RESEARCH

ones have been made into neat hydro generators by a local company appropriately called Ecoinnovation. The 20cm diameter motor in the Smart Drive washing machine is an example of the nice big motors just around the corner.

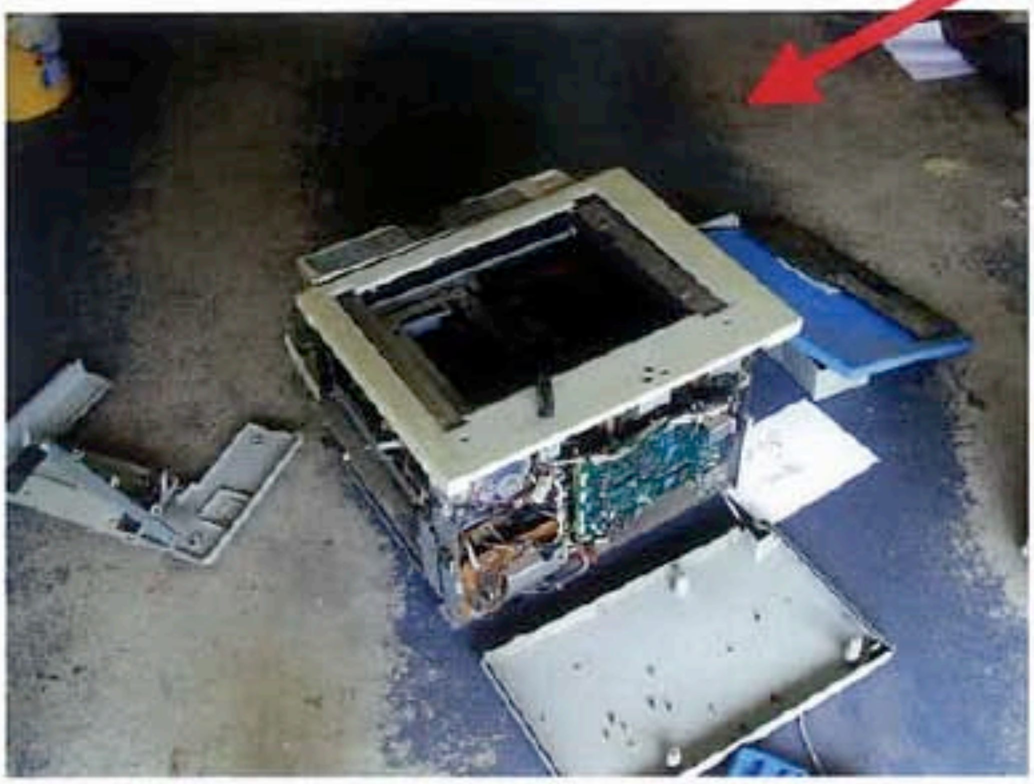
20/10/09 5:29:02 PM
Options
Conclusive justification of the technological practice undertaken.

Testing

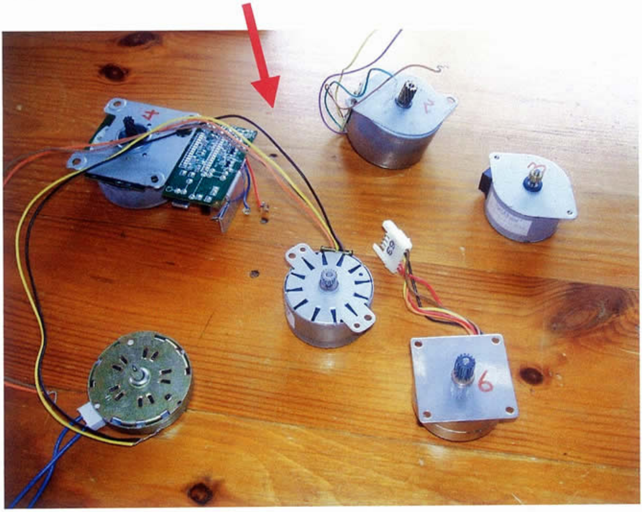
~ The above research shows that I can get stepper motors from things like printers. So I went down the road to the Toner Shop and told him who I am and what I am doing and asked if he had any old printers that he did not want that I could take apart to get the stepper motors out. He was very kind and helpful and gave me 2 large printers and 2 smaller ones for free.

~ He showed be briefly what angle of attack to take to easily recover all the stepper motors from each printer and said there would probably be 2-3 in the big printers and 2 in the smaller ones.

These two pictures show me taking a part one of the larger printers



All five usable stepper motors recovered from the printers



Individual stepper motor voltage testing

~ To test these stepper motors that I have collected I had to do some additional research as to measure output voltage, it is not just as simple as a black and red lead coming out of the motor/generator that I can use to measure output voltage, there are varying numbers of leads coming out of them.

~ Because I did not know how to orientate the leads coming out of the steppers so that I could spin them at certain rpms and them test what there voltage was, I had to do some research to find out what exactly is going on in a stepper motor and which lead is which.

Inside a Stepper Motors

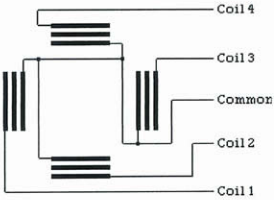
Inside a stepper motor are **four coils of wire** located 90 degrees away from each other - i.e. at positions 12, 3, 6, and 9 o'clock. In the middle is the *rotor* which spins and has **permanent magnets** fitted around its circumference. As the rotor spins each magnet in turn approaches, passes, and moves away from each of the four coils in turn. A magnet passing a coil of wire causes electricity to flow through that coil and so each of the four coils will have different amounts of electricity flowing through it either one way or the other - **alternating current**.

Since a **stepper motor** has four coils of wire, it is said to be a **four-phase** motor. (read more about three-phase electricity here to better understand **multi-phase electricity**). The advantage of this multi-phase set-up for **electricity generation** projects is that when one coil has no electricity flowing through it, the next coil will have reached its maximum. When the four-phases are brought together and *rectified* (more on rectification later) into direct current (DC), the total electricity generated therefore has a near constant voltage and current.

Stepper Motor Wiring

Most stepper motors have 6 wires, however there are motors with 4, 5, or 8 wires also. Each of the four coils is made up of one length of wire with two ends. One end is called *live* and the other end is called *common*. In a five-wire stepper motor all four *commons* are joined together, in a six-wire stepper motor two pairs of *common* wires are joined together, and in an eight-wire stepper motor none of the four *common* wires are joined together.

Identifying the Wires in a Stepper Motor



If you do not have a schematic diagram for your stepper motor - for example if it was salvaged from an old printer - it is very easy to work out which wire is which.

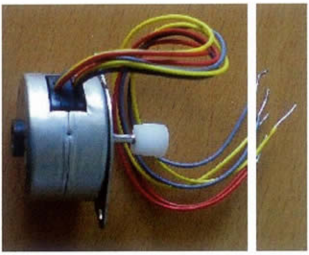
Systematically use a **multimeter** to measure the resistance between different pairs of wires. All four coils will have near identical resistances - if they did not the motor would not function properly. Therefore if the pair of wires being measured are both *live*, the resistance measured will be double that measured if one of the wires is a *common*. Why is this? Because two live wires have two coils between them whereas a common and a live have just one coil between them. (see diagram above)

When you have identified the *common* wires, be sure to label them.

The Stepper Motor

Our **stepper motor** is an old MB 11 sized Philips model with a 7 1/2 degree step angle. That means that it has 360/7.5 = 48 steps which means it would not be ideal for electricity generation and battery charging. As mentioned in our article **Electricity with Stepper Motors** it is best to choose a stepper motor with the most steps possible - usually 200 - since these motors generate higher voltages at lower RPMs; perfect for small wind turbine generators.

Labelling the Wires



There are six wires emerging from the stepper motor: two red, two yellow, and two grey. One red, one grey, and one of the yellow wires have a dark mark on them, the other wires are clean. Therefore we can use that to individually identify the wires. If the wires all looked the same, then we would have individually identified them with small pieces of labelled tape. We will call the wires R1, Y1, G1, R2, Y2, and G2 where the letter is the first letter of the wire's colour, and the number 1 or 2 identifies if the wire was clean (1) or marked (2).

Measuring Resistances

Systematically we connected the testing leads of the **multimeter** to pairs of wires coming out from the stepper motors and put the measured results into the following simple table:

	R1	**R2**	**G1**	**G2**	**Y1**	**Y2**
R1		-	117	-	117	-
R2	-		-	117	-	117
G1	117	-		-	234	-
G2	-	117	-		-	236
Y1	117	-	234	-		-
Y2	-	117	-	234	-	

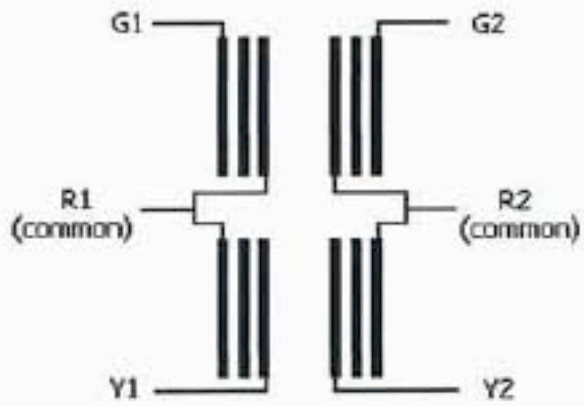
All of the above results are measurements taken in Ohms. Infinite resistance is represented by a '-'.

Analysing the Stepper Motor Resistances

Where the resistance between two wires is infinite we know there is no connection between those two wires within the stepper motor - for example, between R1 and R2 or G1 and G2. We have two different values of resistance between the other wires - 117 Ohms and 234 Ohms with one being half of the other. This is because this stepper motor has four phases and therefore four identical coils. When the resistance measured between two wires is 117 Ohms, the wires are connected across one coil, and when the resistance is 234 Ohms the wires are connected across two coils.

R1 is connected to G1 and Y1 across

one coil. R2 is connected to G2 and Y2 across one coil. G1 and Y1 are connected across two coils, and G2 and Y2 are connected across two coils. None of the 2's are connected to any of the 1's. Therefore we can draw the following simple diagram of the wiring of this stepper motor:



Our four *live* wires are G1, G2, Y1, and Y2, and there are two *common* wires R1 and R2. We now know everything we need to know to rectify the output from this small **stepper motor** into DC electricity for battery charging or to light some LEDs.

20/10/09 5:30:18 PM
Options
Description of the wide investigations that occurred around the issue in order to identify the specific problems that required resolution.

What I learned form the above research

~ From the above research it shows that to find out which wire is which, you have to put an ammeter across different pairs of wires and test the resistance. There are four coils of wire in a stepper motor making them good for power generation as multi pole motors are good for power generation because when one pole is at its maximum current production another is at zero current production and so when rectified, the current is very smooth. For six outlet wire stepper motors, were the resistance is infinite, there is no connection inside the stepper motor between these two motors and were there is a resistance which is double the size of other values, there are two coils between these two wire that you are testing and if the resistance between two wires is half the value of other values, there is one coil of wire between these two wires and on wire is the common wire (a common wire is like a positive or negative wire for two coils). If there are four wires coming out of the stepper motor, then to test output voltage, you have to join the wires into two pairs. Then attach one end of you voltmeter to each pair. The two wire that you join are wires that have a resistance between each other.

Test results

The following pictures and tables show the results of the tests that I conducted using the information gained from the above research.

20/10/09 5:
Optior
Trialling and testing to gain evidence of the understandings gained from exploring understandings which were used to inform their own practice.

Stepper motor number 3

RPM	VOLTAGE
600	3.1
700	6.2
800	10.1
900	12.6
1000	17.9
1100	21.5
1200	22.9

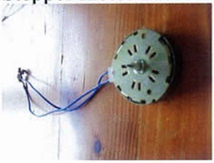
Stepper motor number 2

RPM	VOLTAGE
600	4.5
700	9.9
800	17.9
900	22.2
1000	25.5
1100	28.4
1200	30.5

Stepper motor number 9

RPM	VOLTAGE
600	7.9
700	14.3
800	22.5
900	27.6
1000	31.4
1100	34.5
1200	37.2

Stepper motor number 10



RPM	VOLTAGE
600	7.4
700	10.3
800	17.6
900	25.4
1000	29.5
1100	37.5
1200	41.3

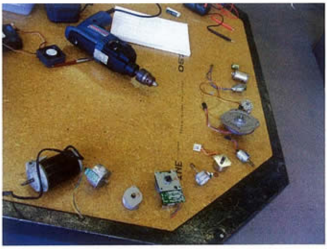
Stepper motor number 4

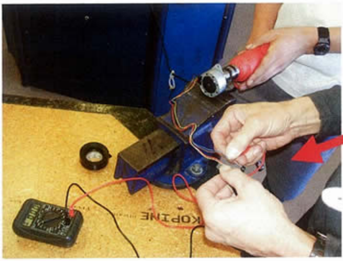
RPM	VOLTAGE
600	3.9
700	5.1
800	17.2
900	20.5
1000	24.9
1100	28.6
1200	30.7

Stepper motor number 6

RPM	VOLTAGE
600	2.4
700	4.7
800	7.9
900	13.6
1000	19.9
1100	20.2
1200	21.3

These pictures show when I was testing all the motors.





This picture shows me and my Mentor testing out what I learned in the above research. I tested the resistance across the wires and then joined them into their correct pairs. I then put a small bridge rectifier across the wires and D.C voltage came out, confirming what I learned is correct and true. So I can confirm that my tests are correct

What I learned

~ From my research, stepper motors are permanent magnet, multi pole A.C motors. These types of motors seem to be the best type of generator due to the properties of the multiple poles explained earlier in this section. My research also tells me that stepper motors are the best type of generators but are only good for lighting a few L.E.DS. So what I think would be ideal is a pretty much a large stepper motor.

~ From my testing, this is definitely 100% confirmed as the most voltage that I could produce at the max wind turbine rpm possible for a very good blade design, about 200 –300 rpm, was a couple of volts at the best. This is definitely not suitable, as I require at least, to be comfortable and safe, about 40 - 50 volts EMF. So further testing on alternative generators will need to be done from what I have learned hear.

20/10/09 5:32:17 PM

Options

Critical reflection on information, understandings and the practice of others, across a range of contexts, that were used to inform the development of their technological outcome.

Plain D.C motor

Research

How does a DC motor work?

A DC motor works by converting electric power into mechanical work. This is accomplished by forcing current through a coil and producing a magnetic field that spins the motor. The simplest DC motor is a single coil apparatus, used here to discuss the DC motor theory.

The voltage source forces voltage through the coil via sliding contacts or brushes that are connected to the DC source. These brushes are found on the end of the coil wires and make a temporary electrical connection with the voltage source. In this motor, the brushes will make a connection every 180 degrees and current will then flow through the coil wires. At 0 degrees, the brushes are in contact with the voltage source and current is flowing. The current that flows through wire segment C-D interacts with the magnetic field that is present and the result is an upward force on the segment. The current that flows through segment A-B has the same interaction, but the force is in the downward direction. Both forces are of equal magnitude, but in opposing directions since the direction of current flow in the segments is reversed with respect to the magnetic field. At 180 degrees, the same phenomenon occurs, but segment A-B is forced up and C-D is forced down. At 90 and 270-degrees, the brushes are not in contact with the voltage source and no force is produced. In these two positions, the rotational kinetic energy of the motor keeps it spinning until the brushes regain contact.

Problems with a DC Motor

One drawback to the motor is the large amount of torque ripple that it has. The reason for this excessive ripple is because of the fact that the coil has a force pushing on it only at the 90 and 270 degree positions. The rest of the time the coil spins on its own and the torque drops to zero. The torque curve produced by this single coil, as more coils are added to the motor, the torque curve is smoothed out.

The resulting torque curve never reaches the zero point and the average torque for the motor is greatly increased. As more and more coils are added, the torque curve approaches a straight line and has very little torque ripple and the motor runs much more smoothly. Another method of increasing the torque and rotational speed of the motor is to increase the current supplied to the coils. This is accomplished by increasing the voltage that is sent to the motor, thus increasing the current at the same time.

Brushed

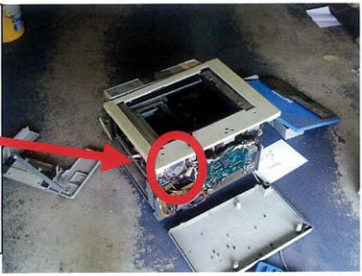
The brushed DC motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary permanent magnets, and rotating electrical magnets. Advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses. Maintenance involves regularly replacing the brushes and springs which carry the electric current, as well as cleaning or replacing the commutator. These components are necessary for transferring electrical power from outside the motor to the spinning wire windings of the rotor inside the motor.

Testing

~ I collected a range of small D.C motors, some from the same printers that I got the steppers out of and one of them is a model aircraft starter motor. Another one of them is just a small plain D.C motor form an electric toy car, I want to look into the voltage producing properties of these motors and see if they do what is necessary for my clients wind turbine.

These are the three plain D.C motors that I tested as generators. Using an electric drill and a voltmeter, all three maxed out at 1200 rmp with not much more than 10 volts being produced, so they do work as generators but do not produce enough voltage at lower enough rpm for what my client wants

This picture shows that the above D.C motor came from one of the printers the guy at the toner shop gave me.



These two pictures show me testing two of the above motors using the electric drill and the voltmeter

Test Results and what I learned

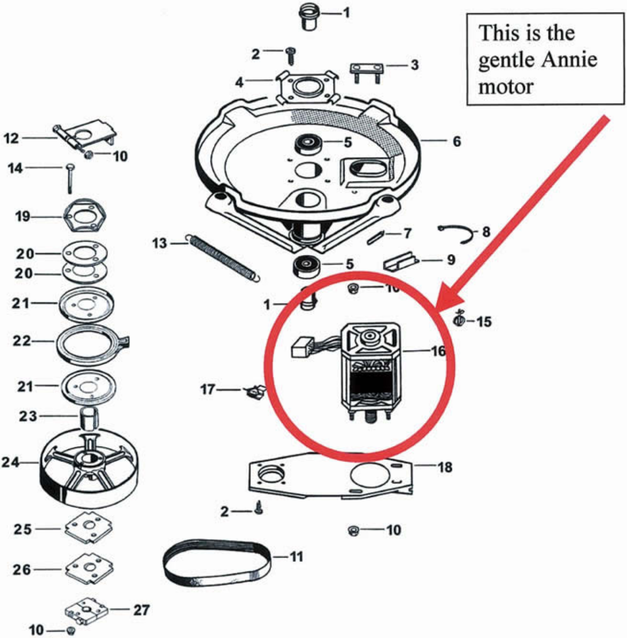
~ From the research, D.C motors are probably the plainest type of motor that you can get and they use a slip ring commutator to produce D.C (without it, A.C would be produced). Running these simple motors backwards does produce current as I found out from my research and from my testing but they are not designed to be generators and so are not at all efficient, again exactly what I found out form my testing. These motors to act as generators require a huge amount of rmp (far more that a wind turbine would deliver) to produce any voltage at all and that is not even enough for what my client wants and so I will not use a plain D.C motor for my clients wind turbine.

Gentle Annie Washing Machine motor

Research

RESEARCH

MOTOR AND CLUTCH



Test results

~ The Gently Annie was quite a surprise because it produced the best results that I had had so far, the fact that the weight of the motor was half the weight limit for the whole wind turbine was a definite issue but will be resolved latter at the moment I just want to find something that can generate the required power.

RPM	VOLTAGE
70	2.9
200	8.7
220	9.4
270	11.4
360	15.8
600	27

What I learned?

~ From the results above, the Gentle Annie is very good relative to the motors that I have already tested but in reality, the results are not too good as a whole because I am measuring the E.M.F of the motor/generator and at the wind turbine max r.p.m of about 300 the E.M.F of this generator would be at about 14 volts which is above the aprox. 13 V battery voltage but when the load of the battery is put across the generator and current actually starts to flow, the internal resistance of the generator will eat up some of that voltage and the battery will not actually charge so I need a generator with a small internal resistance and one that produces excess of about 30 – 40 V at about 200 r.p.m if this whole wind turbine is going to be of any use to my client at all. So I am going to look into fisher and pickle again and try some of their newer motors as generators and see if they produce the Voltage needed.

Testing

~ After testing the small stepper motors and all the other types of motors as generators and none of them being able to produce the amount of voltage that is needed to charge my clients batteries in a useful amount of time, I had to have a serious think of what I was going to do. From all the tests and research that I had done so far, I have learned that small D.C motors are not going to work, car alternators and scooter alternators are also not going to work as they do produce more voltage that other motors but their voltage produced/weight ratio is very poor and I am definitely going to have to find something that produces a lot of voltage (enough and perhaps a bit more to be safe) and has a good voltage produced/weight ratio. After doing a lot of asking around, thinking and research into the matter, I thought that I should have a look into washing machine motors. They did come up earlier in the design process of this wind turbine but were thought to be extremely big and very heavy but I thought that I should just look into them. I found out that Fisher and Pickel used to make washing machines called gentle Annis. They are old and so are probable quite hard to find. I phoned and visited a few washing machine manufacturers and repair places and then finally found a small family home business in Papamoa which repaired washing machines and he actually had an old Gentle Annie washing machine sitting in his drive way that he was about to through out, I told him who I was and what I was doing and he agreed to give me the motor out of the machine. It is pretty heavy but does have potential.

~ The Gentle Annie motor is really just a big three phase stepper motor which is ideal as this is exactly what I wanted because of how well the small steppers preformed. The way that I tested it was by placing the voltmeter across one end of two of its phases. I turned the motor my placing the axle in the lathe and holding the body of the motor with my hands and then changed the speed on the lathe and recording results.

The Smart Drive motor

Research

RESEARCH

Advantage of a Smart drive:

· Low speed generator due to large diameter
· Brush less design
· Low cost and widely available
· Generator windings cannot be burnt out
· Very efficient
· Easily converted for different voltages
· Large stainless steel shaft for easy mounting
· Good corrosion resistance

Smart Drive Parts you need to find

The motor comprises the following components:
· 25m Stainless Steel shaft
· Aluminum bearing holder
· Stator (3 types available)
· Magnetic Rotor (2 types available)
· 4 fixing screws
· 2 stator washers
· 1 large flat washer

How to find your own Smart Drive unit for free


If you live in either New Zealand or Australia you should be able to locate suitable parts at the local tip, transfer station, or recycling center. Another option is to place an advert in the wanted column of your local paper "Broken F&P Smart Drive washing machines for parts".

Unfortunately, in New Zealand the Health and Safety laws often prevent private individuals from entering local tips as the owners are liable should you have an accident while looking for parts. If this is the case ask the people that work at the yard to put aside a few Smart Drive washing machines for you and that you will either pay for them or drop them off a few dozen beers for their trouble. If you are after significant numbers then approach the owners formally with a proposal and make it clear that your organization takes full responsibility for the safety of your workers while on site. You'll need hard hats and fluorescent jackets and the workers sent will need to be trained etc, but it can be done and it is worth your while if you wish to locate significant numbers of these units. I'm aware of another company that is already actively doing just this in New Zealand. I believe they pay $10 per unit to the tip owners.

How to get the parts you need

There is very little to a Smart Drive washing machine, they can be dismantled in a matter of minutes. Remove the plastic top; unhook the 4 bowl hangers from inside and lift out the entire bowl as shown. Remove the cap from the top of the agitator, reach inside and undo the plastic nut
that holds the agitator onto the shaft. Remove the agitator then undo the screws on the retaining ring.

You can now remove the stainless steel bowl from within the plastic outer bowl.
Turn the unit over and work from the bottom, remove the magnetic plastic rotor. It should look like the picture below.

RESEARCH

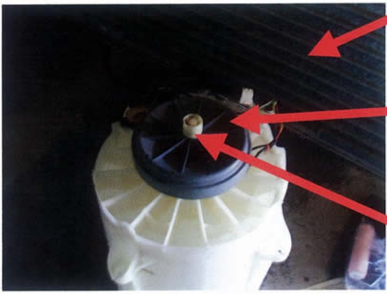
Undo the four fixing screws that hold the copper wire wound stator onto the bearing assembly; you can now cut out the bearing assembly from the plastic bowl with a saber saw. If you don't have a saber saw you could hire one. The other way would be to use a jig saw to cut the bottom off the plastic bowl and then use a band saw to cut the bearing assembly from this piece. Resist the temptation to use a chain saw; it is not a good idea.
The cut bearing assembly should look like this:

The pictures show the rough cut bearing assembly viewed from both ends, and then the same view after the unit has been machined on a lathe. Note that the seal has been removed.

Testing

~ After reading and researching into these smart drives by Fisher and Pickel, they showed great potential to be able to produce the voltage needed by my client. What they are is pretty much just a very big stepper motor which is exactly what I thought would be ideal after testing the small steppers. I needed to find one of these smart drive motors. So I phoned around some more washing machine repair places and one of them was again someone who runs a small business form his house, fixing washing machines. I went to his house and told him what I needed. He was very helpful, and showed me what smart drives where and said he would give me one. He also gave me some tips on how to get it out easily.

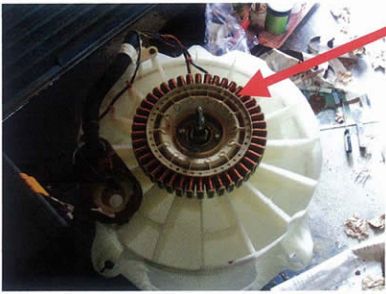
This is the smart drive, attached to the washing machine hub that the Peter gave me.



This is the hub that contains the magnets on the inside edge.

This is the plastic screw, which you have to undo to detach the magnetic hub from the axle.

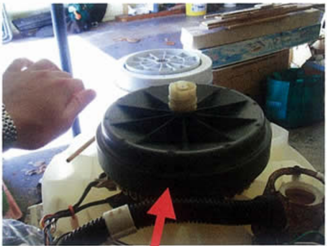
This is the stator, which has 42 coils of copper wire and steel heads



This is the steel axle, which is free to move in the bearing embedded in the plastic. The magnetic hub is screwed onto this bearing

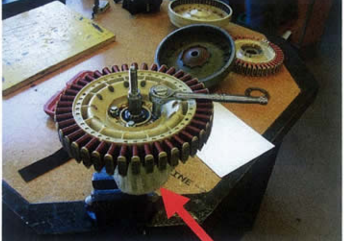
These are the bolts that firmly attach the stator to the plastic.

When I first got the smart drive, whilst it was still attached to the big plastic barrel, I attached to leads coming out of the smart drive to a small 40 Watt bulb and hand spun the magnetic hub and the bulb would glow which was extremely promising.



These two pictures show me hand spinning the magnetic hub when I was doing the 40-Watt bulb test.

I wanted to cut the bearing embedded in the big plastic barrel so that I could continue my tests of the smart drive on the lathe to se how the results compared to others.



Another smart drive that I got form the dump out of a Fisher and Pickel washing machine, which was deferent to the first one as it had different thickness wiring

Plastic bearing housing, recovered form the plastic barrel.

Test results

~ From the results, it is definitely 100% clear that the smart drive is perfect in performance for what my client wants as it produces nearly 70 Volts at as little as 200 R.P.M which is ideal. The down side for the smart drive is its weight. This will have to be discussed with my client but it may be ok due to the shear amazing performance of the smart drive.

What I have learned?

~ From my research, the smart drive is a three-phase A.C highly efficient alternator. The smart drive consists of a copper stator which is fixed and a magnetic hub which raps around the end of the stator and is lined with large square magnets on its inside edge. From research, the thing that is very voltage restricting in generators is the internal resistance. I have found out that there is actually a company, which specialises in making energy producing devices and for some of their wind turbines they actually use the smart drive. They believe that the smart drive is good for a generator due to its large amount of coils, which I found out when I did my tests, but for it to be even more suitable for wind turbine use, you need to rewire it to lower its internal resistance. I will now have to consult with my client, show him what I have found out from my research and see what he wants to do.

Test results

RPM	VOLTAGE
70	21.3
200	66.5
220	73.2
270	88
360	121.8

~ From the results, it is definitely 100% clear that the smart drive is perfect in performance for what my client wants as it produces nearly 70 Volts at as little as 200 R.P.M which is ideal. The down side for the smart drive is its weight. This will have to be discussed with my client but it may be ok due to the shear amazing performance of the smart drive.

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20/10/09 5:33:02 PM
Options
Evidence of ongoing client interaction. This also supports the identified key factors.

Client consultation

~ Because of my findings from my motor/generator research, I need to now consult with my client as the smart drive will fulfil his power requirements (so long as wind is blowing) but it weighs 4-6 kg which is half of the given weight specification and that is only the generator part, with still quite a lot more components to come.

Consultation with client

1) Your specification for the weight of the whole wind turbine when packed into the container is 10 kg. I have found the lightest and most efficient generator, which fits the budget, and power requirements but not the weight specification. It weighs nearly half the weight specification for the entire device. Do you have any comments or suggestions for where you would like me to continue from here?

The power requirements are definately an important aspect to this divice. It must be able to produce the necessary power and so I am comfortable with incresing the weight specifiation in order to get the necessary power out put. I realize the initial weight specifications was unrealistic and increasing it to 40kg will still alow me to easily transport it from the vehicle to the near by set up destination.

Signed Roy Anderson

Anderson

21st June 2008

20/10/09 5:33:44 PM
Options
Explanation of why the outcome addresses the problem.

Generator decision

~From my last consultation with my client, I found out that I could use the smart drive as the generator in my clients wind turbine. I will now continue the design of this device using the smart drive.

The weight limit

~ The weight limit looks like it is going to be an issue for this project, but with some careful planning and design I feel that I will be able to overcome it. As my client is concerned with the overall weight, he did still have the ability to allow some more weight for the overall device. He wants to be able to carry the whole thing in its container with no more that two people. I did a test to see what the max weight limit two people could carry comfortably for about three hundred metres. Considering that my client said that he would be setting the turbine up never more than a couple hundred metres away from the vehicle, I feel that this test was a fair conclusion to go on.

These images show the weight that I used in my lifting and carrying experiment. The bottom picture shows the scale reading when all the masses that we lifted and carrying were on the scale.

Client consultation

As we have decided to use the smart drive as the generator and you have allowed for the increased weight limit. I have found a number of methods, which I plan to use to make the motor/generator more efficient my means of rewiring and reshaping the stator finger heads.

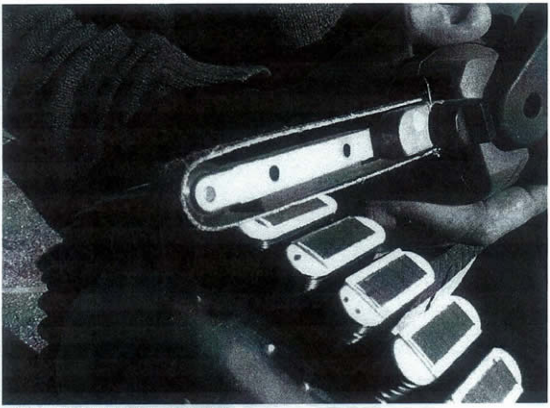
My proposal is that this is necessary to make the weight/power output ratio better, are you comfortable with this or would you rather I left the motor as it is?

I am happy for any modifications to be done on the motor so long as it benifits the wind turbins overall preformance with out adding any extra weight.

Signed Roy Anderson

Banderson 26th June 2008.

Decogging the smart drive



Tip profile you are trying to achieve

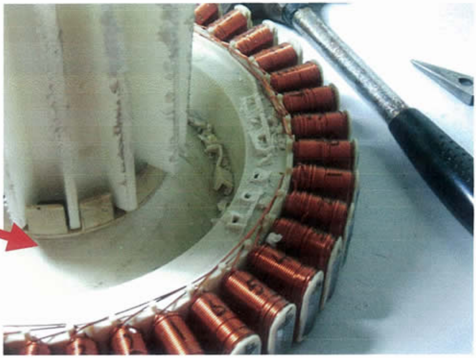
So now that I have, with client consultation and approval as well as a change in brief, this smart drive was chosen to be the generator in my clients wind turbine. This was due to the fact that it is a motor/generator that will produce my clients power requirements whilst camping and also because it has and extremely good weight/efficiency ratio. After running it also past one technologist who has guided me during this project, he agrees that this is exactly the right generator to use. He also said that for a wind turbine to be as good as possible, it must have a low cut in speed, which is the speed at which it starts producing usable power. And for it to do this at as lower wind speed as possible it should be as easy to turn as possible. The smart drive has quite bad cogging, which is the resistive 'bumpy' feeling felt when the motor spins. In order to reduce this cogging affect, you need to 'decog' the smart drive. This done by filling each coil head so that it has curved edges. This takes the corner of the steel and therefore makes the magnet pass between boundaries of each coil a lot more softly. It means that the magnet has less 'grab' on each steel head when it passes past all of them. This results in an overall loss of EMF of about3-4 volts which is absolutely acceptable considering the start up force required to get the motor turning is reduced by 50 %. Methods to do this are by using a power file which would remove material quickly but I do not have one and they are expensive so I did the same thing by hand with a had file.

Decogging my client's smart drive

This is the smart drive that I got for my clients wind turbine. This is before it was decogged.

This is when I filed down all the corners of the heads on the fingers filled with copper wire.

This is the completely decogged smart drive.



Rewiring the smart drive

Tools needed

Reconnecting a Smart Drive Stator

Tools you will need to reconnect your Smart Drive Unit

Gas torch (to burn off insulating lacquer), selection of insulated wires (up to three different colours), insulating heat shrink tubing (to insulate joins), side cutters, good quality wire strippers, strip joiner, screwdriver, hot-glue gun, solder and soldering iron.

Star and Delta Connections

Smart drive motors are wound with three phases, you will notice 6 connections on a Smart Drive stator these are the two ends of each phase.

Many readers will be unaware of the two types of connection that 3-phase motors and generators can be configured into, theses are commonly referred to as Star or Delta. How the unit is connected has a significant bearing on the operating performance of the units, therefore each unit can be configured to have two operating points. These configurations are illustrated below. The copper windings that make up each phase (14 fingers on a Smart Drive stator) are illustrated below in the Star and Delta configuration. All Smart Drives as connected in Fisher & Paykel washing machines are connected in Star. This point is easy to identify as a 3-pronged brass clip forms the star point as shown below.

33
www.ecoinnovation.co.nz
Email: michael@ecoinnovation.co.nz

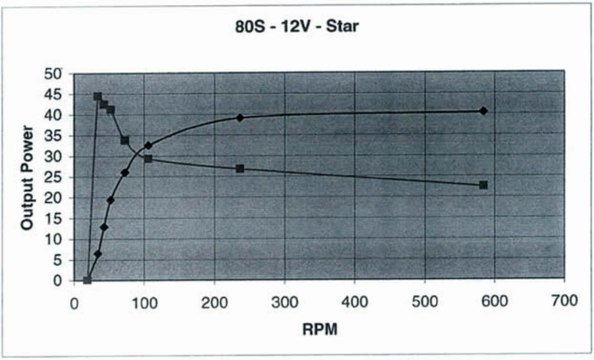
Now that I have decogged the smart drive, I want to increase the amount of current that the generator can push through the circuit at any one time. (And therefore also the power output for each kg of weight will also be increased. The more efficient I can make this generator without adding any extra weight, the better) To do this I need to decrease he internal resistance of the motor, which is done by rewiring the motor in a special way. Ecoinovation is a company in New Zealand that has done testing on the affects on the power output by wiring it differently. I was able to buy a book with many tables in it on power output curves for each way of rewiring the smart drive. You can get smart drives with different wire thicknesses and the first smart drive that I was able to get, lucky enough had the correct wire thickness to be able to produce the best amount of power with reference to my clients specifications. The smart drive that I had, had, from research, the best wire thickness for wind turbine applications. The following pages show different ways to rewire a smart drive, with different results and there is also a graph showing the way that I am going to rewire my client's smart drive with reasons for this choice. The first graph should agree with the voltage tests that I collected when I did the smart drive test on the lathe. These results are different to mine as they show the power output and not the EMF (electromotive force of generator).

At the moment, the smart drive that I have is wired in series, has wire thickness of 80 mm and is wire in three-phase star. Which is exactly the same as this first graph

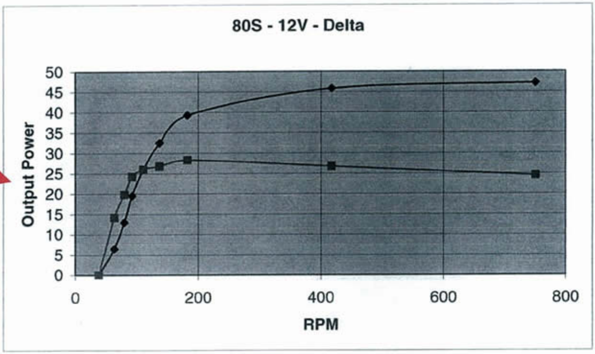
Test Result Detailed Graphs

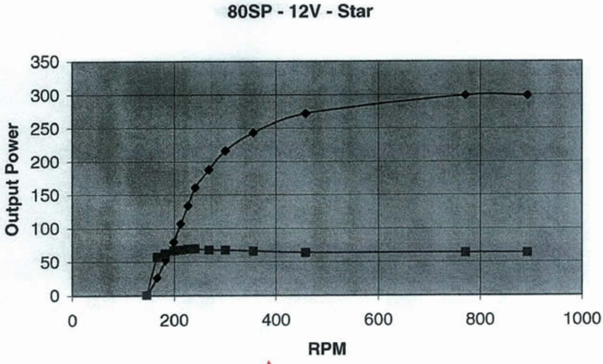
Diamond markers Power (Watts), Square markers Efficiency (%)

80S Stator – 12 volt

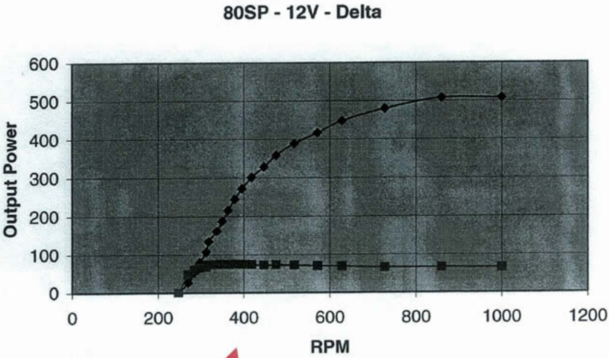


This graph shows a motor similar to mine except wired in three-phase delta and as you can see, the affect on output power is minimal is minimal.





This graph shows a smart drive, with 80mm copper wire thickness, wired with a mixture of series and parallel and connected in three-phase star



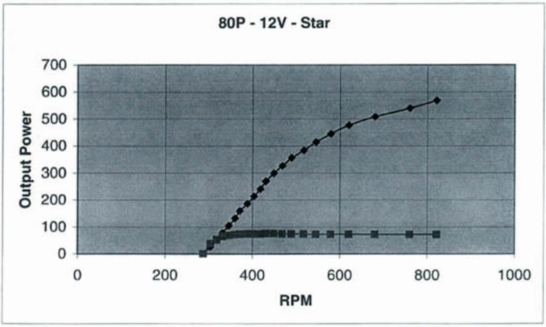
This graph shows a smart drive, with 80mm copper wire thickness, wired with a mixture of series and parallel and connected in three-phase delta

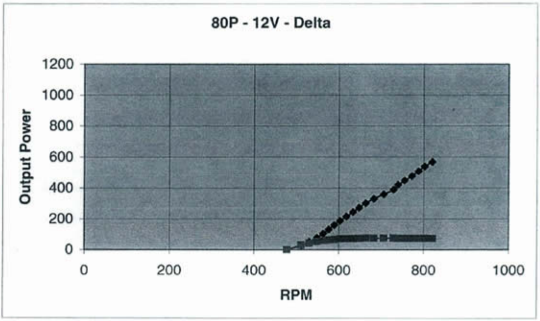
If you wire the your 80mm copper wire smart drive in this SP format, you have the chose to make it delta or stare by just simply rearranging the output wires. This is great because as yo can easily see from the graph, delta is good for higher winds as it can reach a much higher max output but does not start charging until the r.p.m is over 200 which is high but certainly in the wind turbine range. The advantage of star is that it will start producing power at a much lower r.p.m but high-speed performance. So if I wired the motor in SP, my client has the option to very easily change between star and delta, getting the good points from each, making an ideal and very efficient overall wind turbine with good high and low wind speed performance

Test Result Detailed Graphs

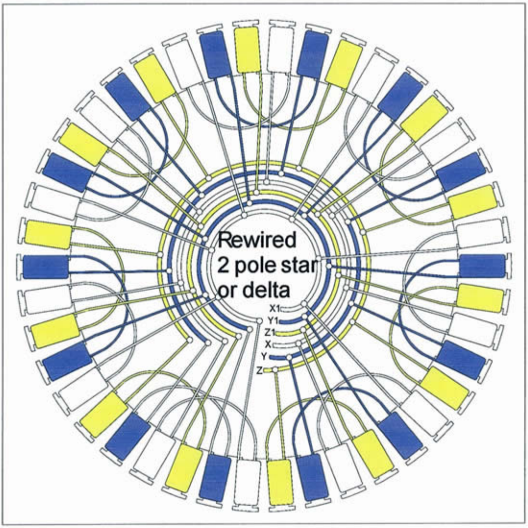
Diamond markers Power (Watts), Square markers Efficiency (%)

80P Stator – 12 volt



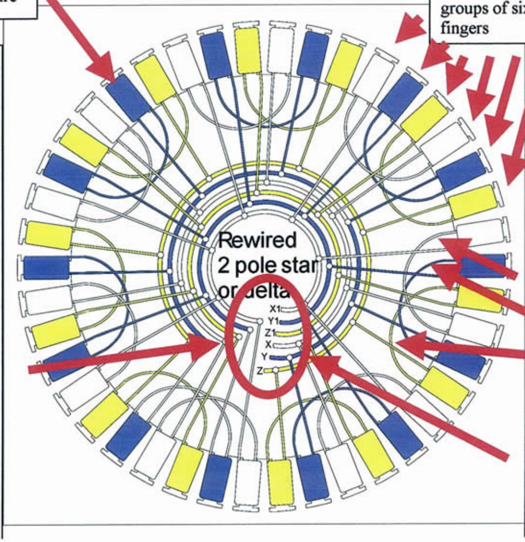


These graphs show similar to the previous except it is not rewired with a mixture of series and parallel but instead, just parallel and the affects of this are obvious. This method for rewiring, especially in star is quite good as max power output is nearing 1 KW. The issue with this rewiring method is that is good for high-speed applications and does not have the added bonus of an easy change to low wind speed mode like the SP does. For these reasons, I will choose the SP method of rewiring for my clients wind turbine and the steps taken by me to rewire the smart drive are show below.



Coils of wire

This is one of the seven groups of six fingers



These wires that come out of the smart drive stator, are connected in different ways to make it overall star or overall delta.

For star

X1, y1 and z1 are all joined together an the remaining three wires become your three phases

For delta

Connect wires

X1 and y

Y1 and z

Z1 and x

The pairs of wire form your three phases

These are the three wires that should still connect each group of six fingers together.

These are the six output wires coming out of the generator.

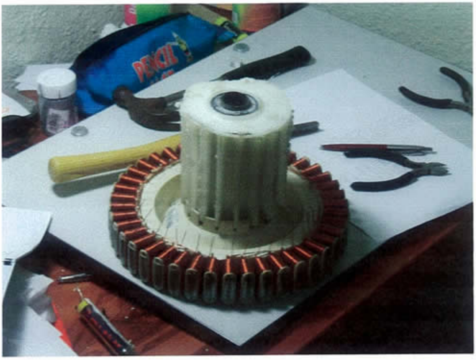
Rewiring steps

This is the wiring diagram for how I am going to rewire my clients smart drive in order to get a half parallel, half series connected three – phase AC generator. These are the steps that I took to completely rewire the smart drive.

1) Remove wires from lugs
2) Remove plastic lugs with a chisel
3) Remove the plastic edge on the inside of coils to provide access to copper wire.
4) I then labelled the ends of each finger in a clockwise rotation 1,2,3,4,5,6 starting with the three wires in on of the group of three lugs being the number 123 and then continuing around the smart drive stator. In other words number one must be the forth of the already cut wires.
5) Cut wire 3 in the middle
6) Cut wire 2 in the middle
7) Cut wire 1 in the middle
8) I then repeated the above three steps for the remaining wires 123.
9) After all the cuts are completed, there should still be three uncut wires within each group of six.
10) I now burned off all the varnish coating from the about the end 1cm of each cut wire. Some sand papering of cut wire after burned is also required.
11) You now need six, roughly 1m long pieces of separate cable, roughly 2.5cm thick.
12) What you have to do is loop each one in turn around the inside of the smart drive and connect firstly all fingers with the number one to it using solder. The new cable should form a loop onto which there should be seven number one wires attached.
13) When you have attached all the seven number one wires to the first loop wire, you now need to insulate the entire layer with a strip of paper or insulation tape and hot glue or silicon.
14) Now repeat this process with another new loop of wire, attaching all seven number 2 wires to it, solder and insulate
15) Now repeat this process with another new loop of wire, attaching all seven number 3 wires to it, solder and insulate
16) Now repeat this process with another new loop of wire, attaching all seven number 4 wires to it, solder and insulate
17) Now repeat this process with another new loop of wire, attaching all seven number 5 wires to it, solder and insulate
18) Now repeat this process with another new loop of wire, attaching all seven number 6 wires to it
19) When all six wires are complete, cover the entire thing with a thick layer of silicon to seel it all off and make it watertight.
20) Look at the pictures below for more information.

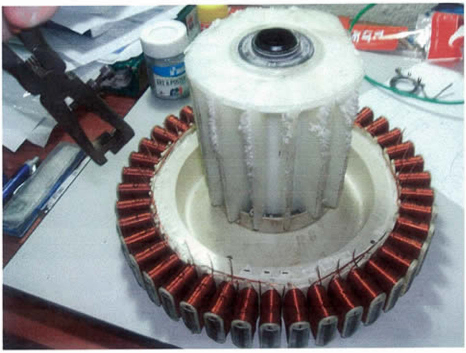
Rewiring my clients smart drive

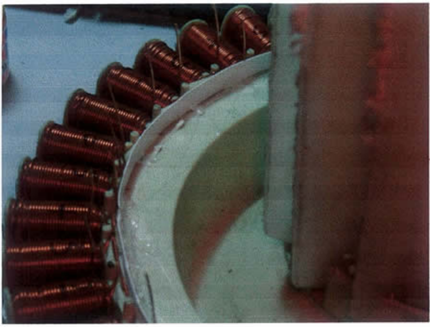
This was the first step that I did which was to chisel of the plastic lugs and plastic near the wire so that I could get at the wire



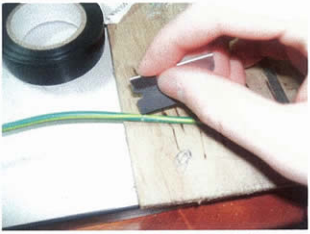
I then cut all the wires according the above circuit diagram

These two pictures show me using some wire strippers to clean the enamel off the cut copper wires. I did also burn it off a bit but these wire strippers worked very well.

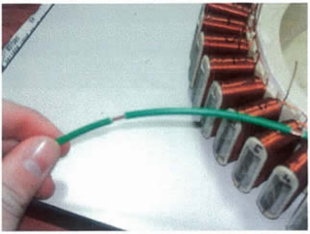




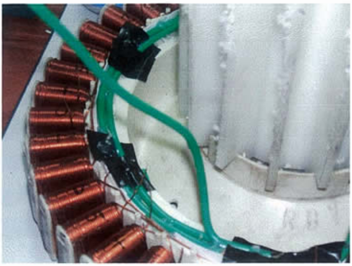
This picture shows a small cardboard wall that I glued in place. The purpose of this was to keep the uncut wires safe and unscratched or damaged whilst I worked on the other side of the wall

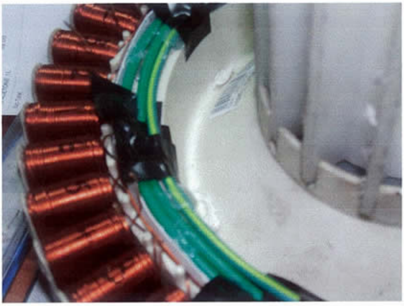


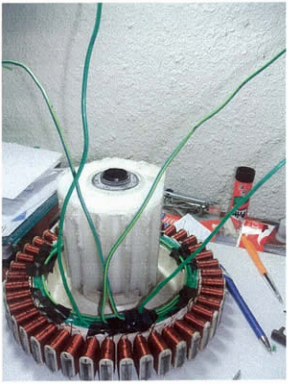
These two pictures show me cutting the small slits in the wire. It is to these small contact points that the cut copper wire on the stator solders to



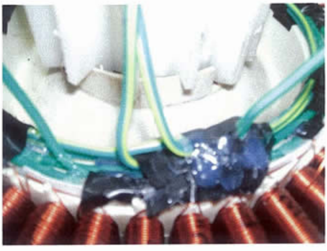
These two pictures show the first two wires complete and secured in place. I used insulation tape to cover each contact point and then glue for extra insulation and support.

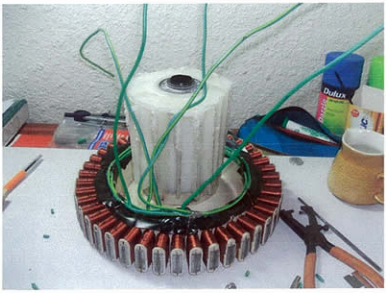


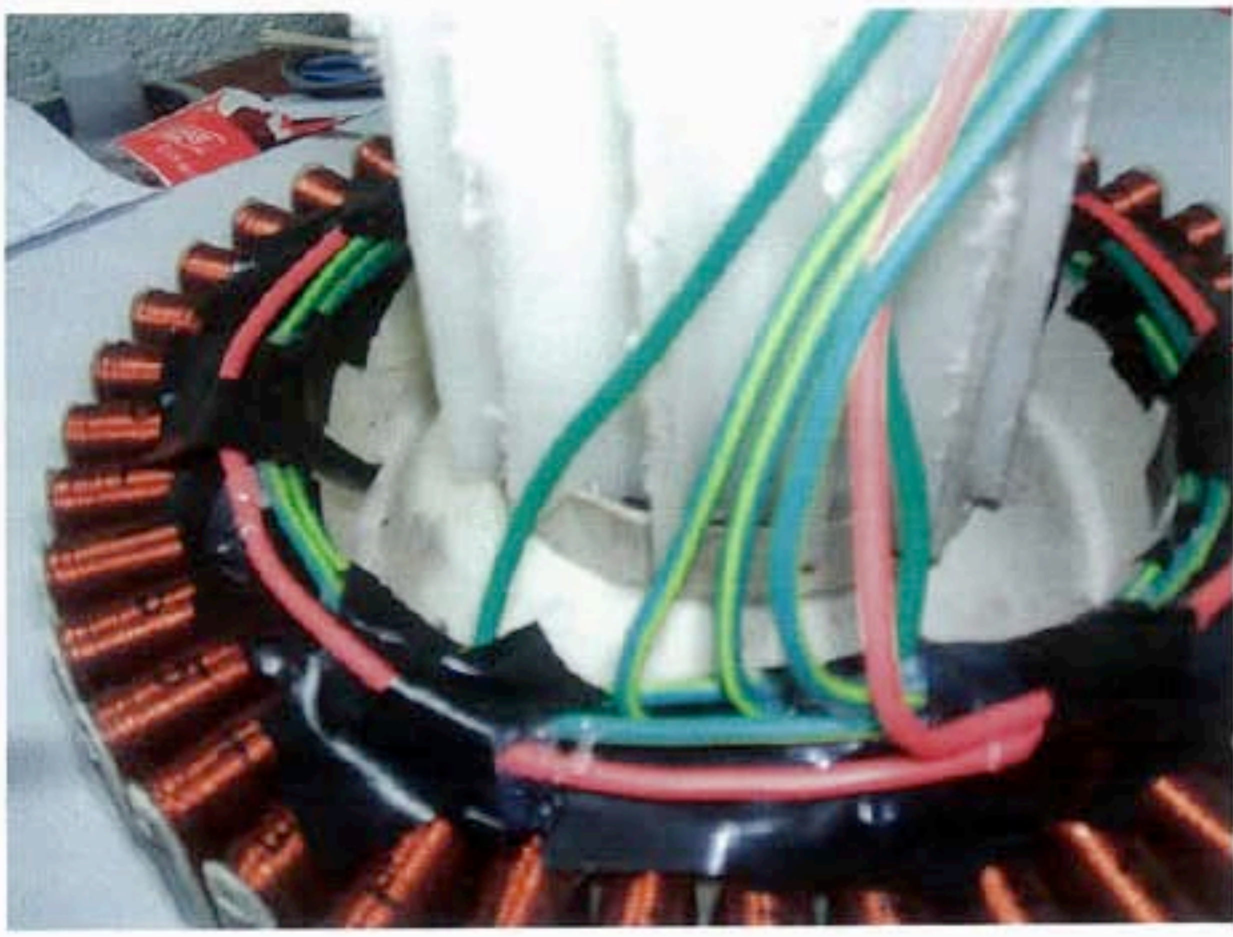




The pictures on this page just show my progress as I complete one layer after another. Until I have done all six

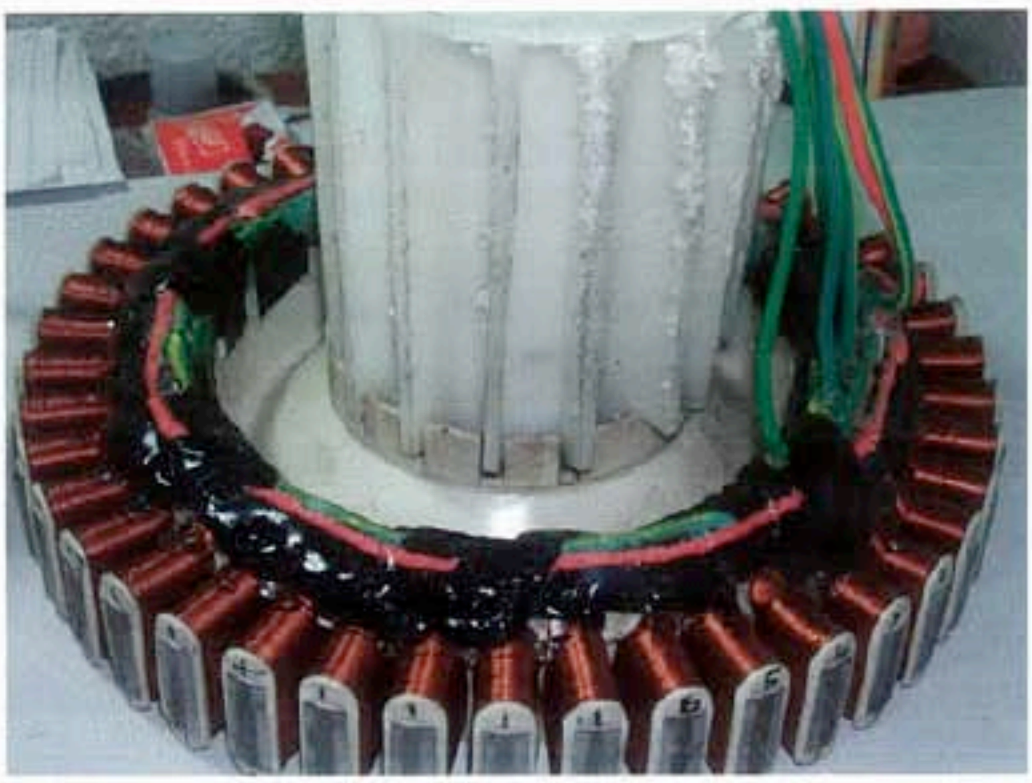






This is a picture with all the completed wires. This is the point at which all the wires emerge from their loops and come away form the stator.

I then put some more insulation and glue for more support and insulation over all the wires. After this, I covered all the wires in a thick layer of silicon to waterproof and protect all the wires.



This is the smart drive motor completely finished being rewired and decogged.

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Options

Explanation of how the complexities of the situation have been identified and explored.

3^{nd} design brief

Brief ~ design and make a portable power generation system to charge a small battery bank

Specifications

~ The device must be **lightweight**. My client wants the device to be 40 kg or less in total.

~ The device must be **easy to set up and pack away**. My client wants the device to be as easy to set up as possible i.e. take no longer than a tent takes to set up. So I will set a goal of: any person must be able to set the device up into full operating mode in eight minutes or less.

~ The device must be designed and made for **under $120**

~ The device must be **safe**. My client wants the device to be as safe as possible to minimise unnecessary accidental injury. The device must be safe enough for anyone to use and be around with out getting harmed by it in any way.

~ The device must be **compactable**. My client wants the device to fold down into a container with measurements of one metre long. 30 cm high and 30 wide and the whole thing being a rectangular shape. This way, the whole thing can fit in his ute

~ The device must use power-generating systems that can charge up the battery bank as quickly as possible. It is understood by me and my client that you will not be able to charge everything all at once and expect the generating source to keep up. Research, my client will have a max power draw of about 150 –200 watts and so a battery bank of roughly 24 AH should be adequate. This means to be able to charge this battery bank, with the average climate conditions, it should be able to produce about 20 – 40 Watts.

~ The device must be **weather proof**. Which means that it must be able to permanently stay outdoors and not get damaged from rain and sun.

~ The device must be **durable,** i.e. it must be made strong so it is not all fragile and cant take a bit of bumping around. This I because were my client drives his car to go camping, they may not always be roads so it will not be a nice smooth drive to the set up destination and the way that the generator and container are designed and built must account for this possibility.

~ The device must be **easily maintained**. This means that the moving parts must not ware down over a short period of time and if the parts waring down can't be helped, they must be buyable, cheap and very easy to replace.

~ The device must be designed to produce the smallest amount of **noise** possible, it is likely that it will be used close to ware the user will be sleeping and because the device will most likely be operating throughout the night, it must be quiet enough so the user can get to sleep.

~ The **materials** used must be the most suitable materials to make it **light weight, durable and weather proof**.

~ The device, once set up, must collect energy throughout the day as **automatically** as possible.

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Options

Demonstration of originality in terms of inventiveness, innovation and elements of unconventionality in the technological practice undertaken, and its resulting outcomes.

Battery research

What I hope to achieve

~ I am going to research batteries for the wind turbines batter bank. I want to find out what type of batteries there are available to day and each of their properties are and how they behave under different conditions. I will also find out what each of their prices are and choose the battery which will suit my clients budget and intended use most effectively. I am also going to find out the proper methods to charge batteries.

RESEARCH

Rechargeable battery

A **rechargeable battery**, also known as a **storage battery**, is a group of two or more *secondary cells*. These batteries can be restored to full charge by the application of electrical energy. In other words, they are electrochemical cells in which the electrochemical reaction that releases energy is readily reversible. Rechargeable electrochemical cells are therefore a type of accumulator. They come in many different designs using different chemicals. Commonly used secondary cell chemistries are lead and sulfuric acid, nickel cadmium (NiCd), nickel metal hydride (NiMH), lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).

Rechargeable batteries can offer economic and environmental benefits when used instead of one-time-use disposable batteries. Most rechargeable battery technology has been adapted into the standard “AA”, “AAA”, “C”, “sub-C”, “D”, and “9-volt” (List of battery sizes) configurations that consumers are familiar with. While the rechargeable versions of these types of cells have a higher up-front cost than disposable batteries, rechargeable batteries can be discharged and recharged many times. Similarly, while the metals and chemicals in rechargeable cells can be more toxic than those in disposeable batteries, disposeable batteries nevertheless do release toxins into landfills and other more sensitive parts of the environment. Some manufacturers of NiMH type rechargeable batteries claim a lifespan up to 3000 charge cycles for their batteries.

Types of rechargeable batteries

Chemistry	Cell Voltage	Comments
NiCd	1.2	Inexpensive. High/low drain, moderate energy density. Moderate rate of self discharge. Suffers from memory effect (which sometimes causes early failure)
Lead Acid	2.2	Moderately expensive. High/low drain, moderate energy density. Moderate rate of self discharge. Suffers from no memory effect Common use - Automobile batteries
NiMH	1.2	Expensive. Useful in high drain devices. Traditional chemistry has high energy density, but also a high rate of self-discharge. Newer chemistry has low self-discharge rate, but also a ~25% lower energy density.
Lithium ion	3.6	Very expensive. Very high energy density. Not usually available in "common" battery sizes (but see RCR-V3 for a counter-example). Very common in laptop computers, moderate to high-end digital cameras and camcorders, and cellphones. Very low rate of self discharge. Loses 5%-10% of its storage capacity every year from the time of manufacture whether it's used or not. Volatile: Chance of explosion if short circuited, allowed to overheat, or not manufactured with rigorous quality standards.

Some more specifications on common battery types

Nickel-cadmium - mature but has moderate energy density. Nickel-cadmium is used where long life, high discharge rate and extended temperature range is important. Main applications are two-way radios, biomedical equipment and power tools. Nickel-cadmium contains toxic metals.

Nickel-metal-hydride - has a higher energy density compared to nickel-cadmium at the expense of reduced cycle life. There are no toxic metals. Applications include mobile phones and laptop computers. NiMH is viewed as steppingstone to lithium-based systems.

Lead-acid - most economical for larger power applications. Lead-acid is the preferred choice for hospital equipment, wheelchairs, emergency lighting and UPS systems. Lead acid is inexpensive and rugged. It serves a unique niche that would be hard to replace with other systems.

Lithium-ion - fastest growing battery system; offers high-energy density and low weight. Protection circuit are needed to limit voltage and current for safety reasons. Applications include notebook computers and cell phones. High current versions are available for power tools and medical devices.

Choice of battery

~ From my extensive look into the four main types of batteries, I have decided that the battery that will most practically fit my client's needs is the lead acid battery. This is because like in a car, that wind turbine is very likely to be stopping and starting a number of times throughout the day which means a battery that suffers form memory will not be suited because if the battery is not fully charged then fully flattened, a false bottom or end point in the battery may be established (NiCd). Also because of cost, the other two batteries that do not suffer from memory, range form expensive to very expensive. Lead acid batteries also have a low self discharge rate which means that they do not discharge on there own very fast (under 10% per year). It is also possible to by (for not much more cost) lead acid batteries that are sealed and have a class matt within them so that acid, if the battery is some how opened, can not spill all over the place which is ideal for my clients needs as the battery will probably somewhere along the line be tipped up side down, making this battery meet design specification number 1 as it will be safe. Lead acid batteries can also come in form called deep cycle which means the battery once fully charged can be flattened almost to zero and this sort of cycle will not harm the battery. The only down side with the lead acid battery is its weight, a 12 Ah battery (capacity suggested by Roger at the Battery Warehouse) can easily weigh up to 5 kg which is ok as this is the capacity needed to be able to charge a laptop (and maybe two other small devices on one charge) and because the wind turbine being able to meet charging specifications is more important to my client that weight which is what the second consultation which my client revealed. So for reasons stated above, the lead acid battery will be used in my clients wind powered system.

Lead acid battery research

~ I am now going to look into specific aspects about lead acid batteries, including general maintenance and charging methods.

RESEARCH

How to charge a lead acid battery

Charging the lead-acid battery *(BU13)*

The charge algorithm for lead-acid batteries is similar to lithium-ion but differs from nickel-based chemistries in that voltage rather than current limiting is used. The charge time of a sealed lead-acid battery is 12-16 hours (up to 36 hours for larger capacity batteries). With higher charge currents and multi-stage charge methods, the charge time can be reduced to 10 hours or less. Lead-acid cannot be fully charged as quickly as nickel or lithium-based systems.

It takes about 5 times as long to recharge a lead-acid battery to the same level as it does to discharge. On nickel-based batteries, this ratio is 1:1, and roughly 1:2 on lithium-ion.

A multi-stage charger first applies a constant current charge, raising the cell voltage to a preset voltage (Stage 1 in Figure 1). Stage 1 takes about 5 hours and the battery is charged to 70%. During the topping charge in Stage 2 that follows, the charge current is gradually reduced as the cell is being saturated. The topping charge takes another 5 hours and is essential for the well being of the battery. If omitted, the battery would eventually lose the ability to accept a full charge. Full charge is attained after the voltage has reached the threshold and the current has dropped to 3% of the rated current or has leveled off. The final Stage 3 is the float charge, which compensates for the self-discharge.

Charging lead-acid batteries with a power supply

Lead-acid batteries can be charged manually with a commercial power supply featuring voltage regulation and current limiting. Calculate the charge voltage according to the number of cells and desired voltage limit. Charging a 12-volt battery (6 cells) at a cell voltage limit of 2.40V, for example, would require a voltage setting of 14.40V.

The charge current for small lead-acid batteries should be set between 10% and 30% of the rated capacity (30% of a 2Ah battery would be 600mA). Larger batteries, such as those used in the automotive industry, are generally charged at lower current ratings. Cells constructed of a non-antimonial lead grid material allow higher charge currents but have a lower capacity. The cylindrical Cyclone is sealed and can sustain a pressure of up to 3.5 Bar (50 psi). A pressurized cell assists in the recombination of gases.

Observe the battery temperature, voltage and current during charge. Charge only at ambient temperatures and in a ventilated room. Once the battery is fully charged and the current has dropped to 3% of the rated current, the charge is completed. A good car battery will drop to about 40mA when fully charged; a bad battery may not fall below 100mA.

After full charge, remove the battery from the charger. If float charge is needed for operational readiness, lower the charge voltage to about 13.50V (2.25V/cell). Most chargers perform this function automatically. The float charge can be applied for an unlimited time.

Battery as a buffer

While dwelling on float-charge, an external load can be connected to a lead-acid battery. In such a case, the battery acts as a buffer. Micro-towers on cell sites work this way. During off-peak periods, the batteries get fully charged. On peak traffic times, the load exceeds the net supply provided by the rectifier (charger) and the battery supplies the extra energy. A car battery works in a similar way.

RESEARCH

Simple Guidelines

- Always store lead-acid in a charged condition. Never allow the open cell voltage to drop much below 2.10V. Apply a topping charge every six months or when recommended.
- Avoid repeated deep discharges. Charge more often. Use a larger battery to reduce the depth of discharge.
- Prevent sulfation and grid corrosion by choosing the correct charge and float voltages. If possible, allow a fully saturated charge of 14h.
- To reverse sulfation, raise the charge voltage above 2.40V/cell for a few hours.
- Avoid operating lead-acid at elevated ambient temperatures.

AGM: The Absorbed Glass Matt construction allows the electrolyte to be suspended in close proximity with the plates active material. In theory, this enhances both the discharge and recharge efficiency. Actually, the AGM batteries are a variant of Sealed VRLA batteries. Popular usage high performance engine starting, power sports, deep cycle, solar and storage battery. The AGM batteries we sell are typically good deep cycle batteries and they deliver best life performance if recharged before the battery drops below the 50 percent discharge rate. If these AGM batteries are discharged to a rate of 100 percent the cycle life will be 300 plus cycles and this is true of most AGM batteries rated as deep cycle batteries.

Choosing the type of lead acid battery

~ Form the above research into lead acid batteries, a SAGM lead acid battery seems to meet my clients needs the most. It is a sealed absorbent glass mat lead acid battery which means it is sealed and all the acid within the battery is absorbed into a kind of glass matt. This makes the battery safer in the case of the battery opening, meeting design specification number 1. AGM lead acid batteries can also be discharged to at least 90 % without hurting the battery or decreasing its life cycle number to much which meets my clients specifications as 12Ah 12v AGM lead acid battery (capacity recommended by Roger at the Battery Warehouse) will be able to charge a laptop and maybe two other small electronic devices after which the turbines battery will probably be 80 – 90 % flat which is all my client wants the turbine to be able to do on one charge (I will aim to design the turbine to be able to fully charge its battery in under two days to meet my clients specification but in reality, the turbine will be continuously charging the battery and the user will probably be continuously charging something of it).

Chose of battery – 12v 12Ah AGM lead acid battery.

Furling and Shutdown Systems

Furling and shut down research plan

~ I want to now research into some fail safe methods or safety features I can put on the wind turbine so that my client is able to control the wind turbine in high winds bringing it to a stop and turning it off or just limit its speed.

RESEARCH

- **Furling Systems--**We use the term "furling system" to describe a mechanism that turns the wind generator rotor at an angle out of the wind, either horizontally or vertically, to protect the machine from damage during high winds. Ideally it will keep power output levels near the maximum even when fully furled. Our early wind turbine designs didn't use furling systems, and we feel fortunate that some of them are still flying. A wind turbine that furls is also much more gentle on your tower and guy wires--the force on an overspeeding wind turbine increases as the wind gets stringer..
  There are a variety of furling system designs:
  - **Variable Pitch--** An ideal but extremely complicated solution is to use blades which change pitch depending on the wind speed....these also have the advantage of keeping power output at the most efficient point for the current windspeed. During low winds, the blades are pitched for best startup. In higher winds, they rotate and adjust shaft speed to the ideal RPMs for the generator. In extreme winds, they turn the blades even further to protect the unit from damage. The problem is the complexity of making a system work reliably...but it can be done! Large commercial wind generators use this system exclusively, as do antique and modern Jacobs turbines, and some old WinChargers.
  - **Tilt-Back--**In these designs, the generator body is hinged just behind the nacelle. When wind speed gets too high, the entire nacelle, hub and blade assembly tilts back out of the wind to nearly vertical. As the wind slows down, it returns to normal horizontal operating position by either springs, wind action on a tilted tail, or a counterweight. Commerical wind generators that use this method are the old Whisper models (from before the buyout), the Windstream, and many homemade designs.
  - **Furling Tail--**The generator is mounted off-center horizontallly from the yaw bearing. The tail is also angled in this axis. The tail is also angled in the vertical axis, and hinged. When the wind force back on the rotor is strong enough to overcome the off-axis generator making it want to yaw and the angled tail trying to keep it from yawing, the tail

folds up and turns the alternator away from the wind direction, forcing the wind turbine to yaw out of the wind. When wind speeds drops, the tail is returned to normal operating position by gravity, or springs. Many commercial and homemade designs (including ours) use this system, and it has proven to be very reliable.

  - **Folding Vane**--Similar to the furling tail, but the tail boom is fixed, with a hinged vane underneath. Used on some older Winchargers and homemade designs, the disadvantage is that tail and vane are more highly stressed from wind force during furling, as they still are sticking out there in the gale.
  - **Flexible Blades**--The theory is that the blades flex both back toward the tower and around their main axis, and therefore protect themselves from overspeeding. It does work if the materials and details are correct...for example, the blades must not flex back far enough to hit the pole, and they must withstand flexing during cold weather too. The popular Air 403 and new Air X from SouthWest Windpower use this system for furling. One problem is that it is noisy....in fact the Air 403 is noisy even in gentle 15 mph winds, BEFORE it starts producing power. The Air X has some fancy electronic circuitry to reduce noise.
  - **Air Brakes**--Noisy and full of vibration, but they do work. Older WinChargers used this system. Metal cups extend from the hub from centripetal force during high winds, and noisily slow the machine down; they retract back into the hub when the wind slows.
- **Shutdown Systems**--This is a manual control that completely shuts the wind generator down. It is not allowed to spin at all, and should be able to survive extremely violent winds in this condition. It can be electrical or mechanical.
  - **Electrical Shutdown**--With permanent magnet alternator machines, simply shorting the main AC power output leads together should effectively shut down the wind turbine. The problem is that when the machine is spinning at high RPMs during a windstorm, the shutdown may be either impossible electrically (the turbine is performing too inefficiently for shorting the output to have any effect), or too damaging to the alternator (the heat produced in the stator coils by shutdown at high speeds turns the coils into molten slag.) Our normal method is to simply wait for a space between high wind gusts to short the mill with a switch. We have successfully shut down Ward's turbine while it was putting 30 amps into 12vdc...numerous shutdowns at 10-20 amps of output have caused no vibration or problems. You can use a manual switch, or simply a shorting plug to do this. Our homebrew deisgns have never had problems with refusing to stop in high winds when shorted.
  - **Mechanical Shutdown**--These systems physically brake the wind generator, or force it out of the wind by turning the tail parallel to the blades. Even the mighty Bergey Excel 10kW wind turbine has a mechanical crank for emergency shutdown. Generally, a cable is attached to a hinged tail, with a small hand winch located at the bottom of the tower for the operator.

What I learned?

~ From the above research I learned that you could have a furling system on you wind turbine. A furling system is a special tale that is in a position, calculated, and on a specific angle so that when the wind gets up to a certain speed, the whole spinning rotor gets pointed slightly out of the wind (the stronger the wind is the more the rotor will be pushed out of the wind). And because the rotor is pointing out of the wind, it slows down a bit and does not spin out of control and self-destruct the whole wind turbine. This seems good but the problem with it is that getting the correct angles, positioning and size of the tail is very tricky and I think that the whole system would be good if you could get it to work but because I do not have the time to fiddle around trying to get it to work I am going to have to look for an alternative method.

~ I also from the above research found numerous other methods to furl the wind turbine but they are even more complicated that the first so I am going to have to look into the shutdown system. This is an electronic or manual brake that you pull or push, that will slow the turbine down eventually bringing it to a complete halt. This sounds a lot more feasible as it sounds simpler which is what I am looking to find for my client. For the electronic brake, some sort of electronic ram or car brake type system is out of the question but I have read about a switch that you can flick and it will short all three phases of the smart drive together. As this is a short circuit, the wind turbine will lock up and become very hard to turn because you will be trying to push too much current through the wire (as there is no resistance. This is part of Lenz's law). This sounds like it could be what I am looking for but I also found out, which makes sense, that if the wind turbine is running flat out and you just went a flicked that switch, the blades have so much momentum and now suddenly the smart drive just doesn't want turn almost at all. This results in so much energy released that the smart drive steel coil heads turn to molten metal and the whole device will start to tear it's self apart. I then looked further into my research and found the manual brake which looked like it may also work quite well but once you have pulled the manual brake and the turbine has stopped, who do you keep it stopped whilst you leave it sitting up there or whilst you take it down. The solution to this problem soon came to me, have both a switch and a manual brake, use the manual brake to slow it down and then when it has stopped, flick the switch to keep it stopped.

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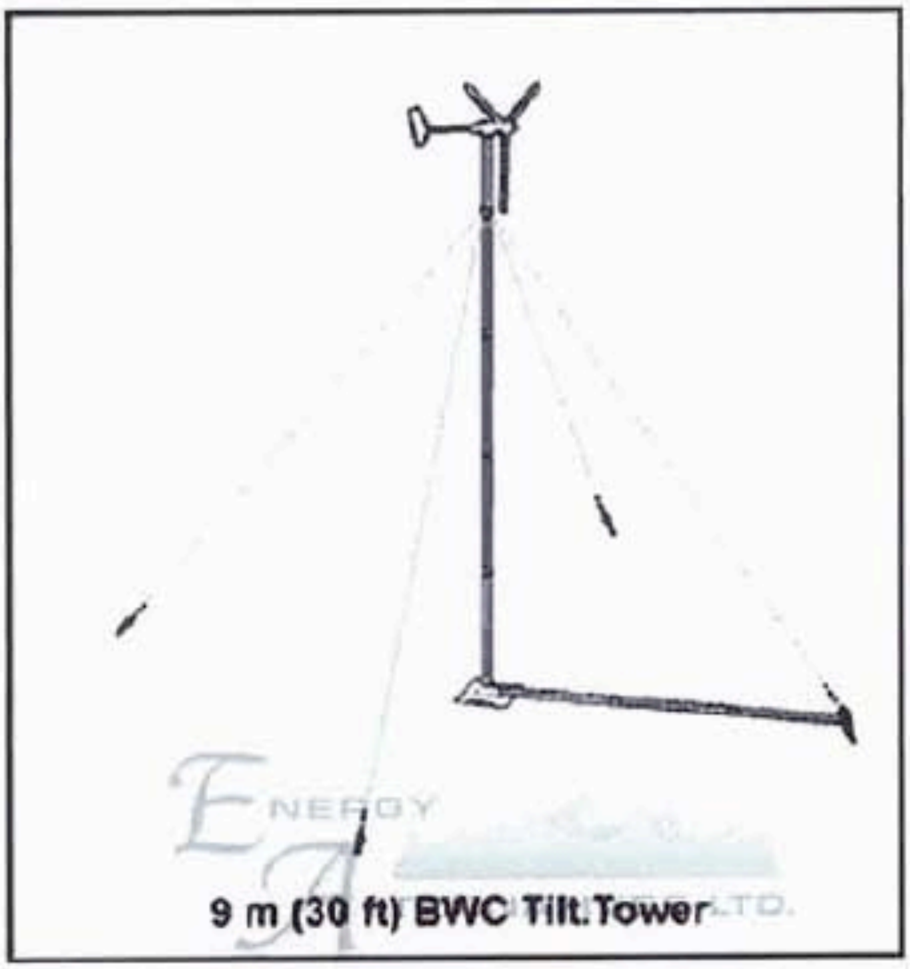
Options
Explanation of how the complexities of the situation have been identified and explored.

Tower research



This is research for the tower and how the tower folds down. This first picture shows quite a large wind turbine with a furling tail that is flapped to the side. The tower consists of a trigonal pyramid shaped base. This rises up to about half the entire high of the turbine when in normal operational use. On top of this is what looks like a wide steel pipe attached to the trigonal pyramid section by a hinge. On top of this section, which extends up the final quarter seems to be the horizontal swivel section. I cant really see how I could use this sort of tower for my clients wind turbine as it has to be portable and fit into quite a small box and this tower although is bigger that I would use, is very bulky. The pivoting ideo could however be adapted and possible be looked into for the final tower design. The next picture down shows a tower, which is used mostly for small D.I.Y homebuilt wind turbines. The main tower looks like it is a solid pole, which straight away can't be used in my design; as my design must be able to fold down to meet one of the design specifications. The lever, which is used, for rising and lowering the turbine pole is a handy idea but again as the pole used in the wind turbine that I am going to construct is not likely to be over about four metres, the extra weight and bulk would not be worth it. From this wind turbine, the plate is definitely worth looking into as it would give the whole system stability. The guy ropes would also be an absolute definite also for the stability of the whole system especially during strong winds.