EcoInnovation

Environmental solutions to environmental problems

Fisher & Paykel Smart Drive Washing Machines

Disclaimer

Systems running on 60 volts and lower cannot, under normal circumstances, cause death in humans by electrocution. Smart Drive units when free spinning can produce over 1500 volts and have the potential to deliver a lethal current through the human body.

Extreme care must be taken to ensure that no contact is made with these high voltages.
EcoInnovation accepts no responsibility for any damage, injury or death resulting from working on Smart Drive washing machine motors. It is your responsibility to ensure your safety and the safety of others that may come into contact with the generation unit.

Introduction

This introduction is intended to give an overview of the use of Smart Drive motors as generators in renewable energy systems. In contains an overview of results for 18 Smart Drive generator options at 12/24/48 volts. For detailed information on how to reconnect a Smart Drive you will need to purchase the EcoInnovation Smart Drive manual.

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email:ecoinn@paradise.net.nz

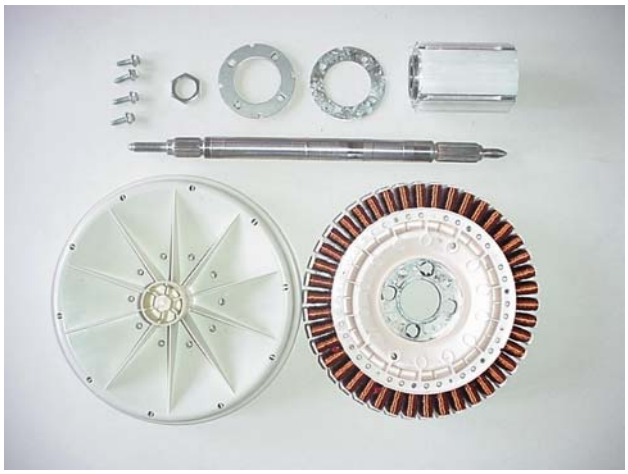
Advantage of a Smart drive:

- Low speed generator due to large diameter
- Brushless 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

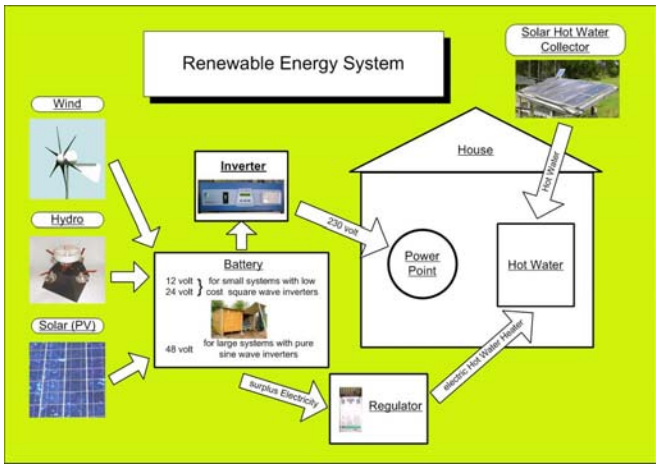
Smart Drive Parts you need to find

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



Renewable Energy Systems



The above diagram shows the main components in a Renewable Energy system.

- Smart Drive wind turbine
- Smart Drive turgo turbine
- Photo Voltaic panels (PV)
- Solar hot water heating
- Battery bank
- Inverter – converts battery dc power to 230 volt ac for normal house use
- Regulator – controls battery charging and diverts power not required to hot water

Hydro is the most cost effective; a single Pelton or turgo turbine can generate all the power that an energy efficient house needs. An off grid house without hydro will normally need both a wind and solar PV system.

If you want Renewable Energy to succeed, establish your house to be energy efficient:

- Good energy efficient refrigeration
- Compact florescent lights
- LCD flat screen TV and computer (preferred)
- Good insulation and double glazing with passive solar heating
- Good energy efficient habits
- LPG cooking
- Sparing use of electric appliances that produce heat
- Solar hot water heating with wood fire (or LPG gas) back up

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 organisation takes full responsibility for the safety of your workers while on site. You’ll need hard hats and flouro 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

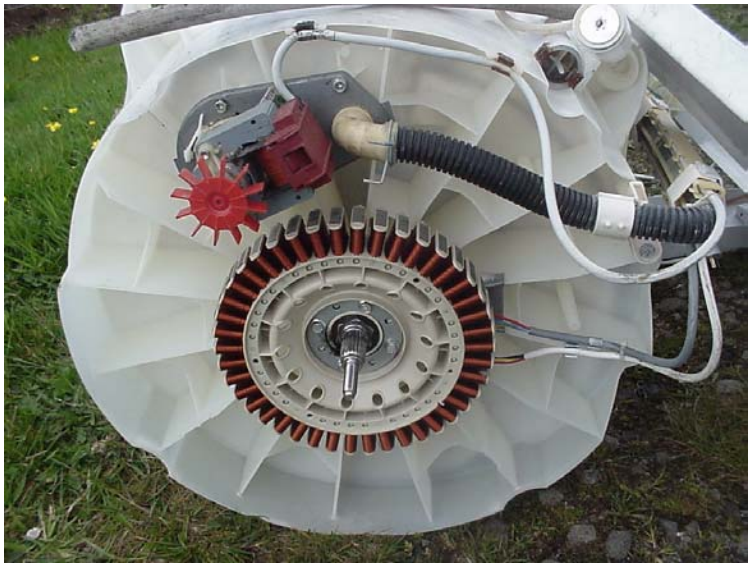
significant numbers of these units. I'm aware of another company that is already actively doing just this in New Zealand. I believe they pay $10 per unit to the tip owners.

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.

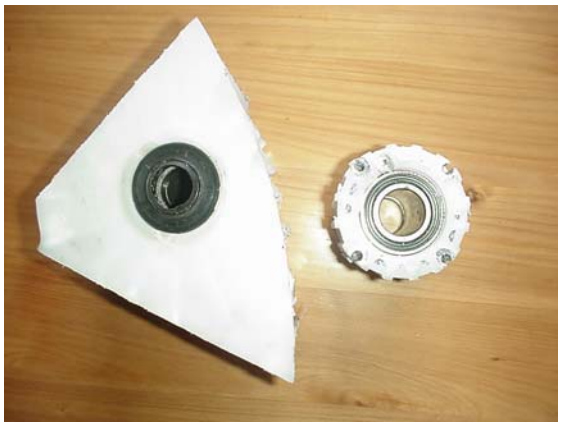
Remove the cap from the top of the agitator, reach inside and undo the plastic nut that holds the agitator onto the shaft. Remove the agitator then undo the screws on the retaining ring.

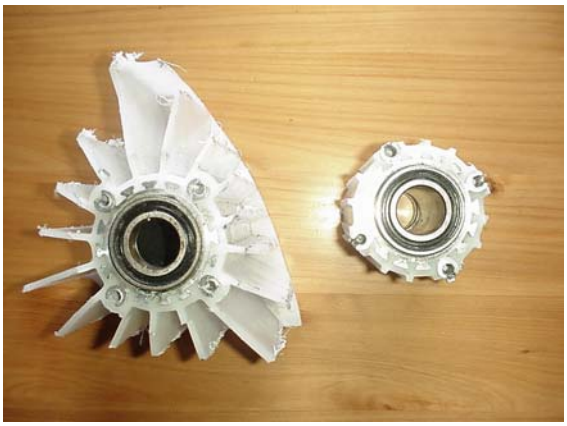
You can now remove the stainless steel bowl from within the plastic outer bowl.
Turn the unit over and work from the bottom, remove the magnetic plastic rotor. It should look like the picture below.



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.

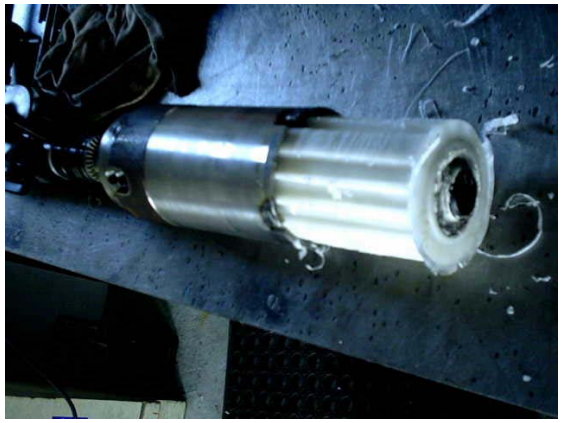
The cut bearing assembly should look like this:





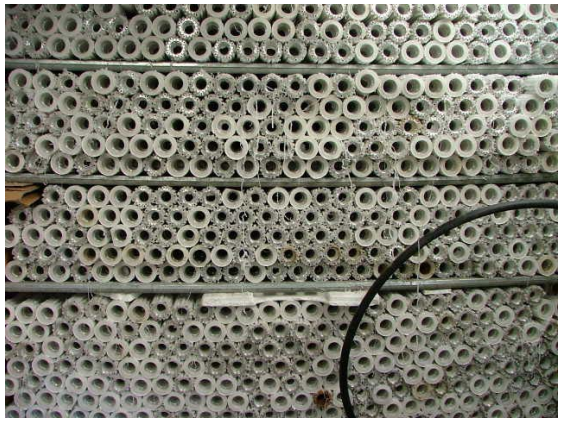
The pictures show the rough cut bearing assembly viewed from both ends, and then the same view after the unit has been machined on a lathe. Note that the seal has been removed and the plastic machined down to expose the aluminum fixing channels. This allows the unit to be fixed to a mounting surface.

EcoInnovation removing bearing assemblies the easy way



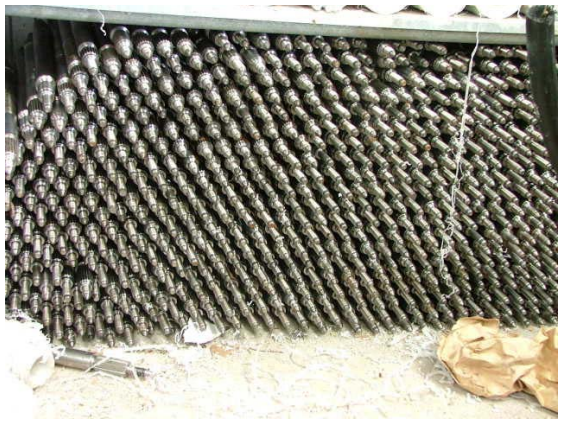
Recycling at EcoInnovation

Rough cut bearing assemblies by the 100's direct from Fisher & Paykel Recycling



Bearing assemblies cleaned up and ready to make into products.

EcoInnovation shafts and bearing assemblies – just a few and the many thousand in stock

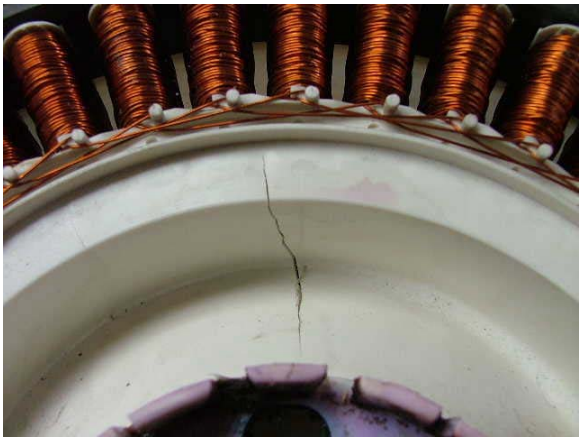


Machining the bearing assembly plastic housing

To machine on a lathe, put the shaft into the 3-jaw lathe chuck, slide on the bearing assembly with the four fixing screws half in, so that the screws rest in between the jaws of the chuck. When the lathe is started the bearing assembly will rotate with the shaft and can be machined down. Take only small cuts otherwise you will shear off the fixing screws from the bearing housing. For production work make a dedicated jig to hold the rough cut bearing holders securely so that large cuts can be made.

Condition of units

The Smart Drive units you manage to locate may not be in excellent condition. It is fairly common on these units for radial cracks (like spokes on a wheel) to have formed in the plastic housing of the copper wound stator. To date they do not seem to be a problem, in a washing machine applications the motor stator is subjected to repeated high torque reversals (not the case in renewable energy applications). The cracks are made by the high torque reversals and temperature changes in the motor. The cracks form but generally do not get any worse. We have never had a unit fail yet due to a cracked stator. We sell cracked units in our invertors kits at a very good price, if you want to get your hands on a the complete history of the Smart Drive in one hit then the inventors kit is the way to go. All other units sold by EcoInnovation are in excellent condition with up to 1 hairline crack or no cracks present in the rotor. You pay a little more for them.



Typical crack on an inventors kit stator

Bearing replacement

The bearings are easy and cheap to replace. To replace bearings knock the old ones out from the inside (use a length of steel rod or old bolt) and press the new ones into place, use a mallet to tap them fully home. Suggest you thoroughly clean the new bearings and housing surface and apply a small amount of Loctite onto the surfaces prior to assembly.


Spinning of shaft in bearings

After a number of early failures, EcoInnovation became aware that in order to prevent the bearing spinning on the shaft is it **absolutely necessary to loctite the shaft onto the bearings**. Remember to thoroughly clean the surface to be glued first. This prevents the bearing from spinning which would otherwise damage the shaft leading to misalignment of the stator and rotor.

Another good tip is to lightly knurl the bearing surface on a lathe, this roughens the surface and provides good adhesion for the loctite. Knurling also increases the outside diameter so the fit changes from a clearance fit to an interference fit and the shaft will need to be tapped into the bearing with a mallet. This is advisable on highly loaded shafts where there is significant side loading from a chain or V belt.

If you do forget to do this and the shaft spins in the bearing, if the damage is only minor to the shaft you can dot punch to raise the bearing surface, then loctite and tap the bearing on with a mallet, this usually fixes the problem. It pays to loctite it first. EcoInnovation can supply replacement shafts very cost effectively if required.

Dealer Enquirers

EcoInnovation has in stock hundreds of Smart Drives and are open to discussion on volume orders of Smart Drives to individuals or companies wishing to make their own Renewable Energy products with them. We usually send a sample Smart Drive airfreight at cost to an interested company, quantity orders would then be a minimum of 50 units sent by sea freight. All units are checked and cleaned prior to dispatch and are sold in as new condition. A significant discount is offered on such orders.

Testing of Smart Drives at EcoInnovation

EcoInnovation tested Smart Drives on a modified lathe that was fitted with a variable speed drive. The power of the driving motor limited the test results to 600-700 Watts of output. However, the performance trend has been established by these tests and it is possible to extrapolate this trend to estimate the performance at high rpm's. The Smart Drive rotor is not balance and runs very smoothly in the 1-1200 rpm range. Vibrations can be detected above 1200 rpm and the magnetic rotor should be balance above this speed. In the 1200-1800 rpm range guard against rotor failure and cover the Smart Drive in case of failure. This tends to apply to engine driven Smart Drives and high-speed water turbine applications. In the wind turbine applications ensure your maximum rpm is kept under 1800rpm and that the stator is balanced.

Tests were conducted on a simulated 12/24/48 volt battery system with Xantrex C40 charge controller maintaining system voltage at 13.8/27.6/55.2 volts respectively. The test results accurately represent the performance of a Smart Drive connected directly to a battery bank at constant voltage. The tests included rectification losses and the efficiency graphs should be used to indicate the most suitable unit for a particular application.

EcoInnovation is currently having more tests done using only 36 fingers of the Smart Drive and including the latest type four (cog-free 36 finger) design. The 36-finger option results in many different reconnection options not available if all 42 fingers are used. These tests will generate over 1000 data sets and the information will be available for sale on CD only.

Maximum Power Point Trackers (MPPT)

The technology behind MPPT is likely to revolutionize the use of generators in wind and hydro applications in the future. To date MPPT's are too expensive for the DIY enthusiast. These units allow the generator to run at its optimum power point while delivering the voltage required to your battery bank. In effect they have the ability to match the generator to the application for you. In steady state hydro applications this is not required but in wind turbine applications could result in significant increased output of the turbine. EcoInnovation is keeping a close eye on such developments as in time it will hopefully become more cost effective.

The other advantage of MPPT is that you can generate a much higher voltage than you require at the battery end to save on cabling losses. There are a number of hydro schemes remote from the battery banks that do just this. A MPPT at over $1000 is still much more expensive that using 3 x toroidal transformers to do the same job. Transformers require much more skill in setting up but cost less than $300 and they are less sensitive to being accidentally damaged by a high voltage spike. A MPPT would be more efficient at about 95% compared to 80% for 3 transformers.

Transformer Applications.

Smart Drives are high frequency 3 phase generators, the frequency of the unit = rpm/2.15. Smart Drives running at 500 rpm will have a frequency of 232 Hz. Units running at maximum power of 1.4 kW can put out over 700 Hz, which is too high for normal off the shelf transformers.

EcoInnovation has developed a transformer application using 3 toroidal transformers, these operate well at high frequencies and are cheap to purchase. It is possible using 3 x 300 VA transformers to make a transformer pack capable of delivering 1.4 kW of power at 24 and 48 volts. The transformers will need good air circulation and a small fan to assist cooling if pushed above the 900 VA rating.

In setting up transformers you will be dealing with voltages in the 300-500 volt range so you need to be careful, we do not recommend that the DIY enthusiast work with these higher voltages unless sufficiently skilled and qualified to do so.

The transformer primaries can be connected in Star or Delta, as can the secondaries. The transformer will almost certainly have multiple primary and secondary taps. The Smart Drive can also be configured in Star or Delta and used with the 100S, 80S or 60S stators in this application. The typical configuration of this setup is indicated below:

- 3 x Jaycar transformers 110/230 to 12/24
- 230-volt primary connected into star of delta
- Secondary connected into star or delta
- S Smart Drive in either star or delta

Note the 24-volt tapping is used for 48-volt systems (as the transformers are running above 230-volt they were designed for) and the 12-volt tapping for 24-volt applications.

How to decide which model you to make or purchase

Refer to the attached Smart Drive Test Result Summary Graphs these are the first 6 graphs. The test rig was not able to test the units beyond 600-700 Watts of output power. By studying all test results it is possible to observe the trend and therefore make fairly accurate estimates of the performance of Smart Drive above the 600-700 watt range tested.

Further tests conducted by EcoInnovation indicate that the maximum power output of a Smart Drive is in the region of 1.4 kW at 1600-1800 rpm. This was achieved an 80SP unit connected to a 48-volt battery bank.

Notation

- **160**= 1.6mm wire diameter (30 turns/finger), you can rewire the units by hand if you wish
- **100**= 1.0mm wire diameter, as used on first generation Smart Drives
- **80**= 0.8mm wire diameter, as used on second generation Smart Drives
- **60**= 0.6mm wire diameter, as used on third generation Smart Drives
- **S** = series connection, as standard
- **SP** = half series half parallel connection
- **P** = parallel connection

Smart Drive generator data

Model	Wire Diameter mm	Wire Configuration	Number Of Turns per Phase	Effective Wire Area mm^2	Approx Current Rating Delta/Star Amps
100S	1.0	Series	616	0.79	12/8
100 SP	1.0	Series/Parallel	88	5.50	84/56
100 P	1.0	Parallel	44	11.00	168/112
80 S	0.8	Series	1610	0.50	4.5/3
80 SP	0.8	Series/Parallel	230	3.52	32/21
80 P	0.8	Parallel	115	7.04	64/42
60 S	0.6	Series	2380	0.28	2/1.5
60 SP	0.6	Series/Parallel	340	2.00	14/10
60 P	0.6	Parallel	170	4.00	28/20

Changing from an **S** to a **SP** increases the wire area by 7 times and reduces the number of turns by 7 times. The operational performance will therefore be at seven times the speed and good for 7 times the current. Likewise, changing from an **S** to a **P** increases the wire area by 14 times and reduces the number of turns by 14 times. The operational performance will therefore be at 14 times the speed and good for 14 times the current.

The Smart Drive rotor provides excellent cooling, it is very unlikely overheating will be a problem. The max currents indicated in the above table should not be taken as the continuous operational current rating but the absolute maximum that the unit can deliver. Continuous operation should be at less than the above values. Some of the values in the above table, 100SP for example, will require rpm's much higher than the maximum recommended running speed of 1800 rpm.

It is possible to reconnect the units into more configurations. The nine options presented here have been adopted as the reconnections utilize all 42 fingers of the unit. Other options such as a third in series and two-thirds parallel would use 36 fingers and would yield a performance between the SP and P configuration. The Smart Drive units can therefore be tailored to you exact requirements.

The unit you manage to obtain will have a certain wire size. If you locate a unit with 0.8mm wire size then this unit is referred to as an 80S model. From this model you can make either an 80SP or 80P. You will need to decide which model you wish to make; this will depend on the operational speed and power you require for your application. You should peruse the performance graphs in order to determine this. Refer to the summary graphs for all models grouped by voltage 12/24/48.

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Decide which voltage system you intend to use. Avoid 12-volts if possible as such systems have high inherent losses. Most countries telephone exchanges are run on 48-volt systems. These telephone companies are a good source of equipment such as second hand batteries, charger/rectifier sets (for generator charging your battery bank), cabling, inverters, cabinets, meters, and on occasions PV panels. If you choose a 48-volt system then there is a good chance you can scrounge retired equipment from them. For these reasons EcoInnovation installs predominantly 48-volt systems. Also 48-volt systems have higher generator efficiencies and fewer losses in cabling and rectification.

12 and 24-volt systems are very common and the cheaper type square wave inverters from Taiwan are readily available at these voltages.

Once you have decided the system voltage, you need to select a performance curve that meets the requirements of your application.

The performance of the units can be tuned by packing the magnetic rotor up from the fully home position; this reduces the magnetic field strength and increases the operating speed on the units.

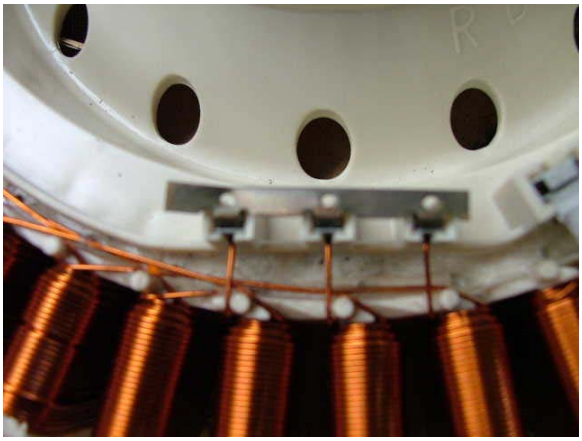
The following examples should assist you in selecting the correct Smart Drive for your application.

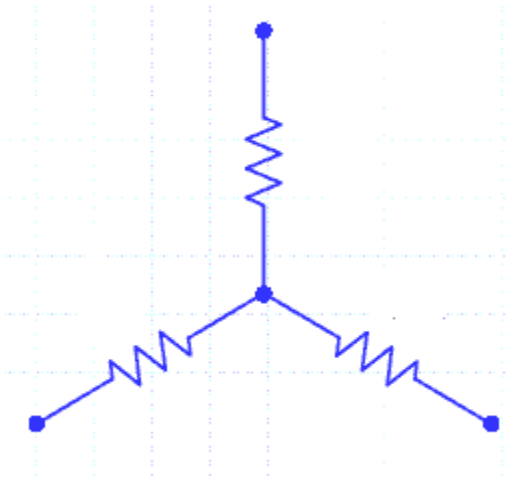
Star and Delta Connections

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.

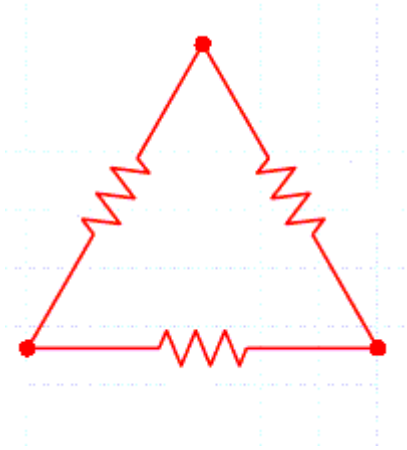
Many readers will be unaware of the two types of connection that 3-phase motors and generators can be configured into, theses are commonly referred to as Star or Delta. How the unit is connected has a significant bearing on the operating performance of the units, therefore each unit can be configured 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.

Smart Drive Star Point





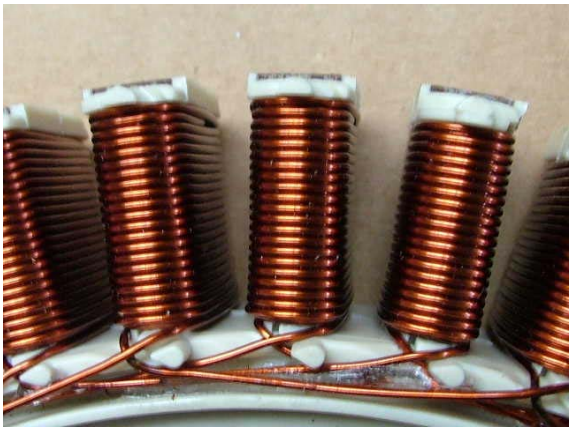
Star Connection



Delta Connection

First Generation stators (100S Star units)

These units can be recognised quickly by the wire diameter used to wind the stator. It is approximately **1.00**mm diameter and **S**eries wound in **Star** hence the name **100S Star**.



Resistance of each phase = 1.0 ohms

Second Generation stators (80S Star units)

These units can be recognised quickly by the wire diameter used to wind the stator and their very tidy appearance. It is approximately **0.80**mm diameter and **S**eries wound in **Star** hence the name **80S Star**.

Resistance of each phase = 5.8 ohms

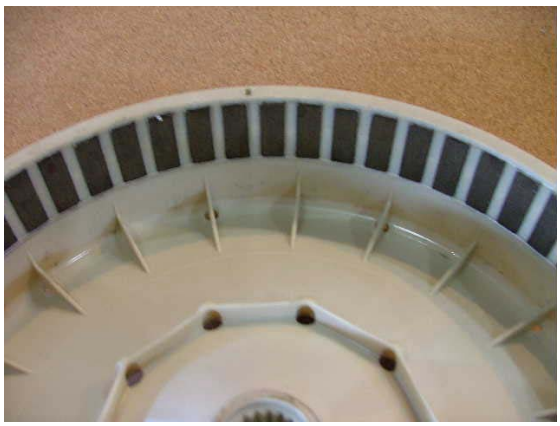
Third Generation stators (60S Star units)

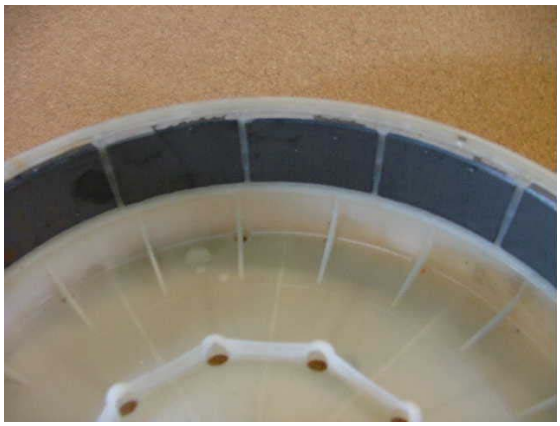
These units can be recognised quickly by the wire diameter used to wind the stator. It is approximately **0.60**mm diameter and **S**eries wound in **Star** hence the name **60S Star**.

Resistance of each phase = 15.2 ohms

Type One and type Two rotors

The early type one rotors are very distinctive with 56 separate magnets. These rotors are commonly found on washing machines that have 100S stators inside. The type two rotors appear to have 14 large magnets, this however is an illusion, as within each magnet there are in fact 4 separate magnets.





Type 1 rotor (old design) Type 2 rotor (latest design)

3 Phase Rectification

A Smart Drive is a 3-phase alternator. It has to be for it to be for brushless design. For DC output you need to use a 3-phase rectifier. You can either buy one or make one yourself. Single-phase rectifier blocks are very common, from three of these blocks you can make a 3 phase rectifier which is less expensive than buying a dedicated 3 phase unit. Car alternators also have inside them 3 phase rectifiers and shops that supply car alternators can supply you.

Automotive type

Electrical component type

DIY from 3 single phase rectifiers

On the automotive type unit shown the heat sinks are the positive and negative terminals, the three AC terminals are clearly shown.

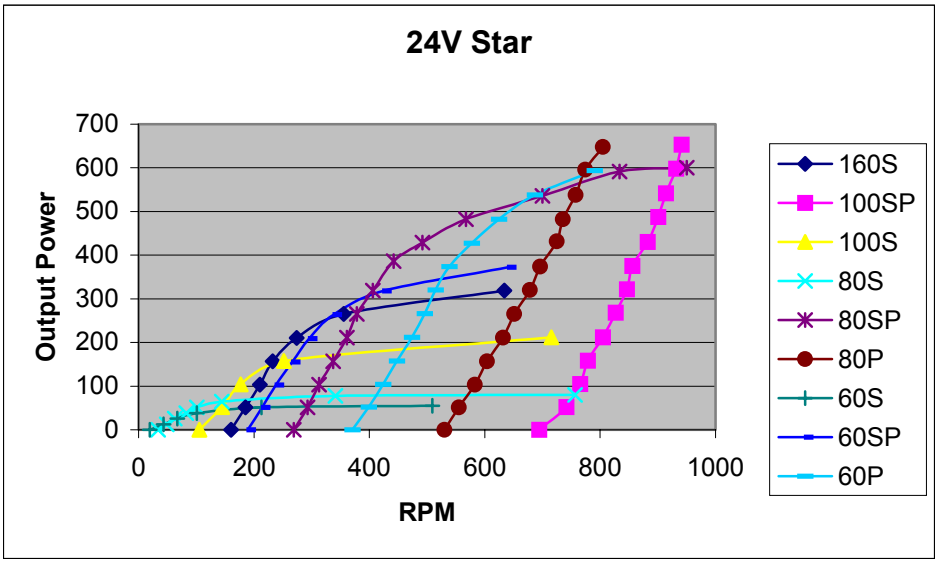
Electrical component 3 phase rectifiers can be expensive in the large sizes, these have 5 terminals as shown.

DIY rectifiers you can make yourself with 3 single-phase rectifiers at shown. Solder all the positives and all the negatives together and each phase onto the two AC pins on each single rectifier block.

Smart Drive Reconnections

After many years of experimenting with Smart Drive motors for use as generators EcoInnovation has developed a method of reconnection that is relatively straight forward, and provides secure connections with the option to finally connect the stator into either Star or Delta. You will need to purchase our reconnection manual to obtain how to do this and a full set of test graphs. A selection of a few of these graphs follow.

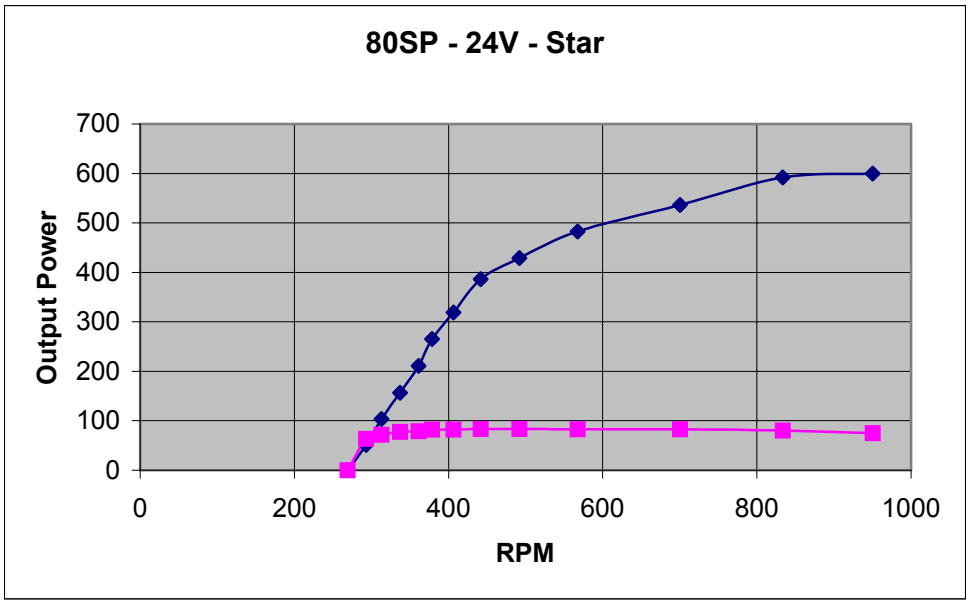
Smart Drive Test Result Summary Graphs
24 volt Star & Delta



Test Result Detailed Graphs

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

80SP Stator – 24 volt



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