Portable Power for Ham Radio Applications

MAY, 2023 – CARS MEETING

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What will you learn today?

- Terms and Specifications for power sources
- What portable solutions are there for ham radio?
- What are the tradeoffs of various approaches?
- Working with batteries and safety considerations
- Do's and Don'ts with batteries and connections
- Solar power systems – typical configurations for ham radio
- Why do you need a solar charge controller?
- How big (in watts) of a panel do I need for my portable station?
- Generators – basic considerations, RFI, and trade-offs
- Summary and recommendations

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Why learn about batteries ?

Batteries of all types are used in our radios and equipment. We should understand them better.

Portable operation

- more popular than ever (POTA, SOTA, etc) and depends on batteries

Having the right battery for the right job is essential to your success

Doing wrong things with batteries can be very dangerous!

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Terms you should know

Power (P) = Voltage(V) X Current(I)

Measured in **Watts** in honor of James Watt, the developer of the steam engine.

Batteries are rated in **Amp-Hours**. (Ah)

This specifies how much charge the battery can hold – ie sustained current over a given timeframe. 1Ah - 1 Amp for 1 hour

Another rating is energy density

This is measured in Watt-Hours per Kilogram usually shows up as Wh/kg

Batteries have various **chemistries**, which contribute to their weight, performance, and cost. We will compare theses types

Examples are:

Lead Acid (SLA), AGM, Gel

Nickel-Metal Hydride (NiMH, NiCd)

Lithium-Ion (LiOn, LiFePO4, etc)

Alkaline (think flashlight batteries)

Key Specifications

Voltage – nominal voltage open circuit. Fully charged batteries measure 5-7% more.

Capacity – Amp-Hours (Ah), some also have a Reserve Capacity(RC) value in minutes at max discharge rate.

Cold Cranking Amps (CCA)– max amps it can deliver at 0 degrees F (-18 C)

Energy Density –Watts/Kg

SLA usually is over 2X the weight if LiFePO4 batteries for the same energy density

Deep Cycle- Specifies if a battery can be deeply discharged without damage. SLA batteries will not tolerate deep discharge.

C-Rate – discharge rate. The capacity of a battery is rated at 1C.

So, for a 1Ah battery at 500mA discharge, rthe rate is 0.5

Battery Types

Primary batteries

- Single use, like standard A,C,D, 9-volt size alkaline cells
- Not rechargeable and must be discarded

Secondary batteries

- Rechargeable cells with more complex chemistries and structures
- Different recharging profiles, based on the chemistry used and MUST be followed

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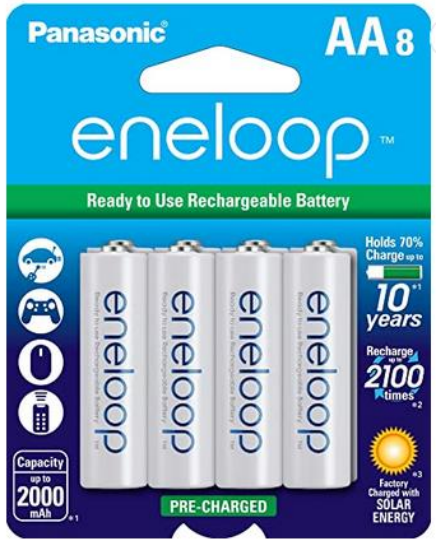
New Types

Lithium Primary Cells

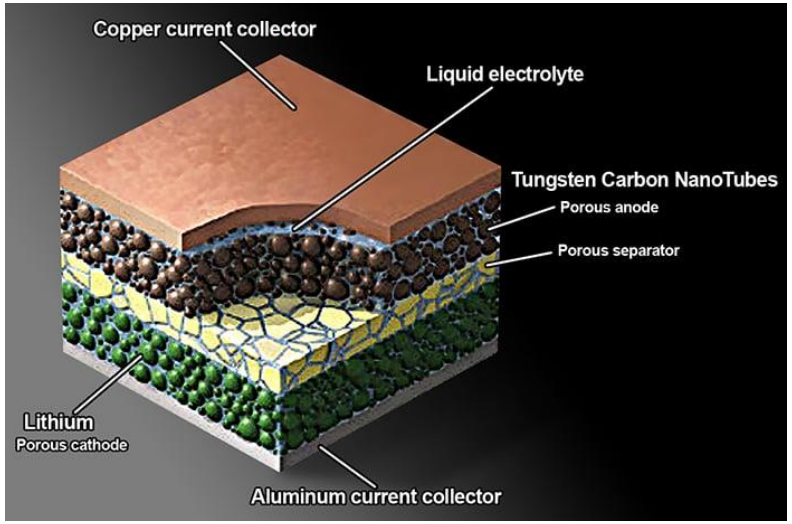
Rechargeable Cells

Better rechargeable cells

- EV's are driving the market
- Safer alternatives with better capacity
- Nano technology being used for new designs



$24.50 for 4 batteries
2100 recharges



NanoBolt Lithium-Tungsten cell

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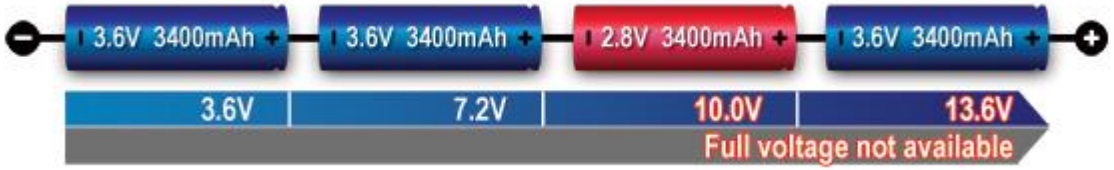
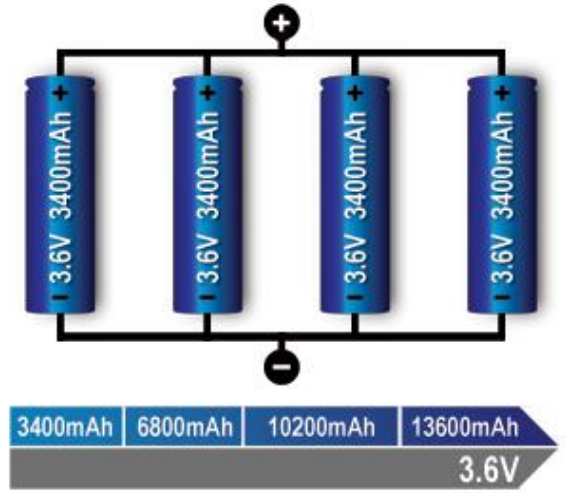
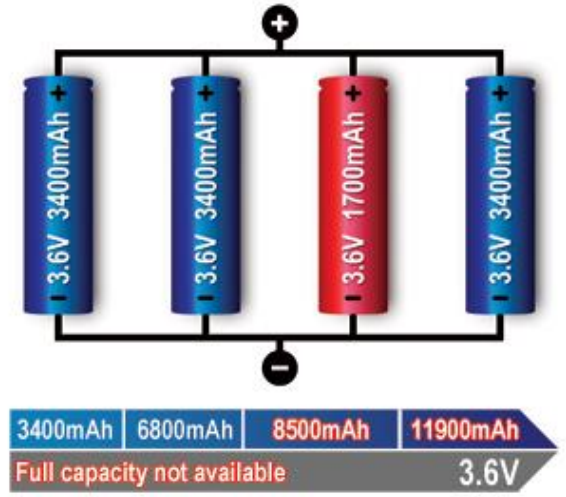
Rules for connections

Series



Parallel





The do’s & don’ts

Never connect batteries of different voltages!

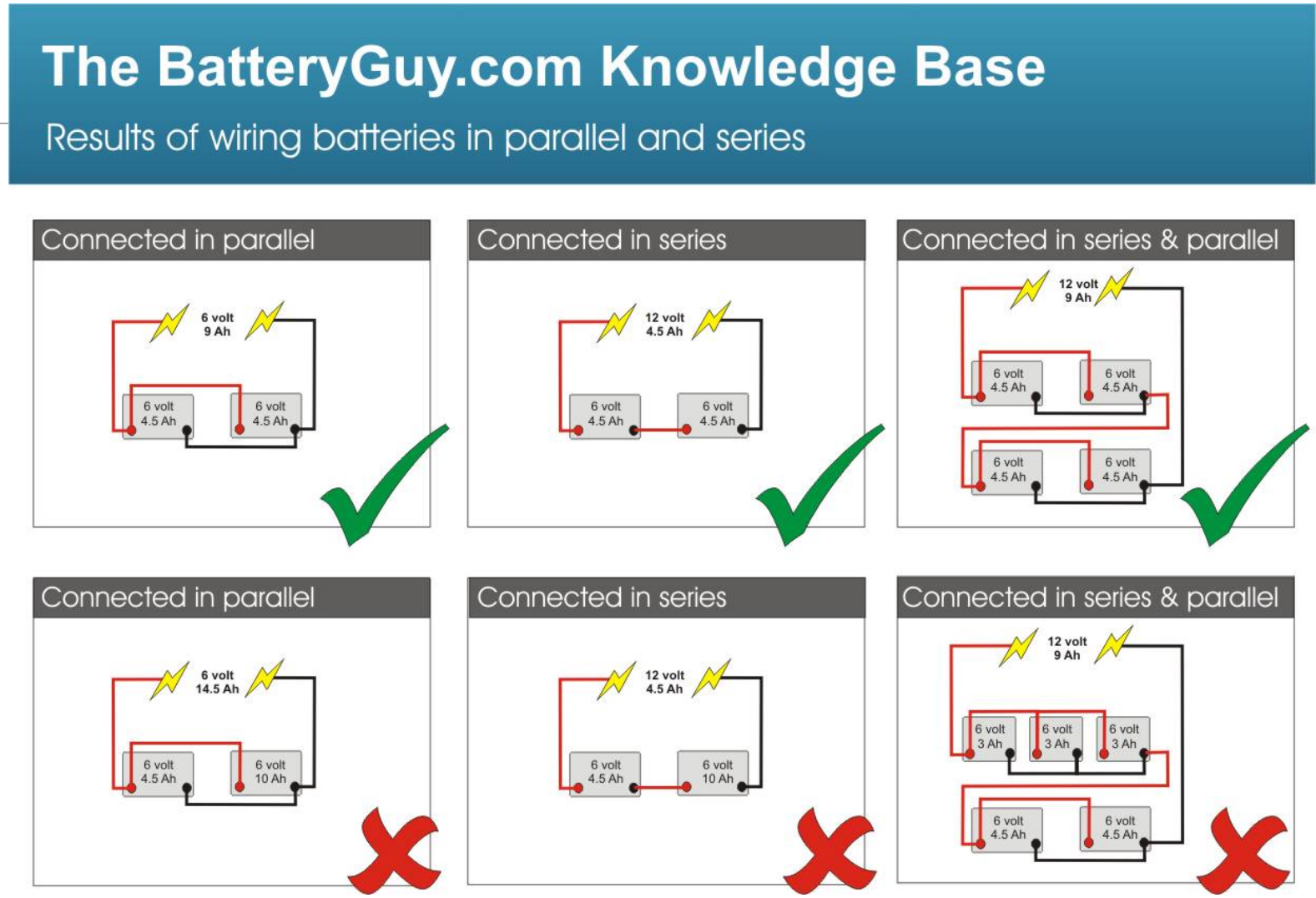
Never connect batteries of differing Ah ratings

Never mix batteries of different chemistries!

Best not to even mix batteries from different brands

Not recommended to mix batteries of **different ages**

LiFePO4 batteries may have special considerations. Check with the manufacturer!



Considerations for the right battery

Is the need for portable operation of base station backup?

If I am operating portable, will it be close to my vehicle or a distance away?

What are the requirements for the power I need for the period I want to operate?

If my application is for EMCOMM, what backup considerations may I need for power shortages or complete loss of power?

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Battery Technology Comparison

Specifications	Lead-Acid	NiCd	NiMH	Li-Ion Cobalt	Li-Ion Manganese	Li-Ion Phosphate
Specific energy density (Wh/kg)	30 – 50	45 – 80	60 – 120	150 – 190	100 – 135	90 – 120
Internal resistance (mΩ/V)	<8.3	17 – 33	33 – 50	21 – 42	6.6 – 20	7.6 – 15.0
Cycle life (80% discharge)	200 – 300	1,000	300 – 500	500 – 1,000	500 – 1,000	1,000 – 2,000
Fast-charge time (hrs.)	8 – 16	1 typical	2 – 4	2 – 4	1 or less	1 or less
Overcharge tolerance	High	Moderate	Low	Low	Low	Low
Self-discharge/month (room temp.)	5 – 15%	20%	30%	<5%	<5%	<5%
Cell voltage	2.0	1.2	1.2	3.6	3.8	3.3
Charge cutoff voltage (V/cell)	2.40 (2.25 float)	Full charge indicated by voltage signature	Full charge indicated by voltage signature	4.2	4.2	3.6
Discharge cutoff volts (V/cell, 1C*)	1.75	1	1	2.5 – 3.0	2.5 – 3.0	2.8
Peak load current**	5C	20C	5C	> 3C	> 30C	> 30C
Peak load current* (best result)	0.2C	1C	0.5C	<1C	< 10C	< 10C
Charge temperature	-20 – 50°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C	0 – 45°C
Discharge temperature	-20 – 50°C	-20 – 65°C	-20 – 65°C	-20 – 60°C	-20 – 60°C	-20 – 60°C
Maintenance requirement	3 – 6 months (equalization)	30 – 60 days (discharge)	60 – 90 days (discharge)	None	None	None
Safety requirements	Thermally stable	Thermally stable, fuses common		Protection circuit mandatory		
Time durability				>10 years	>10 years	>10 years
In use since	1881	1950	1990	1991	1996	1999
Toxicity	High	High	Low	Low	Low	Low

Source: batteryuniversity.com. The table values are generic, specific batteries may differ.

*"C" refers to battery capacity, and this unit is used when specifying charge or discharge rates. For example: 0.5C for a 100 Ah battery = 50 A.

**Peak load current = maximum possible momentary discharge current, which could permanently damage a battery.

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Summary of important specs

Specification	Lead Acid	LiFePO4	Comments
Energy Density	30-50 Wh/kg	90-120 Wh/kg ★	Significant weight difference
Cycle Life	200-300	1,000 – 2,100 ★	Long life
Overcharge Tolerance	High ★	Very Low	BMS required for Li-ion
Charge Temperature	-20C to 50C ★	0C - To 45C	Lead-Acid wide op range
Maintenance	3-6 months	None ★	
Toxicity	High	Low ★	
Safety Requirements	Thermally Stable ★	Protection mandatory	BMS required for Li-ion
Time Durability	36-48 months	> 10 years ★	Long Life
Cost	Low ★	High	Costs can be double or more

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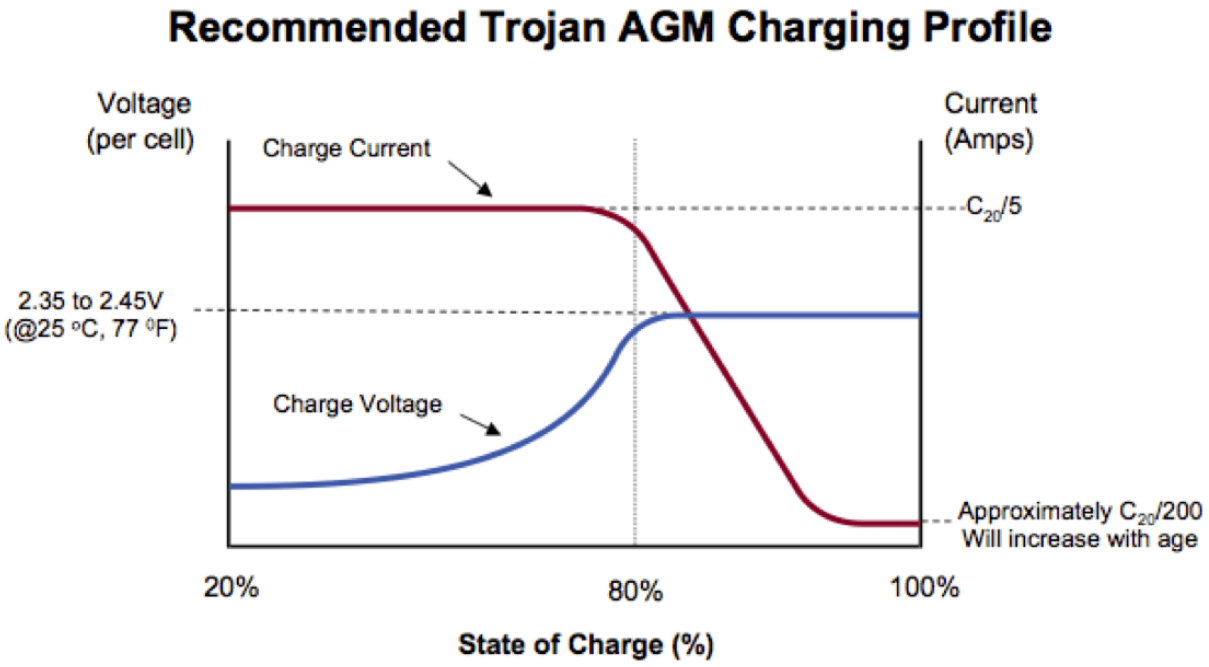
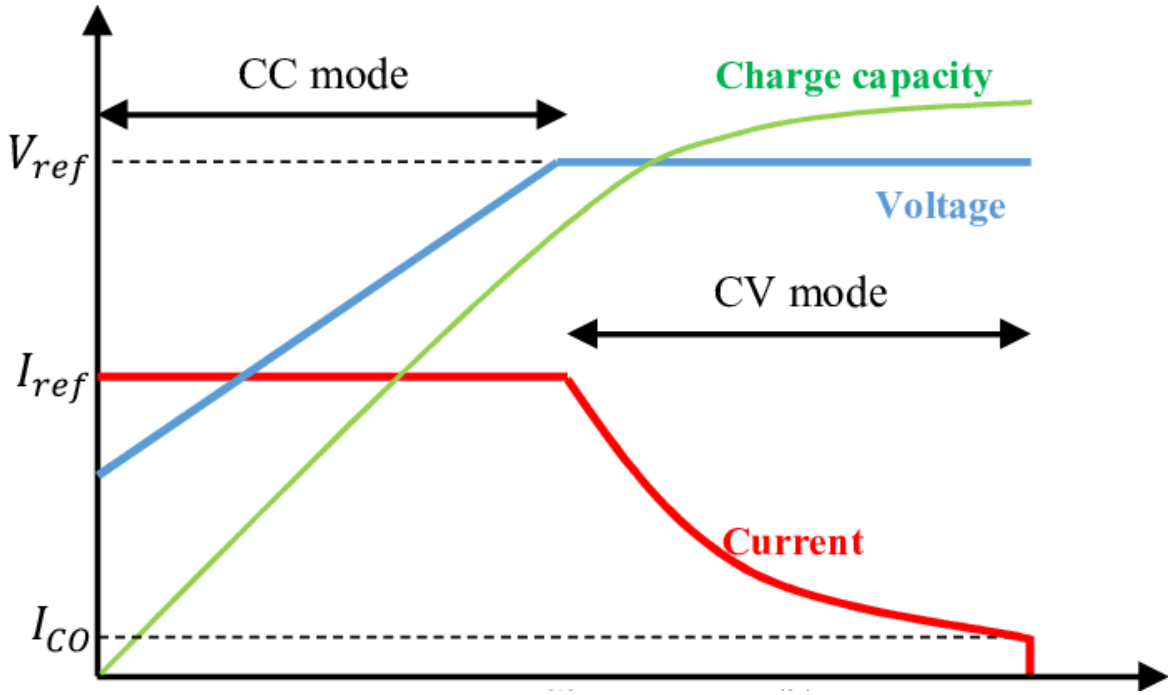
Charging profiles = different chargers needed

AGM (Sealed Led-Acid)



Lithium Ion



Fixed station location – backup system

For fixed stations

- Standard SLA and AGM batteries are well suited for capacity and cost reasons
- Marine batteries may be used as well and provide deep cycle capability

Recommend you have a power gate device to switch the power during a blackout.

- Protects your equipment and the battery

Use **Anderson Power poles** on everything

West Mountain PWRgate

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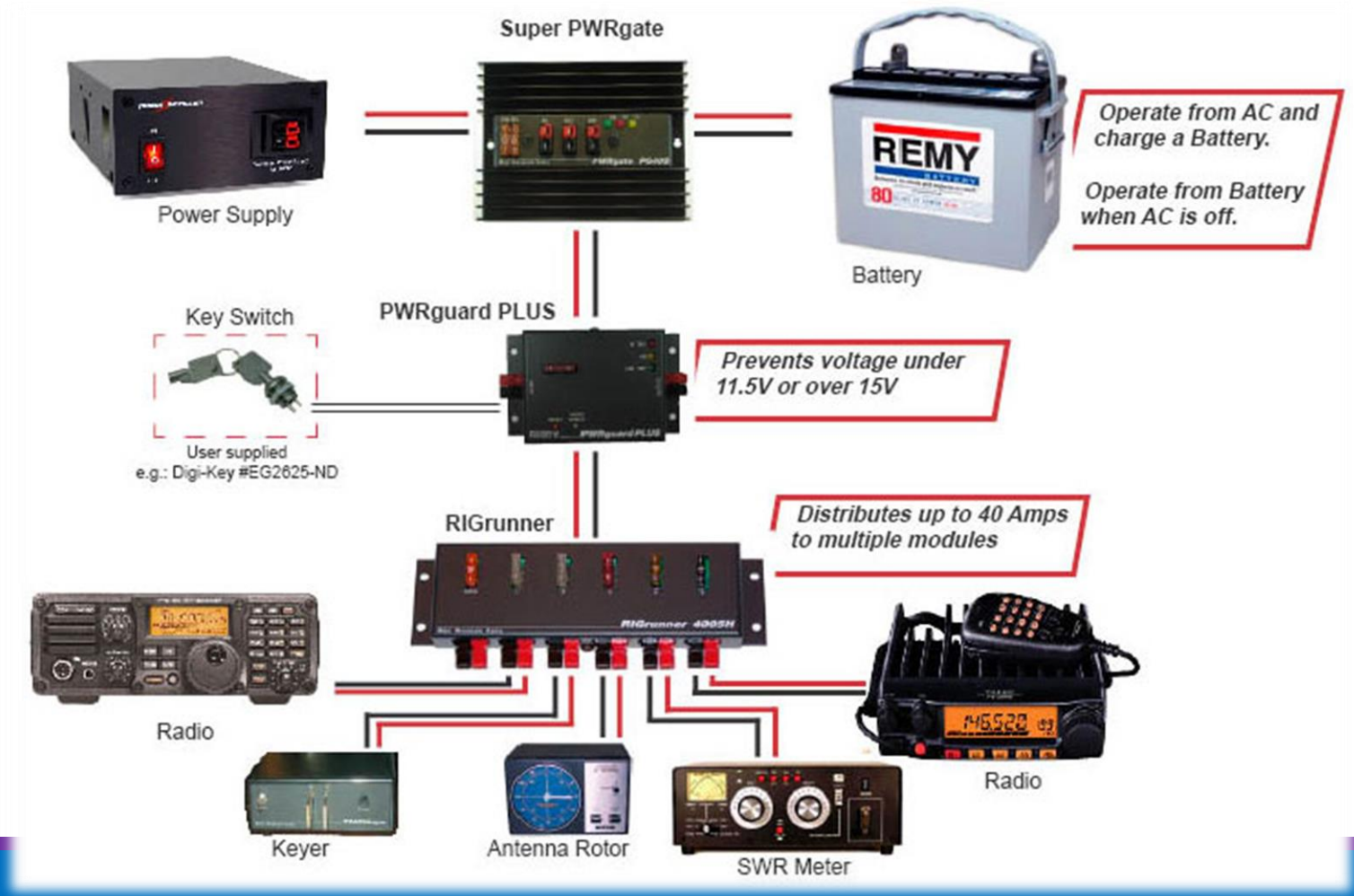
Possible connections with the battery



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Portable operation – near by

Similar to the fixed location recommendations

Use a “battery box” for easy transport and safety!

Use a power guard to protect your equipment from undervoltage (and overvoltage)

Li-Ion works well for all field operations, and is much lighter weight

Anderson Power Poles on everything

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Portable Operation – Longer distance

SOTA and POTA can be cases where weight is one of the most important considerations

Size your battery for the current draw for your rig and the duration of operation (example will follow)

Addition of a small foldable solar panel can extend your operating time

Bioenno Power BLF-1212A LiFePO4 Battery
Peak Pulse Current: 40A (2 sec.)
Max Power Delivered to Load at 12V: 240 Watts (12V x 20A = 240 Watts)
Dimensions:(L x W x H) 8.5 in. x 2.2 in. x 3.1 in. (215 mm x 56 mm x 79 mm)
Weight: 3.3 lbs. (1.5 kg)

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Calculate what you need

Check the manual for your rig and see what the current draw is for receive and transmit

- My ICOM 7300 is 0.9 A for receive and could be 21A on transmit. For field ops you may not run a full 100w, so this value will go down for transmit. 21 Amps is the very max it would ever draw.

The battery is rated in Ah (Amp-hours). For example, a 12Ah battery should, in theory, supply 12Amps for 1 hour straight. It is generally less than that, depending on the battery type.

Consider the “duty cycle” of your operations and mode.

- Assume 50% receive and transmit as worse case (1/2 the time is listening)
- For different mode the transmit duty cycle varies the mode you use:
  - CW is 40%, based on average dots and dashes
  - SSB is way less at 20% for average speech
  - Digital mode are the worst at 100% duty cycle

Ref: W1RFI book on RF Exposure

Hypothetical battery operation

- ✓Assume a 4 hour desired operation time or deployment
- ✓Rig uses 0.9A on receive and 9A on transmit for about 50 Watts RF
- ✓Assume 50% receive and 50% transmit time. For receive you will use 0.9A x 4 hours x 50% = **1.8Ah**
- ✓For transmit it is more complex. Let's assume CW operation. For transmit you must multiple the transmit current, the duty cycle of the mode, and the duty cycle of your operation
  - ✓9A x 4hours x 40% (for CW) x 50% (for operation time) = **7.2Ah**
- ✓With this scenario you need at least a battery with 1.8Ah + 7.2Ah = **9Ah** capacity.
- ✓To be sure you are covered, add another 20% reserve capacity. 9Ah + 20% = **10.8Ah**

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Manufactures chart – (source Bioenno)

BIOENNO POWER 20/80 STANDARD DUTY CYCLE FOR MOBILE TRANSCEIVER (*Compatible with all 12V Mobile Radio Transceivers*)							
TRANSMIT (W)	RECEIVE (W)	TOTAL (W)	MODEL	VOLTAGE (V)	CAPACITY (AH)	CAPACITY (WH)	RUNTIME (HOURS)
5	5	5	BLF-1203W/A/AB	12	3	36	7.2
			BLF-12045W	12	4.5	54	10.8
			BLF-1206A/AB	12	6	72	14.4
			BLF-1209A/AS/WS	12	9	108	21.6
			BLF-1212A/AB/AS	12	12	144	28.8
10	5	6	BLF-1203W/A/AB	12	3	36	6
			BLF-12045W	12	4.5	54	9
			BLF-1206A/AB	12	6	72	12
			BLF-1209A/AS/WS	12	9	108	18
			BLF-1212A/AB/AS	12	12	144	24
			BLF-1215A/AS	12	15	180	30
20	5	8	BLF-1206A/AB	12	6	72	9
			BLF-1209A/AS/WS	12	9	108	13.5
			BLF-1212A/AB/AS	12	12	144	18
			BLF-1215A/AS	12	15	180	22.5
			BLF-1220A/AS	12	20	240	30
25	5	9	BLF-1206A/AB	12	6	72	8
			BLF-1209A/AS/WS	12	9	108	12
			BLF-1212A/AB/AS	12	12	144	16
			BLF-1215A/AS	12	15	180	20
			BLF-1220A/AS	12	20	240	26.7
50	5	14	BLF-1209A/AS/WS	12	9	108	7.7
			BLF-1212A/AB/AS	12	12	144	10.3
			BLF-1215A/AS	12	15	180	12.8
			BLF-1220A/AS	12	20	240	17.1

50 watts, 12Ah
Bioenno LiFePO4
10.3 Hours

Cautions for using batteries

Use the correct wire size (gauge) for the peak current you expect

Follow conventional color coding. Black = negative -, Red = positive +

Take all possible precautions to never short out a battery!

Be certain you have the correct charger for your battery type. Wrong chargers can damage a battery , or worse.

Adding batteries in parallel can be dangerous and cause damage if not done correctly. Follow the manufactures instructions

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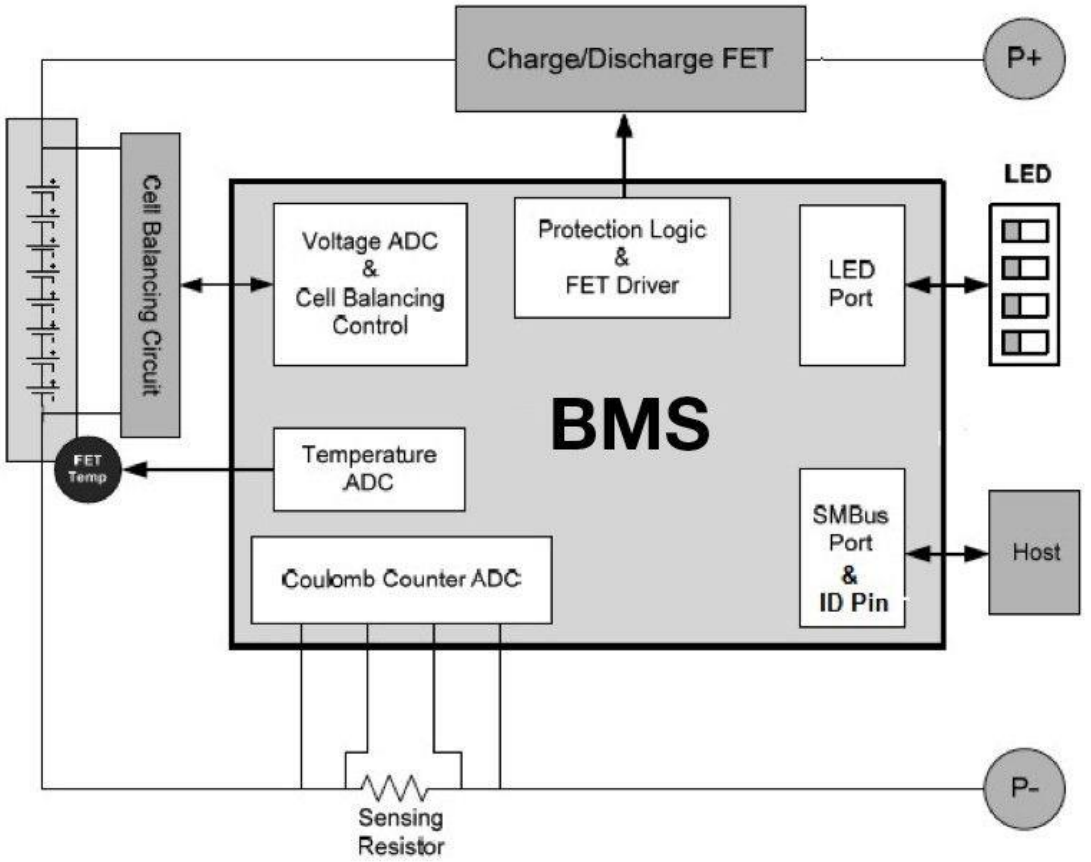
Lithium batteries must have a BMS

BMS = Battery Management System

Lithium batteries have special considerations for:

- Charging
- Excessive discharge
- Cell balancing
- Over temperature



Future Developments

- **Solid-State batteries –**
  - use a solid electrolyte instead of the liquid or gel electrolyte used in traditional lithium-ion batteries. This makes them safer, more energy-dense, and potentially longer-lasting than current batteries.

Lithium-sulfur batteries -

- Lithium-sulfur batteries have a higher energy density than lithium-ion batteries, meaning they can store more energy in the same amount of space. They also promise to reduce cost.

Sodium-ion batteries -

- Sodium-ion batteries are similar to lithium-ion batteries, but use sodium instead of lithium as the ion, which is more abundant and costs less.

Zinc-air batteries -

- Zinc-air batteries use zinc and oxygen to generate electricity. They are lightweight, long-lasting, and have a high energy density, making them a promising candidate for electric vehicles and portable electronics.

Conclusions

Consider what you need your battery to do and chose the type and capacity accordingly

Use the recharger that the manufacturer recommends. You can avoid damaging the battery, or worse

Isolate your battery from your expensive radio equipment with a proper protection device for voltage and current.

Always exercise safety measures and don’t violate the basic rules

Batteries are a great thing for the amateur radio operator, but we have to understand them better than most people

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References

Battery University : https://batteryuniversity.com/articles

- Everything you wanted to know about batteries

Bioenneo : https://www.bioennopower.com/collections/lifepo4-batteries-for-communication-equipment-ham-radio

- Runtime estimates, compatibility charts, solar panel guides

BatteryGuy.com : https://batteryguy.com/kb/knowledge-base/connecting-batteries-in-series/

- Discussions about safely connecting batteries

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Solar Power
Practical Considerations

Rob Bruderer – W1JKU

What You Need To Know: PWM and MPPT Solar Charge Controller. - Off Grid Ham
A Radio Amateur's Guide To Solar Panels. - Off Grid Ham

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Gas versus Solar

Each Solution has Pros and Cons

Can you name a few?

(Not Interested in Woke Ideology, only Accomplishing the Mission…)

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Comparison Gas versus Solar

GAS Generator	Solar
+ Have Gas, Have Power	+ Free Power
- Generator Listening Noise (may become a distraction or limitation of operating during certain hours of day)	+ Have Sunlight, Add Life to your Battery Storage
- RF Noise (Must Account for RF Noise and act via Grounding, RF-Chokes)	+ Ability to operate indefinitely (As long consumption does not exceed Sunlight and Stored/Available Power)
- Requires CLASS-III: Fuel! • How much fuel are you carrying? • How much fuel and can you carry and cost? • What is your resupply plan should mission extend?	+ Listening Quiet
	+ Can be RF Quiet if you plan and test your setup!
	+ Portable
	- Dependent on Battery Storage Capability and Sun to resupply.

Solar Operating Requirements

- Solar Panel
- Battery
- Charge Control (Match to your Battery)
- Wiring between Solar Panel and Charge Controller
- Wiring between Charge Controller and Battery
- Wiring between Battery and your Radio
- Optional Inverter

Amateur Radio gear requires approx. 13.5 volts

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Solar Controllers

- The brains allowing the Solar Panel to safely charge your battery.
- Solar panels greater than 20 watts, generally cannot be directly connected to a load because the voltages they produce are not compatible with most batteries and equipment. A “12 volt” panel can go as high as 17-19 volts in bright sunlight.
- A proper solar charge controller will take care of all these issues.
- The nature of solar panels are that output can change quite a bit according to light levels, temperature, and many other factors.
- Can your Solar Controller adapt?

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Solar Controllers PMW or MPPT?

- **PWM- Pulse Width Modulation**
- **MPPT - Maximum Power Point Tracking**

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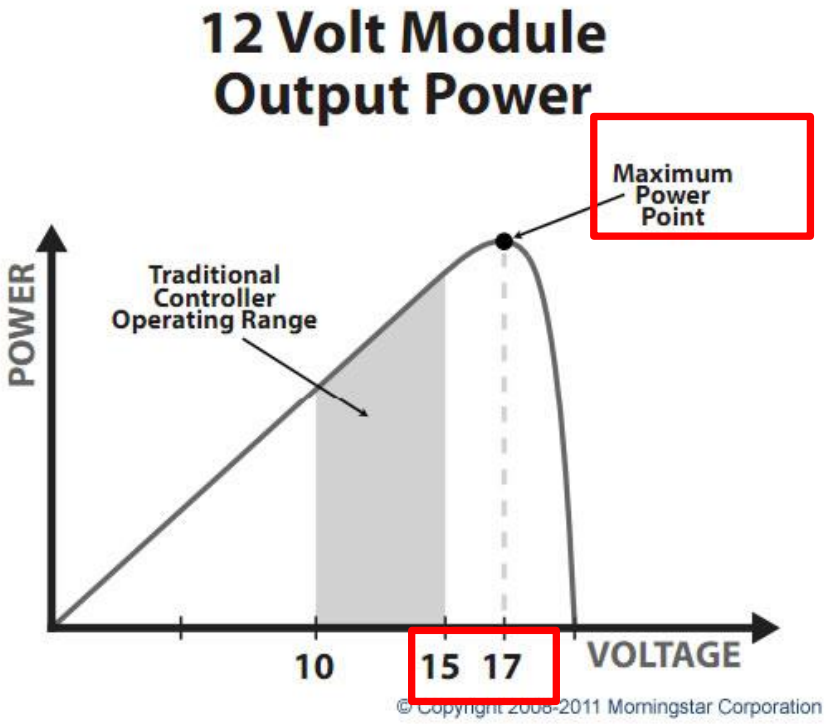
PPM- Pulse Width Modulation

- PWM is the most common, least expensive solar charge controller technology. They are really switches similar to a switching power supply that match the source voltage (solar panel output) to the load voltage (usually a 12-volt battery)
- PWM is relatively simple and has been around for decades.
- One disadvantage is that under most conditions a PWM solar charge controller **will not** take advantage of the full capacity of the solar panels.

PMW Disadvantages

- The chart below for a 12 volt system shows the main disadvantage of PWM devices.
- Notice that the maximum power point (MPP) of the panel is too high for amateur radio use.
- The strip of space between the left edge of the greyed area and the vertical dashed line represents throwaway power.

(15-17 Volts)



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MPPT- Maximum Power Point Tracking

- **MPPT** solar controllers are more than just a passive switching circuit regulating a voltage output.
- MPPT devices have on board computers controlling a complex system of semiconductors and gates that convert solar-produced DC to high frequency AC and then back to DC.
- As the sunlight changes, the MPP is constantly changing; the microprocessor does the math and adjusts in real time.
- MPPT devices convert **90%** of the incoming load into energy.
- An MPPT solar controller it is possible and even desirable for the **output current** to be much ***higher*** than the **input current**.

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Solar Controller Examples

- Nicesolar 20A 12V 24V Solar Charge Controller PWM Regulator for Solar Panel kit System for AGM Lead Acid Gel Sealed Flooded and Lithium Battery, LiFePO4 Lithium Ion Phosphate Deep Cycle Battery

(Amazon $15.99)

- Bioenno Power SC-122420NE MPPT Solar Charge Controllers SC-122420NE

(DX Engineering $89.99 for LiFePO4, AGM/SLA Batteries)

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Solar Panels (3 major variants)

- **Monocrystalline Solar Panels**
- **Poly (or multi) crystalline Solar Panels**
- **Thin Film Solar Panels**

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Solar Panels (3 major variants)

- **Monocrystalline Solar Panels**
  - Monocrystalline panels use the highest quality silicon cut into individual cells (thus the “mono” designation), which gives them their characteristic “cell” appearance.
  - **Most Efficient**

- **Poly (or multi) crystalline Solar Panels**
  - Instead of cells being individually cut from a silicon ingot, the polycrystalline manufacturing process involves pouring melted silicon into a mold.
  - They can have either a “broken glass” appearance or look like one solid panel with thin wires to define the cells.
  - The result is a less expensive but also less efficient panel.
  - Polycrystalline solar panels are by far the most popular and account for a majority of the market.

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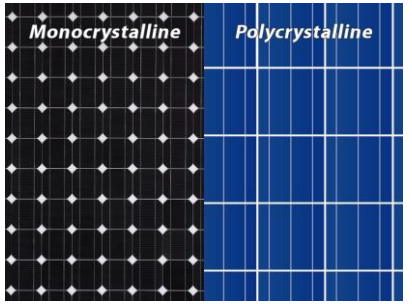
Solar Panels (3 major variants)

- **Thin Film Solar Panels**
  - 3 versions: amorphous silicon, cadmium telluride, and indium gallium
  - Solar silicon material and use adhesive to stick it to a flat plastic base, kind of like a bumper sticker.
  - Flexible and Portable
  - Diminishing returns as power level goes up. At 60 watts panels are larger than Mono/Poly
  - **Disadvantage- Low Efficiency <10% compared to Mono/Poly 13%-19%**

Solar Panels – Which one to Buy ???

- The technical differences between mono- and poly crystalline solar panels are very subtle to the radio amateur. Mono panels produce about 4% more wattage per square meter than polys, which makes them smaller for the same wattage output.
- For Ham Radio the spec differences between Mono and Poly don't justify the higher expense. However, if you were permanently attempting to power your home, business, etc, then you might prioritize Mono versus Poly.
- With solar panels, ***better is not always better***, especially when cost is factored in. Having good quality a deep cycle solar battery is also essential if you have solar panels.
- What do you want to spend and what are your Requirements???



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Solar Panel Examples

- **Thin-Film (**Amorphous silicon solar cells**)**
  - **Thunderbolt Solar 100Watt (Harbor Freight)- $190 before coupons/sales**

(Includes Wiring, USB Controller, 2 LED Lights, Female Cig-Light)

**** Solar Control in package is for Sealed Lead Acid Battery not LiFePO**

**** Must purchase a new Controller to use with LiFePO**

- **Monocrystalline**
  - **Renogy 100Wat 12 Volt Monocrystalline - $99**

**** Needs Solar Controller and wire to connect to Battery of your choice**

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Solar Panel Examples

- **DOKIO 110w 18v Portable Foldable Solar Panel Kit (21x28inch, 5.9lb) Solar Charger With Controller 2 Usb Output To Charge 12v Batteries/Power Station (AGM, Lifepo4) Rv Camping Trailer Emergency Power**

(Monocrystalline - Amazon $129**)**

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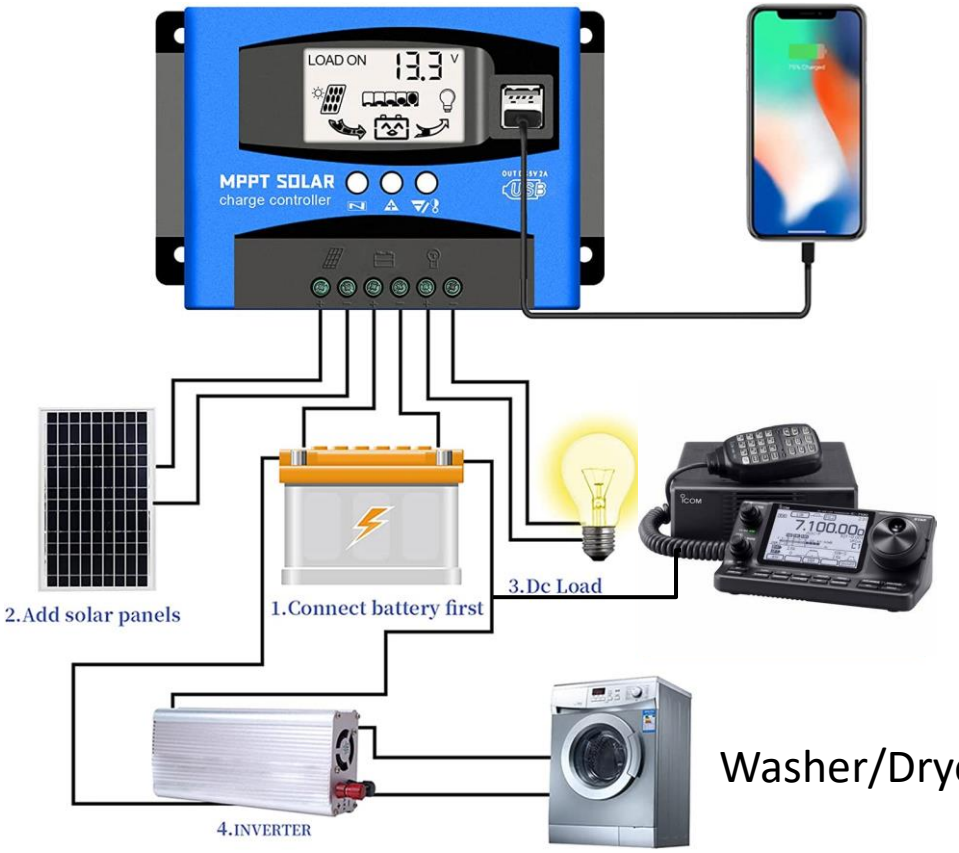
Implementation



- Solar Panel- Connect to Controller
- Controller- Connect to Battery
- Radio- Connect to Battery
- Inverter (Optional)- Connect to Battery
- Lights may connect to Controller
- USB Devices- Connect to Controller

Washer/Dryer for Long Deployments ☺

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Ham Radio -Practicality

- Can you deploy with your setup?

- Is your Power Consumption <= power produced from your solar setup?

  *** Optimal- During the day, operating for free, battery stays topped off with full battery that is ready for night-time operations

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Ham Radio -Practicality

- Plan for Night, Cloudy, or inclement weather
  - Many of these solar panels you see today are generating power during cloudy or limited light
  - Conserve Power and don't waste it:
    - Laptop- Put into sleep mode when not actively sending/receiving Winlink or performing required activities.
    - Change laptop setting if you forget to go into sleep mode > 10 minutes of no activity
    - Avoid using Inverters as much as possible for sustained overnight operations and attempt to operate direct from 12volt battery for your laptop/etc (with the correct power adapter!)
    - Only use the power you need when not regenerating power.

Ham Radio -Practicality

- Inverters MUST connect directly to Battery, NOT through your Solar Controller
  - Reminder Invertors may give off RF. Consider if required, use Inverter to charge laptop, then turn off Inverter to avoid RF and wasting power.
- Radio **Must Be** connected directly to your Battery, NOT through your Solar Controller
- Use the Appropriate Solar Controller for the Battery being used
  - Be Prepared to charge LiFePo (during deployment)
  - Be Prepared to charge Lead Acid/Deep Cycle (during deployment)
- Practice your deployment setup:
  - Safe
  - Efficient
  - Usable
  - Easy to Setup

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Deployments

- Solar is the preferred primary mode to replenish batteries and top off
- Solar used 100% of time at GA Death Race Aid Station 11
- Consider small generator for contingencies
- How else might you recharge your battery?
  - Stan-Van – Start up the Vehicle
  - Inverter to your Vehicle. Let Inverter emergency charge your LiFePO
- Reduce Power on Radio to use only what you need.
- Think outside the box, get creative, have extra cables available incase they one goes bad.
- Create yourself a Checklist and Don't forget your required items, else you may have to improvise and get creative while on deployment!

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Q&A