Using an Alternator in Renewable Energy Projects

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Alternator for a Maruti 800

During the summer of 2000, we attempted to hook an alternator up to a Nepali water mill (*ghatta*) to recharge batteries. A lot of our time on this project was spent working with alternators. We hope to pass on what we learned to others who may similarly not have a strong background in automotive mechanics.

A Rough Outline of How an Alternator Works

An alternator differs from a dc motor in that it contains no permanent magnets. Instead, there are two concentric wound coils of wire within the alternator: a stator coil (the outside coil which does not rotate) and a rotor coil (the inside coil, attached to the alternator's pulley, which does rotate). The rotor is also referred to as the alternator's "field."

An electromagnet is created when current flows through the field coil. The strength of the magnet is directly proportional to the amount of current flowing through the field. As the rotor moves clockwise, the resultant magnetic field sweeps clockwise through the outer coil of wire, and electricity is generated in the stator coil. Since the magnetic field sweeps back and forth through the stator coil, an alternating current is produced. The alternating current has a frequency equal to the frequency with which the alternator's pulley is rotating.

For this process to begin, the alternator's field must start with some kind of current. Rotating the rotor coil itself does absolutely nothing, unless there is current flowing through the coil, producing a magnetic field. Thus, it is necessary to have the alternator hooked up to a battery to supply this initial current.

Since the purpose of the alternator is specifically to charge batteries, the alternating current it produces is rectified through a diode bridge. The resulting current is direct current, which can be used to charge an attached battery. This dc current can also be used to supply the field coil with current during operation. As a result, the field coil draws current from the battery only until the alternator is capable of producing its own electricity. Once the alternator is producing electricity, it is self-sustaining.

The voltage coming out of the alternator depends on two variables: the amount of current flowing through the field coil (i.e. the strength of the magnetic field) and the speed at which the alternator's field is rotating. The alternator has a regulator that tries to keep the voltage across the battery at a steady 14.4V (the optimal voltage to recharge 12V car batteries). It does this by regulating the amount of current flowing to the field coil. Once the alternator is self-sustaining, the only current flowing to the field originates from the alternator itself. If the output voltage is too high, the regulator lowers the current flowing to the field coil. If the output voltage is too low, the regulator increases the current flowing to the field coil. Simply put, as long as the alternator can maintain at least 14.4V across the battery, making the pulley spin faster or slower will have absolutely no effect on the power output. Power output in such a case will depend only on the load attached to the alternator.

It is important to take note that before the alternator is self-sustaining, the current flowing to the field is unregulated. The initial current depends only on the resistance of the coil, the resistance of anything placed in series with the coil, and the state of charge of the battery connected to the field coil. This is critical to understand if the alternator will be run at speeds lower than intended (below 2100 rpm).

How to Connect an Alternator to the Battery

There are four connections that must be made to properly hook up an alternator. The alternator's metal case serves as ground, and must be connected to the battery's negative terminal. There is a post at the top of the alternator; this is the positive post, through which current to the battery will flow when the alternator is operating. It must be connected to the battery's positive terminal. Two additional wires are also connected to the top of the alternator. These connect the regulator and the field coil to the battery.

It is important to determine which wire connects to the regulator and which goes directly to the field. This can be easily determined using a multimeter. Check the resistance between each of the wires and the case (ground). The connection between ground and the regulator will have a very high (near infinite) resistance across it. The connection between ground and the field will have a low (less than 100 Ohm) resistance.

The regulator connection acts as a kind of internal voltmeter for the alternator. With this wire, the alternator checks the voltage across the battery and uses feedback to the field coil to keep it at a constant 14.4V. An extra connection from the alternator to the battery is necessary to allow other voltage drawing devices (such as diodes, etc) to be connected in series with the battery. If the alternator only regulated voltage across its own output, the voltage would have to be split across all components attached to it, and the battery might not receive the ideal 14.4V. Thus, it is important that the regulator wire be attached directly to the battery's positive terminal, and not anywhere else.

It is equally important – perhaps even more so, actually – that the field coil wire not be attached directly to the battery's positive terminal. In a car, the field coil is connected to a switch, a small warning light, and then the battery's positive terminal. The switch isolates the battery from the field coil when not in use. This is important, as otherwise the battery will run itself down powering the field coil when the alternator is not operating. Some kind of switch should always be wired up in between the field connection and the battery. A simple push button (default off) switch can be very effective; to start the alternator, the switch is held down until the alternator becomes self-sustaining. At that point, the switch can be released, since current to the field is internally supplied through the regulator.

The light wired in between the field coil and battery is also very important. For one, it can be an important diagnostic tool, warning the operator that current is flowing from the battery to the alternator (i.e. the switch is closed, but the alternator has not yet become self-sustaining). Much more importantly, however, the light provides an additional resistance in series with the field coil. Current to the field coil is unregulated until the alternator becomes self-sustaining.

Some kind of resistance (not necessarily a light) must be placed in between the field coil and the battery. If the field coil is shorted directly to the battery, a very large current will flow through the field coil. With the alternator we used – the alternator from a Suzuki Maruti 800 – shorting the field coil to the battery drew over 3A. This kind of current is too high for several reasons. For one, it can damage the field coil, which may not be rated to handle such a high current. (We destroyed the field coil of one of our alternators this way.)

The second problem with a high initial current in the field coil is that it makes the rotor extremely difficult to turn. An electromotive force (emf) will oppose any change in current in the stator coil. The larger the change in current, the larger the opposing emf. If a large current is initially flowing through the field coil, even a low rotor speed will result in a large change of current in the stator coil. The opposing emf will make the alternator very difficult to turn. Once the alternator is turning, this emf will disappear; it is generated only by large changes in current, not large currents in and of themselves. However, the initial emf may be too large a force to overcome, and the alternator may never become self-sustaining.

The key is to choose the appropriate resistance to limit the initial current through the field coil. In the Maruti 800, the warning light limits the initial current to the field to 0.15A. The initial change of current in the stator coil is not large, and the emf is easily overcome. The alternator becomes self-sustaining, and the regulator then controls the current flowing to the field coil.

When the Maruti 800 starts, it initially idles at 700 rpm. The pulley ratio between the crankshaft and the alternator is 3:1. Thus, the alternator rotates at a minimum of 2100 rpm. The current in the field coil – 0.15 A – is enough to start the alternator at this particular rotational speed. If the alternator is operated at a lower rotational speed, however, a higher initial current is needed to produce enough electricity in the stator coil to start the alternator.

This, then, is the important trade-off when choosing the resistance to place in series with the field coil. Too high a resistance will limit the initial current and require a high initial rotor speed. Too low a resistance will create a very large initial emf, and require a low initial rotor speed with a great deal of torque.

Suggestions for the Would-be Alternator User

Ideally, the alternator will be run at the speeds for which it was engineered (2000-10000 rpm). In our case, however, we decided we could only run the alternator at half its minimum speed. We used three 22 Ohm resistors (each rated for 10W) in parallel, and this proved enough current to get the alternator running at lower speeds. We tried running it without any resistors, but found that the emf opposing the rotor motion was too great; the whole system ground to a halt under the load. We also tried connecting the original light from the Maruti 800. The resistance in this case was too high, and the system was unable turn the alternator pulley fast enough to turn the alternator "on."

If circumstances do not allow the alternator to be operated at its minimum intended speed, take time to carefully determine what resistance should be placed in series with the field coil. Make sure the resistors are rated for the amps being drawn from the battery. Use several higher resistance resistors in parallel if the amperage exceeds the rating. Once the alternator is self-sustaining, the resistors are no longer a factor in alternator operation; no current is being drawn through this connection.

Belt selection is a critical consideration as well. Our alternator was intended to run with an "A" size car belt (the smallest width). A good fit was very important to avoid slip, and we suggest that the proper belt be used with the alternator. If a different belt must be used, it may be a good idea to change the pulley on the alternator to correspond to the belt.

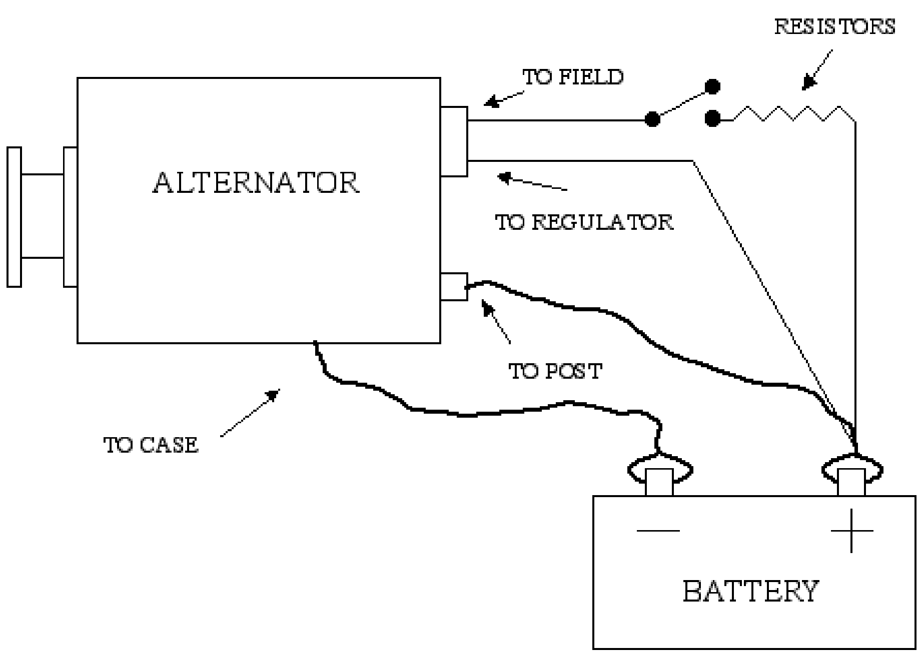
Safety Issues

Alternators must be connected in the way outlined above. Improper connection can seriously damage the electronics in the diode-bridge or regulator. Make certain that the terminals of the battery are not reversed. The negative terminal must be connected to the alternator's ground. Make certain that the alternator's pulley always rotates in a clockwise direction and not in reverse.

Never short the alternator's positive post to ground; if the alternator tries to maintain 14.4V across a short, the results could be disastrous. Never short the field coil wire to ground, either. This will short out the current in the field coil, and the alternator will cease operating.

Finally, alternator manufacturers do not recommend disconnecting the battery from the alternator while operating. In theory, there is nothing really wrong with this, as the alternator is not relying on current from the battery to sustain itself. However, the voltage can spike when the battery is disconnected. This spike can damage the alternator's electronics. In the course of testing, we did disconnect the battery during operation a few times (sometimes unintentionally), and did not observe any resulting damage. There was not much current flowing through the battery at the time, however, and our experience should not be taken to mean that damage cannot occur.

Review



Connections:

- Case is ground; connect the case to the battery's negative terminal.

- The metal post on top of the alternator flows current to the battery's positive terminal.

- The regulator connection (high resistance to case) connects directly to the battery's positive terminal.

- The field connection (low resistance to case) connects to a switch, then to resistors, then to the battery's positive terminal.

Important:

- The alternator turns clockwise.

- The battery’s negative terminal must be connected to the alternator’s case.

- The field coil should not be connected to the battery when the alternator is not in operation. Use a switch to isolate the coil from the battery when not operating the alternator.

- The field coil must have some kind of resistor connected between it and the battery. Shorting the coil directly to the battery will draw too much current and can destroy the alternator.

- If the alternator is not generating electricity at system speeds, try using a slightly smaller resistor in series with the field coil to provide more initial current to the field.

- The alternator regulates the output current to put 14.4V across the battery. If the alternator is producing 14.4V, running the alternator faster will not increase the power output of the alternator.