

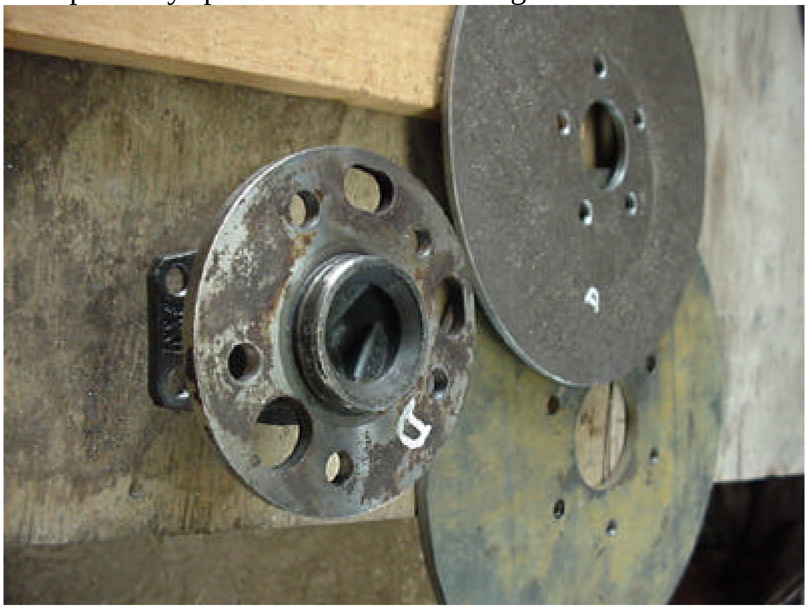
One interesting thing about this design -- note in the picture below all the wires coming out into the white terminal blocks, instead of being soldered together and cast directly in to the stator. This is so the leads of EACH coil are accessable for making different connections -- star, delta, series, parallel, etc. Seminar volunteer and electronics wizard Brian Faley is working on an experimental electronics system to squeeze the most power possible out of the turbine at varying wind speeds -- similar to "Maximum Power Point Tracking" in solar panels, and similar to a Linear Current Booster in water pumping. More on this topic farther down in this article.



Assembling and testing alternator for 12-foot wind turbine. Note that each coil lead runs to external terminal blocks for future testing and R and D.

- ## Some things to think about when first getting started on or contemplating the project:

- **First, check for updates.** If there's anything you need to know about changes in the plans, they will be posted here. Hugh updates and revises his plans regularly. There have been small design and manufacturing process improvements that were discovered in both of the seminars we attended. It's an ongoing evolutionary process! So check here first to be sure you have the latest information.
- **Evaluate your shop and tool situations for both metal- and wood-working.**
  - **Metalworking** -- If you have a good welder, a drill press, and a grinder you'll be able to do it all yourself. However, a metal-cutting bandsaw will save you much time and sweat over using a hacksaw! And we've found that it's worth the $40 or so it costs to have a local metal shop use a plasma cutter with circle cutter attachment to cut the 2 magnet rotors, and use their rotary table drill press/milling machine to perfectly space the holes for the lug bolts.

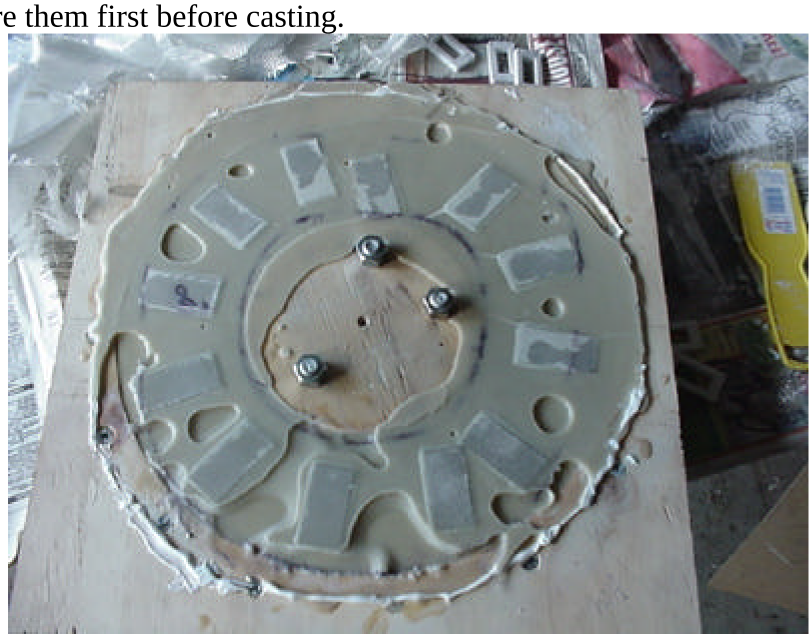
    Note the perfectly circular magnet rotors, pre-drilled with perfectly spaced holes to fit the bearing. Well worth the money versus cutting these out with a torch and grinding them to perfection! These were from the 2004 seminar.

    For folks that don't have a welder -- It *might* be possible to build this turbine without welding, by creative use of bolt-together structural pieces...but I would not recommend this. It would be much more risky -- more chance of something important rattling loose. *"Bits fall off" -- H. Piggott* So get the friendly person at your local welding shop prepped and enthused about the job...let them look at Hugh's Plans ahead of time for a better cost estimate. Be there when they are doing the welding for you so you can be sure it's right! Look at MattB's Photo Essay about the 2004 seminar for some more good pictures.
  - **Woodworking** -- Usually almost anyone can make a rotor, hub and blade set at home, even if they don't have a shop with power tools. You'll need a bandsaw for sure, and a hand drill. If you were patient enough, you could carve the blades with a pocket knife! But that would take a *long* time. A chainsaw might work, too -- but the finished product would be decidedly lacking in aesthetics! At the seminar, most of the instruction was with using a drawknife and scrapers. With certain kinds of wood, this can easily be the fastest and most efficient technique. With other kinds of wood (such as Fir, which is very hard), these tools take lots of effort to make only a small dent. So a power planer can speed things up considerably with harder woods. The planer also requires care in use though -- if you are not careful about how much pressure you apply down the length of the blade, it's very easy to make a big divot right near the blade tip as you run the planer off the end of the blade. This is a bad place for a big divot, so practice first before attacking an expensive piece of blade wood.

DanB running the planer on a blade for the new 12-foot machine design. The blades are Yellow Cedar, which cuts pretty well with a drawknife...but the turbine blades are BIG and the planer did speed up the process somewhat.

- **Here's some of the notes, contruction tips, and design notes that came to light during the 2004 Seminar.**

- **Preventing magnet movement during casting** -- Hal Merrill of Seattle attended the seminar and stayed at the same resort we did, at a nearby cabin. We played music every night at our Forcefield cabin...and found out that Hal is a pedal steel guitar virtuoso! (check out Matt's After Hours Page for more pics! Back to the point, Hal had already begun construction of his own turbine from Hugh's Plans. He was casting his magnet rotors at the 2004 Seminar, and had a problem -- some of the magnets moved in the wet Fiberglas resin when the steel clamps were applied over top of the plywood moulds. They moved very early in the process, since they left no 'trail' in the resin from their movement. You could simply use bricks instead of metal pieces for clamping, but flow in the resin during clamping could still possibly move the magnets around. It would be wise to secure them first before casting.



We discussed how to prevent this from occuring in the future. Probably the best method is to secure the magnets to the rotor with Superglue before casting. If you use thin cyanoacrylate glue, it will wick underneath the magnets and hold them in place tightly. Hit it with cyanoacrylate glue accelerator and they are instantly stuck down. An alternate method would be to spread the initial thin layer of Fiberglas resin and place the magnets as per the plans -- but wait for the resin to harden somewhat before pouring the rest of the casting and clamping.

- **'Rescuing' magnet rotors with misplaced magnets**-- Fortunately Hal figured that he had nothing to lose at this point, since the magnet rotors had multiple magnets that were way out of place. So with MattB's help, they took an angle grinder and attacked the resin around the misplaced magnets like dentists out of a nightmare!

The operation was a success! The magnets we used were even saved intact, and could be re-used.

In the end, Hal simply cleaned fiberglas off of the magnets, re-placed them on the rotors, and poured more fiberglas to seal them in. It worked!

- **Truck testing** -- On the last day of the seminar, of course there was no wind. We'd all spent the entire week building these wind turbines, and everyone wanted to see them in action. Hugh and Ian were prepared for this 'wind anchor' phenomenon, where the erection of a new windmill stops the wind for days at a time. While we were doing final assembly on the turbines, DanB mounted a testing frame to the top of Ian's stylish and functional dump truck.

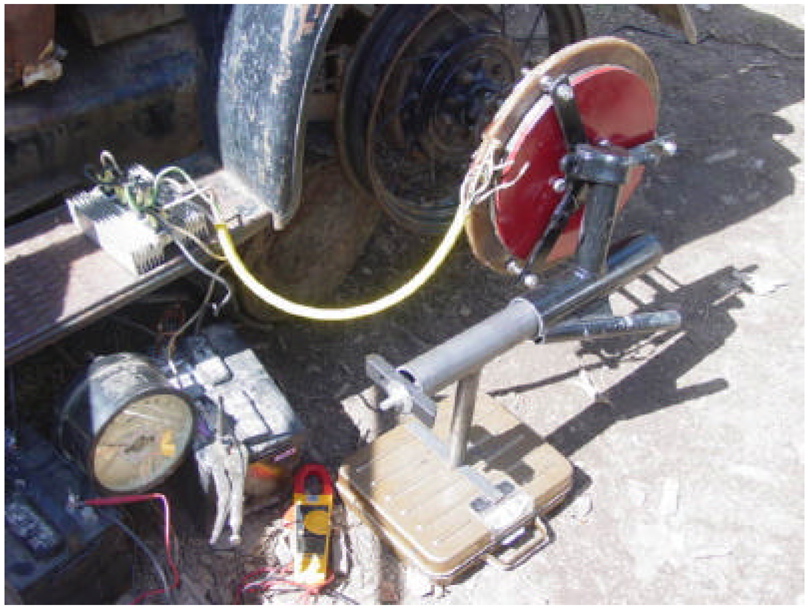
This is not really a very good way to test wind turbines. But it is FUN, and you can start getting an idea of how the alternator performs and when the furling system starts to kick in. Don't rely on windspeed data when truck testing, though -- whether it's from the truck speedometer, an anemometer, or a GPS unit, windspeed readings will be skewed by the airflow around the vehicle.

- **Dynamometer testing** -- This was a *really* interesting alternator testing idea! Bolt the alternator to the wheel hub of a truck, instead of rotor blades. If you measure the RPM, amperes into the batteries, and voltage, you can make a detailed graph of alternator performance at different speeds. By adding scales to determine how much torque is being put into the machine, you can also figure alternator efficiency at different RPMs.

Alternator connected to wheel hub via a plywood adaptor for power testing.

One very interesting issue with this testing method is that the alternator gets no cooling effect from the wind. We had to watch and feel it very carefully during testing, so it would not melt and be ruined. Cooling from the wind makes this a non-issue with an alternator that's flying up in the wind. There's also the factor of continuous vs. intermittant output. In the wind, the turbine is not likely to stay at peak output like we were forcing it to do on the truck hub.

As soon as we returned home to Colorado from the Seminar, DanB made his own version of this truck testing apparatus, connected to his Model A Ford. We added scales on a one-foot long lever arm to derive foot-pounds of torque, and we ran into the same cooling issues that we did at the Seminar. DanB wrote a great web page about testing alternators this way with lots of photos and output data.



DanB's alternator dyno-testing rig

- **Issues with stalling** -- This topic is also covered in detail on Hugh's Plans Update Page. We have also experienced the phenomenon on our Volvo disc brake turbine designs. Like Hugh, we also design our turbines for best performance at low wind speeds--that's how most of the wind comes to us. At higher windspeeds, though, the alternator runs too slow for the blades. You could also think of it as, the alternator is too powerful for the blades at that windspeed. *This stalling is easy to spot -- the blades get to a certain speed, and won't go any faster even if the windspeed increases more.* Thus power output does not increase past a certain point either.
- Part of the reason this happens is that these permanent magnet alternator designs are very efficient -- to there's not as big a range of RPMs that happens between cut-in and full power.
  - There are quite a few simple ways to fix this problem -- if it even causes a problem for you! You can almost look at stalling in higher windspeeds as an added safety factor. The blades have no tendancy at all to overspeed. If you are looking for optimum low-speed performance and don't need the extra power from high winds, there's no need to fix something that ain't really broke! If you have a 12 volt turbine with a long run of wire to the battery bank, there's a good chance you won't experience stalling and don't have to change anything. You are more likely to run into stalling with a 24- or 48-volt mill and/or a short run of thick wire to the batteries.
  - The easiest 'fix' is to simply back the magnet air gap off a bit. This decreases the magnetic flux through the coils, and lets the alternator spin faster. It will also mean a slightly higher cut-in speed, thus will give a small decrease in low-wind performance. We've actually continued to build our turbines so they stall at first, then we gradually back off the air gap until it's performing just right for the site.
  - Another way to accomplish the same thing (letting the alternator spin faster) is to wind each coil with a couple less turns per coil, before you cast the stator. If you are planning a 48v turbine that's located right next to the batteries, you might do this right from the start. With a 12v turbine and a long wire run, you might not need this at all -- and another method listed here could be used after construction.
  - Another possibility for reducing stalling problems is to increase the resistance in the line. This increases the machine's RPM range, and does very little harm at low speeds--when power output is low, so are line losses from resistance. We found that our 12v mill at the Caboose had such a long power run at only 12v that it already had no stall problems. We tried a similar thing with TomH's 12v mill -- added a 100 foot length of thinner wire to the line. His mill is right next to his battery bank, with thick wire...so the line was very 'stiff.' The extra resistance made it more 'spongy' and let his mill go thru a wider range of RPMs. Though it seems counter-intuitive to 'waste' incoming power as heat, it makes the blades perform at better efficiency throughout their whole speed range, so the power is not really wasted. It's only making a significant amount of heat when the mill is near full power anyway.
  - A larger diameter rotor will also prevent stalling. That's really what the alternator wants at higher speeds--it's powerful enough to deal with the huge increase of power that a higher windspeed has

available, but the blades aren't big enough to harvest it all. But think first -- are your tower, guy anchors, frame, bearings, furling mechanism, etc. sturdy enough to handle the extra force? At least think about this before building a bigger prop.
   - Ultimately, the ideal solution is some sort of electronic control that loads the system perfectly at all windspeeds (also discussed above). That's what Brian Faley is working on for the 12-foot machine that we built during the seminar, and that's why we left every lead to every coil accessible.

Related Links

MattB's detailed photo essay about the entire seminar. Pictures of everything!

Hugh Piggott's Website is full of information about homebrew wind turbines, pictures of his seminars, and fun reading.

Solar Energy International put this seminar on for us. Hats off to them!

Home Power Magazine--SEI northwest coordinator Ian Woofenden is also an editor for them. Great magazine! How does Ian get any sleep? He played music with us every night too. Blue Energy is a non-profit with plans to help small communities in Central America set up small wind power systems. They were here... great folks.

Guemes Island Resort, this is where we stayed both this year, and last year.

Whidbey Sun and Wind is a local company that designs and installs RE systems in Washington. Kelly came by this year and last, and played harmonica with us.

Questions or comments? Click here to send us an email!