Doin' It with DC

Bruce Johnson

Above: This old DeWalt radial arm saw has a 12 volt DC motor tucked inside the case of the original 220 volt AC motor.

When we began using wind power to provide electricity for our home twenty years ago, the inverters that are available today were not even dreamed of. If something couldn't be made to run on DC, then we simply didn't have it.

We get our power from a Whisper H900 wind generator and an assortment of PVs. The total PV output is about 300 watts. Our area of Oklahoma is excellent for solar and wind power. We're a middle aged couple without kids and we do fine without any generator backup.

System Loads and Equipment

Our loads include an RF12 Sun Frost refrigerator, basic lighting and electronics, a washing machine, and the tools described in this article, among others. We use an EnerMaxer controller, which dumps surplus power to a water heating element. Our metering is very basic—we've got a voltmeter built from plans in *HP2* and an ammeter with a homemade shunt built from plans in *HP6.* Our modest battery banks include a pair of L-16s, a pair of T-105s, and some used standby batteries we recently acquired. Our water is pumped into a storage tank by a seventy-year-old Aermotor windmill and is gravity fed into the house.

Our home and all the outbuildings on our little homestead are built from recycled lumber. Having DC powered tools to cut and shape lumber has been very helpful. Going DC has saved us the expense of a large inverter. The increased efficiency of DC motors is an added benefit. In this article I will describe how I've converted a number of tools to run on DC. I'll start with some general discussion of things to consider and then describe each tool individually.

Not for Everyone

One of the wonderful things about home power systems is that each system can be built to suit the needs, skills, and finances of the owner. A system that would serve the needs of a poet might not work well for a welder.

Converting power tools to run on DC is not for everyone. If your system already includes a big inverter, then the extra trouble and expense of converting each tool to DC is probably not worth it. But if you are getting along fine using mostly DC and perhaps a small inverter, you might like the luxury of some stationary power tools. Converting them to DC could work for you, as it has for us.

Basics First

When I began collecting my assortment of used and homemade tools, I was careful to consider only those that were belt driven, with motors that were easy to remove. Tools that have the motor mounted internally are not good candidates for easy conversion. The conversion process boils down to two basic problems—finding the DC motor that will efficiently do the job, and then figuring out how to mount the motor on your tool.

Motor Selection

There are four basic types of DC motors to consider—series, shunt, compound, and permanent magnet. Each of these motors is defined by the way the magnetic field is wired and produced. (*HP34* has an excellent article on electric motors.)

In a series wound motor, the field is wired in series with the armature. Series motors have lots of starting torque. They are less efficient at high speeds and if not connected to a load, they can even rev up to the point of self destruction.

In a shunt motor, the field is wired parallel to the armature. Shunt motors don't have a lot of starting torque, but will maintain a constant speed, independent of load.

The compound motor is a combination of series and shunt. One field coil is in series with the armature and the other in parallel. Compound motors sort of average the best characteristics of both types.

The permanent magnet (PM) motor uses permanent magnets instead of an electromagnet to create the field magnetism. PM motors have the obvious advantage of not consuming any power to create the field. They also have good starting torque, though not quite as much as a series motor. A PM motor runs at a constant speed (whatever the designer wants), and that speed is proportional to voltage.

Second Life for Old Motors

The motors used on my tools all started out life doing something else. They've been obtained from surplus houses, flea markets, and salvage yards. Yes, you *can* buy a brand new low voltage DC motor, and many of the RE catalogues have them. I've never had to be in a hurry to convert any tool. This has made it easier to wait for the right motor to show up at a bargain price. Sometimes I've found the motor first and then decided what to do with it later.

It is important to know what the specifications in a catalogue or on the side plate of a motor mean so you can predict whether or not the motor will do the job you have in mind. The information should include the type of motor (series, shunt, compound, or PM), voltage, amperage, rpm, horsepower, duty rating, size and length of shaft, direction of rotation, and perhaps what type of mount.

Right: This six inch grinder runs on 12 volts DC.

I've found the PM motors to be the most useful, though I use some of the other types too. Usually, series motors are very high speed and not rated for continuous duty, so I use this type the least.

Voltage

The voltage of the motor should be compatible with your system. Generally, the voltage of a series, shunt, or compound motor should be the same as your system voltage. For example, if you have a 12 volt system, you

Below: Rear view of the grinder: The motor is an old generator from a Ford automobile.

Above: This twelve inch band saw is powered by a 12 volt Delco automotive generator.

should stick to motors rated for 12 volts. With PM motors, there is a little more latitude. You may use a PM motor rated for a higher voltage than your system as long as you don't let the motor draw more current than it is rated for. The speed and power will be proportionally less. For example, take a 24 volt, 40 amp, 2,000 rpm, 1 hp motor. It could be safely and efficiently used at 12 volts, 40 amps, 1,000 rpm, 1/2 hp.

Amperage

Do *not* exceed the amperage rating of the motor. That is what the brushes and commutator are designed for. If the motor specifications are not available, the gauge of the wires to the brushes can give you an idea of how much current the motor was designed for. All motors will draw more current when starting. It's the current that the motor draws when the machine is up to speed and doing work that is important. For a 12 volt PM motor you can figure 20 amps per 1/4 hp, and for 24 volts it will be 10 amps per 1/4 hp.

Motors with wound fields will consume slightly more. After each conversion, I always connect the tool to an ammeter and check what it draws. If the motor draws more current than it was designed for, it will overheat and be damaged. It is also very important that you use wire of adequate gauge for the volt and amp rating of your motor. Voltage drop caused by inadequate wire will kill an otherwise good conversion. Switches and circuit breakers must also be properly sized.

Duty Cycle

The duty cycle is closely related to the amp rating of the motor. If the motor is rated for continuous duty, then it should be able to run indefinitely at the rated current and not overheat. If it is rated at a 50 percent duty cycle, it will have to be off one minute to cool for each minute that it is on, and there will be a limit to how long it can be on. It's best to stick to motors that are continuous duty rated, if possible. When using a tool that has a motor that is not continuous duty rated, I'm in the habit of putting my hand on the motor periodically. If it's hot to the touch, I turn it off.

Speed, Direction, and Size

The speed that the shaft rotates is also an important consideration. If the tool you are converting is belt driven, there will be some latitude here because you will be able to adjust the speed of the tool with different pulley sizes. Most of the AC motors that you will be replacing will be 1,725 or 3,450 rpm, so DC motors in this speed range are the easiest to work with. It's difficult to make good conversions with high speed motors (over 4,000 rpm), so I avoid these.

The direction that the shaft rotates is also something to consider. A table saw running backwards won't make you the envy of your RE neighborhood. The good news is that most motors can be reversed quite easily. On a PM motor, it's as simple as reversing the polarity of the power. On series, shunt, and

Left: A 12 volt 1/2 hp 1,725 rpm Delco motor found at a flea market powers this belt sander.

Right: Another view of the belt sander showing the simple V-belt drive.

compound motors it involves reversing the polarity of the field coils in relation to the armature. Or, just by rotating the motor 180° on its mount, the shaft will be turning the opposite direction in relation to the pulley on the tool. On a few motors, the brushes are mounted at a slant rather than perpendicular to the commutator. This indicates that they were designed to operate in just one direction.

It's nice when the shaft size is something common like 5/8 or 3/4 inch (16 or 19 mm), but any size is usually adaptable. It is also good when the motor has a standard mounting bracket, but again, if that's not the case, it can be overcome with a little creativity. Sometimes the motors with oddball shafts and no mount are the best bargains. As I discuss individual tools, I'll give some examples of how to solve some of these problems.

Putting Words Into Action

Well, that's basic DC motor ground school. Now we'll head out and see how these things fly. With each tool (and a few non-tool items), I'll describe the DC conversion. While I will try to give as much detail as space permits, I think the *process* of conversion is probably more important than the details. Since we are dealing with used equipment, the treasures that you find will probably be slightly different than the ones I've found.

Many of the motors described here are from Surplus Center. The bad news is that none are listed in the current catalogue. So, the success of your project will depend on your own careful creativity. Remember to be patient. What I describe here represents twenty years of enjoyable tinkering.

Drill Press

An old drill press was one of the first tools I converted. I used an old automotive generator for the motor. Until about 1962, cars used generators rather than alternators. The construction of the generator is identical to a shunt wound motor. When it is used as a generator, the field circuit is completed by the voltage regulator. To use it as a motor, just complete the field circuit with a wire.

For some generators this will mean grounding the field terminal, and for others it means connecting the field terminal to the armature terminal. To distinguish one from the other, check where the other end of the field is connected (you will have to disassemble the generator to do this). If the other end is grounded, then the one that comes out through the case will have to be connected to the armature. If the internal connection is to the armature lead, then the field terminal will need to be grounded.

Right: The radial arm saw with the blade and blade guard removed, showing the newly fabricated aluminum plate that holds the 12 volt motor.

In *HP40* I described how I use one of these automotive generators to run our washing machine. Twenty years ago, old generators were cheap and easy to find. They are harder to find now, but they are still around and make a pretty good 1/4 hp 1,000 rpm motor. The rest of the drill press conversion simply involved making some angle brackets for the mounting. I used the V-belt pulley that was already on the generator.

Grinder and Band Saw

A six inch (15 cm) grinder and a twelve inch (30 cm) band saw also use old generators for motors. For the grinder, I wanted to increase the speed, so I used a six inch (15 cm) pulley on the motor and a two inch (5 cm) pulley on the grinder. The generators have an odd shaft size between 5/8 and 3/4 inch (16–19 mm). My six inch (15 cm) pulley had a 3/4 inch (19 mm) bore; so I used a piece of 3/4 inch (19 mm) copper tubing to make a shim for the pulley to fit snugly on the motor shaft.

On the band saw, I used the stock generator pulley and a seven inch (18 cm) pulley on the saw shaft. This runs the saw at a good speed for wood cutting. For metal cutting, I wanted to slow it down. The two inch (5 cm) pulley I had on hand had a 5/8 inch (16 mm) bore. The

Right: The rear of the eight inch table saw, showing the 1 hp 12 volt DC motor and power relay.

Left: This twelve inch planer is powered by a 24 volt 1 hp DC motor.

motor shaft was easily turned down to size just by running it and holding a file to the shaft. I mostly end up cutting aluminum, but when I need to cut wood, I swap the pulley back to get the higher speed. Angle brackets were used to mount the motor and a spring holds it in tension with the belt.

Cement Mixer
An old generator also makes a great motor for our three cubic foot (0.08 m^3) cement mixer. Again I just use the stock pulley. It draws about 15 amps when churning up a batch of concrete. It will run all day long and be barely warm to the touch, and is easily powered by two golf cart batteries. Since the mixer is not used very often, the motor is made to be easily removed so it is available for other seldom used tools.

Belt Sander
The six inch (15 cm) belt sander is powered by a 1/2 hp 1,725 rpm shunt wound motor I found at a flea market. I don't know what this motor came out of, but I considered it to be a good find for $15. It has the Delco name on it and weighs 50 pounds (23 kg). A few years later, I found another one that looked identical but was a 3/4 hp compound wound motor. Whenever I spot a motor at a flea market or salvage yard, I always look at the size of the wires coming out of it. If they appear to be #8 (8.4 mm^2) or larger, I take a closer look.

Radial Arm Saw
A few years ago I departed from the belt-drive only rule and tackled the conversion of a radial arm saw. The cosmic forces of the universe must have been in proper alignment or something, because this project came together nicely. I started with a sturdy old DeWalt saw that had a 3 phase 220 volt motor. As I was contemplating the project, the yearly Surplus Center catalogue arrived and in it was a 12 volt 1 hp 3,600 rpm PM motor with a 5/8 inch (16 mm) shaft. The price of $97 was a little steeper than I was used to, but the specifications were exactly what I wanted.

I began the conversion by disassembling the DeWalt motor and removing the field coil assembly from the case. Then I made a new end plate of 3/16 inch (5 mm) aluminum with a hole in it for the shaft of the new motor. The PM motor had a mounting bracket welded to the case which I cut off with a hacksaw. It also had tapped holes in the end plate, so I bolted it to the new end plate I had made for the motor housing. It was fortunate that the diameter of the PM motor was just slightly smaller than the case of the old motor so it could just slip inside.

The radial arm saw requires a left hand threaded bolt to hold the blade tight. I bought a 5/16 inch (8 mm) tap and cut threads in a 1/4 inch (6 mm) hole I drilled in the end of the motor shaft. I couldn't find a left hand threaded bolt anywhere, so I bought a left hand threaded die and made my own bolt.

The saw originally had a twelve inch (30 cm) blade, but I thought a ten inch (25 cm) blade would be more appropriate for the 1 hp PM motor. I made a new blade guard from aluminum plate. For ripping, I use a purchased hold down and anti-kickback system that is attached to the fence. I also mounted a heavy duty knife switch to turn the power on and off.

Table Saw
For the table saw, I used a PM motor. For several years I used a 1/2 hp motor I got from Surplus Center. This was fine for one inch (2.5 cm) lumber, but underpowered for two inch (5 cm) stock. I now use a 1

Below: When one motor isn't enough, try two. A second motor added to the walking tractor gives it enough power to pull a plow.

hp motor identical to the one on the radial arm saw. The extra power is especially nice when ripping. Thin kerf, carbide tipped blades help the saw run more efficiently. This motor came with a mounting bracket welded onto the case, and had a 5/8 inch (16 mm) shaft, so the conversion was very easy.

The table saw shares its motor with the electric rotary tiller for a short time in the spring. It doesn't make sense for a valuable motor to sit unused most of the time. So when I'm done tilling in the cover crop, the motor goes right back to the table saw. Designing mounts that allow a motor to be easily moved from one tool to another is a good money saving idea.

Planer

Several years ago we salvaged the lumber from a 100-year-old house. That gave birth to the desire for a planer in order to make the best use of this high grade material. We took a deep breath and purchased a new twelve inch (30 cm) planer from R.B. Industries. We purchased this machine without the AC motor. I already had a 24 volt 1 hp PM motor I found at a salvage yard. This motor had come out of a battery powered floor scrubber and at $5 it was about my best motor bargain ever. Mounting the motor was a simple bolt-up job. To provide the 24 volt power for the planer, I park my 12 volt tractor (see *HP53*) next to the planer shed and connect it in series with the 12 volt system in the shop.

This planer normally has a 3 hp AC motor, so the 1 hp DC motor might seem a little small. I don't know why, but a DC motor seems to have more power than an AC motor of the same rating. I don't think this is true of the 3 phase induction motors found in industry. But the single phase induction motors found in home appliances and shop tools gobble more power for the amount of work they do. As I use the planer, I check the ammeter so it doesn't draw more than the 42 amps it is rated for. If it does, I simply decrease the depth of the cut and do the job in two passes.

Two Become One

Another strategy to consider is to use two motors if you don't have one that is strong enough to do the job alone. This wouldn't make much sense if you were buying new equipment, but the rules are a little different for the tinkerer.

I couldn't find a more powerful motor for the walking tractor, so I simply added a second motor identical to the one on the machine. It has the same size pulley and drives the same V-belt. A three inch (7.6 cm) o.d. sealed ball bearing is mounted as an idler so the belt gets a good wrap around both pulleys. The second motor is easily removed, so when the extra power isn't needed I take it off and run with just one.

Right: This hammermill-type compost shredder is powered by a 24 volt aircraft starter motor run on 12 volts.

Air Compressor and Compost Shredder

Quite some time ago I ran across two surplus 24 volt aircraft starter motors. I run these on 12 volts and they have lots of power, though they are not nearly as efficient as the PM motors. On 12 volts they run a useful length of time before they get hot. A 12 volt starter motor would draw too much current and heat up too fast to be useful as a tool motor.

One of these motors powers an air compressor and the other a compost shredder. In both these applications, the high starting torque of the series wound motor is a real benefit. These motors had no mounting brackets or holes, so I made some big U-bolts out of threaded rod to fasten them onto angle iron mounting brackets.

Water Pump

We live in an area where brush fires are a threat during winter and spring dry spells. When we retired our '68 Datsun pickup from road service, we mounted two 60 gallon (227 liter) plastic drums on it for water. I rigged a DC centrifugal pump, and it became our homestead fire truck. The motor is a PM 1/2 hp at 2,800 rpm.

The DC pump that I converted had the impeller mounted on a shaft separate from its AC motor, and was fastened with a set screw. To mount the DC motor, I made a plate (like the one for the radial arm saw) and bolted it to the pump frame. The pump delivers about five gallons per minute (19 lpm) at 25 psi, and I'm happy to say that we haven't had to use it yet.

Ceiling Fan

One hot summer a number of years ago we were really longing for a good ceiling fan. I knew from a little experimenting that top speed for a 54 inch (1.4 m) fan should be no more than about 200 rpm. About that time the trusty Surplus Center catalogue arrived and it listed

Above: A 24 volt aircraft starter motor run at 12 volts powering this air compressor.

a motor rated at 48 volts, 2 amps, 800 rpm continuous duty. Knowing that speed is proportional to voltage made me think that it was just what I was looking for. Sure enough, it checked out at 200 rpm at 12 volts and draws 2 amps when going full speed. We usually run our fans at lower speeds using a speed controller and they produce a pleasant, quiet breeze and consume only about 10 watts.

When I saw how well it worked, I ordered four more motors (at $15 each) to make fans for every room and for the shop, too. This is another rule I try to follow: If I find a bargain, I stock up. Most of the time these things show up in the catalogue or flea market once and they never show up again.

Below: This surplus 12 volt DC motor made a neat conversion for a centrifugal pump.

A Little AC, Too

Our system has grown over the years and now includes a Trace UX1100 inverter. This gives us all the AC power we will ever need for home appliances and portable shop tools. One portable tool that most do-it-yourselfers use is the circular saw. Most of these draw 10 to 13 amps at 120 volts AC, which is pushing the capability of the inverter. I found the 5 1/2 inch (14 cm) Skil model HD5510 circular saw to be a very good tool. It draws 6.5 amps and works great on the inverter. I recently built a room addition using this saw and it breezed through hard, 100-year-old two by fours. I couldn't find a source for this tool locally, so I ordered it from Tool Crib of the North. Sears also sells an identical saw with the Craftsman label.

Still Crazy After All These Years

I hesitated some before writing this article, thinking that the new generation of inverters has made this information obsolete. But then I realized that if I were starting today knowing what I've learned from the last twenty years, I would probably still do things pretty much as I have. I hope this information will be useful to others. I'd be happy to answer any questions that you might have.

Doing it with DC has enabled us to do a lot on our small energy and dollar budget. All of our electricity comes from a modest wind and solar system. We have been off-grid for twenty years and have never owned or needed a backup generator.

Access

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