

# Electric Power Systems

Presented By:

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# Why Fly Electrics?

## PROS

- No Mess, Easy Clean-up
- Less Noise
- Consistent Operation
- Low Cost Per Flight
- Easier than Glow
- High Power to Weight
- Lighter airframes needed due to lower vibration
- Easier to do Scale projects, no exposed engine parts

## CONS

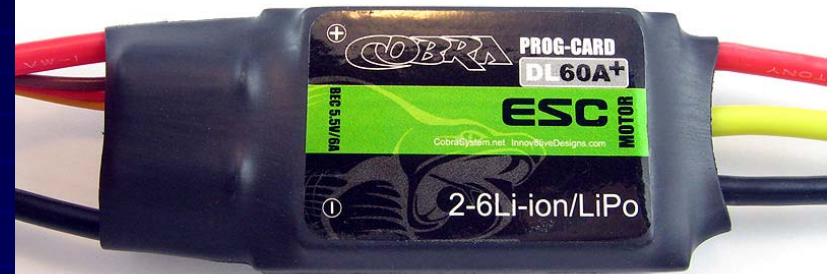
- Unfamiliar Technology
- Steep Learning Curve
- Soldering skills required
- Prop Selection is Critical
- Extra care must be taken around the props
- Motor will run until you shut it off, even after a crash
- Batteries must be cared for

# Basic Power System Overview

**Battery**



**Speed Controller**



**Motor**



**Propeller**



# Component Details

- Each part of the system has specific parameters associated with it that describe the part.
- For a properly designed power system, all of the components must be matched together.
- There are two types of electric power systems, Brushed and Brushless.
- For the sake of this discussion, we will only be discussing Brushless power systems today.

# Batteries



- Provide the power to run the motor
- Many different types are available today
- Lithium Polymer (Li-Po) most common
- Ni-Cad, Ni-NM, Li-Fe and A123 (LiFePo4) batteries are also used in some cases
- Each cell type has Pros and Cons associated with it
- There are 3 parameters used to describe batteries, Voltage (Cell-count), Capacity and Discharge rate

# Battery Voltage

- Voltage is normally expressed as a number of cells when talking about Li-Po batteries.
- Li-Po's have a nominal voltage of 3.7 Volts per cell, so a 2-cell pack is called 7.4 Volts, a 3-cell pack is 11.1 Volts, a 4-cell pack is 14.8 Volts and so on.
- Li-Po's should be left at 3.7 to 3.8 Volts per cell for long term storage of the battery packs
- Fully charged Li-Po's are 4.2 Volts per cell.
- The voltage drops under a load, and typically, it is around 3.5 volts per cell for most of the flight.
- Li-Po cells are considered depleted at 3.0 volts.

# Battery Capacity

- Usually measured in Milli-Amp Hours or mah.
- This is similar to fuel tank capacity in Glow models.
- The larger the pack, the longer you can fly.
- Battery capacity can also be given in Amp-Hours.
- There are 1000 milli-amps in 1 Amp, so a 2200mah battery can also be called a 2.2 AH battery.
- Typically, the battery size is determined by how long you want to fly per charge.
- Battery weight is directly proportional to capacity.

# Battery Discharge Rate

- Also called C-Rate, it is a measure of how fast you can pull energy from the battery without harming it.
- C is the Capacity of a cell. For a 2200mah battery, a 1C discharge rate is equal to 2.2 Amps.
- A 1C discharge rate will drain the battery in 1 Hour.
- A 2C discharge will drain the battery in  $\frac{1}{2}$  hour or 30 Min.
- To calculate flight time, you divide 60 by the C-rate.
- 10C = 6 minutes, 15C = 4 minutes, 20C = 3 minutes
- Early Li-Po batteries had discharge rates of 7C-10C.
- Current batteries come in 15C up to 65C.
- Most typical batteries are in the 25C to 45C range.

# Speed Controllers



- Takes the DC energy from the battery and converts it into 3-phase AC to power the motor.
- Virtually all Brushless power systems are 3-phase.
- 2 Parameters for ESC's: Max Voltage and Max Current
- Typically have a built-in BEC circuit to power servos.
- The Speed Controller should be sized to handle the full rated current of the motor.
- Speed Controllers need airflow to keep them cool.
- A larger speed controller not will harm the motor.
- Also called ESC's, short for Electronic Speed Controller (Not "Escapes" like the ESC key on a keyboard!)

# Speed Controller Settings

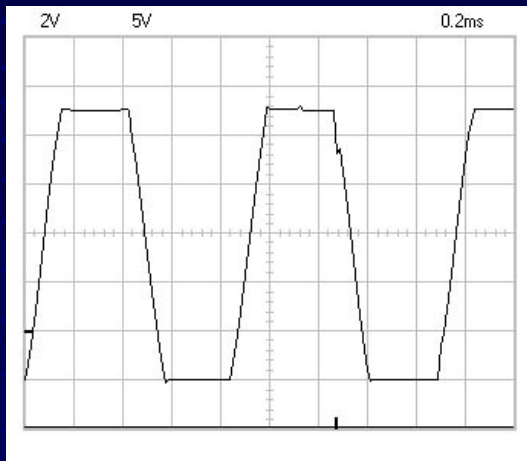
- Brake: Electrically stops the prop when motor is off
- Brake Level: How quickly the prop stops
- LVC: Low Voltage Cutoff, stops motor if battery gets low
- Cut-off Type: Hard (0% Power) or Soft (50% Power)
- Timing: Like timing in a gas engine to increase power
- PWM Frequency: How fast the ESC chops up the power to the motor to run at reduced throttle, 8KHz common
- Acceleration: How quickly the ESC responds to throttle
- Motor direction: Reverse motor without swapping wires
- Other parameters on more advanced speed controllers

# Battery Eliminator Circuits (BEC)

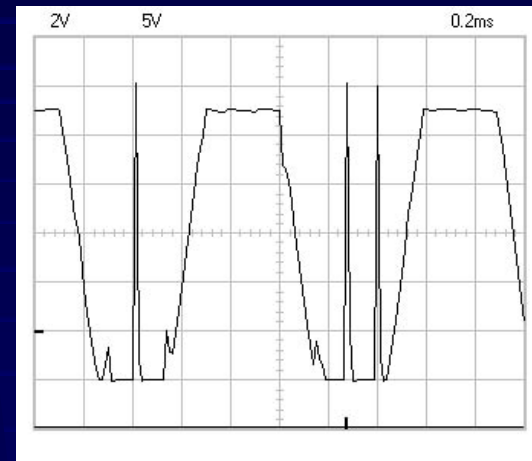
- Basically 2 types: Linear and Switching
- They drop battery voltage to 5v for Servos & Receiver
- Linear BEC's are typically seen in smaller ESC's
- They convert excess voltage to heat energy
- Must be de-rated as battery voltage goes up
- Typically must be disabled for use on 4 Li-Po cells
- Switching BEC's work by chopping up the input voltage into small pieces and filtering it out to get 5 volts output
- They are very efficient, up to 95%, so there is little waste
- They can work with a wide range of input voltages, and deliver full power, regardless of input voltage

# What a Speed Controller Does

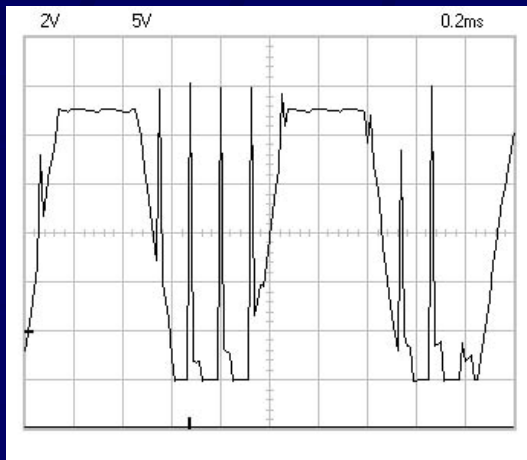
100%  
Power



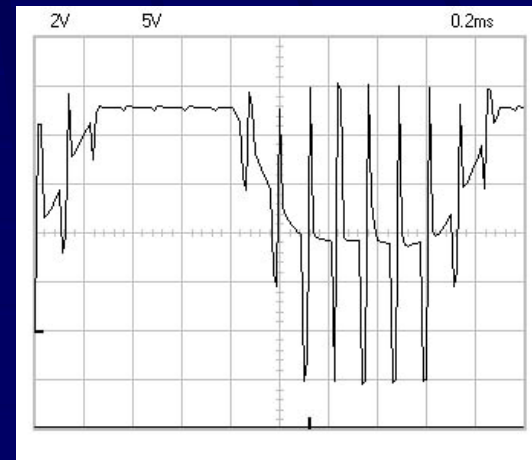
75%  
Power



50%  
Power



25%  
Power



# Brushless Motor



- Like name implies, no brushes or commutator
- Simple design, nothing to wear out except bearings
- 3-phase design is most common
- Typically 3 Parameters: Size, Power Rating and Kv
- Motor Size can be quite confusing since many manufacturers use different naming conventions
- Some use Stator Size to determine model number
- Some use Outside Dimensions for model number
- Some use glow motor size equivalents or even old brushed motor designations

# 4 “Different” Motors, Same Size

**Cobra  
2820**



**E-Flite  
Power 25**



**Leopard 3542**



**Torque  
2814T**



# Motor Parameters

- Current Rating: How many Amps?
- Current based on size of wire used to wind motor
- Power Rating: How many Watts?
- Basically a function of how big the motor is
- Power rating changes with voltage used
- Kv value: How fast does it Spin? RPM per Volt
- A 1000Kv motor will spin 10,000 RPM on 10 V
- Kv is the “No-Load” speed of the motor
- Kv has nothing to do with size or power output

# Electric Motor Vs Glow Engine

- How do Electric Motors differ from Glow Engines?
- Basically, they are exact opposites of one another
- Glow Engines are Constant Power Machines
- Electric Motors are Constant Speed Machines
- Glow Engines produce a given amount of power from burning gasses during each ignition cycle
- The speed of the engine varies with changing load
- Electric Motors try to spin at a constant speed
- The current draw of a motor changes with load

# Electric Motor Vs Glow Engine

- Glow Engines can be damaged by using a prop that is too small
- The Engine will speed up until something breaks
- Electric Motors can be damaged by using a prop that is too large
- The Motor will pull more current until it burns up
- Glow Engines push power into the propeller
- The prop pulls power out of an Electric Motor

# Electric Motors and Propellers

- The propeller is one of the most important parts of an Electric Power System
- Prop selection is critical for correct operation
- Aircraft performance is determined by prop used
- Every time you change the prop, you change the power output of an Electric Motor
- Choosing the wrong prop can destroy the Motor, Speed Controller or the Battery

# Examples of Power Changes When Using Different Props

## Cobra C2826/6 Motor Propeller Data

Motor Wind 6-Turn Delta		Motor Kv 1470 RPM/Volt		No-Load Current I <sub>o</sub> = 3.00 Amps @ 10v		Motor Resistance R <sub>m</sub> = 0.018 Ohms		I Max 65 Amps	P Max (3S) 720 W
Outside Diameter 35.0 mm, 1.38 in.		Body Length 46.0 mm, 1.81 in.		Total Shaft Length 66.0 mm, 2.60 in.		Shaft Diameter 5.00 mm, 0.197 in.		Motor Weight 171 gm, 6.03 oz	
Prop Manf.	Prop Size	Input Voltage	Motor Amps	Watts Input	Prop RPM	Pitch Speed	Thrust Grams	Thrust Ounces	Thrust Eff. Grams/W
APC	8x4-E	11.1	30.19	335.1	14,097	53.4	1331	46.95	3.97
APC	8x6-E	11.1	48.12	534.1	13,100	74.4	1530	53.97	2.86
APC	8x8-E	11.1	59.56	661.1	12,330	93.4	1351	47.65	2.04
APC	9x4.5-E	11.1	43.36	481.2	13,396	57.1	1925	67.90	4.00
APC	9x6-E	11.1	49.60	550.6	12,939	73.5	1831	64.59	3.33
APC	9x7.5-E	11.1	72.25	801.9	11,684	83.0	1811	63.88	2.26
APC	10x5-E	11.1	60.60	672.6	12,300	58.2	2201	77.64	3.27
APC	10x6-E	11.1	63.11	700.5	12,262	69.7	2364	83.39	3.37
APC	10x7-E	11.1	71.89	798.0	11,691	77.5	2453	86.53	3.07

# Determining Power Needed

- If you purchase an Electric Kit, you normally get a motor recommendation. This makes Motor selection easy.
- For powering a Glow model with Electric power, you need to figure out what size motor to use yourself
- For Glow to Electric Conversion, there are a few rules of thumb to follow:
  - 1 cubic inch of Glow Engine = 2000 watts Electric power
  - For a .60 size Glow Engine,  $2000 \times .60 = 1200$  Watts
  - For a .40 size Glow Engine,  $2000 \times .40 = 800$  Watts
  - For a .15 size Glow Engine,  $2000 \times .15 = 300$  Watts
  - For 4-stroke Engines, use 1500 watts per cubic inch

# Determining Power Needed

- Another common method to determine motor size is to use Watts of power per pound of aircraft weight
- For power gliders, 50 watts per pound is usually enough
- For trainers, like a PT-40 or AeroStar model, 75 Watts of power per pound works well
- For sport models, such as an Ugly Stick or Great Planes Sportster, 100 Watts of power per pound is enough
- For pattern planes and warbirds, 150 Watts per pound will provide good performance
- For 3D and competition Fun-Fly, 200+ Watts per pound will allow you to hover at  $\frac{1}{2}$  throttle and climb straight up

# Selecting a Battery

- After you determine power requirement for your model, you need to choose the correct size battery
- Volts x Amps = Power (Watts),  $11.1V \times 35 A = 388.5 W$
- Rule of Thumb: Current should be 2 to 5 times voltage
- Example: 3-cell (11.1 V) between 22 and 55 amps
- You can go lower current for longer run times
- Higher currents can be used for special classes such as pylon racing and limited motor run events

# Common Power Ranges

- 2-cell Battery – 100 to 300 Watts
- 3-cell Battery – 250 to 600 Watts
- 4-cell Battery – 450 to 1,100 Watts
- 5-cell Battery – 700 to 1,700 Watts
- 6-cell Battery – 1,000 to 2,500 Watts
- 8-cell Battery – 1,800 to 4,000 Watts
- 10-cell Battery – 2,800 to 6,500 Watts
- 12-cell Battery – 4,000 to 10,000 Watts

# Determining a Power System

- **Step 1:** Calculate the required Watts of power needed based on the weight and type of aircraft
- **Step 2:** Select an appropriately sized battery to provide the desired flight time
- **Step 3:** Choose the correct Motor based on the number of cells you are using and prop size
- **Step 4:** Select a Speed Controller to match the Motor being used
- **Step 5:** Select the right prop to get the desired performance of the model

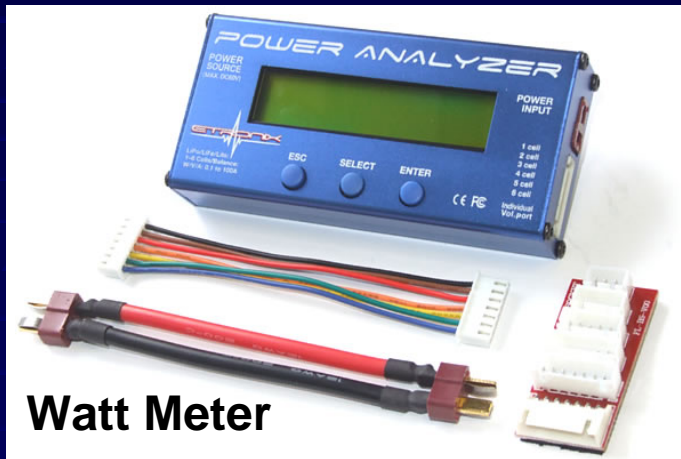
# The 80% Rule

- The 80% rule is the most important thing you will ever learn about flying electric models!
- Never run components at more than 80% of their maximum rating
- Virtually all problems with Electrics are caused by people pushing their system past 80% power!
- If a Motor is rated for 80 Amps, use 64 Amps Max
- If an ESC is rated for 100 Amps, use 80 amps Max
- If a Battery is rated for 4000mah, use 3200mah
- If a Battery is rated at 25C never pull more than 20C
- Following the 80% rule will ensure trouble-free operation and get the maximum life from your parts

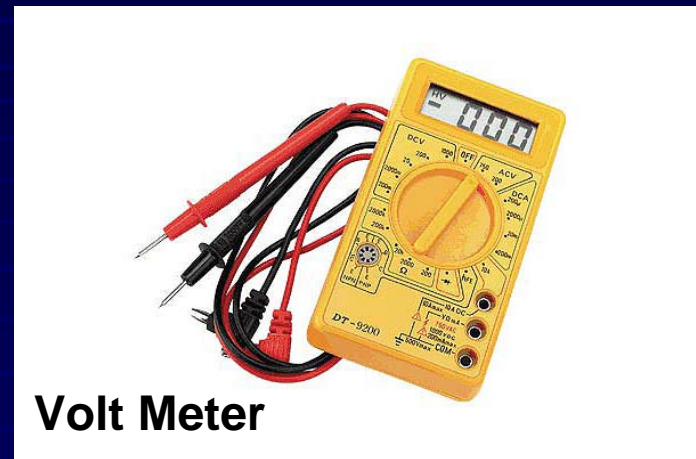
# Tools for Electric Flying

- Electric Flight does require some special Tools
- Not having the correct tools can cause problems
- Do not be afraid to spend the money on the required tools, it will actually save you money
- If you burn up 1 Motor or Speed Controller, it will cost you more than all the tools put together!

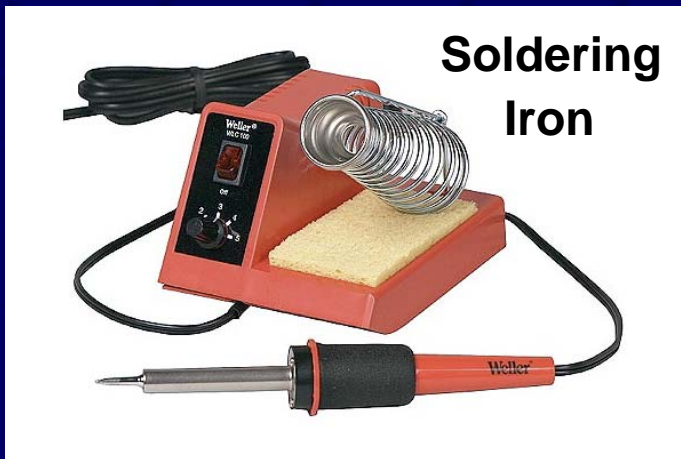
# “Must Have” Tool List



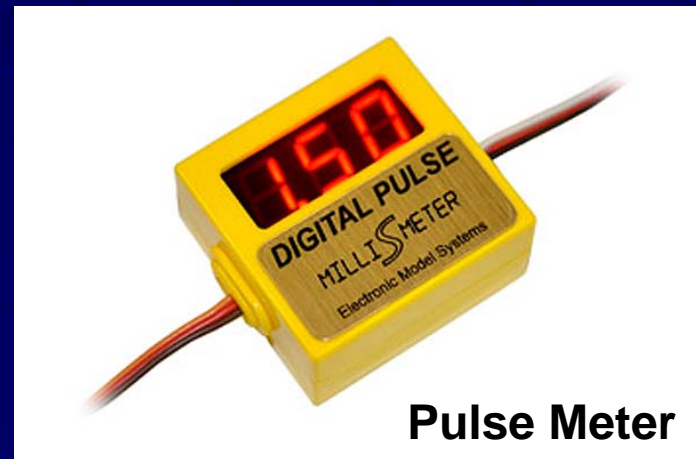
**Watt Meter**



**Volt Meter**



**Soldering  
Iron**



**Pulse Meter**

# A Few Words about Soldering

- Proper soldering is the most important skill needed for flying Electric Powered Models
- One bad solder joint can destroy a motor or ESC
- Do not trust “Pre-Tinned” leads on components
- ROHS solder melts at a higher temperature than standard 60-40 or 63-37 Tin-Lead solder
- Always re-tin the leads and connectors before soldering any motor or ESC connections
- Never use Acid-Core plumbing solder!

# Selecting a Power System

- Let's look at the complete process for selecting an electric power system from start to finish
- For this example, we will use a .45 size Ugly Stick that will weigh about 6 pounds ready to fly, and want to have pattern ship type performance
- **Step 1: Calculate how many watts of power is needed**
- Using the 2000 Watts per cubic inch method, if you take  $2000 \times .45$  you get 900 Watts of power
- Using the 150 watts per pound method, if you take  $150 \text{ watts} \times 6 \text{ pounds}$  you also get 900 Watts
- For this model it looks like we need 900 Watts of power

# Selecting a Power System

- **Step 2: Selecting the proper size battery**
- Battery capacity is determined by current needed and how long you want to be able to fly
- Start by determining number of cells required
- A 4-cell pack is good for 450 – 1100 watts, and a 5-cell pack is good for 700 – 1700 watts
- Higher voltage = better efficiency, so we will use 5 cells
- Just to check  $900 \text{ watts} \div 18.5 \text{ Volts} = 48.6 \text{ Amps}$
- $48.6 \text{ amps} \div 18.5 \text{ Volts} = 2.6 \text{ Ratio}$ , between 2 – 5
- Next we determine battery capacity
- 48 Amps at full throttle, about 24 amps at 2/3 throttle

# Selecting a Power System

- The current value you should use to determine battery size depends on the type of model you are flying
- For a pylon racer or similar model, use full throttle current for determining battery size
- For a sport model that will be flying around at  $2/3$  throttle most of the time, use half of the full throttle current
- For a trainer type plane that will be flying at  $1/2$  throttle most of the time, use  $1/3$  of the full throttle current
- Since this model is a sport type plane, we will use half the full throttle current, which is 24 Amps
- Next we need to determine how long we want to fly

# Selecting a Power System

- For this example, we will use 10 minutes
- From before, a 1C discharge is 60 minutes, so 10 minutes would be equal to a 6C discharge rate
- If we need 24 Amps on average and will be running a 6C discharge rate, the battery size is  $24 \text{ A} \div 6\text{C} = 4 \text{ AH}$
- A 4 AH battery is the same as a 4000mah battery, so now we know we will be using a 5-cell 4000mah battery
- **Don't Forget the 80% Rule!**
- Flying 10 minutes would completely drain the battery, so to use the 80% rule, we would actually fly for 8 minutes
- We could also step up to a 5-cell 5000mah battery and get the full 10 minutes of flying time

# Selecting a Power System

- So far we know we need 900 watts of power and will use a 5-cell 4000 or 5000mah battery for 8 or 10 minutes
- **Step 3: Selecting the Motor**
- Now we need to look for a motor that will deliver 900 watts of power from a 5-cell Battery and pull 48 Amps
- Using the 80% rule, if we need 900 watts, the motor should be rated for  $900 \div 0.8$  or 1125 watts
- Another consideration is prop size, a .45 size Ugly Stick can only use a 12" maximum size prop, so we will need to find a motor that can use an 11 or 12 inch prop

# Selecting a Power System

- Prop Charts come in very handy at this point, without them it is pretty much a guessing game
- At Innov8tive Designs we have taken a LOT of time to create the Prop Charts so the data is available
- Without a Prop Chart, you need to look at the manufacturers ratings for the motor and try to determine if the prop will work good for your application
- Let's take a look at an excerpt from a Prop Chart for the Cobra 3520/10 motor from the Innov8tive Designs Website

# Selecting a Power System

## Cobra C3525/10 Motor Propeller Data

Motor Wind 10-Turn Delta		Motor Kv 780 RPM/Volt		No-Load Current $I_0 = 1.65 \text{ Amps @ } 14\text{v}$		Motor Resistance $R_m = 0.023 \text{ Ohms}$		I Max 62 Amps	P Max (5S) 1150 W
Outside Diameter 43.0 mm, 1.69 in.		Body Length 51.0 mm, 2.01 in.		Total Shaft Length 73.0 mm, 2.87 in.		Shaft Diameter 5.00 mm, 0.197 in.		Motor Weight 253 gm, 8.92 oz	
Prop Manf.	Prop Size	Input Voltage	Motor Amps	Watts Input	Prop RPM	Pitch Speed	Thrust Grams	Thrust Ounces	Thrust Eff. Grams/W
APC	10x7-E	18.5	38.10	704.8	11,633	77.1	2295	80.95	3.26
APC	10x10-E	18.5	53.59	991.5	10,833	102.6	2072	73.09	2.09
APC	11x5.5-E	18.5	41.47	767.1	11,458	59.7	3024	106.67	3.94
APC	11x7-E	18.5	48.82	903.2	11,076	73.4	3126	110.27	3.46
APC	11x8-E	18.5	53.42	988.3	10,848	82.2	2899	102.26	2.93
APC	11x8.5-E	18.5	56.95	1053.5	10,665	85.8	2908	102.58	2.76
APC	11x10-E	18.5	63.71	1178.7	10,310	97.6	2645	93.30	2.24
APC	12x6-E	18.5	54.61	1010.2	10,789	61.3	3694	130.30	3.66
APC	12x8-E	18.5	65.01	1202.7	10,289	77.9	3214	113.37	2.67
APC	13x4-E	18.5	46.39	858.2	11,206	42.4	3781	133.37	4.41
APC	13x6.5-E	18.5	72.85	1347.7	9,856	60.7	4065	143.39	3.02

# Selecting a Power System

- **Step 4: Select a Speed Controller**
- The speed controller should be sized so that it is about the same as the max current rating for the motor and meets the 80% rule
- From the prop chart we just saw, the Cobra 3525/10 motor had a max current rating of 62 amps, and we are pulling 48 Amps with the 11x7E prop
- $48 \text{ Amps} \div 0.8 = 60 \text{ Amps}$ , so a 60 Amp ESC is required
- Cobra has a 60 A 6-cell ESC, so we will use that one
- You can go larger on the ESC if desired, such as an 80 Amp. It will not hurt anything, it will simply run cooler

# Selecting a Power System

- Step 5: Selecting a prop

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APC	11x10-E	18.5	63.71	1178.7	10,310	97.6	2645	93.30	2.24
APC	12x6-E	18.5	54.61	1010.2	10,789	61.3	3694	130.30	3.66
APC	12x8-E	18.5	65.01	1202.7	10,289	77.9	3214	113.37	2.67
APC	13x4-E	18.5	46.39	858.2	11,206	42.4	3781	133.37	4.41
APC	13x6.5-E	18.5	72.85	1347.7	9,856	60.7	4065	143.39	3.02

# Wrapping It All Up

- Hopefully I have not made your brain hurt!
- Electric Power Systems do require a new set of skills to be learned and do take a little more work to put together
- In the end, the benefits do outweigh the extra time and effort needed to set up a good power system
- Hopefully you have all learned something today, and for those of you that have been scared to try Electrics, this information will enable you to take the plunge

# Thanks for Listening!

