DC Fuse/Breaker sizing and positioning.

In this presentation the term “Protection Device” is referring to either a fuse or a circuit breaker

Fuse Sizing Rule of Thumb

My rule of thumb is the Protection Device should be the lower of

1) The capacity of the power source

or

2) 1.25 x the expected current on the wire.

This is large enough to prevent nuisance trips/blows but will still offer adequate protection.

(The following is some good structure added by @DZL)

The general design 'flow' should be:

1. Determine the greater of charge current **or** discharge current, in most cases it will be discharge current (DC loads + Inverter/AC) that might run at one time (or determine the maximum you want to design for).
2. Size your wire based on this (accounting for both *Ampacity* and *Voltage Drop*)
3. Size your fuse greater than the maximum designed for load, and less than *ampacity* rating of the wire.

Wire Ampacity > Fuse > Maximum Total Current flowing in or out of the battery

Placement of DC Fuse or Circuit Breaker protection Devices.

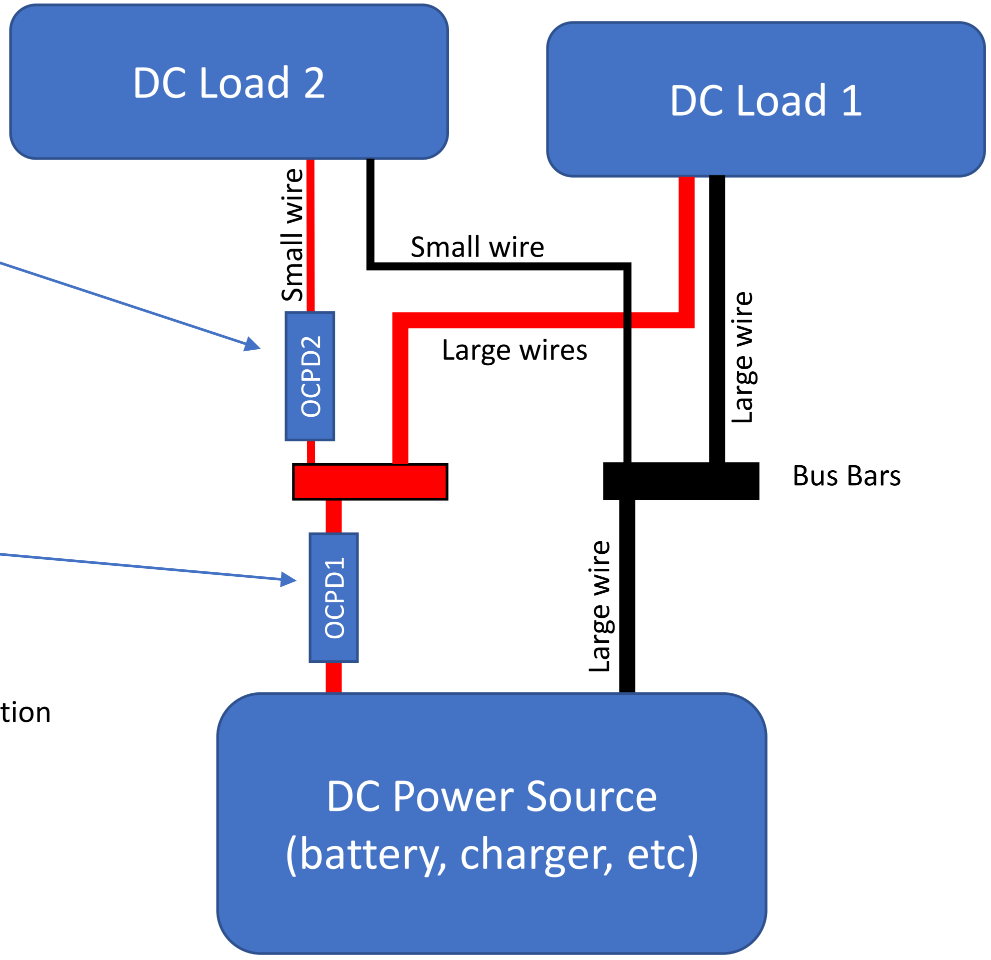
1. Protection Devices should be sized small enough to prevent *any* wire it is protecting from smoking/burning
2. Protection Devices should be placed as close to the power source as possible.

OCPDn = Over Current Protection device. (A fuse or circuit breaker)

- OCPD2 is only protecting the small wires in this diagram
- OCPD 2 should be as close to the bus bar as possible (The bus bar is the 'source' for the smaller wire)
- OCPD2 is sized small enough that it will blow before <u>any</u> wire it is protecting burn. This includes the negative return wires

- OCPD1 is only protecting the large wires in this diagram (It is not protecting the small wires)
- OCPD1 should be as close to the source as possible
- OCPD1 is sized small enough that it will blow before <u>any</u> wire it is protecting will burn. This includes the negative return wires
- OCPD1 is sized large enough to handle current for both load 1 and load 2
- The large wire going to DC load 1 is only protected by OCPD1 and therefore must be able to handle the current rating for OCPD1.

Note: Some sources have built in protection devices. In this case, an external / additional protection device is optional.



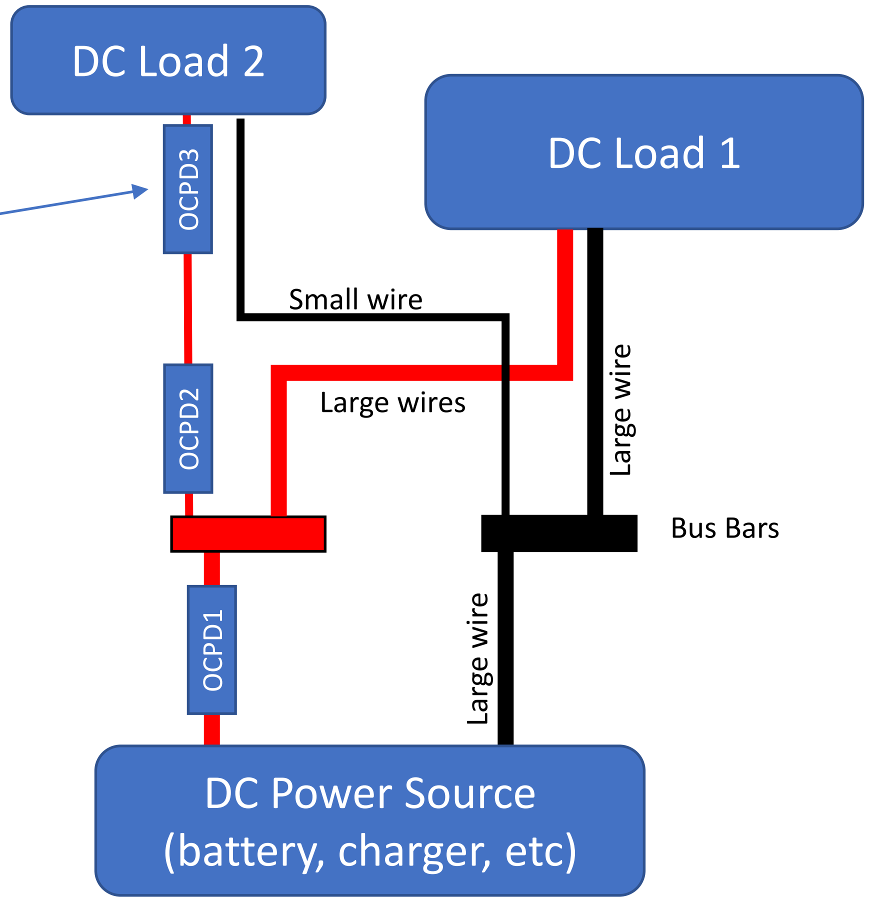
Device Fuses.

DC devices often come with in-line 'Device' fuses on their input power line.

1. Device fuses/breakers prevent a bad device from burning/smoking due to an internal Fault/short.
2. Device fuses/breakers do not prevent a device from going bad due to overload.

OCPDn = Over Current Protection device. (A fuse or circuit breaker)

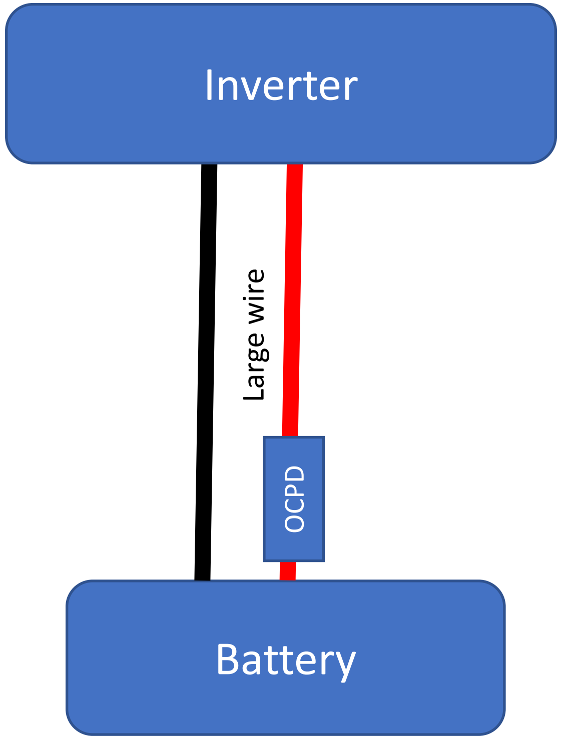
- PD3 is there to prevent load 2 from smoking/burning due to an internal fault/short
- PD3 should be the size specified by the manufacturer of Load 2.
- PD3 does NOT protect the wire going to DC load 2
- PD3 can be anywhere between OCPD2 and DC Load 2
- PD2 should be the same size or larger than the size specified by the manufacturer of Load 2.
- The wire going to/from DC Load 2 must be large enough to handle the current of OCPD2
- If PD2 is the *same* size as specified by the manufacturer of load 2, PD3 can be omitted.

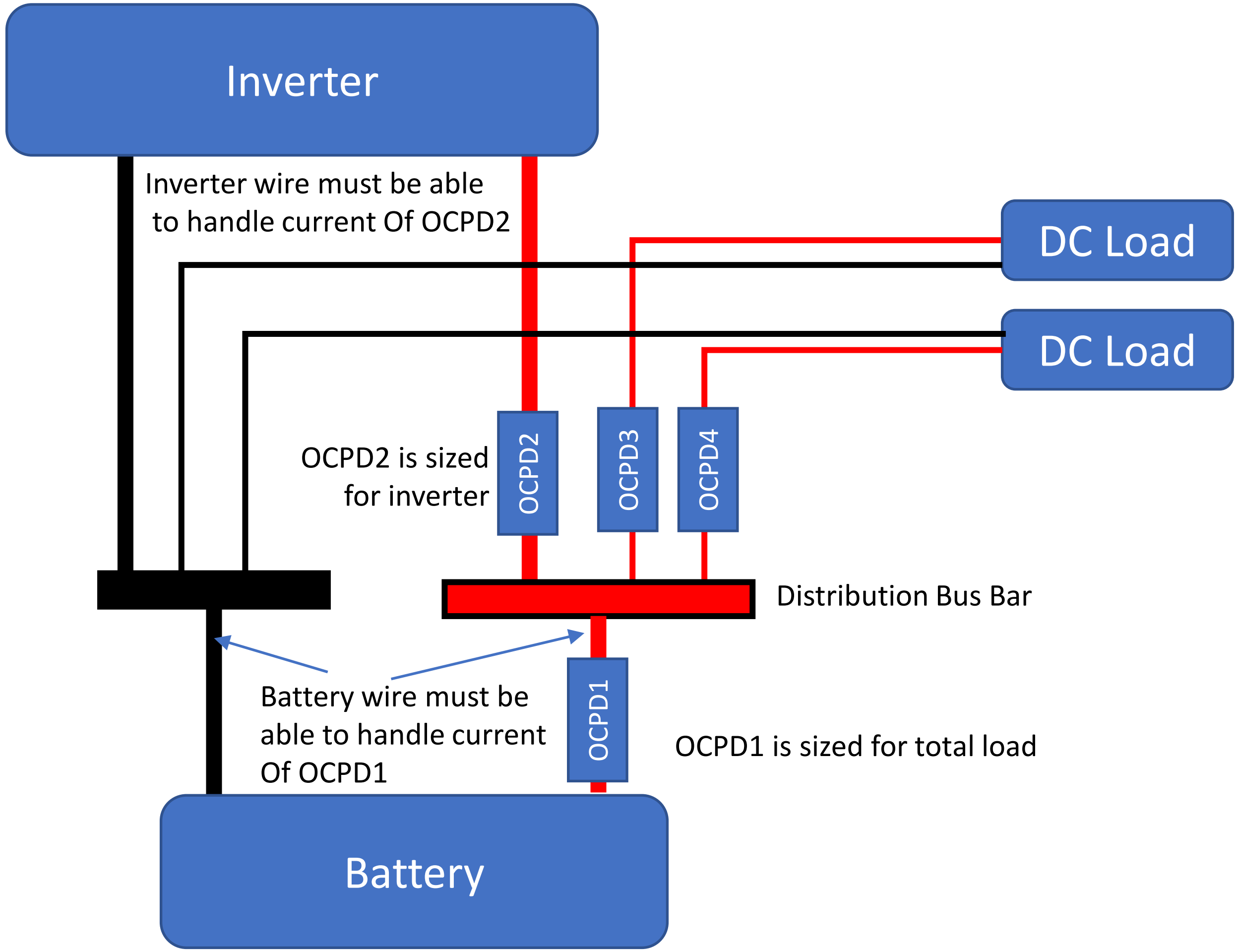


Inverter

1. Inverters are often the largest load in a solar system, and therefor have the largest wires from the battery.
2. IF the inverter is the only load, a single protection device sized for the needs of the inverter is sufficient.
3. If there are additional loads, a protection device separate than the battery protection device should be used.

OCPDn = Over Current Protection device. (A fuse or circuit breaker)

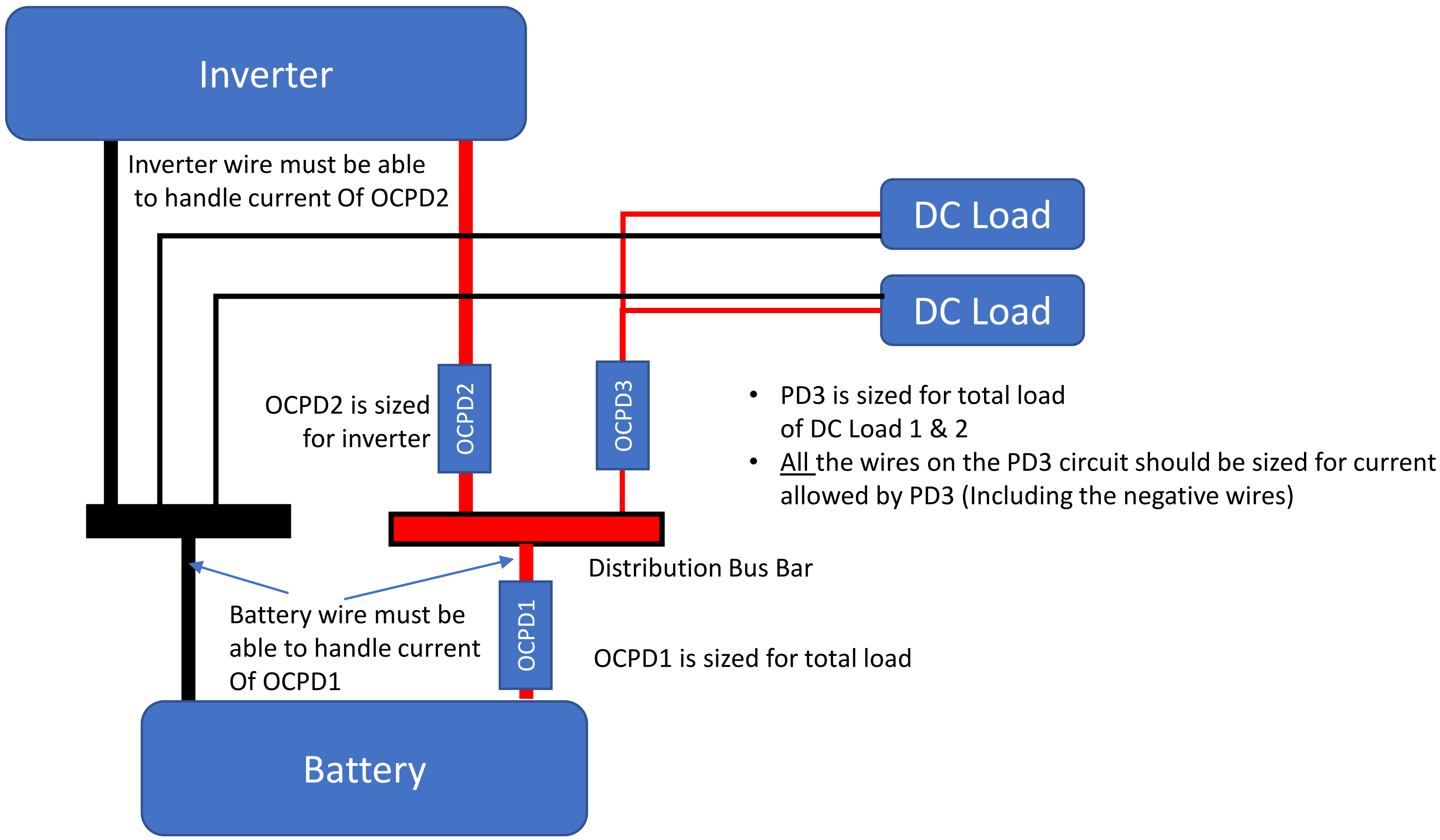




Shared Protection Devices

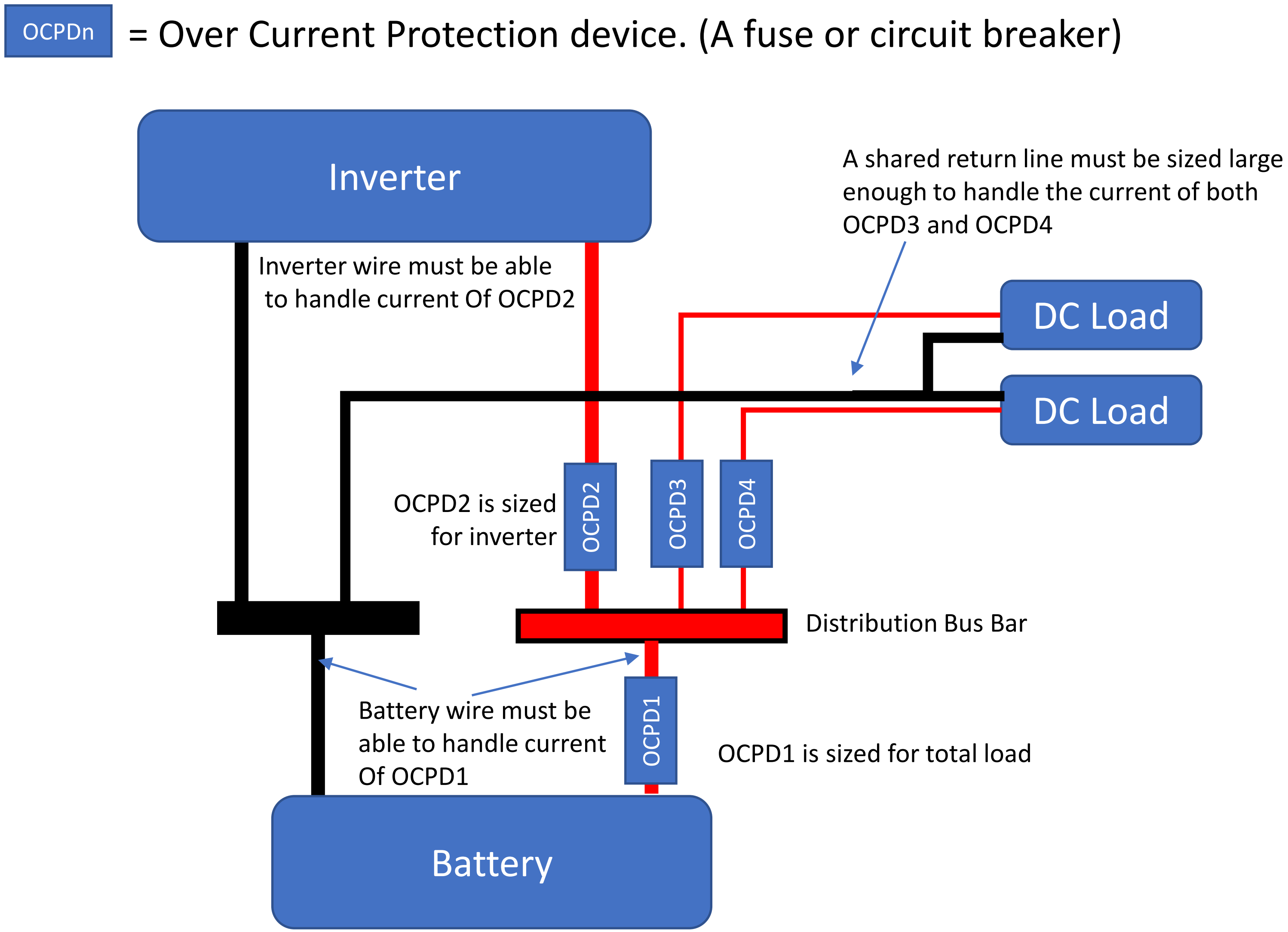
1. **It is best for each load to have its own protection device.**
2. If multiple loads are on one protection device, all the wires and the protection device should be sized for the total load

OCPDn = Over Current Protection device. (A fuse or circuit breaker)



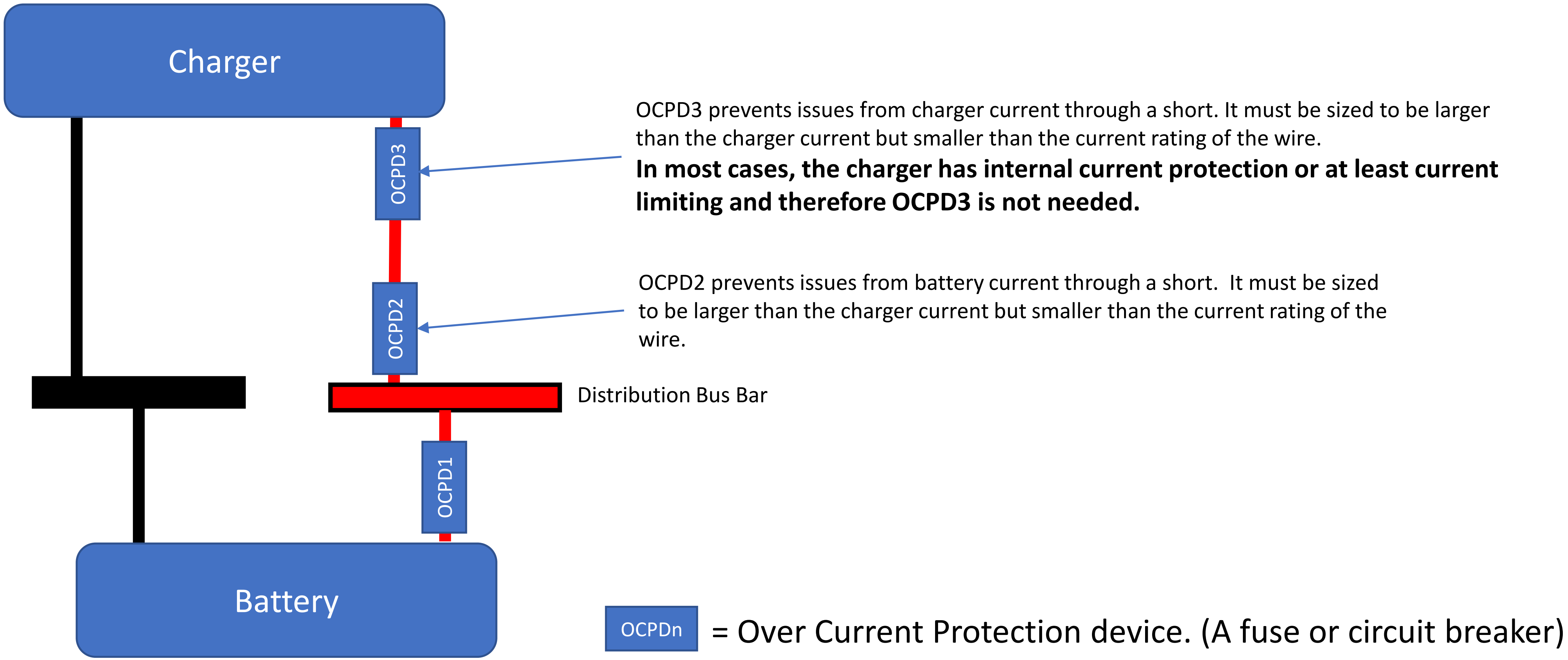
Shared Return Lines

1. **Sharing return lines for multiple protection devices should be avoided.**
2. If return lines are shared, they must be sized large enough to handle the combined current allowed by the multiple protection devices



Chargers

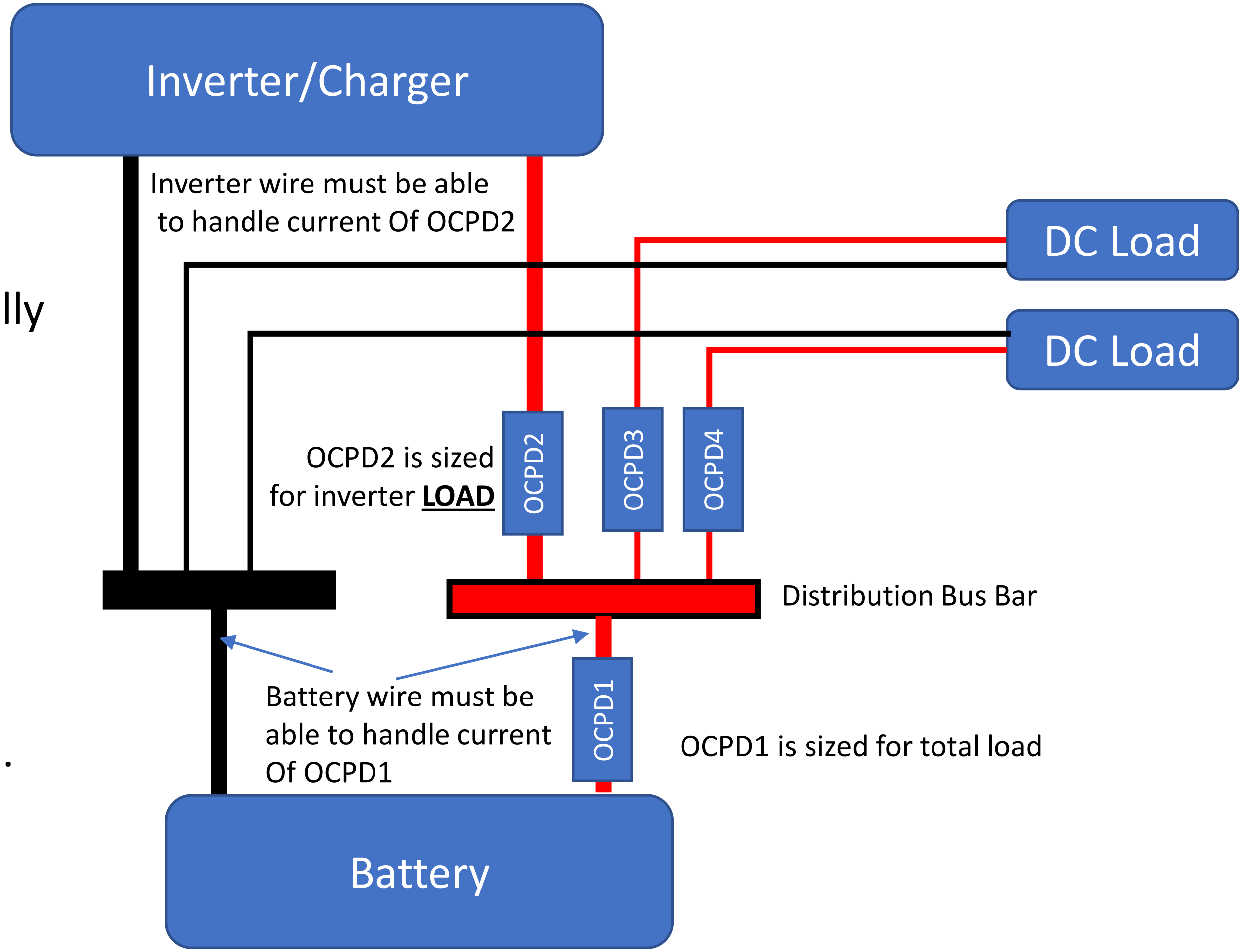
1. Chargers are current sources, but almost always have current capabilities considerably lower than the battery. Consequently, the wiring to the charger must be protected from current from the battery. This means there must be an OCPD at the battery end of the wire going to the chargers. The wires to the charger must be sized to be larger than the charger current rating and the protection device must be sized smaller than the current rating of the wire.
2. Notice that if there is a short between the charge and OCPD2, OCPD2 will blow but current from the charger could still be flowing through the short. Most chargers use in solar systems have internal OCPDs. However, if the charger does not have internal protection, a second OCPD should be added at the charger to stop the charger current from flowing.



Inverter/Charger

1. An inverter charger can be either a load or a source… this makes it tricky conceptually but does not really change things.
2. The inverter load is always larger than the charger source, so the protection device and all the wires should be sized for the inverter load.
3. The protection device should be placed closest to the battery.
4. The inverter/charger must have internal over-current protection or a current limiting system for the charge current

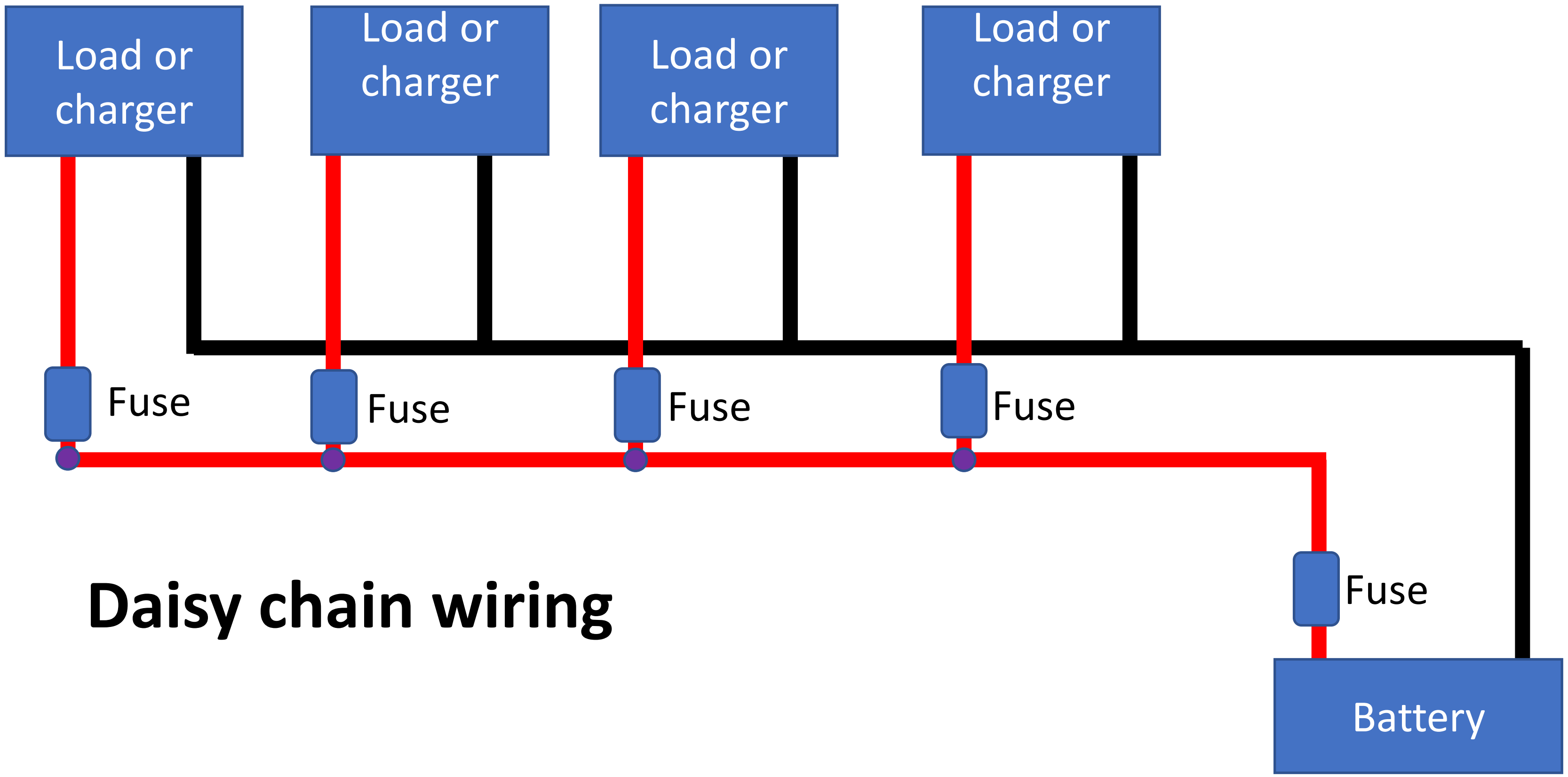
The Fusing for an inverter/charger is typically No different than the fusing for a regular Inverter.



OCPDn = Over Current Protection device.
(A fuse or circuit breaker)

Daisy Chain Wiring as shown below can be made to work but is generally frowned upon

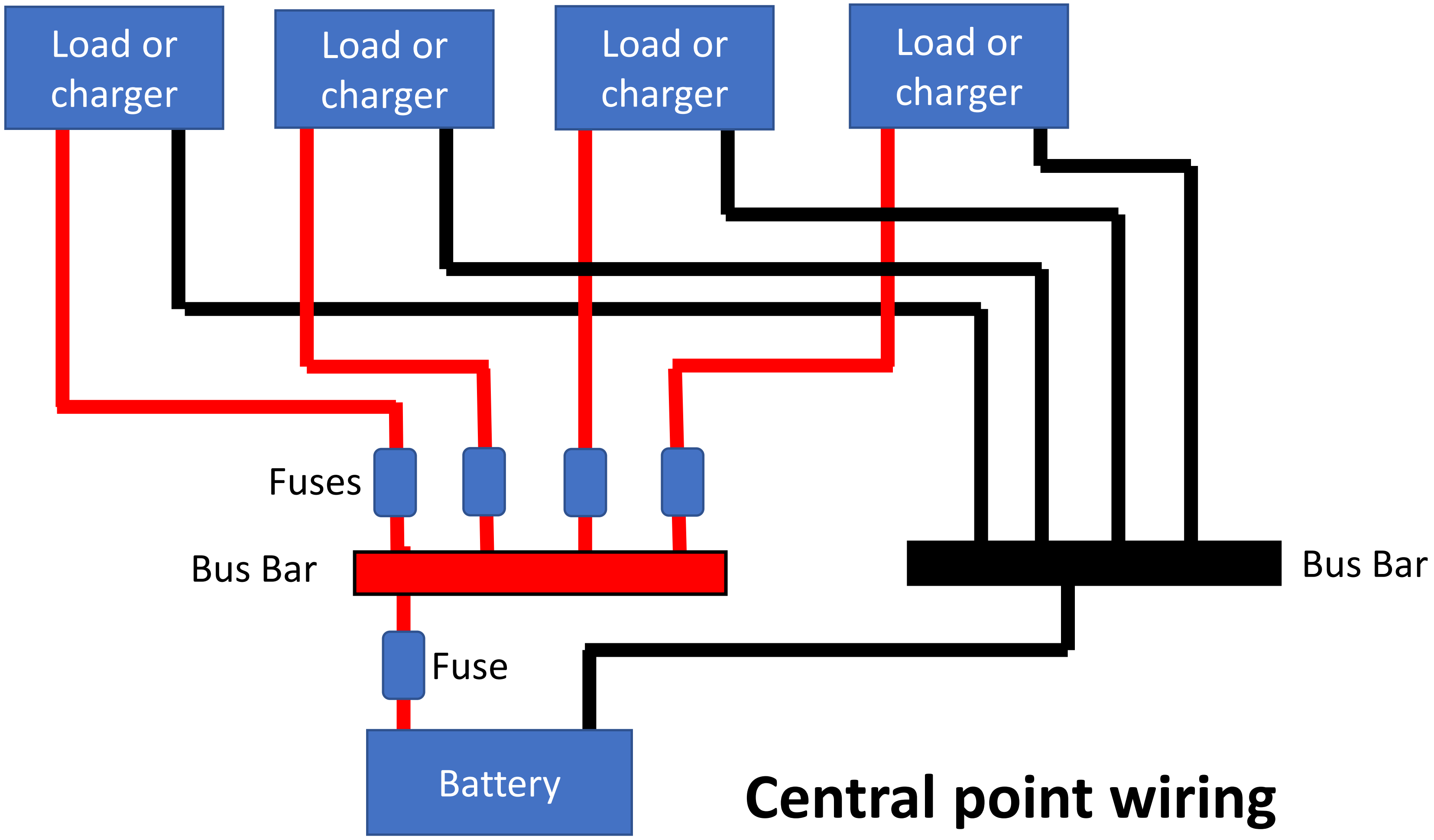
- The fuses end up all over the place and often hard to get to (or even find)
- The wiring can easily turn into a rat’s nest.
- The connections at each fuse adds points of failure
- This exacerbates issues with voltage drops across the lines.
- Maintenance and modification is often very difficult.



Daisy chain wiring

Central point Wiring as is generally considered better than daisy chain wiring

- The fuses are in one spot
- Even though there is more wire, it is generally easier to keep a clean install.
- Issues with voltage drops across the lines are minimized
- It is much easier to service and modify.



Central point wiring

Fuses vs Breakers

- Either a fuse or a breaker can be safely used to protect circuits
- Breakers and fuses must be DC rated for the voltage of the circuit.
- The Amperage Interrupt Capacity (AIC) must be high enough for the Max Short Circuit Current. For LiFePO4 the short circuit current can be verry high (>>10,000A). Note that for a main battery fuse on a battery, a Class T fuse is usually the proper choice. There are breakers with very high AIC but they can be very expensive.
- Fuses are usually significantly less expensive
- There are manufacturer defined temperature deratings for fuses when operated above 104^{o}F/40^{o}C ambient.
- Breakers are resettable, but a well-designed system should not be blowing a breaker or fuse in normal operation.
- Breakers are not generally designed as a switch that can be used regularly. However, a breaker can be use for a disconnect that is rarely used.
- Unless otherwise noted by the manufacturer, fuses and breakers should only be run at ~80% of their trip rating.

My personal preference is to use Fuses with high AIC ratings for any circuit over ~100A

Directional or Polarized DC Breakers

Many DC breakers are designed to trip on excessive current in only one direction. With these breakers, the positive should be on the 'source' side of the circuit the breaker is protecting. Typically, this means the + will be toward the + of the battery.

Fuses vs Breakers: The authors preference

I used to hold the opinion that only breakers should be used… but have changed my opinion significantly.

1) An event that blows a fuse or breaker rated at 50 Amps or more is a significant event, and the system design should make this very rare.   If a design is such that an event like this is common, <u>it is a bad design</u>.
2) Quality large current breakers can get very expensive…. Particularly anything over 150 Amps.   (see note below)

Consequently, I now use fuses for almost anything over 100 amps. Below 100 amps, I will do either fuses or breakers, but fuses are often the most convenient for DC wiring. (Fuses are certainly the most common for DC wiring)

A Warning about knock-offs of this style breaker.

Eaton/Busman make this style breaker and they are excellent products. (Blue Seas sell them as well, but they are sourced from Eaton/Busman)

However, there are many knock-offs that are notorious for being very poor products.   Some of the knock offs <u>might</u> be OK, but I do not recommend taking the chance.   Stay with Busman/Eaton or Blue Seas for this style breaker.

Eaton/Busman make these with ratings up to 150 amps.   Some of the knock-offs advertise up to 300 amps.   Anything over 150 amps in this style is dangerous.

Directional or Polarized DC Breakers – Be Careful

Many DC breakers are designed to trip on excessive current in only one direction. With these breakers, the positive should be on the 'source' side of the circuit the breaker is protecting). However, Directional breakers can fail catastrophically and catch fire if you try to manually turn them off while they have a reverse current. There are places that polarized breakers can be safely used but in general, I would avoid them.

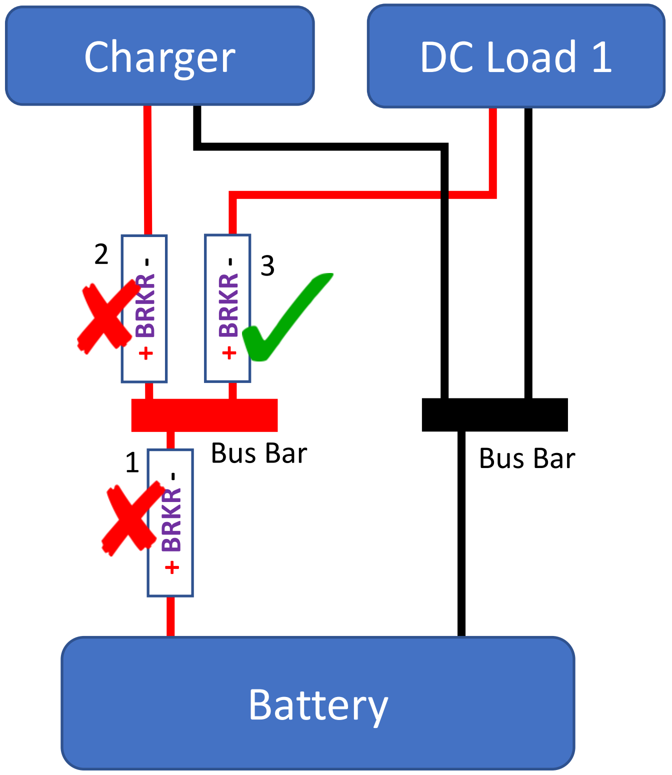


Figure 1

Breaker # 1, and 2 in Figure 1 are there to protect from too much current from the battery, so the positive is toward the battery. However, they could have a reverse current from the charger when someone turns them off so they should NOT be polarized. Breaker #3 will only ever have a forward current, so a directional breaker is acceptable.

OCPD for Solar Panels.

Special considerations for Fuses/Breakers on Solar Panel Arrays are covered in the following DIY Solar resource

https://diysolarforum.com/resources/fusing-guidelines-for-solar-panels.143/

FUSE SELECTION CHART

Calculations are based on 105°C wire.
For lower temperature rated wire, consult the Circuit Wizard at www.circuitwizard.bluesea.com

LEGEND: Outside Engine Room (dark grey) / Inside Engine Room (light grey)

AWG WIRE SIZE

AWG	AGC® / MDL® (.25A to 30A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside	ATO® or ATC® Fuse (1A to 30A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside
16 AWG	25A	20A	20A	15A	25A	20A	20A	15A
14 AWG		30A	25A	20A		30A	25A	20A
12 AWG			30A	25A			30A	25A

AWG	MAXI™ Fuse (30A to 80A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside	AMI® or MIDI® Fuse (30A to 200A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside
14 AWG	30A	30A			30A	30A		
12 AWG	50A	40A	30A		50A	40A	30A	
10 AWG	60A	50A	40A	40A	60A	50A	40A	40A
8 AWG	80A	70A	60A	50A	80A	70A	60A	50A
6 AWG			80A	70A	125A	100A	80A	70A
4 AWG					150A	125A	125A	100A
2 AWG					200A	175A	150A	125A
1 AWG						200A	175A	150A
0 AWG							200A	175A

AWG	MRBF Terminal Fuse (30A to 300A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside	MEGA® or AMG® Fuse (100A to 300A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside
14 AWG	30A	30A						
12 AWG	50A	40A	30A					
10 AWG	60A	50A	40A	40A				
8 AWG	80A	70A	60A	50A				
6 AWG	125A	100A	80A	70A	125A	100A		
4 AWG	150A	125A	125A	100A	150A	125A	125A	100A
2 AWG	200A	175A	150A	125A	200A	175A	150A	125A
1 AWG	250A	200A	175A	150A	250A	200A	175A	150A
0 AWG	300A	250A	200A	175A	300A	250A	200A	175A
2/0 AWG		300A	225A	200A		300A	225A	200A
3/0 AWG			250A	225A			250A	225A
4/0 AWG			300A	250A			300A	250A

AWG	CLASS T Fuse (110A to 400A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside	ANL® Fuse (35A to 400A) Single Wire – Outside	Single Wire – Inside	Bundled Wires – Outside	Bundled Wires – Inside
12 AWG					35A			
10 AWG					50A	40A	40A	35A
8 AWG					80A	60A	50A	40A
6 AWG	125A	100A			130A	100A	70A	60A
4 AWG	175A	150A	110A		150A	130A	100A	80A
2 AWG	200A	175A	150A	125A	200A	175A	150A	130A
1 AWG	250A	200A	175A	150A	250A	200A	175A	150A
0 AWG	300A	250A	200A	175A	300A	250A	200A	175A
2/0 AWG				200A	350A	300A	225A	200A
3/0 AWG					400A	350A	250A	225A
4/0 AWG					400A	400A	300A	250A

Typical AIC ratings:

Class T:	20,000A
Class G Midget:	10,000A
MRBF @14V:	10,000A
ANL:	5000A
AMI @ 12V	5000A
MRBF @58V:	2000A
Mega	1000A
AMG	1000A
MAXI @32V:	1000A
ATC	1000A
AGC	1000A

Although this process uses information from ABYC E-11 to recommend wire size and circuit protection, it may not cover all of the unique characteristics that may exist on a boat. If you have specific questions about your installation please consult an ABYC certified installer.

Additional replacement fuses available from Blue Sea Systems:

GMA® Fuse	1A to 10A
AGA® Fuse	20A
ATM® Fuse	5A to 30A

Standard and Metric Wire Comparison Table

Available Wire Size AWG	Available Wire Size Metric
16	1.5
14	2.5
12	4
10	6
8	10
6	16
4	25
2	35
1	50
0	
2/0	70
3/0	95
4/0	120

KEY: AWG WIRE SIZE — CLOSEST EQUIVALENT IN METRIC

CIRCUIT TYPE / CURRENT FLOW IN AMPS

Circuit Length: 10% Voltage Drop, Non Critical		3% Voltage Drop, Critical		5A	10A	15A	20A	25A	30A	40A	50A	60A	70A	80A	90A	100A	120A	150A	200A
0 to 20 ft.	0 to 6.1 M	0 to 6 ft.	0 to 1.8 M	16 AWG	16 AWG	14 AWG	14 AWG	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	1 AWG	2/0 AWG
30 ft.	9.1 M	10 ft.	3.0 M	16 AWG	14 AWG	12 AWG	12 AWG	10 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	1 AWG	2/0 AWG
50 ft.	15.2 M	15 ft.	4.6 M	16 AWG	12 AWG	10 AWG	10 AWG	8 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	2/0 AWG
65 ft.	19.8 M	20 ft.	6.1 M	14 AWG	10 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG
80 ft.	24.4 M	25 ft.	7.6 M	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG
100 ft.	30.5 M	30 ft.	9.1 M	12 AWG	10 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	1 AWG	0 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG
130 ft.	39.6 M	40 ft.	12.2 M	10 AWG	8 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	0 AWG	2/0 AWG	2/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG
165 ft.	50.3 M	50 ft.	15.2 M	10 AWG	6 AWG	6 AWG	4 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	3/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG	
200 ft.	61.0 M	60 ft.	18.3 M	10 AWG	6 AWG	6 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG	4/0 AWG		
		70 ft.	21.3 M	8 AWG	6 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG				
		80 ft.	24.4 M	8 AWG	6 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG					
		90 ft.	27.4 M	8 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG	4/0 AWG						
		100 ft.	30.5 M	6 AWG	4 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG							
		110 ft.	33.5 M	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	0 AWG	3/0 AWG	4/0 AWG	4/0 AWG							
		120 ft.	36.6 M	6 AWG	4 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG								
		130 ft.	39.6 M	6 AWG	2 AWG	2 AWG	1 AWG	0 AWG	2/0 AWG	3/0 AWG	4/0 AWG								

Note: The first line in this chart gives minimum sizing to handle current. The subsequent lines give the gauge to also avoid excessive voltage drop.