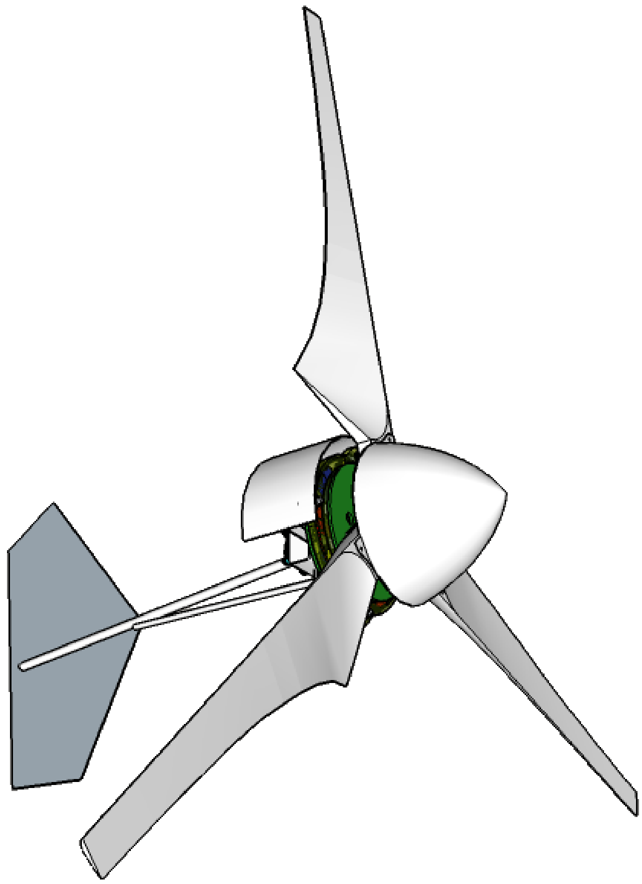
Build A DIY
800W Axial Flux HAWT
(Horizontal Axis Wind Turbine)



A step by step build guide from

RST
RENEWABLE SYSTEMS TECHNOLOGY

Table of contents

Introduction

This is a step by step instructional guide on how to build an efficient axial flux horizontal axis wind turbine. The build video series for this project can be viewed at the following link:
https://www.youtube.com/watch?v=vBWKsx_8is4&list=PLdO3Wk-XPC_DTE9lrMG72I95s_6iPlwgX

Axial flux HAWTs are among the most efficient wind turbines in use today, and the key to their well known reliability lies in the stator, or what isn't in the stator to be more accurate.

Most wind turbine generators are of the radial design, which means that the flux produced by the magnets flows perpendicular from the rotor shaft through the coils and back. The stator coils are wound around laminated steel cores which attract the flux and helps direct it long distances through the coils and back to the rotor magnets again. The downside with this configuration is that the magnets mounted on the rotor shaft are naturally attracted to the steel stator coil cores, so as each magnet passes a coil a 'tugging' or resistance against the rotor is created by the attraction between the magnet and the steel, commonly called 'cogging'. Cogging has a negative effect on both start up speed and overall efficiency.

An axial flux generator is configured so that the magnet flux runs parallel to the rotor shaft. The stator is commonly referred to as an 'air core' stator because it contains no steel to cause the cogging effect. Instead of wrapping the coils around a steel core to direct the flux, the axial flux coils are encased in resin and the subsequent stator is mounted between to large, round steel rotor plates to which the magnets are attached on the inside faces. The steel plates move in unison and direct the magnet flux from one plate, through the coils to the other plate and back without causing any resistance on the rotor.

The other advantage to the axial flux design is that anyone motivated and with access to basic hand and power tools can build it - no expensive professional machining equipment needed!

Tools required

Measuring tape, pencil

Square, straight edge & protractor

Centre punch (for metal)

Hammer

Wire brush

1” wood chisel

Coarse flat and round files

Three or four 12” bar clamps

Small weigh scale

Hand saw

Jigsaw

Palm sander w/ 80-200 grit sandpaper

Table saw or circular saw

Mini-grinder w/ cutting and grinding wheels

Welder (mig or arc)

Power drill w/ ⅛”-½” metal drill bits, & 1” hole saw

Digital multi-meter

Soldering iron

Bill of materials

One piece of 1-½”x12”, and one piece of 2”x12” schedule 80 steel pipe

One piece of 1”x8’ schedule 40 steel pipe

One piece of 1”x24” steel rod

One piece of 2”x4”x6” rectangular steel tubing

One piece of 1”x1”x24” steel angle

Three pieces of ¼”x12”x12” steel plate

One piece of 1”x1/8”x4’ steel flat bar

Two pieces of ½”x4’ threaded rod w/ 70 hex nuts, lock washers and flat washers.

Four pieces of 5/16”x2” hex bolts w/nuts, flat washers and lock washers

One 5/16”x4” hex bolt w/nuts and lock washers

Five pieces of ¼”x 3” hex bolts w/ wing nuts and flat washers

Two 1” ID flanged bearings

One piece of 4’x4’x1” polystyrene

One piece of 4’x4’x5/8” melamine

One piece of ¼”x4’x4’ plywood

One piece of ½”x24”x24” plywood

Twenty one pieces of 2”x4”x4’ clear (knot free) kiln dried cedar

Large bottle of outdoor wood glue

Four cans of primer spray

Bill of materials continued

Six cans of satin white enamel spray

Two litres of slow cure epoxy resin w/ catalyst

Twelve square feet of fibreglass mesh or cloth

One large can of Bondo w/hardener

Seven pounds of 14 awg enameled copper wire

Four feet of insulated fine strand 14 awg wire

Twenty four 1”x2”x1/2” N52 grade neodymium magnets

JB Weld kit

Rosin core solder

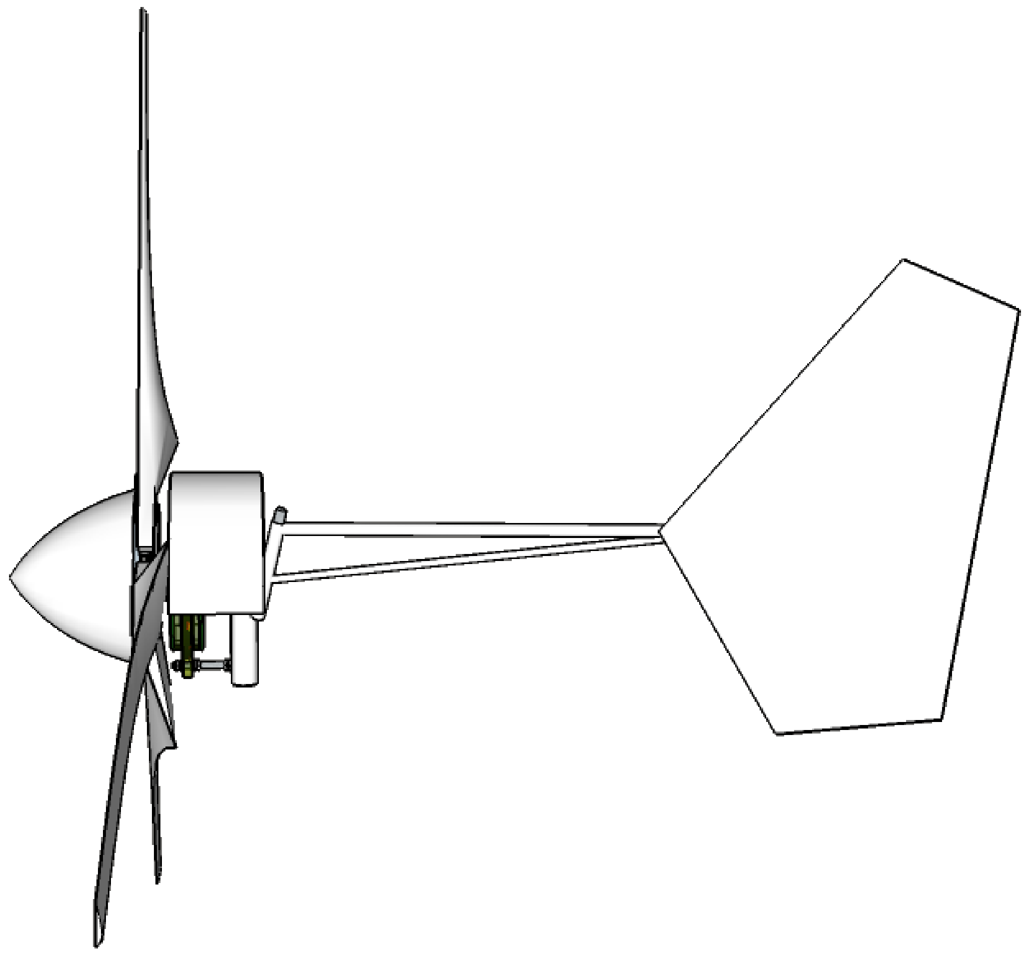
80-200 grit sandpaper

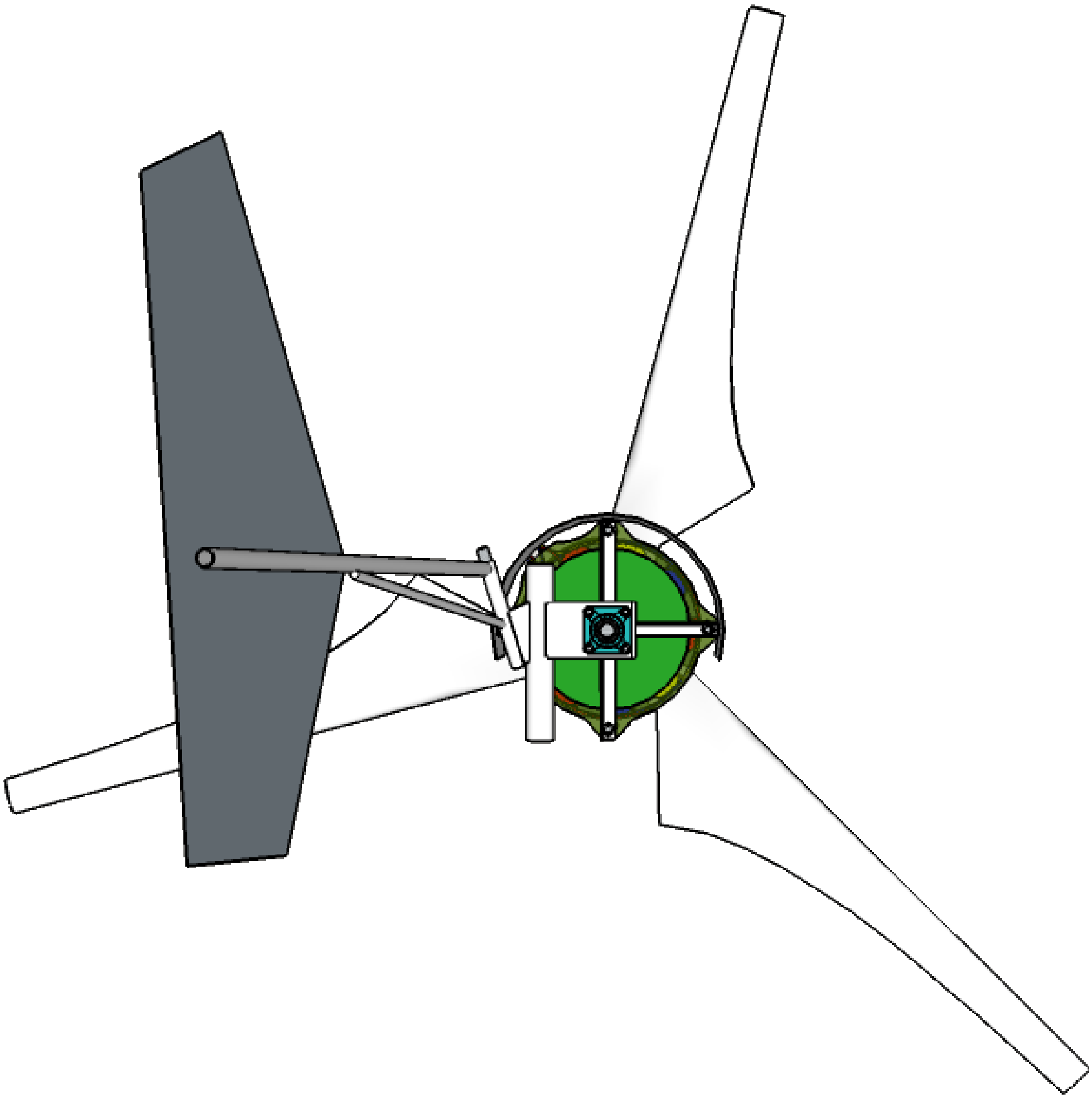
Small bottle of acetone

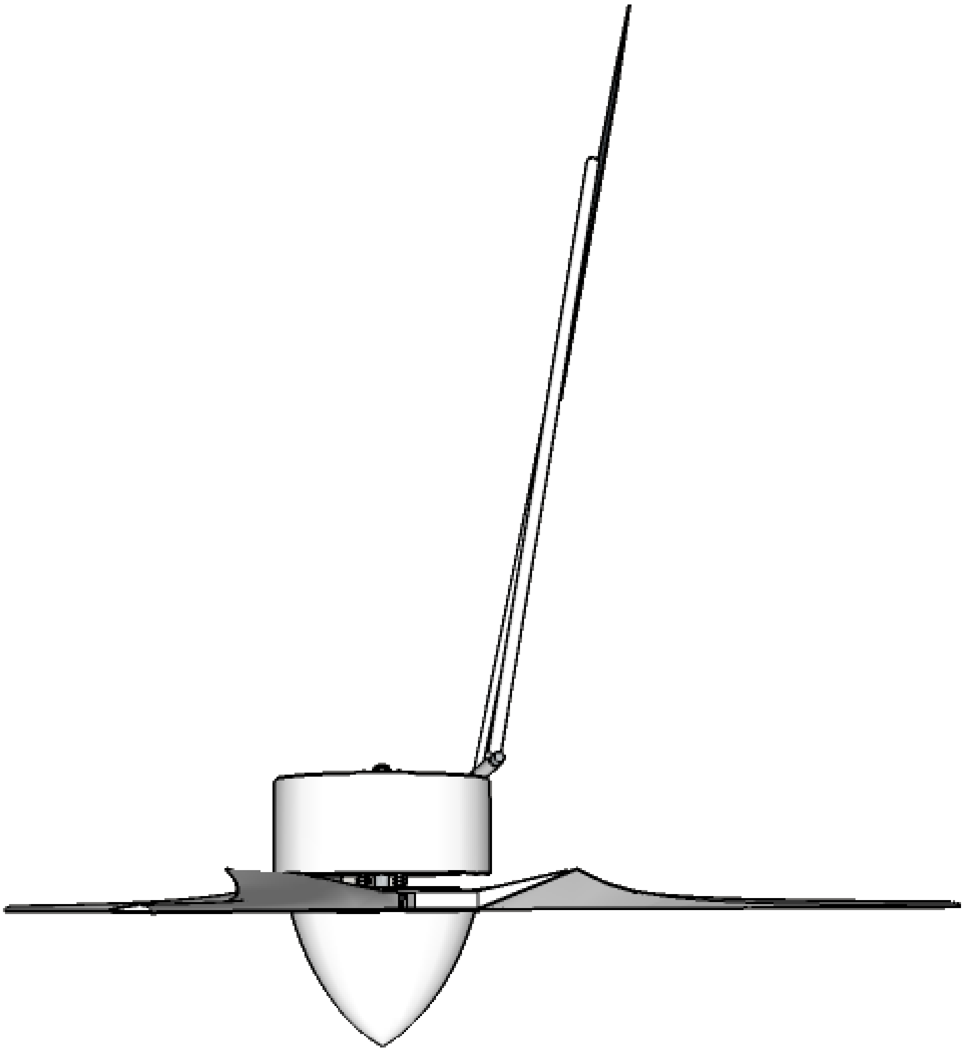
Turbine specifications

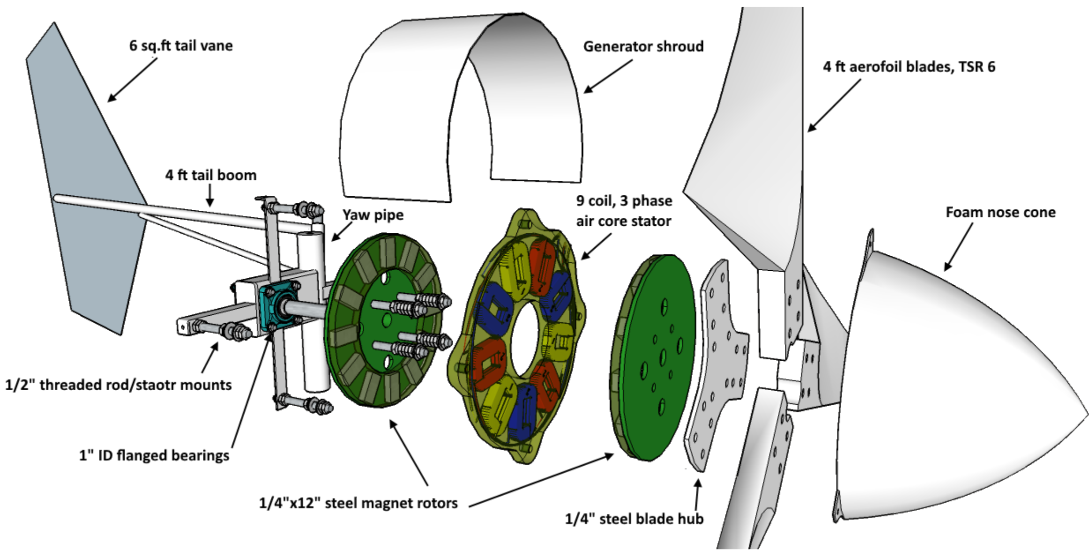
Rotor
Diameter: 8 ft
Swept area: 50 ft^2
Blades: 3 at 48”, TSR 6

Generator
Type: dual magnet rotor axial flux
Power: 800 watts
Rated wind speed: ~26 mph
Cut-in rotational speed: 180 rpm
Poles: 12
Coils: 9
Phases: 3



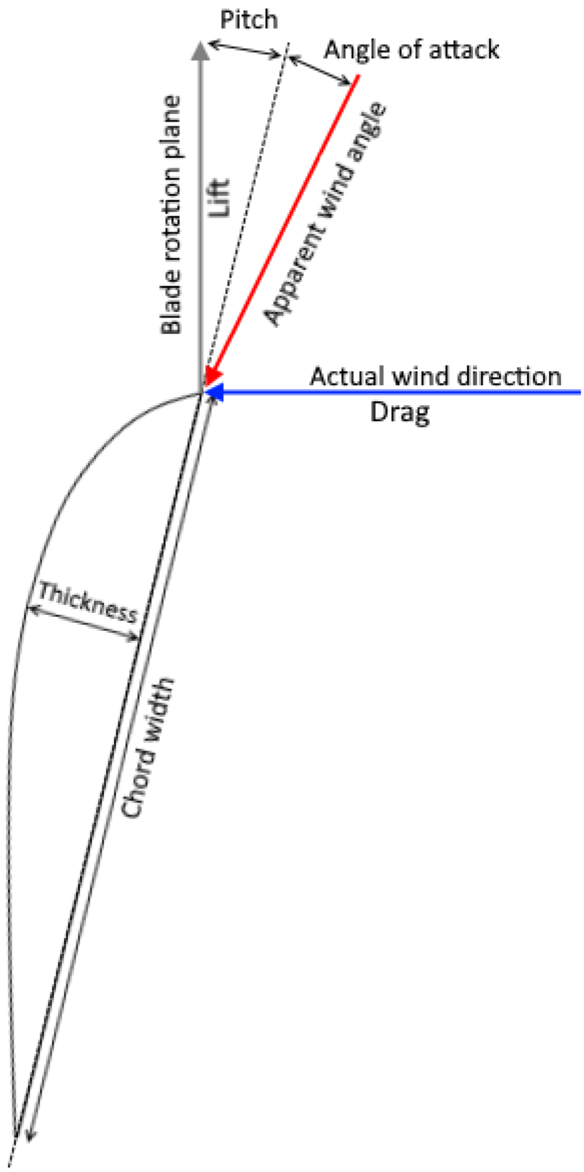




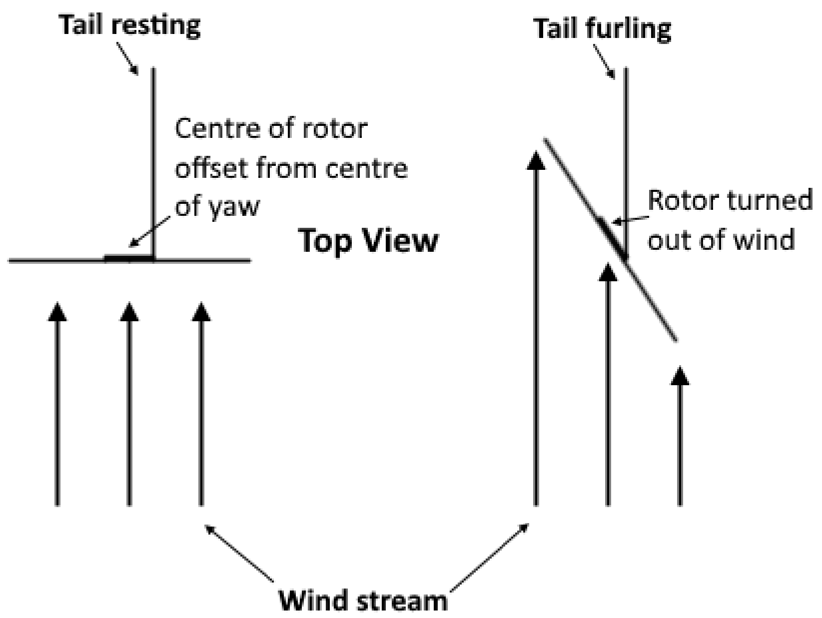

6 sq.ft tail vane
Generator shroud
4 ft aerofoil blades, TSR 6
4 ft tail boom
Yaw pipe
9 coil, 3 phase
air core stator
Foam nose cone
1/2" threaded rod/staotr mounts
1" ID flanged bearings
1/4"x12" steel magnet rotors
1/4" steel blade hub

Wind power basics

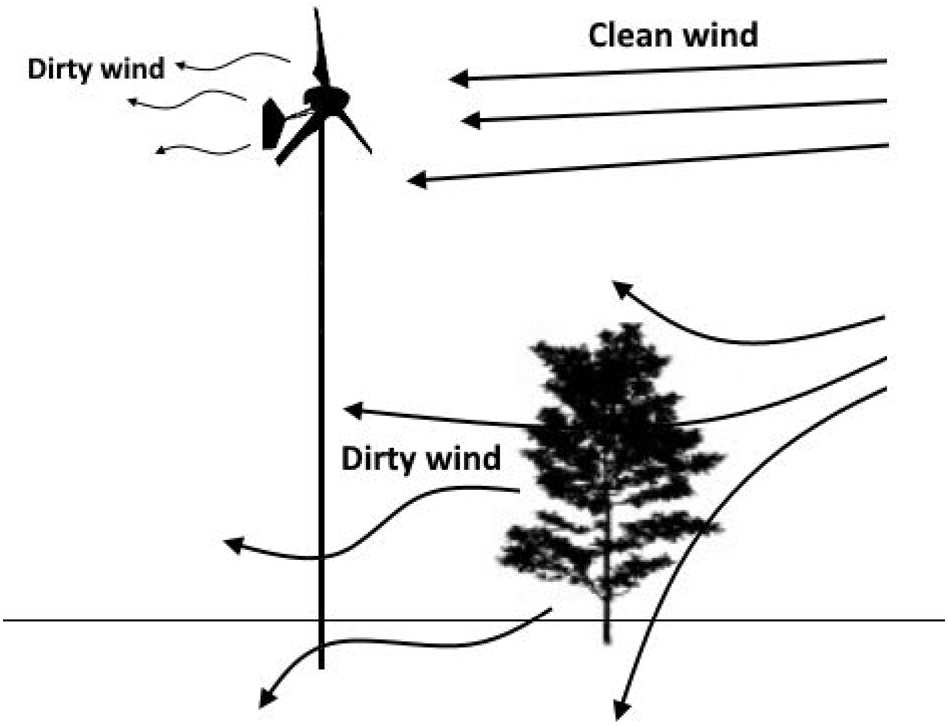
Objects in the path of a wind stream experience a downwind force known as drag. Some of the earliest wind turbine designs utilized this force and are called vertical axis wind turbines (VAWT). Wind can produce another force called lift, which always works at right angles to the wind direction and is the force utilized by horizontal axis wind turbines (HAWT).



Due to their lift base design, HAWTs require more clever blade designs to convert the downwind drag force to a lift force. This blade lift configuration gives an advantage of increased rotational speed in relation to the incoming wind speed when compared to VAWTs. The blade tips on a HAWT can travel up to 7 times faster than the incoming wind speed, whereas the blades on a VAWT will never travel faster than wind speed due to it's drag based design. However, a VAWT doesn't require a tracking mechanism like a tail and so it can take better advantage of low level turbulent winds, while a HAWT will always need to face in the direction of the oncoming wind and therefore requires a tail to track it, as well as overspeed protection. For DIY turbines this is typically achieved with a furling tail that both tracks the wind and furls to turn the rotor out of the wind when it's speed gets too high.



There are also two main types of wind that each turbine is better suited for: clean wind and dirty (turbulent) wind. Clean wind originates from the upper atmosphere and is pulled down to open land and water by temperature and pressure differentials. These winds are considered clean because there are no obstructions in the path of the currents to collide with, and thus little to no turbulence is created. Because a HAWT needs to face in the direction of the oncoming wind, they operate more efficiently in clean wind environments where there's the least variability in the wind direction.



Surface currents that are travelling back to the upper atmosphere generally encounter resistance from things like trees and buildings, which slows the currents down and creates a lot of turbulence that can be difficult if not almost impossible for a lift based turbine design to harness. VAWT's are most suitable for such low, turbulent wind environments due to their simple drag based designs. However, since VAWT rotors can't travel faster than the wind speed, they remain less efficient overall in comparison with a properly installed HAWT in medium to high wind environments.

To estimate the theoretical power output from a HAWT in a specific wind speed, use the following equation:

$P = 1/2C_tdAV^3$

Where:

P = power in watts
C_t = turbine coefficient (between 15-25% for DIY systems)
d = air density in the wind stream (1.225kg/m^3 @ sea level and 15°C)
A = swept area of the rotor blades in square meters
V = wind speed cubed in meters per second

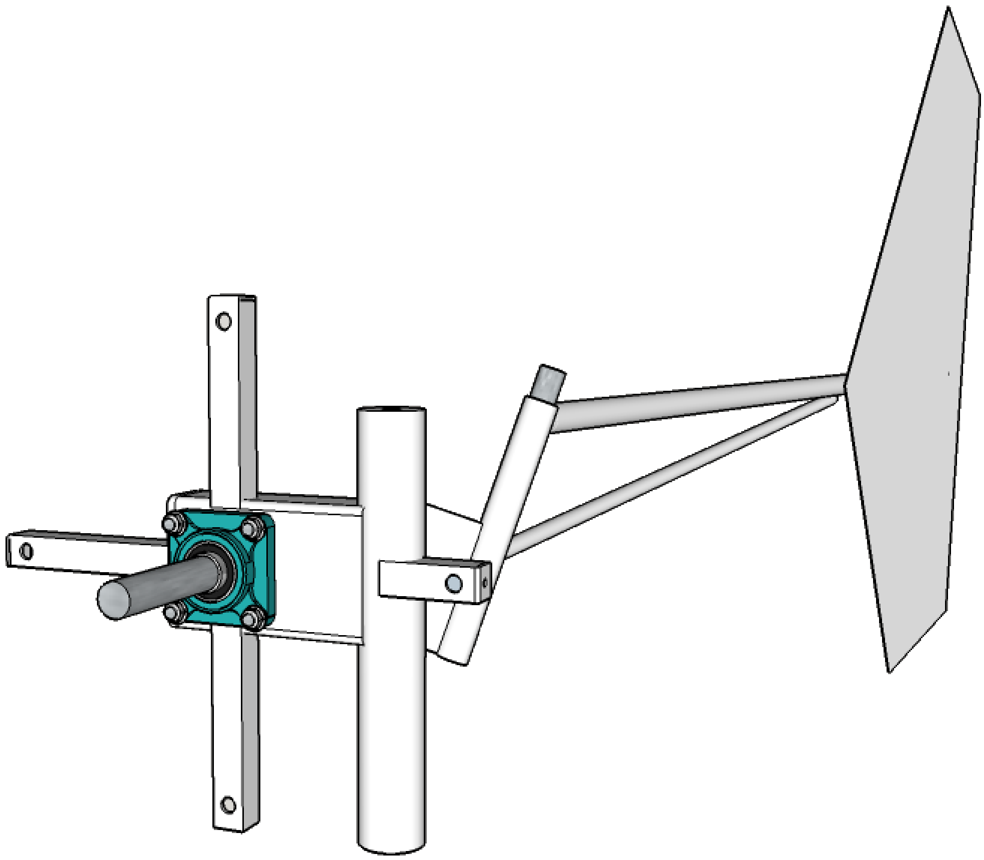
Example using a 2.4m (8ft) diameter rotor in 11.8 mps wind (26.5 mph/42.6 kph):

Swept area = Pi x radius^2
= 3.1459 x 1.2 x 1.2
= 4.5m^2

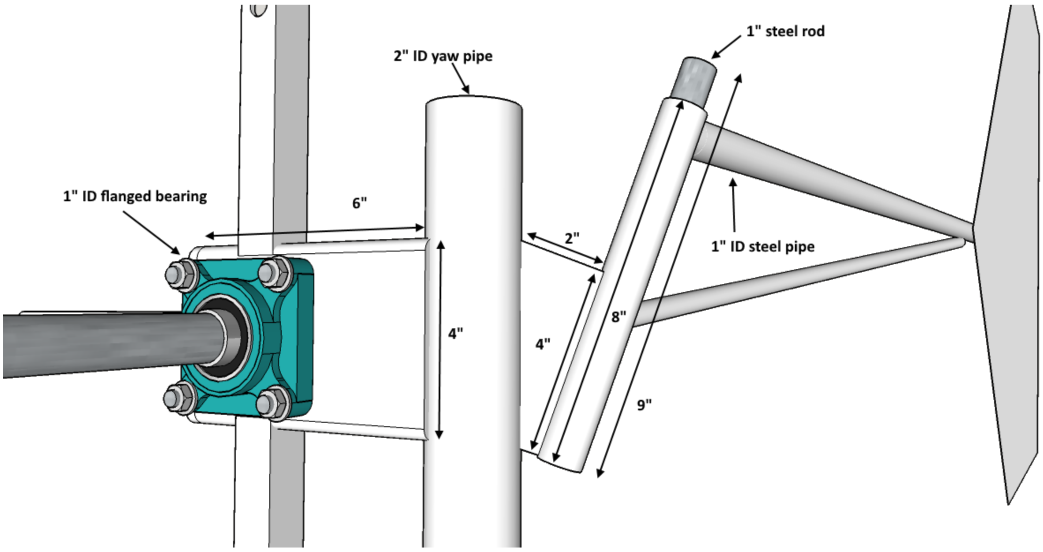
Power = ½(0.17 x 1.225 x 4.5 x 11.8^3)
= ½(0.17 x 1.225 x 4.5 x 1643)
= ½ x 1539.70
= 769.85 watts

So in a 26.5 mph wind, an 8ft DIY turbine could produce around 770 watts of electricity. Bare in mind that this figure is based on ideal conditions and with the turbine working in conjunction with an MPPT charge controller. The actual efficiency of both the turbine and the controller are also factors, as well as tower height, wind turbulence, blade design/quality, etc, and the theoretical wind power equation should only be used for reference purposes - on site measurements during operation is the most accurate method of determining a turbine’s performance. To make the most out of a wind turbine investment, a cost benefit analysis should be established based on available wind resources and site conditions, turbine design/size and the subsequent production potential.

Building the frame



Step 1
Using a mini-grinder with a cut off wheel, cut the 2”x4” rectangular tubing to length and notch one end so that it can be welded to the yaw pipe as shown below. Be sure to spot weld all corners before running continuous beads - this will help hold the pieces together and counter any twisting or warping caused by heat expansion from the welding.


1" steel rod
2" ID yaw pipe
1" ID flanged bearing
6"
2"
1" ID steel pipe
8"
4"
4"
9"


WWW.RESYSTECH.COM

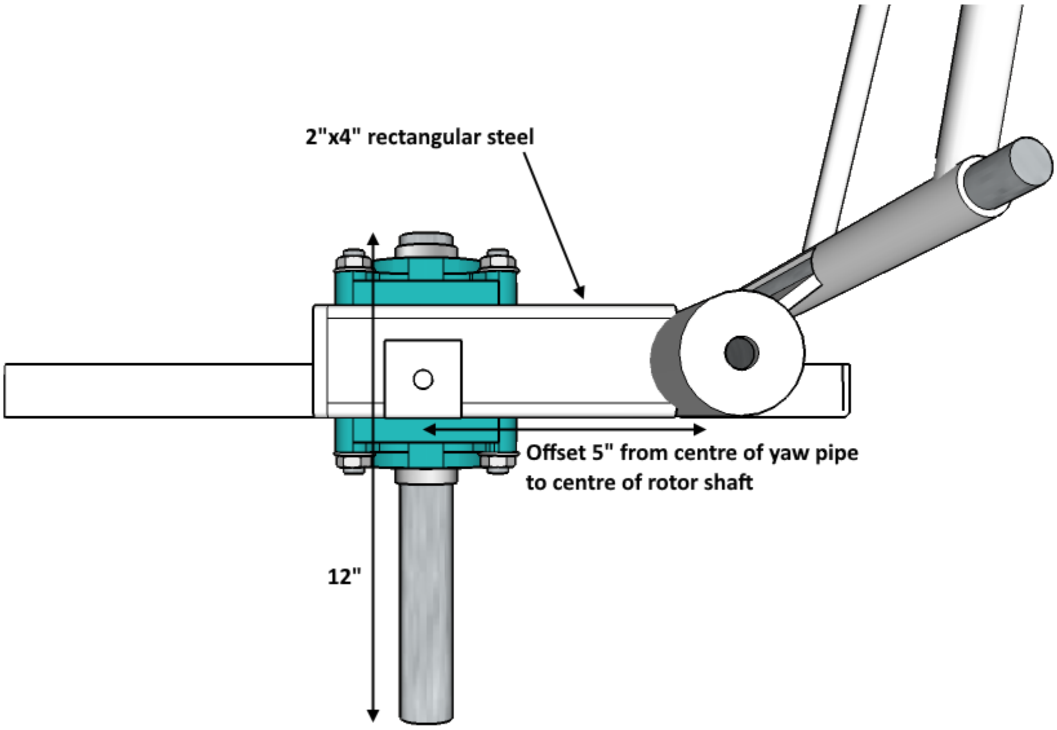

WWW.RESYSTECH.COM


WWW.RESYSTECH.COM

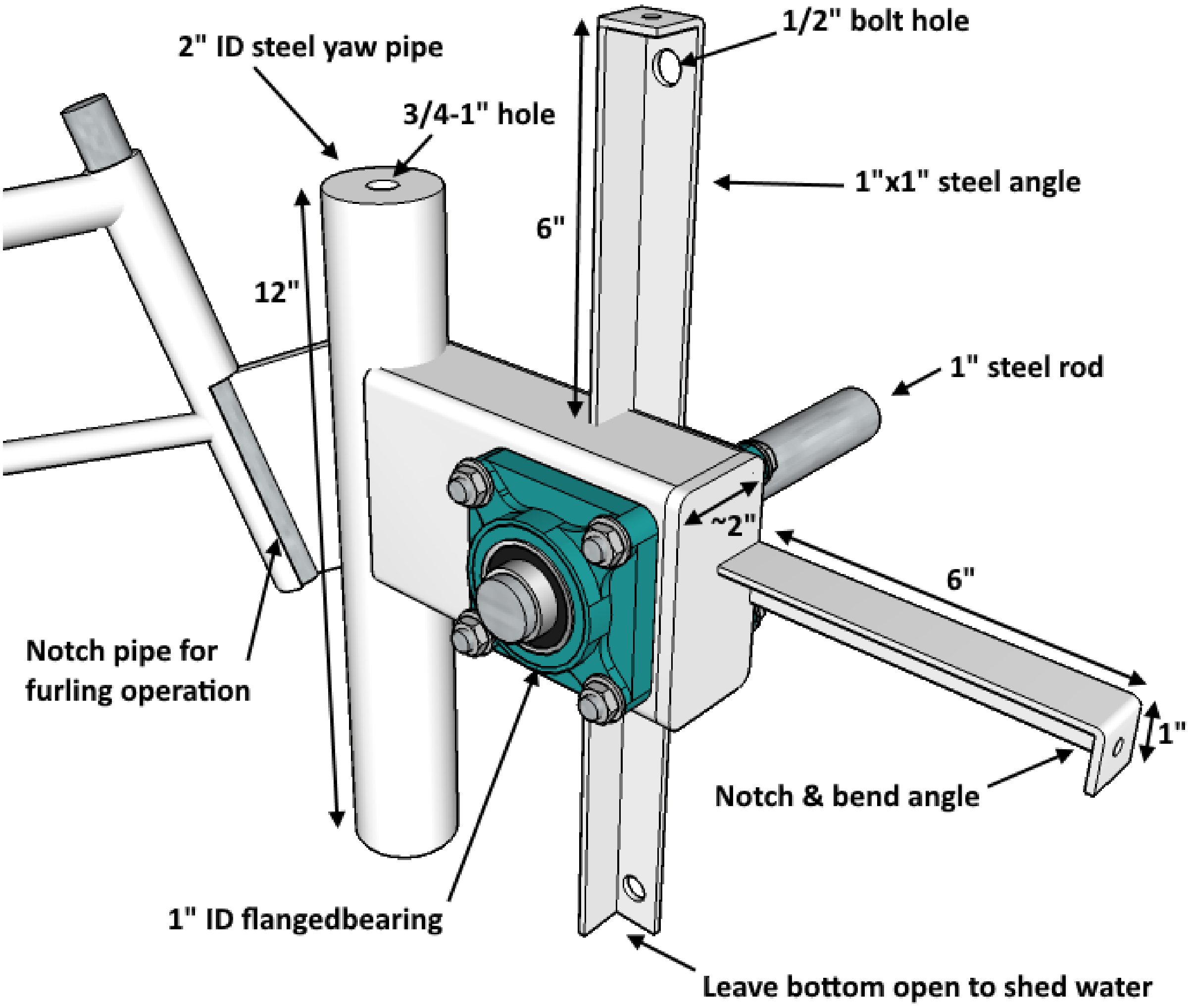

WWW.RESYSTECH.COM


WWW.RESYSTECH.COM

Step 2
Cut a 1”x1” hole in both sides of the rectangle tube at 5” from the centre of the yaw pipe as shown in the image above. Then cap the end of both the rectangle tube and the yaw pipe with ¼” steel plate, and drill a ¾”-1” hole in the yaw pipe cap to allow for wiring later.



Step 3
Cut three pieces of 1”x1” steel angle at 7” long, and one piece at 6” long. Place a mark at 6” on all three 7” long pieces and notch one end of each as shown below, then bend it over to form an ‘L’ shape. These will serve as the top and side stator mounts as well as anchor points for the shroud that helps protect the generator from ice and snow build up in cold climates.



2" ID steel yaw pipe
3/4-1" hole
1/2" bolt hole
1"x1" steel angle
6"
12"
1" steel rod
~2"
6"
1"
Notch pipe for
furling operation
Notch & bend angle
1" ID flangedbearing
Leave bottom open to shed water

WWW.RESYSTECH.COM


WWW.RESYSTECH.COM


WWW.RESYSTECH.COM


WWW.RESYSTECH.COM

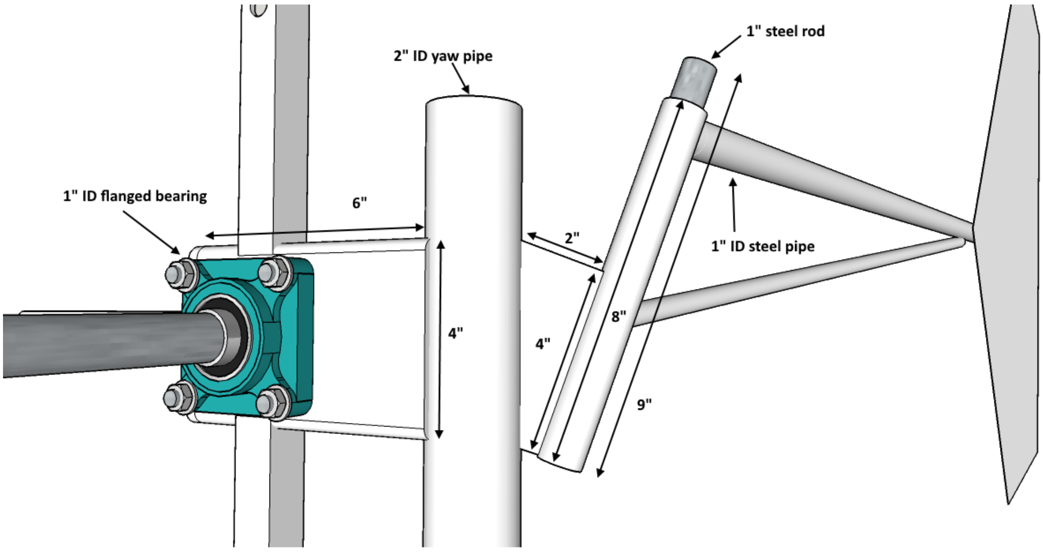
Step 4
Weld the angle to the rectangle tube, making sure to check that everything is straight and square as you progress. Remember to spot weld in the corners first to help hold it in position and counter heat expansion while you finish.

Step 5

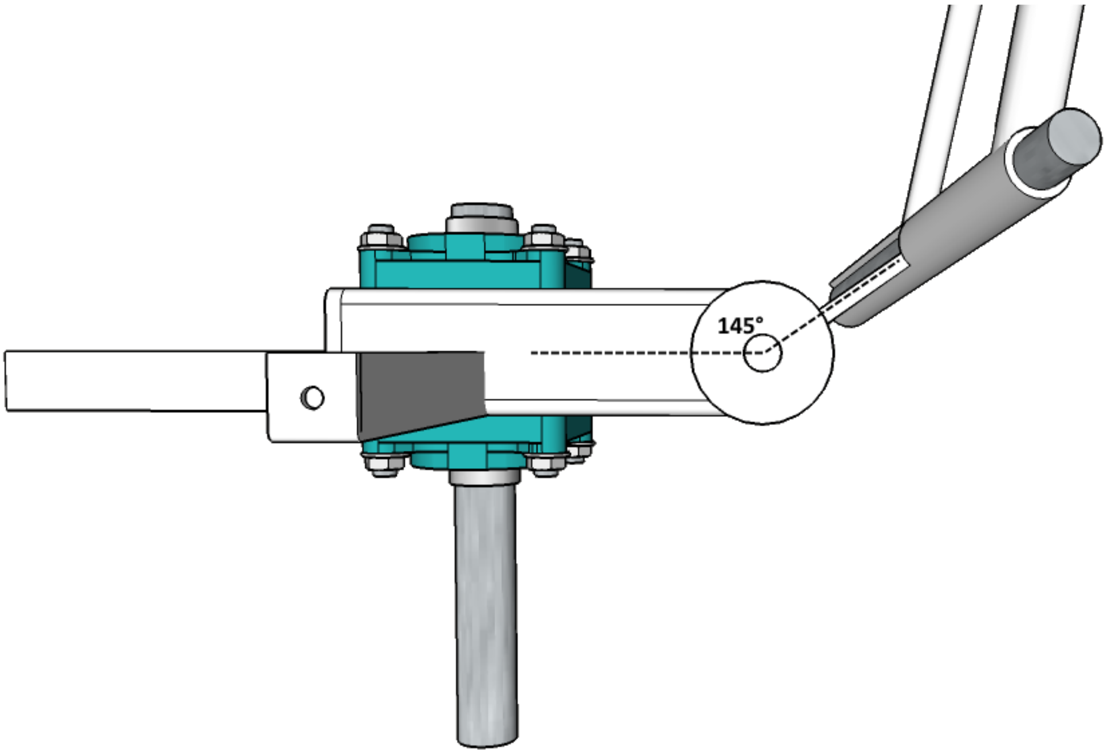
Drill a ½" hole approximately ⅝-¾" in from the end of each stator mount - these will receive the mounting bolts later. At this point you can either weld hex nuts on the back side of the stator mounts to make installation easier, or you can wait and use double nuts and lock washers to secure the mounting bolts to the mounts when you install the stator. If you choose to weld the nuts on now, be sure to thread a small piece of rod into the nut before you weld to prevent spatter from getting in the threads of the nut, and be careful not to weld the rod inside.

Step 6

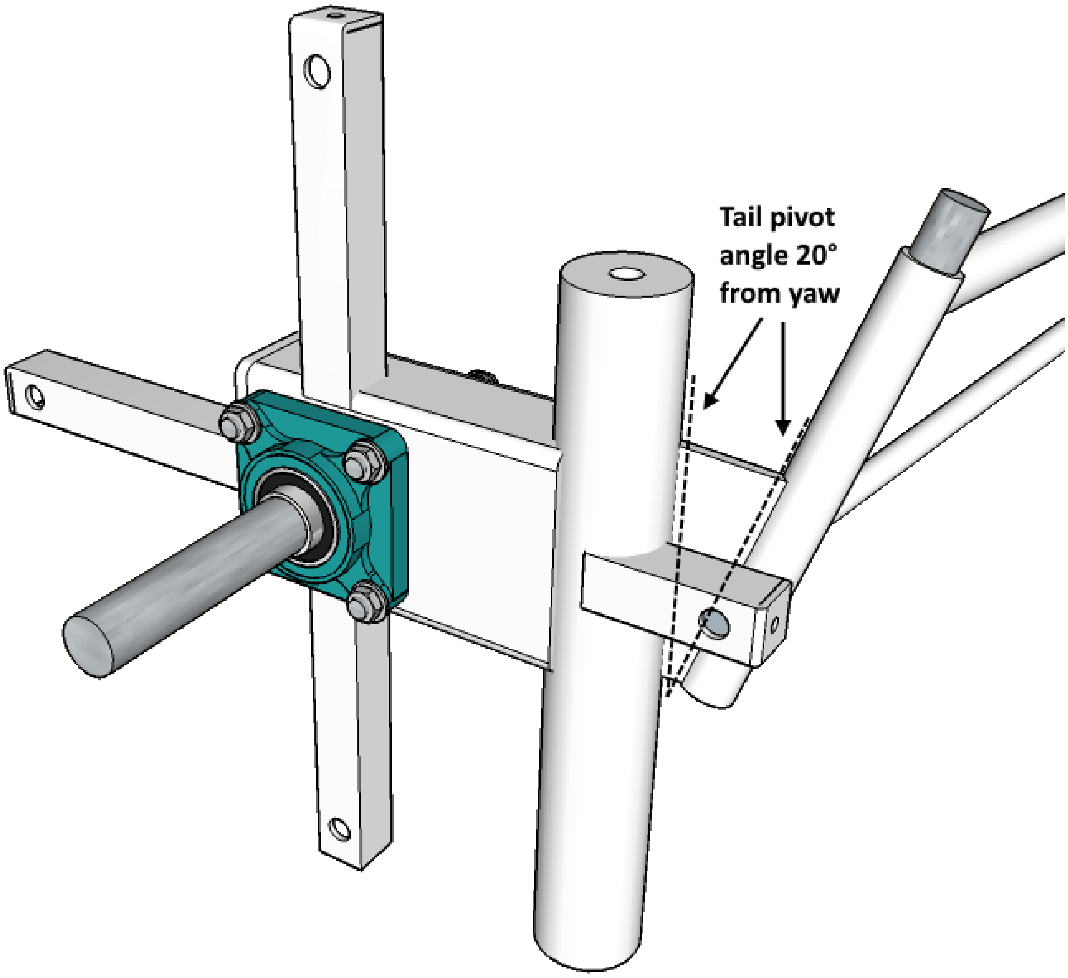
Cut a piece of flat ¼” steel in the shape of a right angled triangle, with one side measuring 2” and the adjacent side measuring 4” - this piece establishes the 20° angle for the tail mount. Once cut, weld it to the yaw pipe at a 145° angle to the rotor plane as shown below, then weld a 1”x9” steel rod to the back edge. This is where the tail will pivot, and it will need to be secured in a way that allows it to furl but doesn’t fly right off of the mount when it does. You can accomplish this buy using a large flat 1”ID washer and a cotter pin at the top of the mount, or you can weld a short piece of threaded rod and use a hex nut with a locking pin.



1" steel rod
2" ID yaw pipe
1" ID flanged bearing
6"
2"
1" ID steel pipe
8"
4"
4"
9"



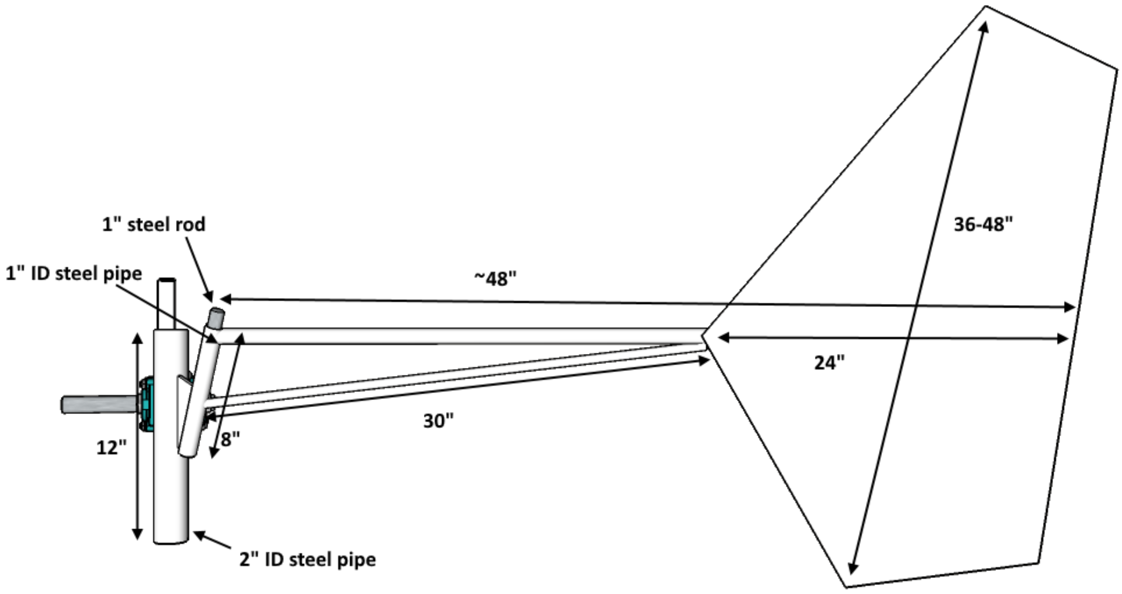
145°

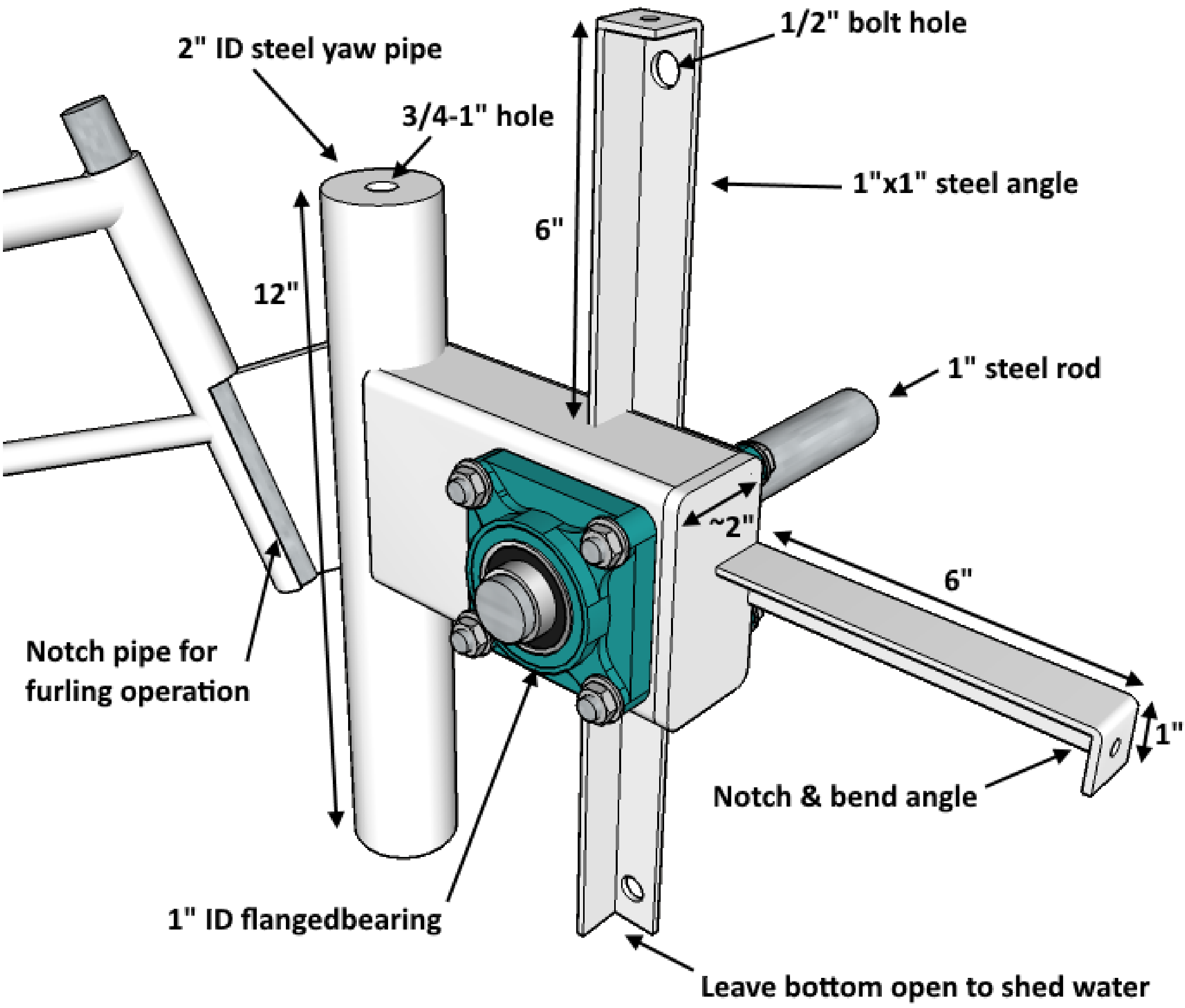


Step 7

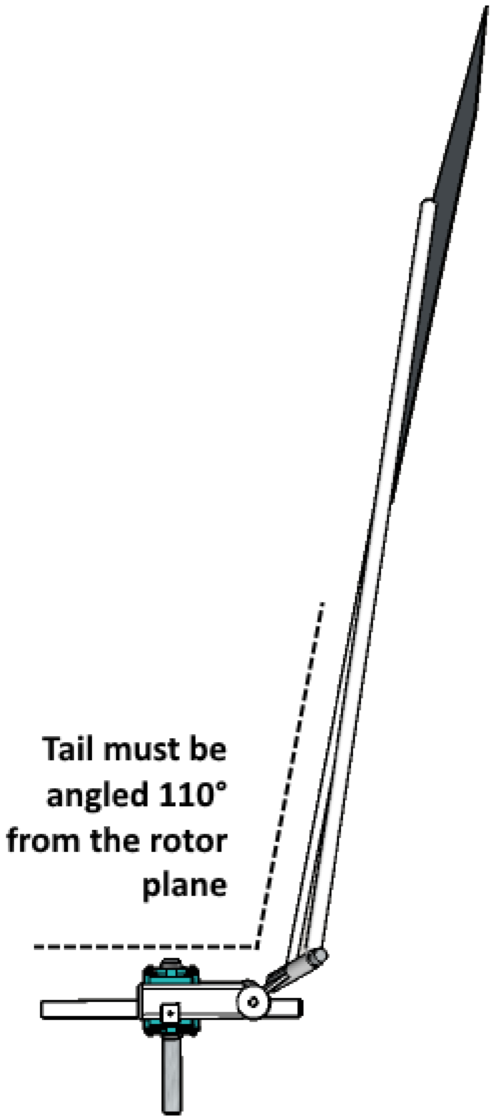
Cut the pieces needed to make the tail boom from 1” ID steel pipe. You can get creative with the design here and make it your own - especially when it comes to the tail vane - as long as you follow the basic dimensions below, ie: tail boom length and vane area, then you can make the tail look as you wish. Also keep in mind that this tail is a furling tail, which serves as an overspeed brake to prevent the turbine from self destruction in high winds. The ‘furling moment’, ie: the wind speed that activates the furling function, depends on a number of factors like vane area, tail weight, pivot angle, rotor to yaw offset, etc. This turbine will begin to furl at approximately 30 mph. When it furls, the wind lifts the tail in the air and pushes the rotor out of the wind at an extreme angle to slow it down while the tail - though in a raised position - continues to track the wind. When the wind speed decreases then the tail will drop and the rotor will turn back into the wind again.

When you notch the pipe that goes on the tail mount, keep in mind that **when the tail furls it needs to stop before it hits the blades**. Generally, stopping it within 10° of the rotor plane is fine, but check it to be sure!


1" steel rod
1" ID steel pipe
~48"
36-48"
24"
30"
8"
12"
2" ID steel pipe


1/2" bolt hole
2" ID steel yaw pipe
3/4-1" hole
1"x1" steel angle
6"
12"
1" steel rod
~2"
6"
1"
Notch pipe for
furling operation
Notch & bend angle
1" ID flangedbearing
Leave bottom open to shed water

The resting point for the tail boom also needs to be considered, as the furling mechanism requires that the boom rest at approximately 110° to the rotor plane to function properly. This has very little if any effect on performance.

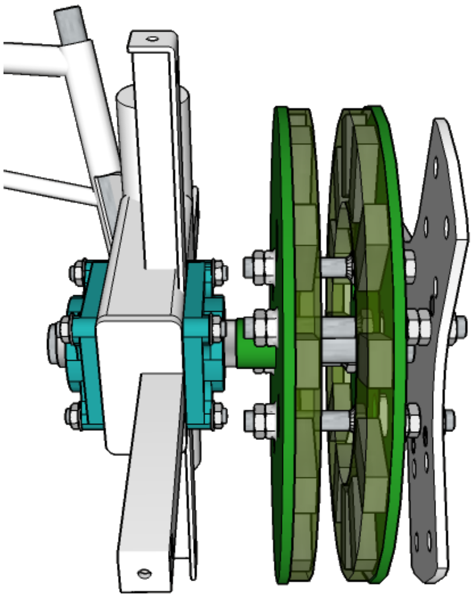


Step 8
Mark the bolt holes for the rotor bearings and drill them using a ½” bit. Clean the frame of any surface rust with a wire brush or wheel and wipe it down with acetone, then prime and paint it using exterior paint.

Step 9

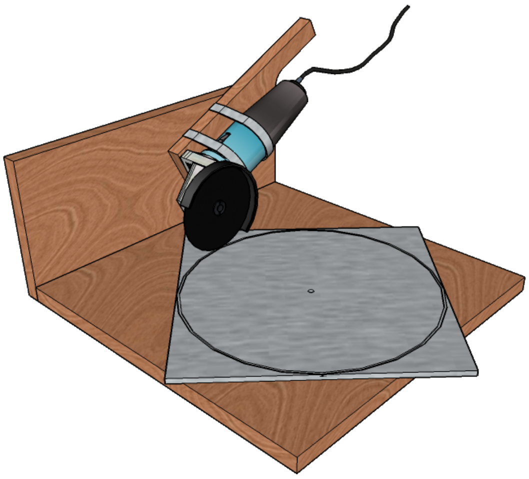
Install the rotor bearings using ½” threaded rod and hex nuts. Then install the 1”x12” rotor shaft and secure it using the set screws in the bearing housing.

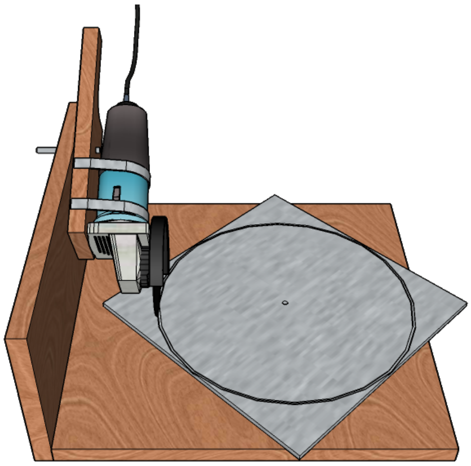
Making the magnet rotor plates & blade hub

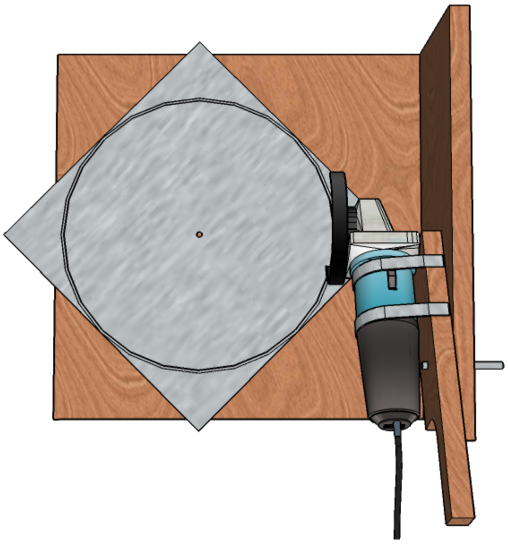


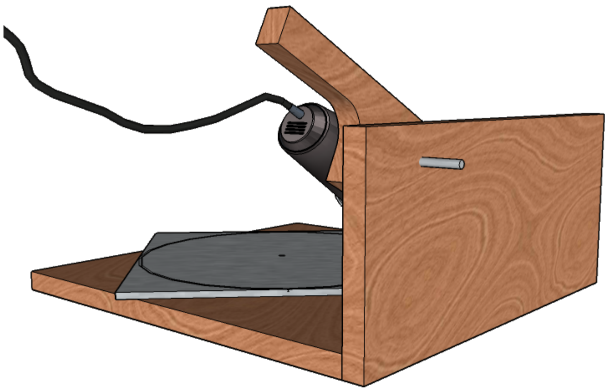
Step 1
Using a mini-grinder and cut-off wheel, carefully cut two 12” diameter magnet rotors out of ¼” thick steel. It’s absolutely important that these plates be as true as possible so that the rotor can be balanced properly. To help accomplish this, rough cut the plates to slightly larger than 12”, then drill a ⅛” hole directly through their centres and fasten them to the top of a work bench using a wood screw. Don’t over tighten - leave the screw loose enough so that the plates can spin freely. Then with a grinding wheel in the grinder, hold it to the edge of the rotor plate to finish grinding the edge down to size while spinning the rotor plate at the same time.

You can also build a simple jig like the one below to hold the grinder in place and use gravity to control it’s cut so that you can use both hands to control the plate. This method will give you a perfect circle with a really smooth edge when you’re done, and is the recommended method. A demonstration video for this jig can be viewed at the following link:
https://www.youtube.com/watch?v=PcEJslayQec



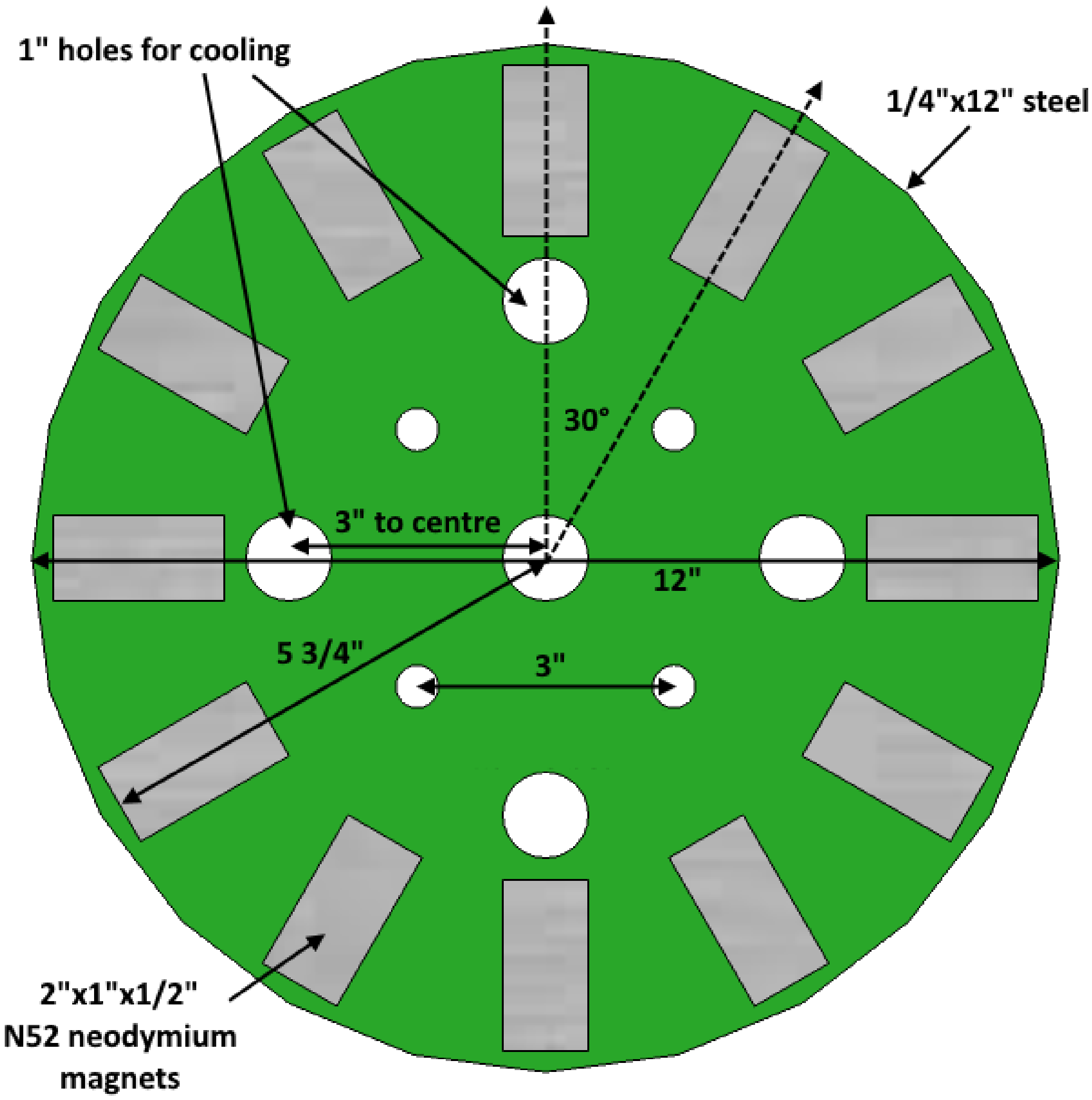






Step 2

Determine the bolt spacing for the flange bearings, then mark and drill them in both plates using a ½" drill bit - clamp the plates together before drilling for better accuracy. Then using a 1" hole saw, drill the centre hole for the rotor shaft and the cooling ports as shown below.



Once the holes are drilled and with the plates still clamped together, draw a centre line across the plates and cut a small notch in the edge of both approximately $\frac{1}{8}$” deep. This notch will be used for reference purposes when the magnets are installed to ensure that they’re positioned properly when the generator is assembled.

Cut a piece of 1”ID steel pipe 1” long and as straight as possible. Lay one of the rotor plates on a wooden workbench and clamp it down using screw and large washers in every location possible - this is to prevent the plate from warping as you weld so make sure it’s clamped well!
Centre the 1” pipe over the rotor bore hole, then weld it square to the plate (be sure to tack weld in 3 or four points around the perimeter first). This will serve as both the spacer between the inside rotor and the flange bearing, and the stabiliser for the rotors so this needs to be as ‘true’ as physically possible.

Step 3
Cut a 12” diameter circle out of a piece of ½” plywood. Draw twelve lines from the centre to the outside edge spaced 30° apart - use a protractor to do this. Using a drawing compass or a piece of string attached to the centre of the plywood on one end and a pencil on the other, and draw a 7 ½” circle. Measure along one of the 30° lines from centre of the plywood to where it intersects with the circle that you just drew - it should be 3 ¾”. This circle represents the back edge of the magnets, and the 30° lines represent the centre of each magnet. Draw 2”x1” rectangles on each 30° mark and then cut them out as shown below. This will serve as a jig for mounting the magnets to the rotors. The magnets are extremely powerful and this will help keep them separated properly as you’re installing them.

Once the jig is cut out, drill a ⅛” hole through the centre.

Step 4
Clean the rotor plates with acetone and secure the jig over one of them by fastening it through the centre to the top of a workbench using a wood screw. Make sure that the centre of one magnet hole is directly over the notch that you cut into the edge of the rotor earlier.

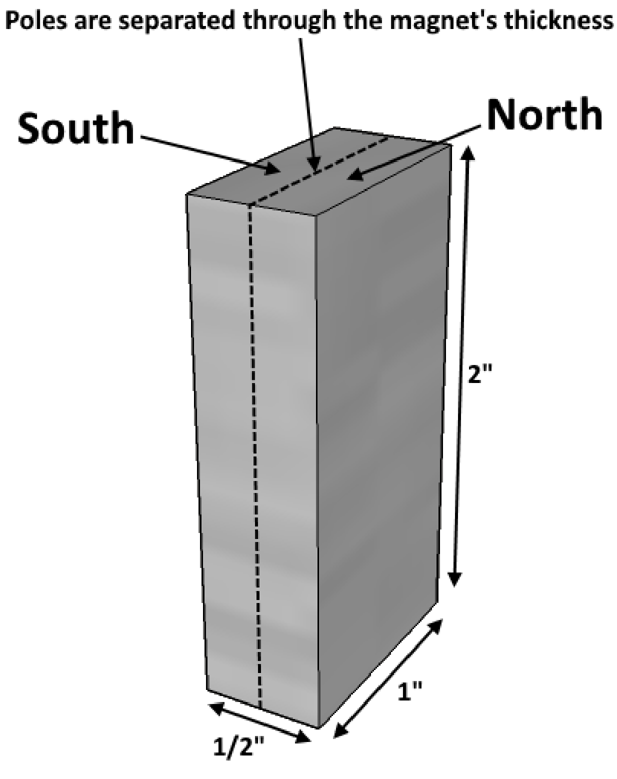
Once the jig and plate is secured, mix a small batch of JB Weld and apply a small coat over the entire exposed surface of the rotor in one of the magnet spaces.

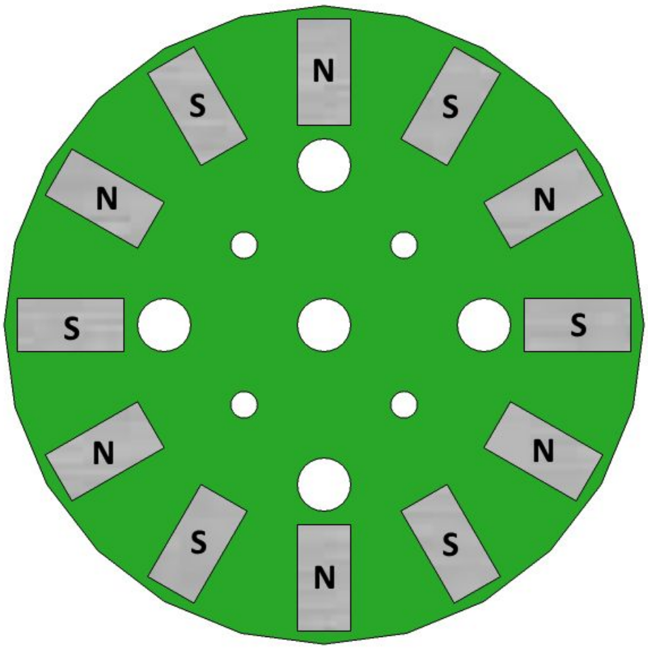
Then, very slowly and carefully place a magnet to the edge of the rotor, and roll it into position. Work it back and forth while applying a downward pressure to make sure the magnet makes full contact with the JB Weld. Be VERY careful as these magnets are strong enough to cause serious damage to your fingers.

Step 5

The magnets placed on either side of this one will have the opposite poles facing up. With a magnet firmly clasped in your hand, hover it over the one you just affixed to the rotor plate. You will feel it either attract or repel your hand away. When it comes

to magnetism, opposites attract. If your hand is repelled away, then the faces of the two magnets facing each other have the same poles, ie: north and north or south and south, and the magnet in your hand should be installed on the plate in the same position that it’s sitting in your hand (don’t flip the magnet). Be carefully to keep a firm grip so that the magnet doesn’t fly out of your hand and hit the other one beside it as you’re installing it.
Whether you start with the north or south poles doesn’t matter with this rotor, as long as the poles are alternated around the rotor plate as shown below. After the second magnet is installed, repeat this process around the entire rotor until all of the magnets are installed - it’s easiest to work in one direction around the rotor.

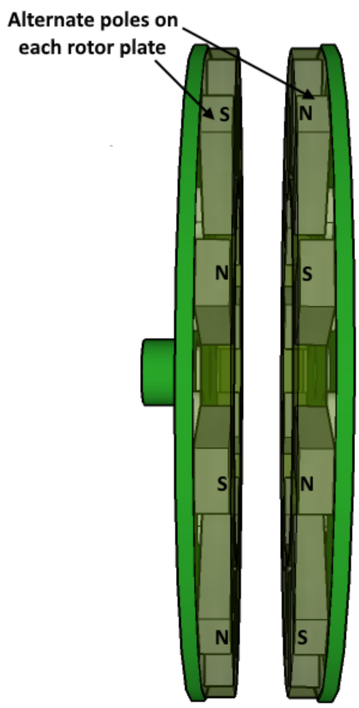



N
S
S
N
N
S
S
N
N
S
S
N

Step 6
When you're finished setting the magnets on the first rotor, you can immediately remove the jig to use on the second rotor - just be careful removing it and keep the rotor away from anything metal. DO NOT place the rotors side by side! If they attract and you're in the way, you're going to be heading to the hospital after. If you manage to avoid injury, you can almost count on never getting the rotor plates separated without seriously damaging everything because the magnets' pull is just too strong.

When you're ready to start the second rotor, bare in mind that these magnet poles have to alternate compared to the other rotor plates, so that when the plates are assembled in the generator the north poles on one will be facing the south poles on the other. This is the purpose for the notch in the edge of the rotor plates.

To place the first magnet, check it's polarity by hovering it above the magnet that's fixed over the notch in the first rotor. If the magnet repels, then place it in that position in the jig space over the notch in the second rotor. Once this magnet is set, then you can repeat the same process for the rest of the magnets - just check the polarity of each one with the magnet beside it. For reference purposes, the image below shows how the polarity of the magnets on each rotor alternates - this ensures that when the generator is in operation, the magnetic flux will be attracted from one rotor plate, through the coils, then to the other rotor plate and back again.



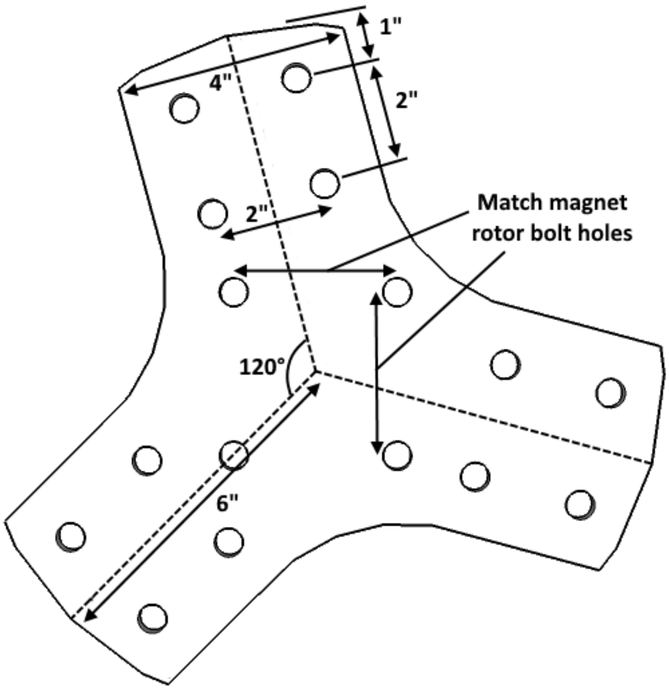
Step 7

Cut two 7” diameter circles out of a piece of ½” plywood, then tape the edges. Fasten them directly in the centre of the magnet rotors. Place tape around the perimeter of each rotor (must be at least ¾” wide). This will serve as the mould for the resin casting, so be sure to use a tape that’s rigid and smooth. Aluminium foil tape works the best.

Once the edges are taped, mix up ¾-1L of epoxy resin according to the manufacturer’s instructions, then slowly fill each rotor until the resin is just below the top face of the magnets. Allow to fully cure.

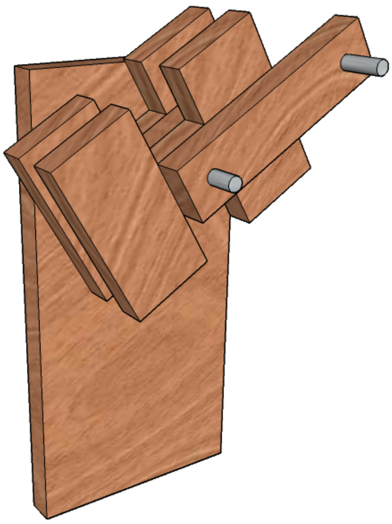
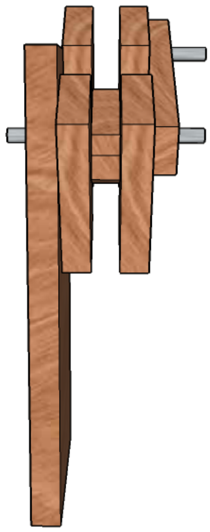
Step 8

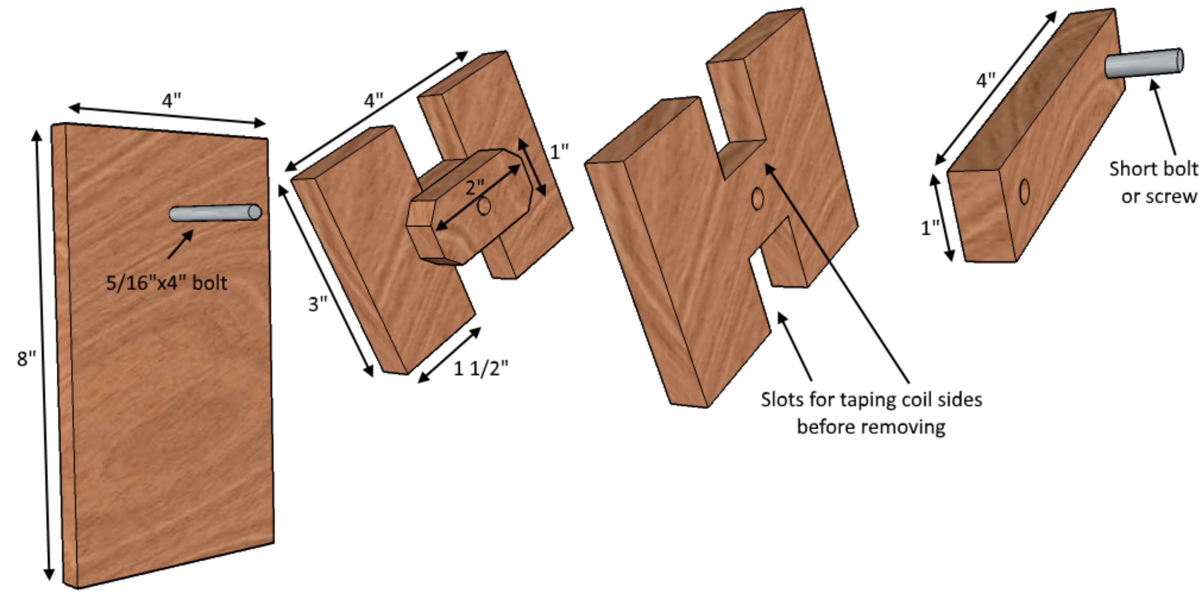
Cut the blade hub out of ¼” steel according to the dimensions shown below. Clean the hub and both magnet rotors with acetone, then prime/paint with exterior paint.



Wiring & casting the stator

Step 1
You will need to build a simple coil winder to wind the coils. This will help keep the windings straight and the coils uniform and of the same size so that they will fit neatly within the stator casting. Cut the pieces required to make the winder below out of ½" plywood, and fasten them together using a 4" hex bolt w/ flat washers and nuts. Don't over tighten the bolt to the winder support, it needs to spin freely, and keep in mind that you will need to be able to disassemble and reassemble for each coil. You are free to modify some of the components, but you must make the inner core of the winder the same size as the magnets, (1"x2"x1/2" thick). Once the winder is constructed, clamp it in a bench vice or screw it to the side of a workbench and prep for winding.



Step 2

Fasten your wire spool to your workbench so that it will turn and release wire as you wind the coils - DON'T unwind the spool and then wind the coils, the more twists and turns in the wire before you wind, the messy your coil will end up being. Also keep in mind that the wire has an insulating enamel coating which prevents the windings from shorting out on each other when the generator is running - take care that this coating doesn't get damaged.

To start winding, place the wire against the inner core of the winder and leave approximately 8" of wire hanging out of the winder - this will be the start lead for your coil which will connect to the finish end of the next coil in the phase when the stator is wired up. Carefully turn the coil winder and begin winding the wire around the core. Keep each turn tight against the previous turn so that your coil will have the smallest end dimensions when you're finished winding and will take up the least amount of space in the stator as possible - these coils will be fit very close together so the more 'wiggle' room you can gain the better. Keep track of how many turns you make - every coil needs to have exactly the same number of windings.

If you're building your turbine for a 12V system, then you will need 80 turns per coil of single strand wire. If you're building for a 24V system, then you will need 50 turns per coil of double strand wire. For a 48V system, you will need 100 turns per coil of single strand. The difference between single strand and double strand winding is that the latter is basically just winding two wires in parallel in the same coil at once, instead of just one strand of wire. You will need a total of 9 coils regardless of the system size.

When you’ve reached the required number of turns, leave an extra 8” of wire outside of the winder, then slide a piece of electrical tape through the slot in the winder and wrap each side of the coil to hold it together before you cut the wire and remove the coil from the jig. Don’t try to do this after because the coil will expand as soon as you take the winder apart. When you wind the next coil, do it exactly the same as the first and keep track of your start and finish coil ends.

Step 3

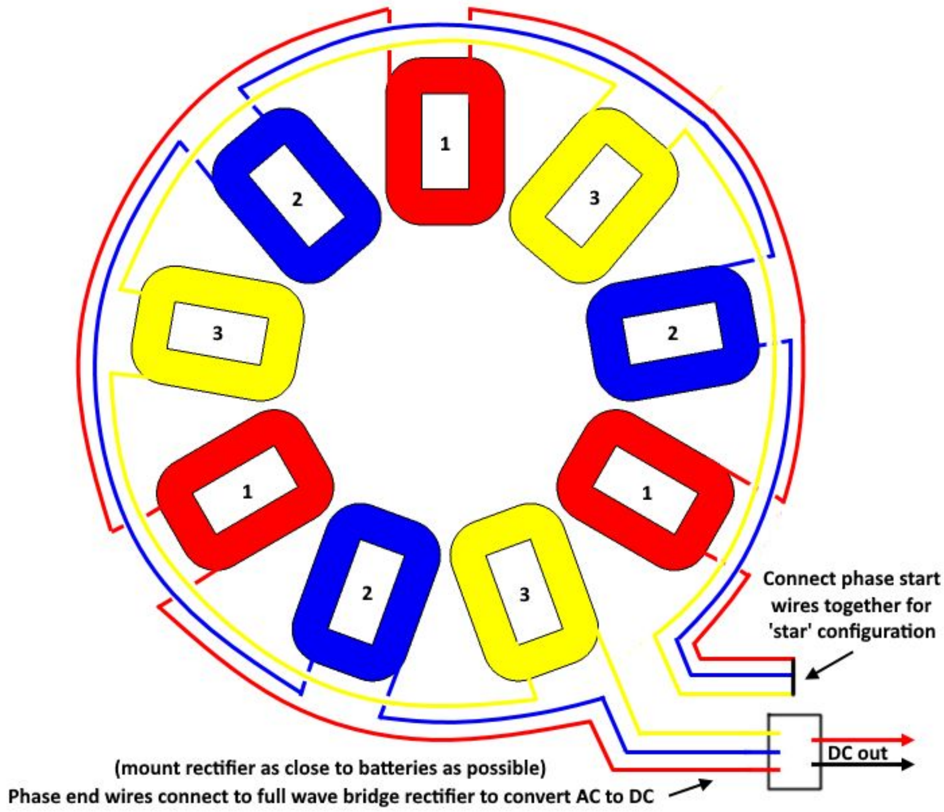
After the coils are all wound and taped, it’s good practice to check the continuity in each coil to make sure the enamel coating wasn’t scratched during winding. To do this, set a multi-meter to ohms and connect each lead from the meter to either end of each coil. If the continuity is fine, you will get a reading of between 1.5-2 ohms. If the enamel was damaged and there is a short, you won’t get a reading at all and you will need to replace that coil.

Once you've verified the continuity in each coil is good, draw an 11 ¾" diameter circle on a piece of wood or a workbench and layout the coils as shown in the image above, spaced 40° apart. The 11 ¾" circle that you drew represents the top edge of the magnets on the rotor plates. When the generator is assembled, the core of each coil should line up directly with the magnets as the rotor spins for optimal saturation of the coils with magnetic flux, so the short inside edge of each coil must line up with the 11 ¾" circle as shown above. Use a screw at each coil location to keep them from moving around as they're being connected together. MAKE SURE that the coils are all laid out the same, with the start wires and end wires all facing in the same direction.

Step 4

Before you can connect the coils together, you will need to remove some of the insulation from the end of the coil wires. You can use a torch to burn it off or just use a piece of fine sandpaper to sand it off - either way it also has to be clean before the solder is applied.

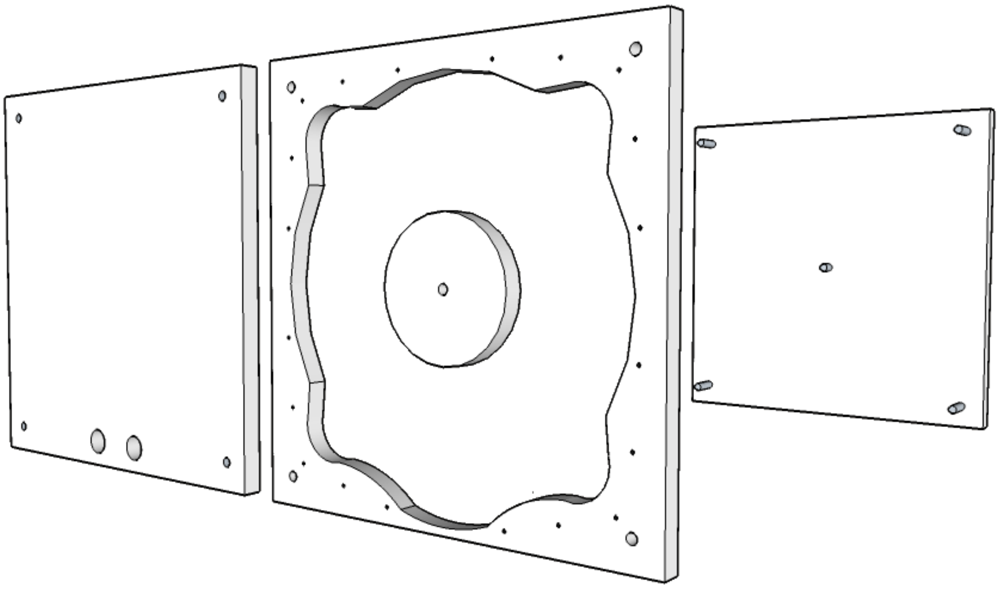
The coils will be wired in 3 phases. With 9 coils in total, there will be 3 coils wired together in series in each phase. To wire them together, the start wire on one coil (the end that you started winding with) connects to the finish wire of the next coil in the same phase, and then so on with the final 3rd coil. This is repeated for all 3 phases. Refer to the wiring diagram below. After soldering, be sure to clean the solder joints and cover them with heat shrink or electrical tape.

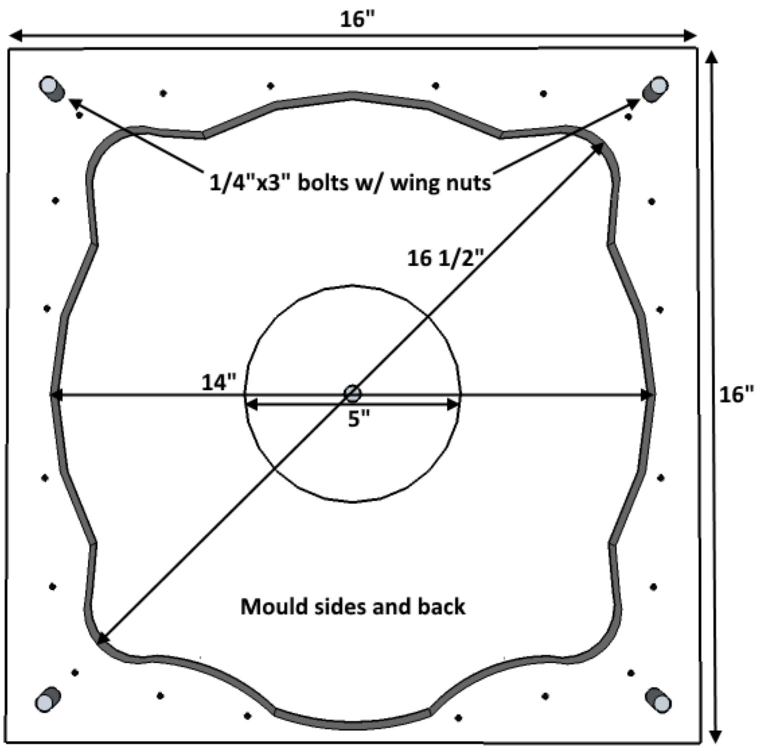


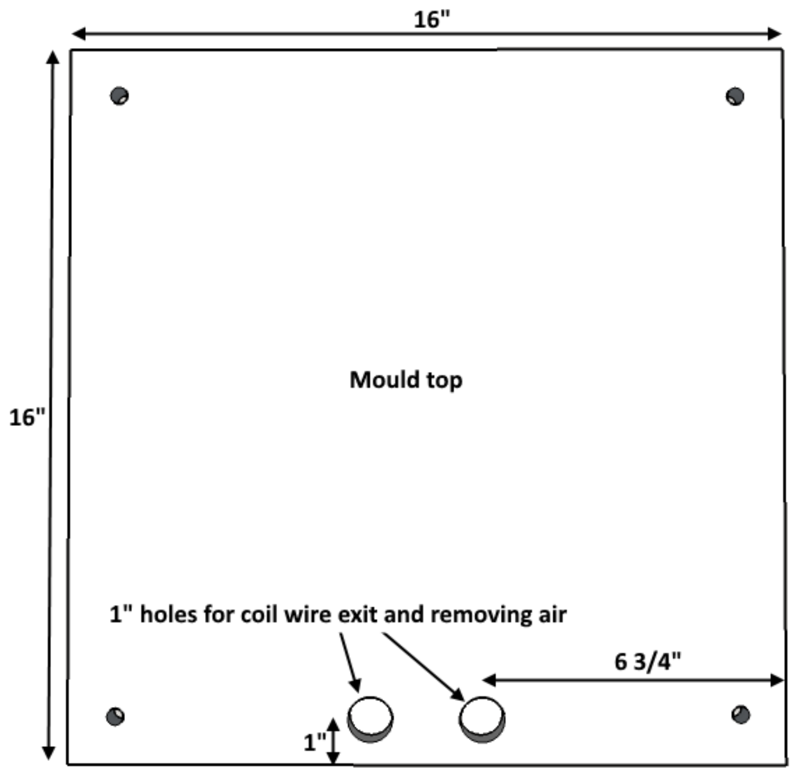
Step 5
Using a multi-meter set to ohms, check the continuity of each phase by connecting one lead from the meter to the start wire in one phase, and the other lead to the finish wire of the same phase. Each phase should give the same reading. If you don't get any reading at all, then there is a short somewhere in the connections between coils and it will need to be fixed.

After you've verified that the continuity is fine in each phase, tape the phase start wires together and then tape the finish wires together so that they will exit the stator mould that you will build in the next step (see the next step for wire exit locations).

Step 6
To cast the stator you will need to make a mould. Cut the pieces needed out of ⅝" thick melamine according to the dimensions below. Melamine has a hard, smooth surface that's ideal for stator moulds - the smoother the surface is, the easier it is to remove the cast from the mould.



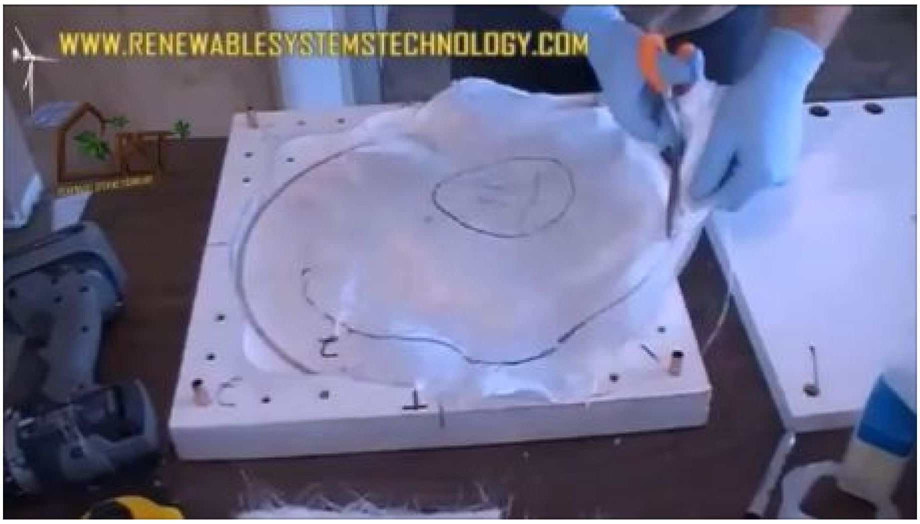

16"
1/4"x3" bolts w/ wing nuts
16 1/2"
14"
5"
16"
Mould sides and back



Because the edges of the melamine are rough, you will need to tape them so that the epoxy doesn’t seep into the pores of the wood. Any smooth tape with good adhesion will work. Melamine edge banding would be even better because of it’s durability.

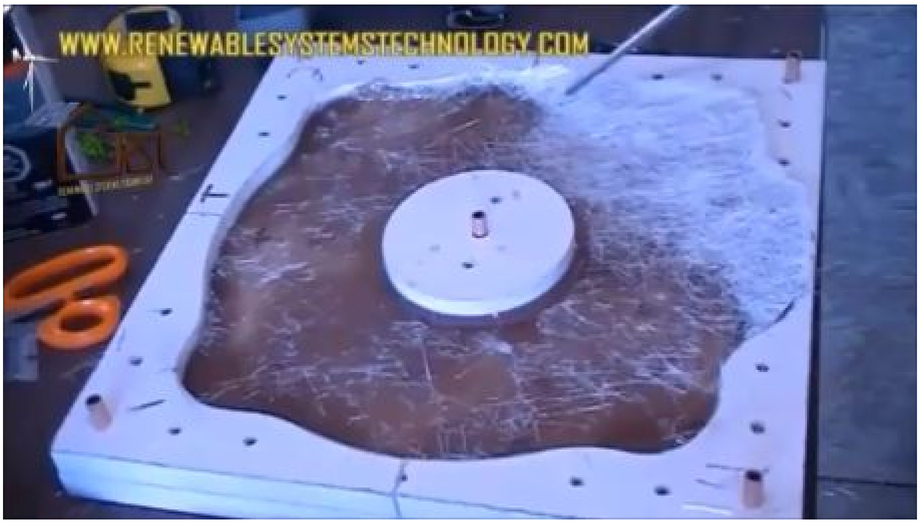
Step 7
When your mould is ready to use, add a thin coat of wax to all of the surfaces that will be exposed to the epoxy (standard car polish is fine). This will serve as a releasing agent to help separate the cast from the mould so that the mould can be salvaged and reused later if needed.

Step 8
Pre-cut two pieces of fibreglass mesh or cloth in the exact shape of the stator, then mix up 1 litre of epoxy (stir slow and be careful not to create any bubbles) and pour a thin layer into the mould, approximately ⅛” deep. Starting with one edge, place one of the pre-cut pieces of fibreglass into the mould, roll it into place and press it into the back - make sure it’s saturated and doesn’t trap any air bubbles behind it.

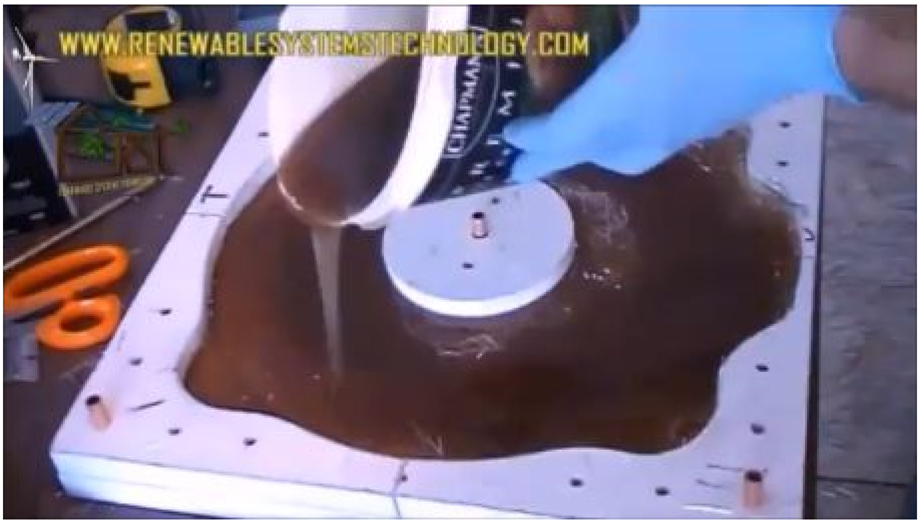

WWW.RENEWABLESYSTEMSTECHNOLOGY.COM


WWW.RENEWABLESYSTEMSTECHNOLOGY.COM


WWW.RENEWABLESYSTEMSTECHNOLOGY.COM

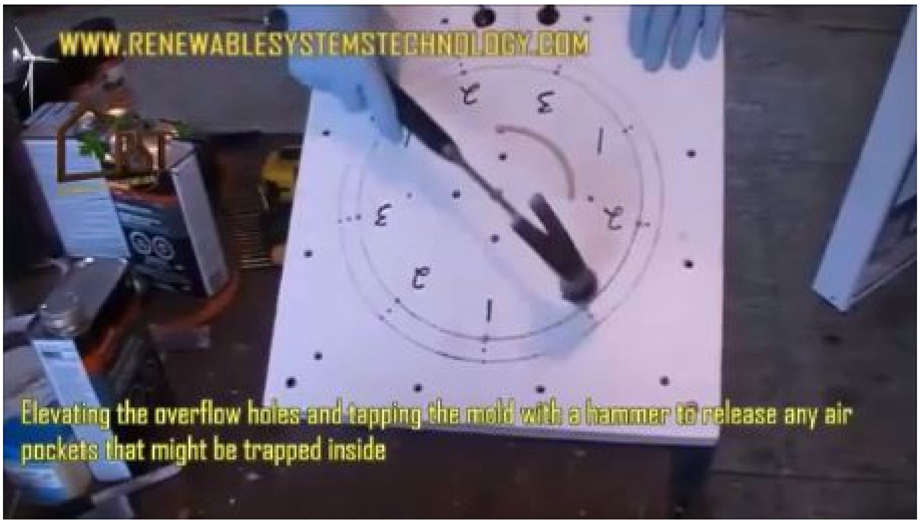


Pour another small amount of epoxy into the mould so that it’s just under half full, then slowly place the coils into the mould starting with one edge and rolling the rest into position. Be sure that the coils are centred in the mould and that the phase start and finish wires are positioned properly so that they will exit the two air holes in the top of the mould.



Pour more epoxy into the mould until the coils are covered by a thin layer, then add the second piece of fibreglass.

After the fibreglass is worked in position and any air bubbles are removed, fill the rest of the mould with epoxy and fasten the top on using wing nuts and wood screws. When you fasten, start from the end opposite of the wire exit holes and work your way towards them to help work out any air pockets from the mould. Once the top is fastened, slightly raise the end with the exit holes and gently tap the mould with a hammer on all sides to remove any remaining air pockets. Don't raise the mould too high as this may cause the coils to slide off centre - adding a few small wooden spacers between the coils and the centre mould before putting the top on would help prevent any movement during this process.



Step 9
Depending on the type, the epoxy can take anywhere from a couple of days to a week to fully cure inside of the mould, refer to the manufacturer's recommendations. After it's fully cured, carefully remove it from the mould.


WWW.RENEWABLESYSTEMSTECHNOLOGY.COM

WWW.RENEWABLESYSTEMSTECHNOLOGY.COM

WWW.RENEWABLESYSTEMSTECHNOLOGY.COM

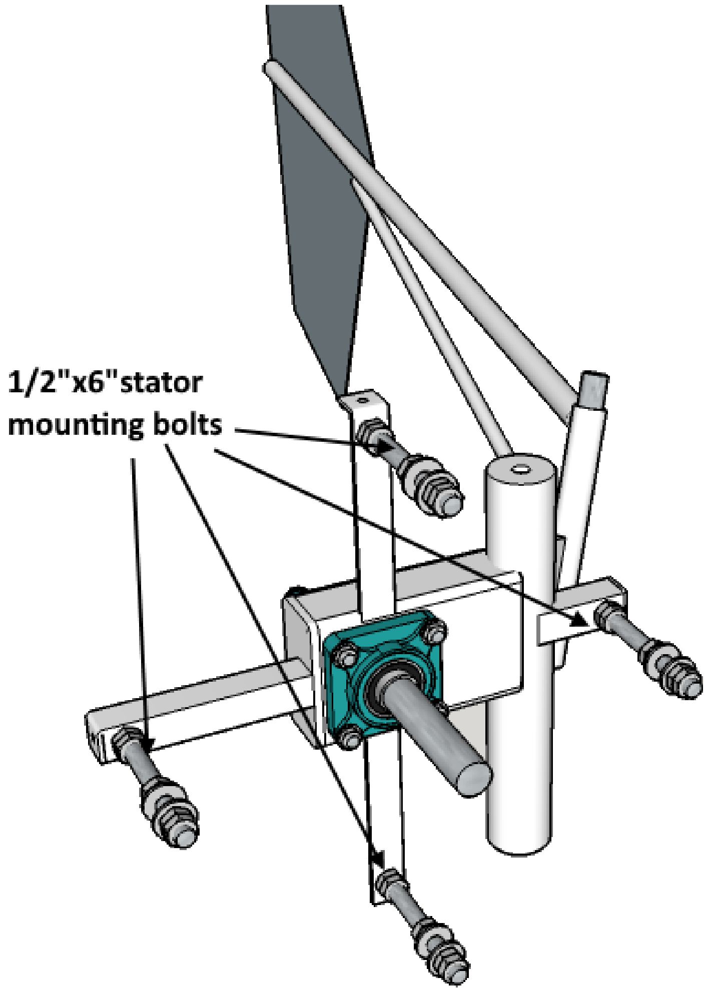
Step 10
Check the casting for things like surface pockets or exposed wires that need to be fixed before moving on. If everything looks fine in terms of structural integrity, give the stator a light sanding with fine sandpaper, clean it, then add a few coats of primer. Once the primer has dried, use the stator mounts on the turbine frame to transfer the locations of the bolt holes and carefully drill them into the stator with a ½" bit.

Give the stator another light sanding, then clean it and add a few coats of exterior paint.

Assembling the generator

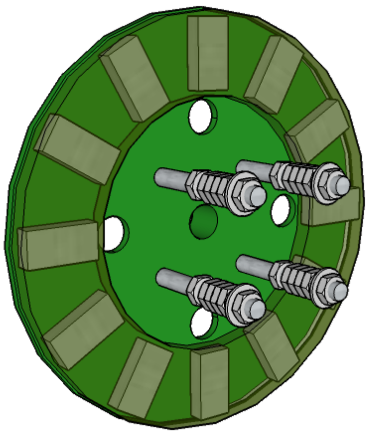
Step 1

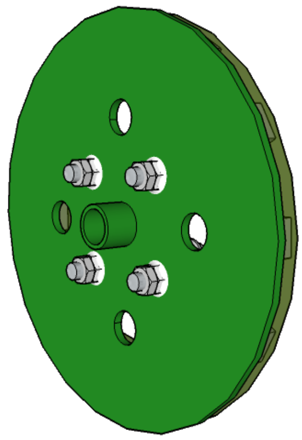
Cut four pieces of ½" threaded rod at 6" and install them on the stator mounts using a pair of hex nuts and lock washers



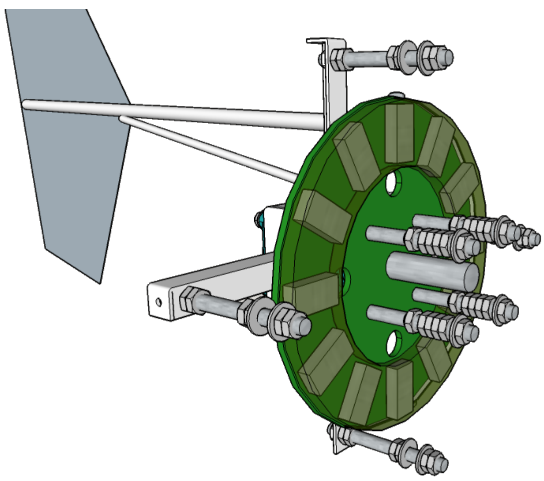
Step 2

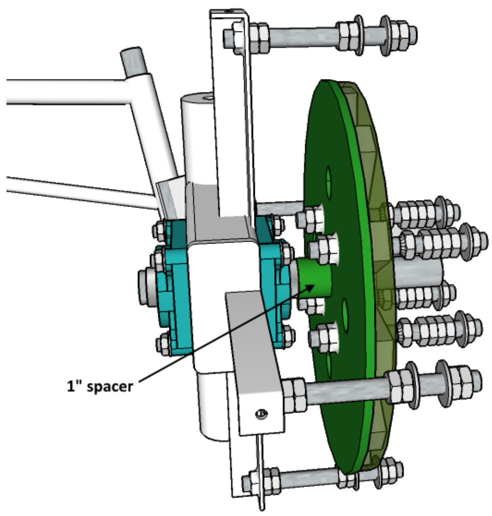
Cut four pieces of ½” threaded rod at 12” and install them on the inside magnet rotor plate using a pair of hex nuts and lock washers. These are approximately 6” longer than they need to be because they will serve as the ‘jack’ bolts to slowly and more importantly - safely - close the gap between the two rotor plates. They’ll be cut to length later.



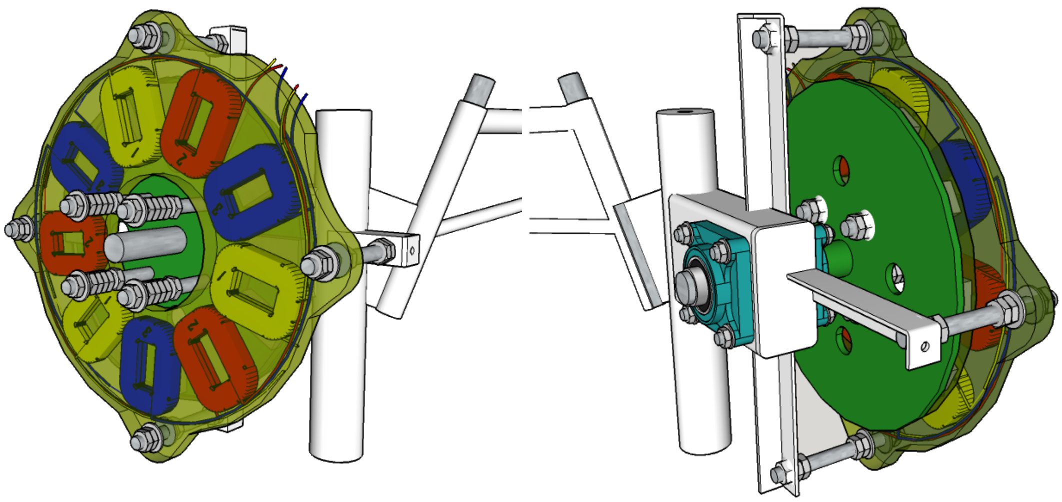


Install the inside rotor plate (with the 1”spacer)on the rotor shaft and against the flange bearing.





Step 3
Once the inside rotor is on, install a hex nut and flat washer on each stator mount bolt approximately 3" away from the stator mount, then install the stator. Install a flat washer and a hex nut on each stator mount bolt to hold the stator in place - don't tighten these yet because you will have to adjust the stator according to the rotors later.



Step 4
Install a hex nut and lock washer approximately halfway on each magnet rotor 'jack' bolt, then VERY CAREFULLY install the second rotor plate onto the jack bolts. MAKE SURE that you line up the notches on the edge of each rotor plate to make sure the magnet poles are alternated N-S-N-S etc. Once the second rotor plate is on, install two hex nuts on each bolt just in front of the plate and lock them together without locking against the rotor - it needs to remain a little loose so that the jack bolts can spin. Once you've locked the hex bolts together, then you can use the outer one to slowly jack the outer rotor plate into the rest of the assembly. You may have to pull the inside rotor and stator away from the frame a few inches as you finish closing the gap, in order to allow room for the bolts to miss hitting the frame. You can also cut them to their approximate length with a mini-grinder as you get closer to finishing, just keep in mind that the metal fragments will be attracted to the magnetised rotor plate so try to direct the sparks away with a sheet of cardboard or sheet metal if possible.

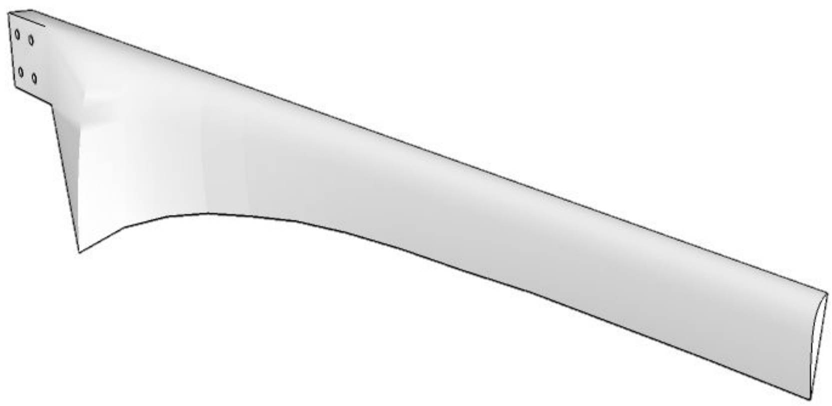
The closer that you can get the rotor plates to the stator without them rubbing, the better. If the plates are too far away then the flux won't be carried through the stator. Generally ⅛" or less between each plate and the stator is ideal. To make the fine tuning easier, use a tape measure to line the stator straight with the frame, then adjust the rotor plates to the stator. Slowly spin the rotor to see if they touch the stator and adjust the jack bolts until the rotor spins as straight as possible and maintains a small gap to the stator. When you're satisfied with the gap, loosen the locked double jack nuts and remove them, then secure the second rotor with a single lock washer and hex nut on each bolt in place of the double nuts.

Step 5
At this point you've probably noticed how easily the rotor spins, and that there is no cogging like with radial turbines that have steel stator cores. BE CAREFUL not to touch the exposed ends of the phase wires while you're turning the rotor because it will be producing AC current and you WILL be shocked.
Temporarily install the blade hub onto the rotor bolts so that you can conduct a bench test. Check the continuity of the stator coils again with a multi-meter. If it's still ok, wire the start and finish wires of one phase together. Spin the rotor. You should notice it 'pulsating', as in it's easy to turn for part of a revolution but suddenly becomes hard to turn for part of a revolution, then easy again and so on. If the rotor still spins freely, check check that you have the right combination of start and finish wires. You should get this pulsation when you check each phase. Once you've confirmed this, wire ALL of the wires together to short them out. Try to spin the rotor. It should be extremely hard to turn. Shorting the phases together effectively brakes the turbine. This is the most common way to brake a turbine in extremely high wind scenarios, or for maintenance, etc. - typically accomplished with a brake switch that shorts the phases together.

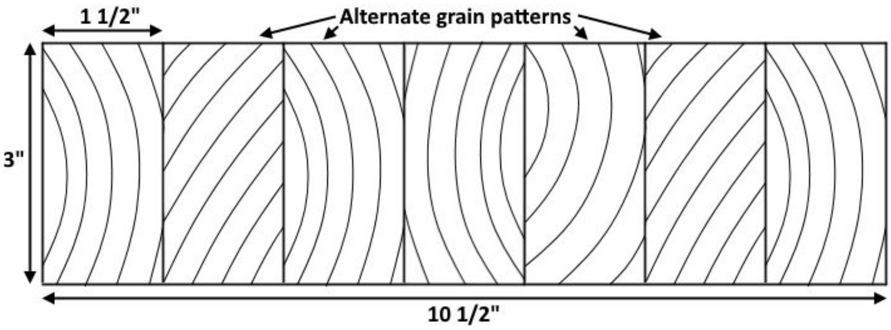
Step 6
Connect all of the start wires together, then connect them to one lead on a multi-meter and connect the other lead to one of the phase finish wires. Set the multi-meter for volts AC. Spin the rotor at approximately 60 rpm, just count off in seconds and complete one revolution per second. The multimeter should give a reading anywhere between 4-5 volts. Check each phase to make sure they produce in the same range.

Carving the blades

Step 1
Some DIY turbine blades are carved from a single solid piece of lumber, however depending on the grain orientation in the wood this may lead to a higher risk of warping or twisting in the sun. This is both bad for cosmetics as well as balance and the aerofoil washout or ‘twist’ that’s designed in the blades to optimise performance.



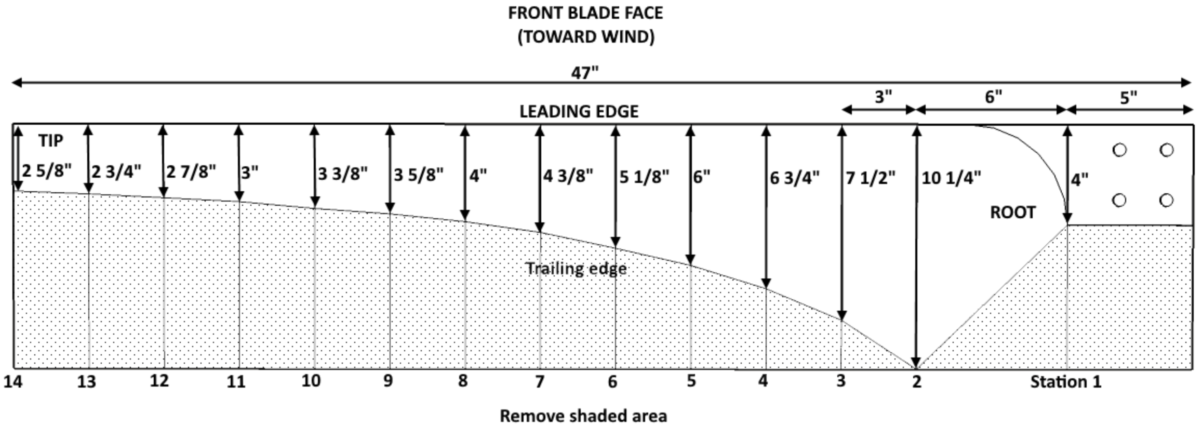
Most of the moisture that’s left in a piece of wood after it’s kiln dried is contained in the grains, mostly as a thick sap but with some water content as well, depending on the moisture content that the lumber is dried to (framing lumber is dried to 19% moisture content and furniture/cabinet material is typically dried to around 5%).
If a piece of lumber is exposed to extreme temperatures - like in a hot mid-summer sunny day - then it could pull more moisture from the grains in the wood and as that happens the grains will shrink, which pulls on the surrounding sapwood and distorts it. If the wood is exposed to moisture, both the sapwood and the grain will absorb it and expand, causing distortion and a weight imbalance. Treating the lumber with an oil stain, marine polyurethane, etc. does help protect from the elements for a time, but maintenance is inevitable.
To help lower the risk of deformation when the wood treatment inevitably fails over time, the blades should be carved from a block of laminated lumber - whereby multiple thinner pieces of lumber are glued with marine grade wood glue and clamped together with their grain orientations opposite to the adjacent pieces, as shown below. This balances any possible shrinkage in the grains across the sum of the pieces so that the lumber will retain it’s original shape. This also helps to increase the blade’s strength for withstanding high wind scenarios as well.



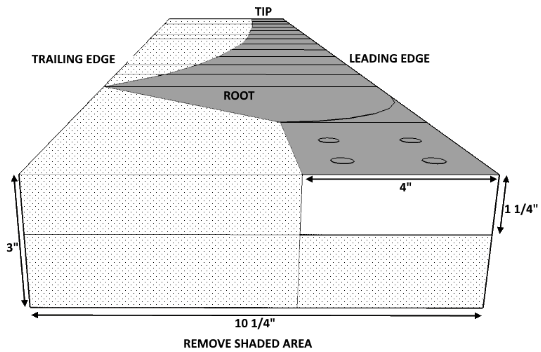
Cut 21 pieces of kiln dried 2”x4” cedar at 48” long, then rip them down to exactly 3” wide. This gives seven 1 ½” thick laminations (2”x4” dressed lumber is actually 1 ½”x3 ½”). Apply glue to the entire 3” face of seven pieces, then clamp them together using bar clamps. If you have enough clamps, repeat this for the other two blades. You can limit the amount of gluing you need to do by rough cutting each lamination to length as seen in the images below, but this makes clamping more difficult - it’s easier just to use full length pieces. When the glue has fully cured, remove the clamps and scrap off any drips/runs with a wood chisel.

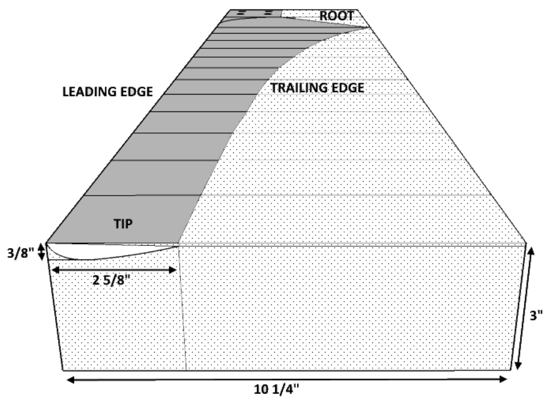
Step 2
These blades were designed using blade element momentum theory (BEMT), which means that the length of the blade is equally divided up into elements or stations, and a specific width, thickness and pitch is established at each station depending on the different relative wind angles and forces acting on each station of the blade at a given rated wind speed. This produces the washout 'twist' that's necessary for optimising performance from a horizontal wind turbine rotor. For more information on how these were designed and how you can design your own, visit the link below:
https://www.resystech.com/hawt-rotor-design.html

Before carving, you will need to layout each station of the blade and the necessary parameters onto the lumber stock. These will mainly serve as reference points for removing the bulk of the material. Transfer the layout lines that you see in the diagrams below to both faces of your lumber stock (front and back).



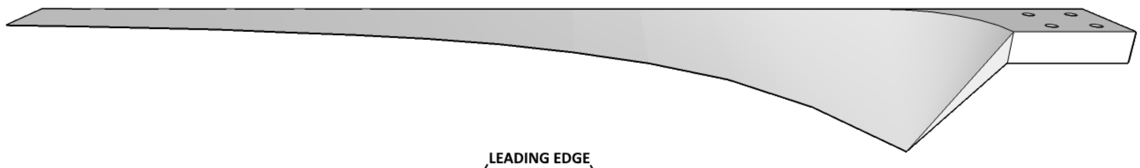
These measurements represent the width of the blade at each station. Remove the area that you see shaded with a jigsaw - if your blade isn't long enough you will need to cut from both sides.

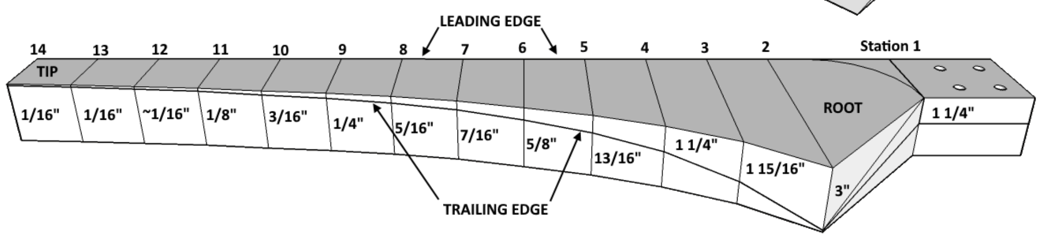


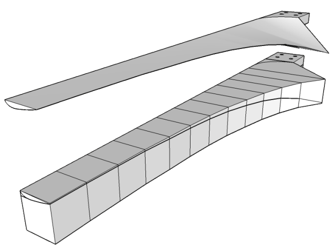


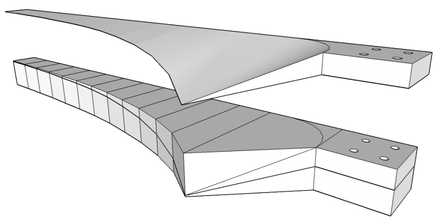
Step 3

From the image below, transfer the layout lines for the blade’s trailing edge to your stock, then carve the front face of the blade. The easiest and most accurate way to do this is to use a handsaw and make saw kerfs approximately every 1-1 ½” along the length of the blade. The bottom of the saw kerf should be straight and connect the front of the leading edge to the layout line that you just drew for the trailing edge. Once the saw kerfs are cut, then simply use a hammer and chisel to knock out the little blocks that were created. Be careful not to break the blocks out below the saw kerfs as this will result in an ugly divot in your blade.

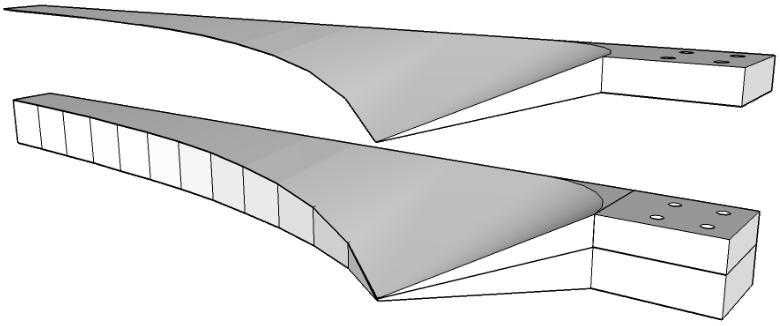


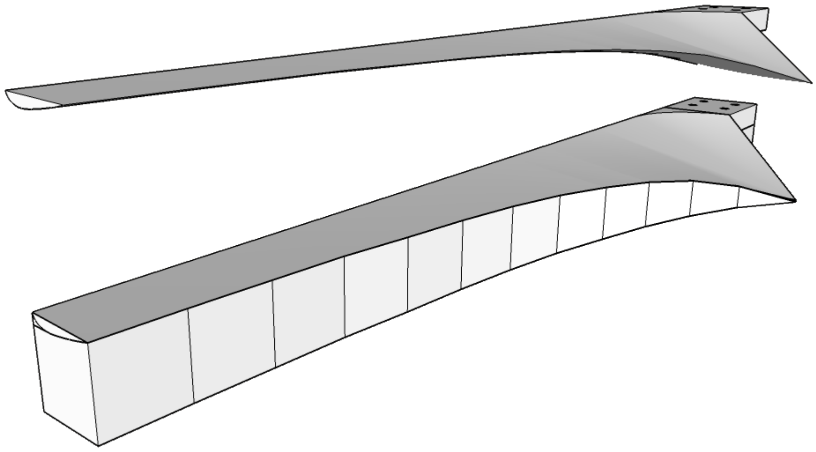






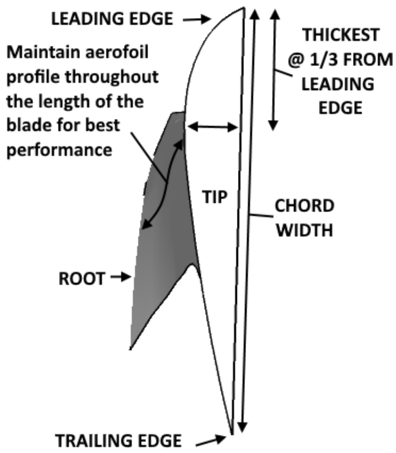

Leading
Trailing

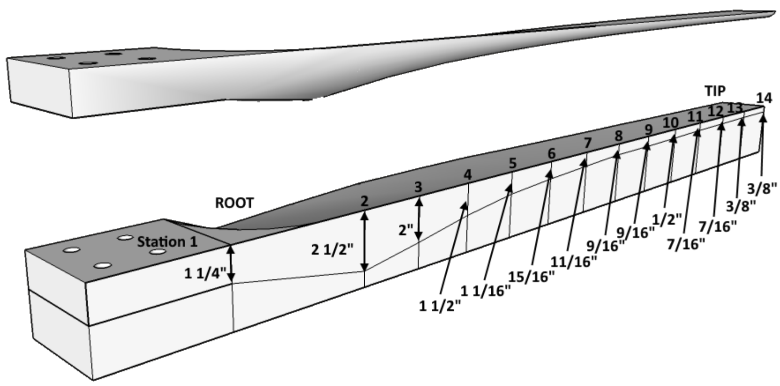


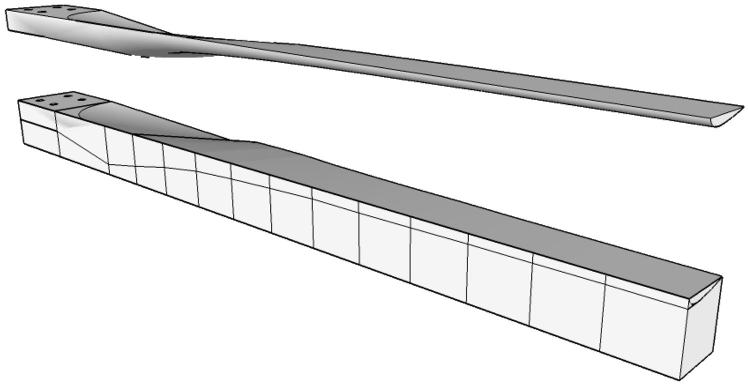


Step 4

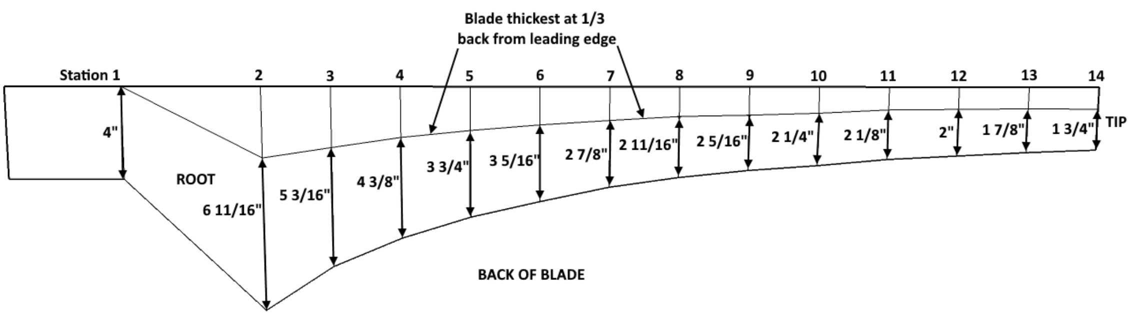
Transfer the layout line from the image below to the leading edge of the stock. This line represents the thickness of the blade. The thickness is is established at approximately ⅓ of the blade’s width back from the leading edge at a given station. This is where the hard curve at the leading edge of the aerofoil begins to flatten toward the trailing edge.







Carve the back side in the same way that you carved the front side by making saw kerfs to the required depth at 1” interval along the length of the blade. HOWEVER, the bottom of these cuts have to be parallel to the original rough back face of the lumber stock from station 5 to station 14. From station 2 to station 4, the bottom of the saw kerfs should connect to the leading edge and the trailing edge because the pitch is much steeper closer to the root of the blade - it’s easier to visualise and establish the pitch at the root if you cut station 5-14 first, then carve the finish aerofoil profile using a chisel and/or sharp knife within that range of the blade. Bare in mind that the blade is thickest ⅓ of it’s width back from the leading edge. Transfer the layout line for the ⅓ point representing the thickest part of the blade from the image below to the back of your blade and use it for reference for carving the finish profile.




BACK


WWW.RESYSTECH.COM


WWW.RESYSTECH.COM

Step 5
Once the general shape has been carved, knock down the high spots with a coarse file and then sand the blade smooth to prep for painting.

Step 6
After you've carved all three blades, check their weight with a set of small scales. For the rotor to run smooth and safe, the blade's weights have to be within a few grams of each other. If you find that one is heavier or lighter than the other two,then balance the blades on a makeshift fulcrum (any stick of wood will work) to see which end of the blade is off balance compared to the others, and remove material from the heaviest end until all three blades weigh the approximately same. Then touch up the fine sanding, clean, prime and paint.


WWW.RESYSTECH.COM

Step 7
If it’s not already, remove the blade hub from the generator and attach the blades using hex bolts, flat washers and lock washers. Before tightening all of the bolts, check the distance from one blade tip to the other and verify that the distance is the same between all blades - this will help ensure a proper balance - then tighten the bolts and install the blade hub onto the generator rotor.

Step 8
Make the flanged coupling below out of a piece of ¼” steel and 1” ID pipe. PRime and paint it, then drill three or four ¼” holes around the perimeter of the flange and securely fasten it to the blade hub. Once fastened to the hub, ensure that the rotor spins fine then drill a ⅛” hole through the pipe and rotor shaft, and install a ⅛” machine screw w/ lock washer and hex nut or a ⅛” cotter pin - this will lock the rotor assembly to the rotor shafter.

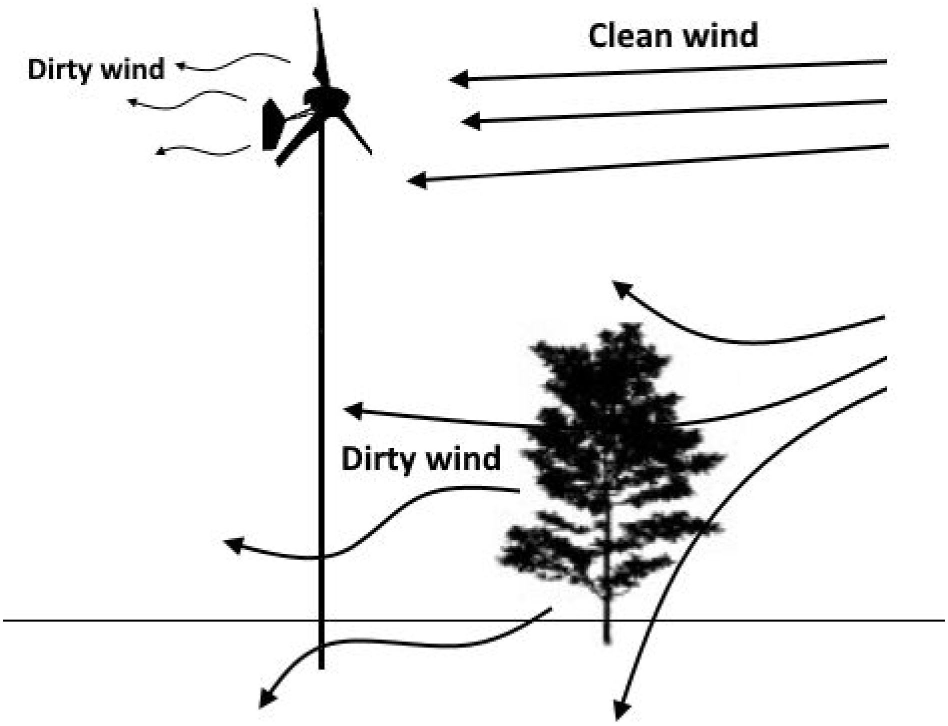
Step 9 (optional)
Most DIY’ers don’t bother with installing one because there’s no real benefit aside from cosmetics, but if you choose to then now is the time to make and install a nose cone. This guide won’t go into the details but if you want to see how a foam core fibreglass nose cone is made, visit the link below:
https://www.youtube.com/watch?v=igjUOnZqLvc

Installing the wind turbine

This section will just cover general information for installing your turbine, as there are many different methods and applications, and you should thoroughly research what will work best for your needs and apply it. If you need assistance, please feel free to contact us at contact@resystech.com

Site analysis

The first thing to do is to decide where to install the wind turbine. As described earlier in this guide, a HAWT performs best in clean wind environments where there are no obstacles in the path of the wind to create turbulence and affect the lift force on the blades. It's strongly recommended that you choose a location where there is at least a 100 foot radius between the turbine tower and any obstacle that could create turbulence, and have your tower high enough that the turbine is above surrounding tree tops and buildings. It's a good idea to purchase a small hand held anemometer online so that you can physically measure the wind speed periodically in the area to ensure the site receives adequate wind power to justify the installation.



You should also be mindful of neighbours, traffic, building codes, etc. Because the blades can travel much faster than the wind, they can be extremely dangerous if an accident were to happen, such as ice throw from the blades which can cause serious damage to property, injure or even kill a person.

The tower
The higher the turbine is, the better it will perform, even in an open field. But you have to know where to set the limit as well because building the tower can be just as if not more costly than the turbine itself. This is part of the reason why choosing the right site is very important. The ROI (return on investment) is the determining factor so weigh the upfront costs with the benefits.

Generally the best method for constructing a tower is to pour a reinforced 4ftx4ft concrete slab in the ground to which a pole would be mounted. The pole should have a hinging mechanism with a locking pin about a foot or so above the slab so that the tower can be easily raised or lowered when needed. The turbine detailed in this guide is designed to fit onto a 1 ½” pipe. This pipe should be approximately 24” long. The tower pipe should be schedule 80 and of the same diameter as the yaw pipe on the turbine. The 1 ½” pipe should be fitted and welded or bolted inside of the tower pipe with approximately 12” protruding from the top for the turbine to mount to. The three phase wires from the generator are fed down through the top of the tower pipe to ground level and into the grid-tie inverter or rectifier and charge controller/batteries.

¼” aircraft cable is strongly recommended for using as guy wires to both lift the turbine and support the tower after it’s erected. If the tower is under 20 ft high, then one set of 3 or 4 guy wires around the perimeter of the tower will be sufficient and the turbine can be lifted by hand with two or three people.

If the tower is higher then another set of wires will be needed - one set attaches to the middle of the tower and the other set attaches just below the tip of the blades at the top of the tower. The other end of both upper and lower wires would connect together at the same anchor point on the ground. The anchors should also be reinforced concrete slabs in the ground with eye hooks anchored on top to receive turnbuckles - the turnbuckles would be used to tighten the guy wires and level and secure the tower.

A gin pole and winch or ‘come alongs’ should be used to raise a high tower. The gin pole adds the advantage of lifting from a higher plane than from the ground, which helps a lot with first getting a high tower off of the ground. The turbine should never be installed on the tower when it’s first lifted - always do a test lift to make sure things will operate smoothly, and to better establish the cable lengths so that they’re ready to be fastened when the tower is upright but don’t twist or tighten when the tower is being raised or lowered.

Battery hookup/grid tie & charge control
This turbine can be connected to either a battery (bank) or an appropriately sized grid-tie inverter designed to handle wind power. If you want to feed power into the main grid and get paid for it, you will need to set up a net metering account with your local utility. When the boring stuff is settled, you can purchase a grid-tie inverter that meets local electrical codes, if you don't already have one. It will need to be able to handle up to 1000 watts of continuous power if you live in an area that regularly gets 30 mph winds or higher. Consult the manufacturer's specifications and recommendations for installing it.

If you want to charge batteries, then you will need a diversion (dump) charge controller to do it safely and efficiently. Without a charge controller, a wind turbine can easily overcharge a battery to a dangerous and damaging voltage level if left unattended in windy conditions. A diversion controller measures the battery voltage during charging and when it reaches a certain level, the controller will either cut off power from the turbine to the battery and divert it to a dump load (an electrical load that is equivalent in size to the peak output from the turbine or higher) that will absorb it, or activate a relay to close a circuit between a dump load and the battery bank to feed directly from the battery and lower it's voltage so that the turbine remains under a load. Either method accomplishes two things: 1 - it maintains a safe battery voltage, and 2 - it keeps a constant load on the turbine so that it doesn't free wheel out of control and self destruct. It's never a good idea to let a HAWT spin freely in the wind without being connected to a battery, grid-tie inverter, or some other electrical load because if the rotor doesn't spin so fast that it will destroy itself, then the bearings will eventually fail prematurely.

There are two main types of charge controllers commonly used today, pulse width modulation (PWM) controllers and maximum power point tracking (MPPT) controllers. PWM controllers were produced before MPPT controllers and are quite a bit more affordable, but they're also quite a bit less efficient. The trouble with a PWM controller is that it doesn't take advantage of the overvoltage produced by a wind turbine. The voltage produced by a wind turbine is proportional to it's rotational speed (rpm), so the faster the blades spin, the higher the voltage it will produce. If the blades are operating in high winds but the turbine is connected to a PWM, what happens is the turbine rpm is 'braked' to within the charging voltage range for the battery bank, and won't spin any faster and therefor a lot of potential wind power is wasted. If the voltage output is limited, then subsequently overall power in watts will be limited too (volts x amps = watts).

In comparison, an MPPT controller will recognise when the turbine rotor is loading up and wants to spin higher than the charging voltage range for the batteries, and will allow it to do so while converting the excess voltage to amps and taking advantage of the extra power. A good quality MPPT controller will increase the peak output from a turbine by as much as 3 times. For example, the turbine detailed in this guide will only produce ~250 watts peak in a 30 mph wind when connected to a basic PWM controller. However, when this turbine is connected to a wind power compatible MPPT controller, it’s peak output at 30 mph is over 870 watts!

Visit the links below to see output from this turbine hooked up to the Midnite Classic MPPT controller:
https://www.youtube.com/watch?v=W4Ajzf4Tysk
https://www.youtube.com/watch?v=X2tUB3XPCGU&feature=youtu.be

Using your new wind turbine

Safety should be your #1 priority when using and servicing your wind turbine. Make sure to follow the controller/inverter and battery manufacturer's recommendations for charge voltage settings, wire/fuse/breaker sizes & placement, disconnect switches, etc. Unless you have experience with wiring such equipment then it's strongly advised that you allow a licensed electrician to make all of the final hook ups to ensure both safety and the manufacturer's warranty for the equipment that you didn't build.

As mentioned earlier in this guide, a brake switch should also be incorporated into the control circuit so that you can safely brake the turbine for servicing or during dangerously high wind situations. Avoid turning the brake on when the rotor is spinning at high speeds as the torque from a sudden stop can do serious damage to the turbine's components - the wind is rarely constant for long so just be patient and wait for it to die down to around 5-10 mph before braking.

It's a good idea to lower your turbine a few days after it's first installed and check the bolts/nuts to make sure they're still tight, the bearings have lots of grease, the blades are holding up ok, etc. You should also schedule a periodic servicing once every couple of months or so to keep an eye out for fatigue and to grease the bearings, and keep a log of the maintenance or signs of progressing 'potential' issues for future reference in case it's needed.

As long as your equipment is hooked up properly and scheduled maintenance checkups work out fine, then between that time all you really have to do is relax and enjoy the thought that every time the wind blows above 4 mph, you're generating free, clean energy.

Enjoy your new wind turbine! If you have any questions or comments, please feel free to contact us.

RST
RENEWABLE SYSTEMS TECHNOLOGY