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Selecting Electrical Power Systems – Part Two
By Bob Aberle

The author selected Tom Hunt's successful original-design Acrovolt as the test model for this series of articles.

(Editor's note: In the March issue, Bob explained the background of how power sources for modeling are rated and specifically how electric motors have been related in power output to glow engines. He covered how to go about sizing, or matching, a specific-size motor to a given model's size, weight, and wing-loading parameters.

Bob provided a list of the various aircraft categories and explained how to measure motor input power, aircraft weight and power-loading considerations, wing loading and how it relates to flying experience and skill, and thrust factors. He included details of the motor-selection process, a comprehensive listing of Web sites containing helpful data, and a listing of computer programs that can help the selection process.

This month Bob gets into the details of the motor/airplane-selection process.)

IT'S TIME TO put all you've learned together with several examples of motor selections. Let's make a glow kit or glow ARF electric-powered.

Many popular glow-engine-powered full kits and ARF "kits" on the market can easily be constructed and/or assembled from scratch with electric power in mind. One such model is Tower Hobbies' "Perfect Trainer-20," or "PT-20" as it is generally called. It is intended for .15-.25 cu. in. glow engines. The PT-20 has 515 square inches of wing area, can weigh 3.5-4.5 pounds, and has a wing-loading range of 16-20 ounces/square foot (sq. ft.).

As a start, take into account that the wing area is 515 square inches (3.6 sq. ft.). Pick a wing loading for the intended skill level. Using Table 3, I picked "Larger trainer," with a range of 15-20 ounces/sq. ft. That is close to the wing loading cited for glow power.

Using an average, I selected 17.5 ounces/sq. ft. as my target wing loading. If I multiply that 17.5 by the 3.6 sq. ft. of wing area, I end up with a target weight of 63 ounces (just less than 4 pounds).

From Table 2 I selected 40-50 watts/pound for the power loading. Wanting a bit more in performance (with some reserve), I specifically selected 50 watts/pound. From that I multiplied 3.93 pounds (63 ounces) by 50 and obtained 197 watts. Since power is amps multiplied by volts, you can work backward using the power (watts) and the estimated motor current.

That motor-current figure will always prove to be the tricky part. It will be an estimate that is a compromise between how long a motor run you desire and how much current your specific motor can tolerate (known as maximum continuous current in motor specifications). This is where the ElectriCalc and MotoCalc motor-selection programs can really help you. For this application I decided on a range of 20.0-25.0 amps and 22.5 as an average. Since power (watts) equals current (amps) multiplied by volts, you can divide 197 watts by 22.5 amps and obtain 8.75 volts.

You can reach a voltage that is close to that figure by using an eight-cell NiMH or Ni-Cd battery pack. It would tend to fall in between two and three Li-Poly cells because the characteristic voltage is 3.7 volts per cell (not 1.2 as with Ni-Cd and NiMH cells). But this gives you a ballpark figure.

From this point you can look up your motor data on one of the six Web sites I listed last month. I generally go for the AXI brushless outrunner motors because they are available in many sizes, and I have found them to be extremely reliable.

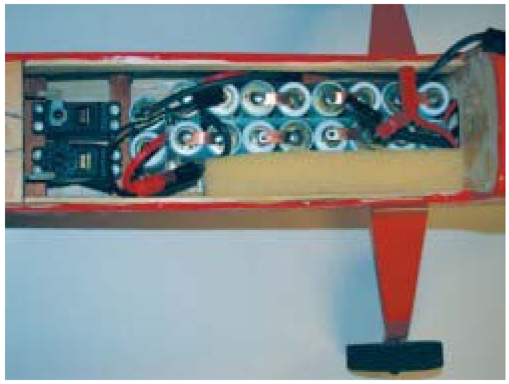
Closer look at AXI 4120/18 motor from rear shows accessory radial mounting plate which Bob highly recommends. Collar on shafts moves up flush with rear of motor.

For the average-size AXI motor I use “The Great Electric Motor Test,” at www.flyingmodels.org. I searched through the data looking at motor current, power (watts), and propeller sizes. You have to be patient because this can take some time.

I finally came up with an AXI 2820/10 brushless outrunner motor. On 8.0 volts and with an APC 10 x 7E propeller, it would have a current of 23.0 amps and 176 watts of power. The 10-inch propeller can easily clear the PT-20’s landing gear.

A battery pack consisting of eight Ni-Cd or NiMH cells should work. The Ni-Cd cells will likely produce slightly higher voltage, current, and wattage. A recommendation is an eight-cell Sanyo 1950 mAh NiMH pack, which will get me slightly over my target but allow me to do some throttling back during a flight. That will stretch the run time to longer than eight minutes. Not bad!

You can fly that PT-20 with this motor, propeller, and battery! As you progress, feel free to “what-if” your parameters in either of the two computer motor-selection programs. You can even work up to Li-Poly batteries by carefully selecting a propeller size that will allow you to use a three-cell pack, but not at excessive motor current.



How the Acrovolt's crowded battery compartment looked when Bob had to employ upward of 18 3000 mAh NiMH cells.

The same battery area today, after switching to Li-Poly!

Converting/Updating: Almost 10 years ago, Tom Hunt designed a large, aerobatic/Pattern, electric-powered model called the Acrovolt. It was inspired by Art Schroeder's Eyeball design from the 1960s.

I flew Art's Eyeball back then. I remember that it weighed 6 pounds with an Enya 60 glow engine. Tom designed his Acrovolt around the use of his then-new Modelair-Tech H-1000 belt drive and either a Speed 700 ferrite motor or a DeWALT 18-volt cordless-drill motor.

In 1995 the Acrovolt was powered by a 16-cell Ni-Cd battery pack, which was later increased to an 18-cell 3000 mAh NiMH pack. The weight at the time was roughly 7 pounds. The wing loading was high, and the motor run time was short—six minutes average with an occasional seven to eight minutes with some throttling! But at that weight, throttling almost got the model back on the ground!

That airplane stayed idle in my shop until recently, when a thought came to me while I was preparing this article. Here I had a .60 cu. in. glow-powered model (40-size by today's standards) that was converted to electric power using the technology that was available 10 years ago. How would the same airplane perform today with a modern and efficient brushless motor, an equally modern brushless/sensorless ESC, and, best of all, a lighter-weight/high-capacity Li-Poly battery pack?

Bob replaced old 2-ounce ACE RC Smart ESC (top) with new 1-ounce Jeti Advance brushless ESC (bottom). New ESC senses battery voltage at every start and automatically sets proper cutoff voltage point. This is crucial when using Li-Poly batteries.

The sequence of the selection process is the same as in the preceding. The 600-square-inch wing area is the same as 4.17 square feet. Referring to Table 3 I selected the skill-level category of the fast sport model (usually with more than adequate power), which calls for 20-25 ounces/sq. ft. of wing loading.

This was roughly the range I experienced with my Eyeball using a 60 glow engine at 6 pounds total weight. The older electric version—at 7 pounds—had a wing loading of 27 ounces/sq. ft., which I knew was way too high.

Top: The 18-cell 3000 mAh NiMH pack as used years ago to power the Acrovolt weighed more than 40 ounces. Bottom: New Kokam 5S2P Li-Poly pack weighs just 20 ounces. The motor run went from six to eight minutes to more than 20 minutes.

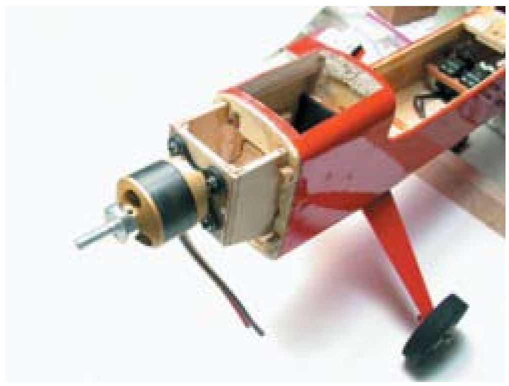
New square Kokam Li-Poly battery pack is mounted ahead of wing LE and before firewall. Because of lighter motor weight, Li-Poly pack's forward position proved to be necessary to maintain proper CG position.

Recognizing that the new motor and battery would save me a great deal of weight, I selected 20 ounces/sq. ft. as my target wing loading. If I multiplied that 20.0 by the 4.17 sq. ft. wing area, I ended up with a target weight of 83.4 ounces (slightly heavier than 5 pounds).

Looking at Table 2 I chose 80-100 watts/pound (for aggressive airplanes) as the power loading. Not wanting to go absolutely crazy, I selected the midrange number of 90 watts/pound. From that I multiplied 5.2 pounds (83.4 ounces) by 90 and obtained 468 watts.

Since power is amps multiplied by volts, you can work backward using the power (watts) and the estimated motor current. Again, the estimate of motor current is all-important and requires your knowledge and judgment.

For this application I settled on approximately 27.0 amps. With the older motor 10 years ago I ran 30.0-32.0 amps. I wanted to use less current this time because my airplane will weigh much less.



After removing DeWALT motor and belt drive, 3¼16 plywood box was made to hold new AXI 4120/18 brushless motor at roughly same prop position.

Upper view shows added plywood motor box and battery-pack position. Jeti brushless ESC is also in battery compartment.

Since power (watts) equals current (amps) multiplied by volts, you can divide 468.0 watts by 27.0 amps and obtain 17.3 volts. For this new application I wanted to use a large Li-Poly pack. Since each of these cells has a nominal 3.7 volts, the closest I could get to 17.3 was five Li-Poly cells (3.7 x 5 = 18.5 volts). I'll get into the Li-Poly capacity selection in a bit.

Having collected all of this information, I needed to select a brushless motor for my application. I mentioned that I favor the AXIs, so I went to their larger-motor data. The Web site containing The Great Electric Motor Test did not list the larger 41-series AXIs, but Dave Radford of Air Craft Inc. provided the data at www.aircraft-world.com/default.asp?id=18. After going through his AXI 41-series information, I settled on the AXI 4120-18 brushless outrunner.

The data specifically called for the use of an APC 12 x 8E propeller and 16 Ni-Cd or

NiMH cells (1.2 x 16 = 19.2 volts). The motor current given was 24.5 amps, and the power was 434 watts. For my purpose this was close enough for a starting point. To my surprise, the actual numbers came out closer to my estimate than the published data.

The photos accompanying this article show how easy it was to swap out the much larger ferrite motor for the brushless motor. Since the Li-Poly battery was much lighter, I was forced to move it farther forward (just behind the firewall) to maintain the proper CG location.

Flying the "revised" Acrovolt was wonderful. The final model weight was 85.3 ounces (5 pounds, 5.3 ounces), yielding a wing loading of 20.5 ounces/sq. ft. The actual motor parameters worked out to be higher than my predictions, but they were in the direction I wanted so I left them that way for my initial flight tests. The motor current was 28.5 amps, voltage under load was 18.0 volts, wattage was 511.0, the watts/pound figure was 95.8, and rpm was 8,600.

The Kokam 5S2P battery pack that I used consisted of 2.0-ampere-hour (Ah)-rated cells (15C-load capable). With two sets in parallel (2P), the actual capacity is 4.0 Ah. Total flying time obtained with this battery pack was approximately 20 minutes, with some throttling management. That means you don't run the motor all the time at full throttle.

In fact, the Acrovolt—now at an extremely light weight and with a high-performance power system—is capable of doing loops from level flight at half throttle. When the model landed each time at this power level, the motor, ESC, and battery pack were hardly warm. This was a perfect power-system choice in every regard! I ended up with a model that flew better than it did with a glow engine or the older ferrite electric motor.

Acrovolt went from 7 pounds to 5 pounds, 5 ounces. Motor run time was increased from six to eight minutes to more than 20 minutes. This was accomplished with new brushless motor and new Li-Poly batteries.

Original Acrovolt motor system, consisting of DeWALT 18-volt cordless-drill motor and Modelair-Tech H-1000 belt reduction drive. Motor and belt drive weighed 21 ounces!

L-R: Older, larger, heavier DeWALT motor with H-1000 belt drive and replacement Hobby Lobby AXI 4120/18 brushless outrunner motor. It weighs 11 ounces!

Estimating Motor Run Time: When you near the end of your motor-selection process, you need to decide what capacity of battery you want to use, regardless of whether it's Ni-Cd, NiMH, or Li-Poly.

Battery capacity is usually rated in mAh or Ah. Your battery's weight is directly related to its rated capacity. The more capacity there is in the battery, the more it will weigh. The motor-selection programs can help you considerably when making this choice.

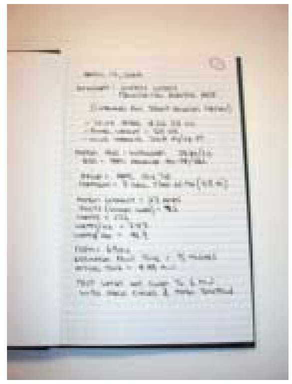
For a quick estimate, I use a simple formula. I multiply 60 by the battery's capacity rating (in Ah) and divide that by the motor current (in amps). The result is an estimated motor run time in minutes.

As an example, let's go back to when we were building a glow-powered kit as an electric-powered model. The battery had a 1950 mAh capacity rating, and the motor current was 23.0 amps. So multiply 60 by 1.95 Ah (the same as 1950 mAh), and divide that by the 23.0 amps. The answer is 5.09 minutes.

Keep in mind that these are static figures. When the model is in the air and the propeller unloads, the current will be less. Also, it is assumed that you will not fly the entire flight at full throttle. As I pointed out earlier, this model's actual flight time was approximately eight minutes. Nevertheless, this formula provides a rough starting point.

Keeping Records: One of the best ways to put your electric-power experience to good use is by keeping accurate records of your various aircraft. With new airplanes especially, I make dated entries in a bound logbook about the aircraft; electric parameters such as motor current, voltage, watts, watts/ounce or watts/pound, rpm, and run time; and flight performance.

As you progress with electric power, these records will provide practical comparisons when you choose power systems for new aircraft.



A page from Bob's logbook. Record data for each new or revised aircraft, and then you have something to compare to when visiting new, similar-size/weight aircraft.

Where to Get Help: When you get stuck and can't find that elusive electric power system, you will need some help. One place to find it is a model forum on the Internet that specializes in electric power, such as RC Groups, E-Digest, RC Universe, and SFRC. Hopefully you will reach an "expert" when you send out your question.

Contacting local modeling clubs that specialize in electric power is another way to learn. But if you live in a remote area, that may not be easy.

In the end, there is a group of many hobby distributors who will work with you, including Kirk Massey at New Creations RC ([936] 856-4630), Dave Thacker at Radical RC (www.radicalrc.com), Dave and Bob Peru at Balsa Products (www.balsapr.com), Sal DeFrancesco at Northeast Sailplane Products (www.nesail.com), Helmut Goestl of Dymond Modelsport (www.rc-dymond.com), and Tom Hunt at Modelair-Tech (www.modelair tech.com).

References: In the past two years I have authored a series of articles specifically about electric-powered flight that have been published in MA, and they are as follows. (You can find the "From the Ground Up" articles on the MA Web site at www.modelair craft.org/mag/index.htm.)

• "State of the Sport: Electric-Powered Flight": April 2002, pages 18-40.

• "From the Ground Up: Introduction to Electric Power": July 2003, pages 56-64.

• "From the Ground Up: Battery Basics": October 2003, pages 54-62.

• "Introduction to Lithium-Polymer Batteries: May 2004, pages 44-58.

I have also written articles that have been posted on MA's Sport Aviator online magazine. They are:

• "The SuperStar-EP Electric ARF" at www.masportaviator.com/ah.asp?CatID=1&ID=16. This is a review. SuperStar EP is similar to the Tower Hobbies PT-20 that I mentioned in this article.

• "Bonnie 20 ARF Electric Trainer" at www.masportaviator.com/ah.asp?CatID=1&ID=39. This is also a review.

• "Bonnie 20—Adapting to Li-Poly Batteries" at www.masportaviator.com/ah.asp?CatID =2&ID=43. This shows in depth how to convert a Bonnie from NiMH/Ni-Cd batteries to the new Li-Poly variety.

In addition, I wrote the book Getting Started in Backyard Flying, which is available from AMA. Pages 58 and 59 explain the process of measuring motor current using an AstroFlight

Super Whattmeter (part 101).

The process of selecting a motor system for a particular aircraft may seem overwhelming at first, but I assure you it's not! Follow the logical steps I have presented here; they work! I would love to be able to reference a single page or table and say, "That's the answer." Joe Beshar thought that was possible when he made his suggestion, but there are far too many variables with electric power.

Buy that meter and take your own parameter measurements. Buy a scale and weigh your aircraft; don't guess! Buy a tachometer and really see if you improved things! Buy one of the two recommended computer programs; you'll be amazed by how helpful they are.

If you hit a snag, please write or E-mail me. I will not only try to answer your detailed questions, but I will include those inquiries/
answers in MA's "Frequently Asked Questions" column if it will benefit other readers. Don't give up on electric power; get more involved! MA

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Manufacturers/Distributors:

Li-Poly batteries, chargers:
FMA Direct
www.fmadirect.com

Optics 6 RC system:
Hitec RCD
www.hitecrcd.com

Bonnie 20 ARF, AXI motors, radial motor mounts, Jeti controllers:
Hobby Lobby International
www.hobby-lobby.com

Acrovolt plans:
Modelair-Tech
www.modelairtech.com

Li-Poly charger:
Peak Electronics
www.siriuselectronics.com

TNC tachometer:
Skyborn Electronics
www.bktsi.com/

SuperStar EP, PT-20:
Tower Hobbies
www.towerhobbies.com/