The Aircraft Charging System

How to avoid an unpleasant surprise when you push the starter button

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■■ Present-day electrical systems have become quite reliable. Unfortunately, reliability often is rewarded by obscurity and neglect. Consequently many pilots are rudely shocked when the starter button is depressed and nothing happens. A basic knowledge of the aircraft electrical system will generally prevent such unpleasant surprises.

The aircraft electrical system is wholly dependent upon its charging system. The charging system consists of three basic components—the battery, a generator or alternator and a system-regulating device. The battery is the auxiliary source of electrical power. The generator or alternator is the main source, and its function is maintained within desirable limits by a suitable control device.

The most commonly used aircraft battery is the lead-acid type which produces 2.2 volts in each of its six cells for a total of 13.2 volts (not 12 volts, even though it is usually referred to as a 12-volt battery). It is capable of accepting numerous discharge-charge cycles, although each charge will bring it up to slightly less than 100% of the previous charge.

Eventually the electrical capacity of the battery will be reduced to the point where it will not be able to start the engine. The useful life of the battery can be extended by proper care and operation, though. Here are a few hints on how to do it.

Keep your engine well tuned so that it will start quickly. If your aircraft is equipped with an external power receptacle and external power is available during cold-weather starts, use it. Change to the recommended lighter lubricating oils when ambient temperatures reach the changeover level. Remember, any situation that requires extra engine cranking will also exact an extra measure of battery life.

Do not allow the battery to become low on water and, when you do add water, add only clean, preferably distilled, water. Never add electrolyte solution; although this may seem like a generous idea, it upsets the original chemical balance, especially with new batteries.

If your battery is completely discharged, do not allow it to be recharged too rapidly. Many batteries are reduced from a normal service life by overheating from fast charging.

Do not allow your aircraft to sit around for months on end with no activity. The battery will gradually go down just from sitting idle; if it goes completely down you risk possible damage from fast recharging.

Keep the battery compartment and battery clean and dry. The battery will get damp on top and eventually that dampness will collect dirt. This condition causes self-discharge because the wet, dirty area between the negative and positive posts will conduct current sufficiently to cause a gradual discharge. It is this condition that causes battery posts and terminals to turn green and corrode. If the battery is kept completely dry and free of any conductive film, this corrosion will not occur.

Incidently, never allow a battery to sit upon the ground or a concrete floor. If the battery has been removed from the aircraft, it should be placed on a dry, nonconducting surface. A battery placed upon the ground or a concrete floor for any length of time will no longer function properly.

Once the engine has started, the electrical power is provided by the mechanical source. This could be a generator or alternator. We will limit our discussion to aircraft equipped with generators. The aircraft electrical system is direct current (DC) and, since the battery is a DC device, DC current must be used for the recharging process.

The generator is sometimes referred to as a DC generator, which it is not. It really produces alternating current (AC) but is equipped with a commutator and brush arrangement that mechanically rectifies AC to pulsating DC, which is compatible with current supplied by the battery.

The generator is a self-exciting machine, which means that it is able to begin generating electrical energy as soon as it starts turning. Once the generator attains the voltage desired, this internal excitation must be regulated or generator output voltage will increase with engine speed beyond desired limits.

Generators are usually rated according to their voltage and maximum current output. A typical example would be a 12-volt generator of 50-ampere capacity. Although such a unit is capable of its rated output on a continuous basis, its service is drastically reduced when operated above the 80% level. The generator is not able to limit itself to the safe amount of maximum current draw and subsequently would attempt to supply the demand placed upon it no matter how great. So this must be controlled as well as voltage.

Here are some ways you can add to the service life of your generator. When washing down the engine, always cover the open ends of the generator and specifically avoid getting cleaning solvents into the generator. Such solvents can wash away generator bearing and brush lubricants, causing a short service life.

Do not needlessly turn the generator switch on and off while in flight. Except for possible emergencies, never turn the generator switch off when the generator is heavily loaded or violent unloading and loading shocks to the generator drive train will be produced. The results are premature drive-belt, gear and bearing wear or possibly even breakage.

The generator installed on your airplane as it left the factory was normally adequate for all standard electrical equipment, plus a reasonable amount of add-on options. Even then there were more optional items available than the generator could handle. With all of the mandatory and optional electrical gear available today it is quite easy to overload the generators on many earlier airplanes. Take care not to install more continuously operated electrical equipment than your present system can handle at 80% generator capacity.

According to FAA regulations, the A&P mechanic is not supposed to install electrical equipment beyond defined limits, but don't count on that. You should know what the 80% duty cycle of your generator is and what the current draw is for each individual piece of equipment; then take care in your operating selection not to exceed that 80% capacity.

The third basic component of the charging system is generally referred to as a voltage regulator, and in the beginning that's exactly what it was. For the past 30 years it would be more definitive to call it a generator regulator instead. It performs three necessary functions.

The first is to prevent the battery from motorizing the generator. At low engine speeds, such as idle, the generator voltage will be something less than 13. Consequently, battery voltage being greater (13.2 volts), current would flow from the battery to the generator and attempt to turn the generator as it would an electric motor. To prevent this, a cutout relay is placed in the circuit between the generator and the battery. The relay is designed to close only when generator voltage reaches a desired minimum, which is always in excess of 13.2 volts. Let's say it is set to close at 14 volts; when the generator voltage reaches 14 volts, the relay closes the connection between the generator and the electrical system. Then power from the generator takes over the electrical load needs besides recharging the battery. The correct terminology for this device is "reverse current cutout," meaning that it prevents reverse current flow to the generator from the battery.

Two malfunctions are possible with this control. It can fail to close; under these circumstances, the generator will not be connected to the electrical circuit and the battery will supply the electrical power needs until it becomes exhausted (dead).

The other malfunction is to stick closed, which causes a battery drain any time engine speed drops below 1,200 to 1,400 rpm. This would be one area to check if chronic battery drain persists.

The second control is a current limiter. Earlier it was mentioned that the generator is unable to limit itself to the loads placed upon it. If the generator were to be loaded beyond its maximum output limit, it would quickly overheat and burn up. The current limiter is a second relay operated switch (points) connecting the generator to the electrical system. This control senses generator output and, if the load exceeds the maximum allowable, it opens the normally closed switch, thereby unloading the generator.

This control seldom causes trouble; however, should it fail to open in the presence of a generator overload, generator failure could result. Should it open, the generator will be disconnected from the charging circuit, leaving the battery to do all the work. The current-limiter is not designed to remain open on a continuous basis; therefore, should you carelessly overload the generator, the heavy arcing caused by continuous opening and closing of the current limiter points will cause burning and eventual failure of the points to close.

The third control is the actual voltage regulator. This is also a relay operated switch (points) connected in series with the generator field circuit. The switch—or points—of the voltage regulator control remains closed until generator output voltage reaches desired limits. When this limit—say 14.5 volts—is reached, these points begin opening and closing to hold the output to that specified limit. Two malfunctions are possible. If these points stick closed, generator voltage will increase with speed and on a 12-volt system this could exceed 36 volts at cruising engine speed.

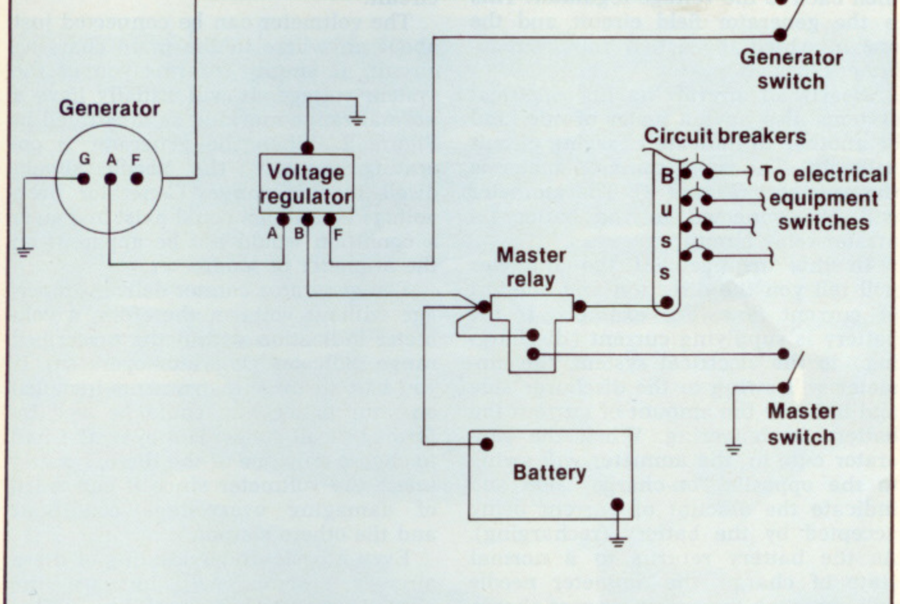
Needless to say, that could cause a lot of damage to electrical gear, especially avionics. But it sure makes the lights bright—while they last.

If the points fail to close, the voltage drops to a value so low that the generator ceases to be useful and the cutout relay will open the circuit.

All three of these controls are generally housed in one weathersealed unit, which, unless tampered with, enjoys a long and reliable service life. On more than one occasion the unit has been replaced when it wasn't really the cause of charging system problems. System failure might have been caused by corroded battery connections, mentioned earlier, or by failure to properly reground the engine to the airframe after an engine change.

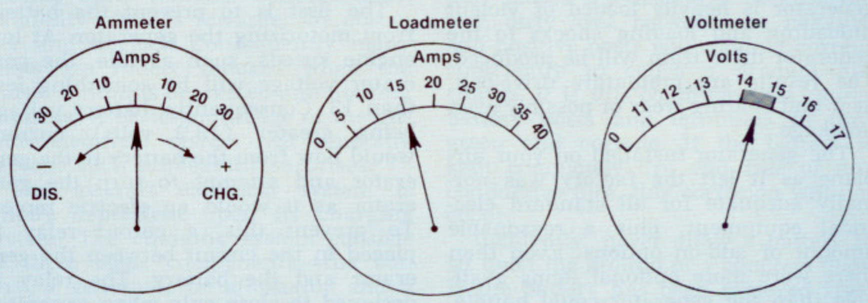
Now let's examine a typical single-engine aircraft charging system. Figure 1 illustrates such a system. In the

Figure 1



Typical DC Generator Charging Circuit

Figure 2



CHARGING SYSTEM continued

lower right-hand corner is the master switch. When it is closed, energy from the battery closes a heavy relay switch, the master relay, which allows current to flow from the battery to the buss bar. Connected to that are circuit breakers leading to switches controlling electrical equipment.

The lead connecting the master relay to the B terminal of the voltage regulator is the reverse-current cutout circuit mentioned earlier. The A terminal on the voltage regulator connects to the current-limiter circuit and current from the A (armature) terminal of the generator enters the regulator at this terminal. The F terminal on the generator leads to the generator switch, then back to the voltage regulator. This is the generator field circuit and the one in which the actual voltage regulator is located.

Nearly all aircraft having electrical systems also have a meter of one kind or another to indicate charging circuit behavior. The most common meter is the ammeter (Figure 2). The ammeter will be connected in the battery-to-master relay circuit.

In this arrangement the ammeter will tell you the direction and amount of current flow. For example, if the battery is supplying current (discharging) to the electrical system, the ammeter will swing to the discharge side and indicate the amount of current the battery is delivering. When the generator cuts in, the ammeter will swing to the opposite "on-charge" side and indicate the amount of current being accepted by the battery (recharging). As the battery returns to a normal state of charge, the ammeter needle will approach the center, or zero-charge state.

Should you lose the generator in flight, the ammeter immediately will indicate a discharge condition and the amount of that discharge. It can give you time to locate an airport and land before battery exhaustion.

The loadmeter shown in Figure 2 reads in one direction only and will be connected in the generator load circuit. This instrument informs you when the generator is delivering electrical power and exactly how much. With such an instrument there should never be any guesswork about the 80% generator load. If you know what maximum capacity is for your particular generator, you simply monitor the loadmeter when adding loads and avoid exceeding the 80% level. Naturally, the loadmeter would inform you of a generator-out condition by reading zero output when known loads were connected to the circuit.

The voltmeter can be connected just about anywhere in the main charging circuit. It simply informs you of the system voltage. It will usually have a normal range marking as illustrated in Figure 2. When the generator is operating properly, the needle should dwell in this range. Generator overvoltage conditions could exist and such a condition would not be apparent on the ammeter or loadmeter.

The generator cannot deliver amperage without voltage; therefore, a voltmeter indication within the prescribed range indicates generator operation. If you had all three instruments installed on your panel, you could be well informed at all times. However, if I had to choose only one of the three, I would select the voltmeter since it can warn of damaging overvoltage conditions and the others cannot.

Even a basic understanding of these aircraft systems will increase the pilot's operating capability. This knowledge could be even more valuable in the event of an emergency. □