

Converting your gas car to electric is no shocker

By Shari Prange

The old advertisement said, "Your car is your freedom," but sometimes it feels more like indentured servitude. Actually, buying the car is only the beginning, followed by the registration, insurance, and inspections.

Then there's fuel. It seems like every time you get into the thing, it's thirsty. There isn't a gas station on every corner any more, and if you need diesel, you may have to hunt even further. This is especially inconvenient if you enjoy the solitude of life away from towns and cities.

Of course, you can put in your own fuel tanks at home. However, they can be as much hassle to refill as the car. And there are all the regulations about monitoring the tanks for leaks.

Then there's maintenance and repairs. An acquaintance of mine once said that you buy an internal combustion car over and over again—one piece at a time. And the newer cars are getting harder and harder for the home mechanic to work on.

The simple alternative

There is another option that can end your servitude: an electric car.

An electric car simplifies your life in many ways. The most obvious one is fueling. What can be more convenient than coming home and plugging in the car? No muss, no fuss. You don't have to go out of your way to find gas or diesel, and you don't have to deal with the regulations connected to home tanks.

Another beautifully simple aspect of the electric car is its maintenance—or lack of it. Say goodbye to the auto repair shop and the parts store. An electric car needs very little care, and

what maintenance there is can be done easily by the owner.

An electric car can simplify your paperwork, too. If you live in a state that requires smog inspections, you don't have to participate any more. Once the state classifies your car as "electric" on its main computer, you are exempted from smog inspections.

As a final bonus, an electric car is a pleasure to drive, because it's so smooth and quiet.

Electric cars today

The electric cars available today are conversions. A small number are new cars converted to electricity by manufacturers. These range in price from \$25,000 to \$150,000, and are generally sold to fleets, such as utilities.

For the average person who wants an electric car, a more economical option is to convert a used car, or have the conversion done by a mechanic.

So just what is involved in converting a car to electricity? First, you remove everything related to the internal combustion system: engine, exhaust system, fuel system, and cooling system.

Then you add a charger, battery pack, speed controller, motor, and a few other small bits and pieces. Let's take a minute to tour a typical conversion, and see what each part does.

The charger

The electricity comes into the car through a charger. The car doesn't care where the electricity originates—a public utility, a small generator, a solar array, or even a wind generator.

The most common chargers use 110 VAC (volts alternating current)/20 amps input. These are popular because the charger is small and light, and 110 volt power is readily available. If the

car has used up its entire capacity, this charger will bring it back to a full charge in about 12 hours. Typically, this means overnight. If the car is only partially discharged, it will come up faster.

There are also 220 VAC/30 amp chargers available. These will charge the car in six to eight hours. However, they are more expensive, some of them are large and heavy, and 220 volt power is not as readily available.

If you want to feed juice to your charger from a solar array, it will need to be a large stationary array. Solar panels on the car itself are not cost effective. Covering the entire roof of the car with panels and letting it sit in full sun all day would only provide about five miles worth of electricity, at a cost of about \$3,000 for the panels.

Batteries

From the charger, the electricity moves into the batteries. The typical conversion has a 96 to 120 volt battery pack. The size of the pack is constrained by two factors. Any less than 96 volts, and the car won't have adequate speed and acceleration to be streetworthy, nor will it have much range. Above 120 volts, compatible components have not been available (although 144 volt components are now coming out). Also, the added bulk and weight of the extra batteries tends to negate the gains in power.

The batteries most commonly used are 6-volt lead acid traction batteries, the same kind used in golf carts. Typically, they are rated at 230 amp/hrs, and weigh about 67 lbs. They are 6-volt batteries because there has not been a suitable 12-volt traction battery available until very recently. There are some 12-volt traction batter-

ies now on the market, but they are too new to know yet what kind of performance they will give.

They are lead acid batteries because any other kind of battery, at this point in time, suffers from one of two drawbacks. Either it is still available only as a laboratory test model, or it is several times more costly than lead acid. Gel cells require low current charging to avoid internal damage. Standard chargers commonly available do not provide the appropriate charging profile for gel cells.

Finally, they are traction batteries rather than starting/lights/ignition (SLI) or marine batteries. SLI batteries can provide high current, but cannot stand up to repeated deep discharges and charges. Marine batteries can take the charge/discharge cycle, but don't last very well when required to provide high current. A traction battery is intended to move a vehicle down the road, and it can handle both deep discharges and high current draws.

Key and throttle

Turning the key turns the car "on," just like a gas car, but nothing happens until you depress the throttle. Then a main contactor closes and electricity flows from the battery pack to the speed controller. A potentiometer, called a *potbox*, is connected to the throttle pedal. It sends a signal to the controller based on how far the pedal is depressed. The controller releases energy to the motor in proportion to the signal from the potbox.

Most controllers in conversions today are sealed solid state units which are very reliable and durable. They are also very efficient, quiet, and smooth in operation.

The controller operates by "chopping" the voltage from the batteries. It functions like a switch that turns the electricity on and off 15,000 times per second. How long each "on" pulse lasts is determined by the throttle pedal and the potbox.

Motors

From the controller, the electricity flows to the motor. In the old days, this might have been an aircraft starter or generator pressed into service in a car. These made great aircraft starters and generators, but lousy car motors. They were designed to operate at much lower voltages and higher rpm. In an automotive application, they were fragile and highly inefficient.

Fortunately, today there are reliable, efficient motors available that are manufactured specifically for electric cars. The most popular for conversions is the series brush DC (direct current) type motor. This motor operates well in the rpm, voltage, and current range of a passenger car. It combines efficiency with affordability, making it very practical for daily driving.

Permanent magnet motors show up most often in ultralight solar race cars. Although they are very efficient, their efficiency is limited to a narrow rpm band. This makes them suitable for endurance races at a constant speed, but not for the ups and downs of daily driving.

Brushless DC and AC units are also available, but at a significantly higher price. The motor itself may not cost more, but the complex control system it requires is much more expensive. These systems are generally only found in production cars or high-budget, high-performance race cars.

Other exotic motors, like exotic batteries, tend to be unavailable or unaffordable for the average person.

Adapter & transmission

The motor is mounted to the original transmission using an adapter. Typically, this adapter comprises one or two precision-machined aluminum plates, and a steel hub. The safest, most reliable hub type is the taperlock. This will not work loose like a setscrew hub.

Conversions are manual transmission cars. The clutch is maintained for safety reasons, and because it provides a much smoother ride.

Why no automatics? There are problems with power losses, delayed throttle response, and mismatched shift points in automatics that produce inferior performance.

What about direct drive? Many production cars use direct drive. However, in order to get acceptable speed and acceleration, they require battery packs of 300 volts or more. This puts them out of the reach of the average person.

From the transmission, the power goes to the wheels, just as it did in the gas car. The drive wheels can be front or rear with equal ease. What is not practical at this time is four-wheel-drive, due to the complexity and cost involved.

Performance

Okay, so here's this electric car. What can it do? Typical range for a 96 volt sedan is 60 to 80 miles. Some of the high-performance sports car conversions can stretch that to 80 to 100 miles. These miles are typical daily driving: some stop and go, some freeway, average speed about 40 mph. The top speed on a typical sedan is about 65 mph, and on a sports car it's about 85 mph.

Night driving is not a problem. A DC/DC converter taps the main battery pack for a few amps to charge a 12 volt accessory battery for lights, horns, etc.

Cold weather is not a problem, either. There are various types of passenger compartment heaters available. Both the cold temperatures and the heater will diminish performance somewhat, but probably only about 15%. There are happy electric car drivers in Maine, Quebec, Alaska, and even the Yukon.

Can they climb hills? You bet. For long continuous climbs, or very steep hills, or hills that require freeway

speeds, a high-performance conversion is recommended: a light, aerodynamic body, with a large motor and at least a 120 volt system. For intermittent climbs of a mile or less on a mild grade at reduced speeds, a typical 96 volt sedan is adequate. Climbing hills will reduce the car's range, under severe conditions (we're talking actual mountains here) by as much as 50%.

What about going downhill? Can that energy be harnessed to recharge the batteries? This concept is called *regenerative braking*. Although much experimentation has been done on it, there is not yet a satisfactory system available commercially. Some systems, like connecting a small alternator to a second motor shaft, simply aren't very effective. Others are not compatible with the available motors and controllers. Others are bulky and complex, and have a potential failure mode of full acceleration (not a good thing when you want braking action).

Also, for a great many people, regenerative braking would not fit their driving patterns. Most people live up high, and their main downhill stretch comes when they first leave home—and the battery pack is fully charged. The ideal application for regeneration would be a long downhill in the middle or at the end of the drive.

Time & money

What does it cost to convert a car to electricity? The cost in dollars is inversely proportional to the cost in time. On the low end, you can buy a bare-bones kit for around \$4,000, add another \$1,000 or so in batteries and miscellaneous materials, and spend about 200 hours of your time installing it. In this scenario, you will be responsible for designing the component layout and designing and fabricating things like battery racks and boxes, various mounts and brackets, and a wiring loom. You will also need to make any necessary suspension modifications.

This is the kit for the rugged individualist who wants the feeling of accomplishment that comes from creating the car with his own brain and hands.

On the high end, you can buy a completely prefabricated kit for about \$7,000, and add about \$750 for batteries and 40 hours of your time. This is the kit for the person who has other outlets for his creativity, and simply wants to get the car finished and on the road.

Once it's built, it will save you about 60% on operating costs. A conversion typically uses about 0.4 kwh (kilowatt-hours)/mile of electricity. The only other maintenance expense is replacing the battery pack at about four to five year intervals, and replacing the motor brushes at 80,000 miles.

There are also various tax benefits available. These change from state to state and from day to day, so check for the current information in your area.

Electric cars tomorrow

In the past four years, public interest in electric cars has increased enormously. With the increased public interest has come increased manufacturer interest. Where will it go from here?

Major manufacturers

The state of California has mandated that in 1998, 2% of the cars offered for sale must be zero-polluting, and that number increases to 10% by 2003. All of the major manufacturers have electric car programs in progress in order to meet this mandate.

American manufacturers, while publicly trumpeting their programs, have been fighting tooth and nail behind the scenes to overturn the mandate. They are concentrating their reluctant programs toward supplying electric vehicles to fleets in the hopes of meeting the mandate without really having to address the public market. With the exception of the GM Impact, these programs are producing production

conversions of existing gas cars, light trucks, and vans.

They tend to use AC drive systems, direct drive or automatic transmissions, and very high voltage packs of unusual batteries. All of this contributes to price tags from \$50,000 to \$150,000.

Quite probably, foreign manufacturers will be the first to offer production electric cars for the mass market. Peugeot and Fiat already offer such cars in Europe. The Japanese and Korean manufacturers are also developing mass-market electric cars. Potential prices for these are unknown, but are likely to be much closer to the \$15,000 to \$20,000 range.

Initially, all of these will be electric versions of existing gas cars, simply due to the time and expense required to tool up for a completely new chassis. As the market grows to support the effort, cars designed from the ground up will appear.

Will private conversions continue? Of course. Americans have a genetic need to modify their cars. The hot rod controller will simply replace the hot rod carburetor.

Components

It seems likely that there will be two parallel tracks of electric vehicle technology for some time. The major manufacturers are concentrating on AC systems and exotic batteries. Due to the difference in cost, grassroots efforts are likely to continue to use DC systems and lead acid batteries.

This is not to say that there will be no improvements. Motors, controllers, and chargers that can handle DC systems up to 144 volts are now coming available. Also, as the market expands, prices will come down.

DC motor technology has been around for a long time, and has been refined to the point where efficiency differences between DC and AC motors are negligible. There are not

likely to be major breakthroughs in DC motors.

Where the improvements will come will be in matching the motor to the overall system. There are trade-offs between rpm and torque, speed and efficiency, and many other factors. With a systems approach, the motor can be engineered to provide the best match with the controller and the performance needs of the car.

Controller manufacturers are also looking to match their components better to the motors and the overall systems.

The debate in controller technology today revolves around MOSFETs (metal oxide semiconductor field effect transistors) and IGBTs (insulated gate bipolar transistors, pronounced *igg-bits*). These are the pieces that actually turn the electricity on and off inside the controller.

IGBT proponents claim higher efficiencies. IGBT controllers are also easier to manufacture, because fewer IGBTs are needed than MOSFETs to do the same job, and production can be more easily automated.

MOSFET proponents question the higher efficiencies in systems under 144 volts, which include most conversions. While fewer IGBTs are needed, each one is much more expensive than the MOSFETs. IGBT controllers tend to be bulkier and noisier, since they operate best at lower frequencies than MOSFETs. They also require more cooling.

It's too early to call the results on the MOSFET/IGBT debate, although it may evolve into parallel tracks like the AC/DC debate. At this time, the MOSFET technology is the more proven and established system.

Batteries

Everyone wants to know, "When will they come up with a better battery?" Like motors and controllers, the battery debate divides into parallel tracks.

On one track are the exotic batteries: sodium sulphur, nickel metal hydride, silver zinc, lithium polymer, and more, too numerous to mention. Each has its proponents. In fact, the U. S. Advanced Battery Consortium was formed to examine and sort out these technologies and develop a better battery to meet the California mandate. The energy-to-weight goals set by the USABC eliminate lead acid from consideration.

There is considerable debate regarding whether any of the exotic technologies can be developed to a marketable stage in time for the mandate, and whether "marketable" is measured by the fleet market or the public market.

On the other hand, there is the Advanced Lead Acid Battery Consortium. This is a group of lead acid manufacturers who have pooled their research efforts to show that lead acid is a more viable immediate alternative.

There are a great many advances being made in lead acid technology. These include new grid alloys for longer life, super-thin plates to minimize heat problems, and radically revised architecture that may give us batteries shaped like thermos bottles.

While the advanced lead acid batteries can't approach the energy-weight goals of the exotic batteries, they may provide the same energy as traditional lead acid batteries at half the weight—and about the same cost.

Like the motor and controller manufacturers, battery manufacturers are looking at how their product interacts with the whole system, especially the charger. In addition to developing lighter batteries that last longer, they are developing batteries that can accept a charge faster, and the chargers to match.

Battery charging time is limited by heat. Fast charging produces heat inside the battery, which shortens the battery's life. Gassing is caused by built-up heat literally boiling the electrolyte.

New battery designs can accept higher charging currents—briefly—without heat problems. New charger designs accommodate this by pulsing the charging current, giving the plates a brief rest between pulses. The charger may even insert a tiny discharge between charge pulses. This kind of technology is still experimental, but is expected to be in production within four years.

With pulsed quick charging, the car would still be charged primarily at home, overnight. Most people would rarely need the quick charge, but when they did, they could stop at a charging station and recover up to 80% of the battery's charge in 15 minutes or less. (The last 20% of the charge is the most difficult to do quickly without damaging the battery.)

The big picture

In the immediate future, for the average person, electric cars will primarily be conversions using improved versions of traditional DC and lead acid technology. Foreign manufacturers will probably be the first to offer mass produced electrics for the general public, with domestic manufacturers limiting their focus to fleets.

The performance of today's technology is adequate for most people's driving needs. However, as new technology becomes available, today's cars can be upgraded. Every time the battery pack is replaced, it will have more energy per pound and a longer lifespan than the pack it replaces.

The electric car is the only car that runs better the longer you own it.

Resources

For a list of businesses supplying conversion kits and components, conversion services, books and videos, and turnkey cars, contact:

Electric Vehicle Industry Assoc.
P.O. Box 59
Maynard, MA 01754
(508) 897-6740

For the location of an electric car club near you, contact:

The Electric Auto Association
(800) 537-2882

For information on tax incentives and legislation relating to electric cars, contact:

Goldschein & Gomez
Alternative Energy Consultants
221 "G" Street, Suite 207
Davis, CA 95616
(916) 753-8057 Δ