Simplified Electrical Power Systems For Model Airplanes

By
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This following material[1] is intended to be a non-technical introductory guide to understanding and selecting model airplane electric power systems. Some liberties have been taken with precise definitions in order to provide practical and workable terms useful for developing electric power systems for model airplanes.

How electric motors work – An electric motor consists of a fixed magnet, a magnet that is free to rotate around the fixed magnet and a timing device that can turn one of the magnets on and off. The rotating magnet may be energized with the application of electrical current. By taking advantage of the inherent opposite-pole features of magnets and by arranging the two magnets properly the electric magnet can be switched on an off to cause mechanical rotation to occur.

Some recommended simple power guidelines:

Scale flying power requirements – 70 Watts per pound of loaded airplane.
Sport flying power requirements – 100 Watts per pound of loaded airplane.
3D flying power requirements – 130 or more Watts per pound of loaded airplane.

(These numbers are empirical and are derived from experience. They are generally accepted in the electric flying community as good guidelines to assemble an electric power system.)

An alternative approach to determining required watts:

Or, here is an alternative approach based on glow motor type and displacement provided by Greg Kamysz of Maxx Products (f http://www.maxproducts.com/)for picking the right power requirement when setting up a glow powered airplane with an electric power system that may be useful: [2]

"We can also approximate the required power based on engine displacement. A survey of available engines resulted in the chart below in terms of watt per cubic inch displacement (W/ci)

Sport 2 or 4 cycle engines	1250 W/ci
Ball bearing 2 cycle engines	1500 W/ci
High performance 2C/4C	1800 W/ci
Racing, ducted fan	4000 W/ci

> Multiply the displacement of the recommended engine by the W/ci rating to find the amount of power required of the electric motor system. For example; a .40 plain bearing engine will make .40ci X 1250/ci = 500W of power. Consider that many .40 size trainer models weight 6 lbs, the power loading works out to be 83 W/lb."

An example:

Assume that you have a glow powered kit (ARF or otherwise) that is intended for a 40 sized 2-stroke motor and is expected to weigh 5 pounds when ready to fly. Assume that you intend to fly the plane with an electric power system as a "sport" model, so it must do standard aerobatics easily and let's assume that we would like it to be capable of flying 10 minutes on a typical flight.

Assume that the weight of the plane with an electric system installed will be similar to the weight that would exist with glow power. This is usually close enough to work out the electric components that would be needed to fly such a plane. Our airplane manufacturer says the plane will weigh between 4.75 pounds and 5.25 pounds, so we will guess that 5 pounds is a good estimate of its weight with the electrical power system installed.

Wattage required (sport flying): 100 X 5 = 500 watts

Possible amperage and voltage (Lipo assumed) combinations to generate 500 watts at takeoff:

> 2 lipo cell pack: 2 X 3.7 = 7.4 Volts, 500/7.4 = 67 amps required
> 3 lipo cell pack: 3 X 3.7 = 11.1 Volts, 500/11.1 = 45 amps required
> 4 lipo cell pack: 4 X 3.7 = 14.8 Volts, 500/14.8 = 34 amps required.
> 5 lipo cell pack: 5 X 3.7 = 18.5 Volts, 500/18.5 = 27 amps required
> And so forth.

Something should be said here about weight of the packs as they increase in size. The following information is based on Hyperion CX 18C/30C Lipoly cells (http://www.allerc.com/index.php?cPath=3_4_93) :

Pack Size	Voltage	Capacity	Weight (OZ)	Weight/cell
2S	7.4	4250	7	4
3S	11.1	4250	11	4
4S	14.8	4250	13	3
5S	18.5	4250	17	3

Notice that the weight per cell is around 4 ounces in these packs. If we add a cell to a pack, we also add a nominal 3.7V to the pack, which if we assume a 30 amperage load produces 3.7 X 30 = 111 additional Watts. Under our sport assumption of 100 Watts/pound of power required, the 111 Watts would add a weight carrying capacity of 1.1 pounds. So, we gain about 3 to 4 times more power than we do weight for each additional cell added. So, unlike glow or gas power options, usually an additional cell in electric flying is more than covered by the additional power provided.

Assume that we want to use a 40 amp speed control which is rated to handle up to 4S voltage. For best efficiency, this would mean that we would need a 4 cell lipo power set-up in order to safely develop the 500 watts necessary to fly the plane as a sport flyer. Also, this 4S pack may provide too much voltage to use a BEC on the speed control so we may need a separate BEC or we may need a separate on-board battery to power the receiver and the servos. If we had chosen a 3S pack, we probably could have used the BEC in the speed control to deliver power to the servos and the receiver. The BEC in most speed controls currently available will only work in 3S or smaller voltage packs. A limited number (called “switching BECs”) are becoming available that can handle more voltage and still provide proper voltage to a receiver.

We also need a battery with a discharge capacity (C rating) that will meet or exceed the expected 34 amps provided in our calculation and that will provide the needed 10 minutes of flight. Let’s assume that for an average flight we will require 50% of takeoff power or 250 watts of power (50% if full power). That means that we would be drawing about ½ of the 34 amp takeoff power or 17 amps on average during a flight. So, 10mins/60mins X 17 = 2.8 amps for a flight. This means a 2800 milliamp capacity battery. Remember that the battery discharge rating (C rating) is a function of the Mah capacity of the battery. (Required discharge capacity {takeoff amperage rate} = (C) (Mah of pack in amps). Or, to solve for the needed C, C = (takeoff amperage rate)/ (Mah of pack in amps) = 34/2.8 = 12.1. So our battery needs a minimum C rating of 12.1, needs to be a 4 cell lipo with a minimum of 2800 milliamp capacity. Probably a 15C 3000 4S1P pack would work nicely in this application. Alternatively a 15C 3000 4S2P pack consisting of 8 lipo cells each with a 3.7 volt and 1500 Mah capacity would provide the same thing. A table provided at the end of this paper provides this calculation in a simplified format.

Lastly, we need to select a motor that will be capable of delivering at least 500 watts of power. I would usually choose a 600 watt motor in a situation like this to provide some slack. One nice thing about electric motors is that the weight penalty paid for installing a slightly larger motor is usually quite small, and the slack provides some flexibility in final set up. I have a preference for outrunner motors as well, since they run slowly enough to eliminate the need for a gearbox to obtain efficient propeller speed.

After the power system is installed, set-up will always require running the power system with a variety of propellers to obtain the takeoff amperage that was planned for the system. Propeller loading (and therefore amperage draw) can be changed by altering either the diameter or pitch (or both) of a propeller. Don't skip this important step before you go flying. Establishing the proper amperage rate will protect your entire power system from damage and will give you the sport performance that you planned for at the beginning of this exercise. *One should be sure that the propeller selected is stressed for the rpm intended. For example, APC notes in the safety section of their website (http://www.apcprop.com) that the maximum rpm for their thin electric props is equal to 190,000 divided by the prop diameter. This also includes folding propellers. The maximum rpm for a slow flier prop by APC is equal to 65,000 divided by the prop diameter. This means that a 10 inch diameter thin electric may be run to a maximum rpm of 19,000 while a slow flier prop of the same length could only run a maximum of 6,500 rpm.*

The easiest way to take the amperage measure of a system is with a watt meter, several of which are available on the hobby market. I use a meter sold by Astro Flight, (http://www.astroflight.com/) but many other good meters are around. The meter is temporarily installed between the battery and the speed control and when the power system with the propeller installed is run a full throttle, the meter will provide the amperage information you require to make a final propeller selection.

After setting a proper amperage load to deliver planned watts, some flyers also prefer to use a tachometer to verify the actually rpm and thrust that the system is generating at the propeller. One should remember that such an rpm measure is static and that propellers unload in flight between 10% and 25% so the static rpm is only an approximation of the rpm that would be obtained in flight. One thrust calculator has been provided by the Licking County Radio Control Club at (http://www.lcrcc.net/thrust_calc.htm). Using the RPM obtained at full throttle in this calculator will provide an estimate of the amount of thrust that your power system will provide.

So, in summary our calculations have yielded the following choices:

- a 4S Lipo pack with a minimum C rating of 15,
- a 40 Amp speed control that is capable of handling 4S voltage,
- a separate BEC or a separate onboard battery to power the receiver and the servos and
- a brushless outrunner motor capable of delivering 600 watts.

Battery Calculation Table (Crib Sheet)

(With some attached explanatory notes)

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A/C Weight	**X**	*Watts/Pound*	=	Watts Required
Watts Required	/	*Pack Voltage*	=	T/O Amps Req'd
T/O Amps Req'd	**X**	0.5	=	Average Amps Req'd
Average Amps Req'd	**X**	0.170	=	Min Battery Amps
T/O Amps Req'd	/	Min Battery Amps	=	Min C Rating

Note:
Items in italics need to be provided by the table user. Everything else is calculated or known. To compare with the example below use Lipo 3.7V per cell.

The above table assumes a minimum desired flight time of 10 minutes and an average amperage rate during the flight of ½ of takeoff amps.

Glossary

Amperage (Amps) – The flow of electric current in a circuit

Amps/hour (Ah) – The capacity (of a battery) to deliver a flow of electrical current per hour or for an hour.

Battery – A combination of two or more cells. Cells may be combined in series, in parallel or both.

Battery eliminator circuit (BEC) – Normally this is a feature of most modern speed controls that provides voltage to a radio receiver eliminating the need for an on-board receiver battery. The use of a BEC is normally limited to 3S or smaller battery packs. BECs can be purchased that are installed separately from a speed control and are useful in situations in which the motor battery will be larger than 3S.

Brushed motor – An electric motor that receives its timing signals mechanically through an arrangement of contacts internal to the motor.

Brushless motor – An electric motor that receives its timing signals electronically from an external device. Since such a motor has no internal contacts which create some drag and friction, they are normally more efficient than brushed motors.

Brushless Speed Control – An electronic device that controls the speed of an electric motor and controls the timing of the electro-magnetic magnet in the motor to enable it to turn. May or may not provide a voltage tap (BEC) to power a radio receiver.

Cell – An electro-chemical device that provides a specific voltage, amperage capacity and discharge rate. For modeling applications cells are normally rechargeable.

C Rating – A battery parameter which expresses the capacity of the battery to discharge current without internal damage. The C rating is a function of the amperage capacity of a battery. For example, a lipo battery with 1000 Mah capacity (1 Amp) and a 20 C rating would be capable of discharging at 1 Amp X 20C = 20 Amps.

Inrunner motor – An electric motor in which the main shaft rotates within the case. These motors usually run at fairly high Kv ratings, so a gear box is needed in order to obtain an efficient propeller rpm. Gear boxes add drag and friction in a power system, and so are often less efficient.

Kv (1000 rpm per volt) – A motor design constant that expresses the no load rpm that a motor will attempt to attain when presented with a specific amount of voltage. A motor with 1000Kv when attached to an electric source of 11.1 volts will attempt to run at 1000 X 11.1 = 11,100 rpm. An efficient electric motor system will usually be loaded (through propeller selection) such that the motor runs about 80% of Kv.

Lipo: This abbreviation stands for lithium polymer and refers to a particular batter chemistry that provides 3.7 nominal volts per cell.

Outrunner motor – An electric motor in which the case rotates around the main shaft. These motors usually have a higher torque constant and run at substantially slower rpms than their inrunner cousins.

Parallel: Refers to a combination of two or more cells connected to one another positive to positive and negative to negative. Voltage for the pack would be the same as a single cell voltage in the pack and amperage capacity is additive. (This would mean that a 1S3P pack combining 3 lipo cells each with a 1000 Mah capacity would then have 3.7 volts and 3000 Mah capacity.)

Series: Refers to a combination of two or more cells that are connected to one another positive to negative. (In series, voltage is the sum of the cell voltages in the pack, amperage stays the same. This would mean that a 3S1P lipo, each cell of which has a capacity of 1000mah would have 3 X 3.7 = 11.1 volts and a Mah capacity of 1000)

Voltage (Volts) – The potential electric power in an electric circuit.

Watts – The total power in an electric circuit equal to the product of amperage and voltage. (W = (V) (A), A = W/V, V=W/A)

Notes:

1. A number of the members of the Valle Del Oro Flyers RC Club including Richard Kelly, Pete Granger, Bill Norwood, Millard Jones and Richard Medved read this paper and provided helpful comments. Errors however, remain the responsibility of the author.

2. This material was taken from a handout provided by Maxx Products International, LLC and was written by Greg Kamysz.