Summary

This article helps ATevo Battery Charger users understand the levels of protection available based on the selected breaker option. Most ATevo models have (4) levels of protection for both the AC Input Circuit Breaker and the DC Output Circuit Breaker. The levels of protection differ based on the ampere interrupting capacity (AIC).

Introduction

Would you like a better understanding of how the circuit breakers on your ATevo Battery Charger protect the charger, wiring, batteries, and loads on the dc bus? This article will discuss the role of both the AC Input Circuit Breaker and DC Output Circuit Breaker found on the ATevo Battery Charger and explain 2 important ratings that indicate the level of protection these breakers can provide. It also describes how to use tables HindlePower provides for specifying your ATevo's circuit breakers.

Questions & Answers

What role do circuit breakers play in the power industry?

Circuit breakers play a significant role in power distribution. Wiring and devices throughout the power distribution network depend on circuit breakers to protect them from damage they might experience if exposed to currents beyond their rating for too long a time. Overcurrent can occur for various reasons, including lightning strikes, short circuits, and overloading. Sometimes an overcurrent condition is transient, and only lasts for milliseconds or seconds; other times an overcurrent condition may last for a long time (until interrupted). Overcurrent may be slightly over the rated current for a line or device, or it may be hundreds or thousands of times the rated current. The heat, and damage that can result to wiring and equipment, depends on the extent of the overcurrent and the length of time it is present.

Individual paths in any electrical network usually have a series of circuit breakers, each protecting the wiring and devices downstream until the next circuit breaker takes over. Figure 1 on the next page shows one example: downstream from a transformer we see multiple circuit breakers, each protecting against lower maximum current levels, until the path finally reaches an ATevo Battery Charger.

Example: A transformer with a maximum rating of 1000 A (typical constant current of 800 A), feeds a 1000 A main distribution panel (MDP). The wire connecting the transformer to the MDP is sized to support 1000 A and is protected by a fuse at the transformer. The 1000 A MDP has a main circuit breaker rated at 1000 A to ensure all combined distribution circuits and/or fault conditions do not exceed the panel's 1000 A rating. A branch circuit from the MDP is used to feed a 200 A sub panel. The estimated current required by the sub panel is 160 A. A 200 A distribution breaker is installed in the MDP and the wire between the MDP and sub panel is sized to support 200 A. The 200 A branch breaker in the MDP protects the wire to the sub panel, and the 200 A main breaker in the sub panel ensures the combined distribution circuits and or fault conditions do not exceed the 200 A sub panel rating. Lastly, a 60 A distribution breaker in the sub panel is used to supply the 60 A circuit required by the ATevo battery charger. The wire between the sub panel and charger is sized to support 60 A and is protected by the 60 A breaker in the sub panel. The 60 A ac input breaker on the ATevo protects the internal components of the charger should a fault condition occur in the charger.

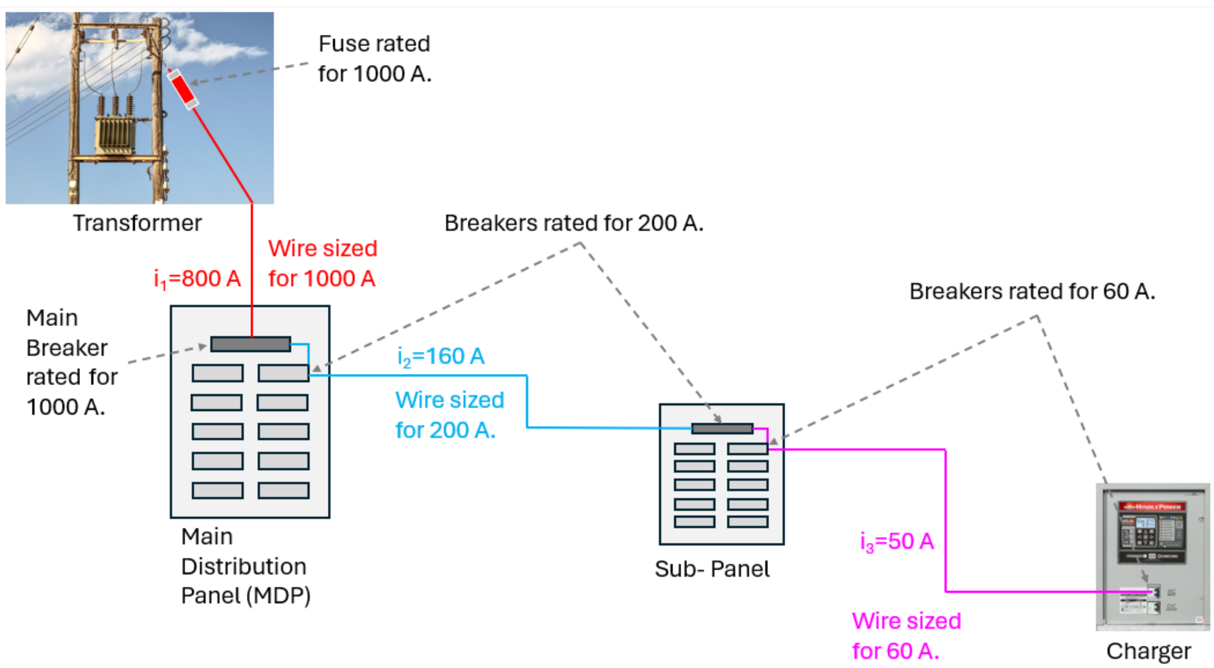

Figure 1 – Example Pathway for AC Current Leading to a Battery Charger

The system is designed such that if a fault occurs, the breaker closest to the fault trips and protects the wires and components affected by the fault. The wires and components upstream of the fault are isolated and are not affected by the fault.

Having circuit breakers in series makes sure when an overcurrent condition arises that it interrupts the fewest number of service lines and devices possible. Hence, if a malfunction inside a charger caused it to draw more current than it is safely rated to handle, the charger's ac input breaker would trip and shut off the charger, but it would not interrupt upstream service, thus allowing many other service lines and devices in the network to continue operating.

How does Ampacity rating describe a circuit breaker's ability to fulfill its role?

Ampacity rating for a circuit breaker can be defined as the minimum amperage that will cause a circuit breaker (CB) to trip (open). To understand this, let's look at an example in Figure 2. The PowerPact BJ125 circuit breaker in Figure 2 has an Ampacity rating of 125 A. As shown in Figure 2, when a current below the Ampacity rating enters the CB, it will not trip so current flows through the CB to the rest of the circuit. When a current above its Ampacity rating flows into the CB, such as 250 A (= 2 x Ampacity rating), the CB will trip (in 140 seconds at 250A) to interrupt current flow and protect all wires and components downstream from the breaker.

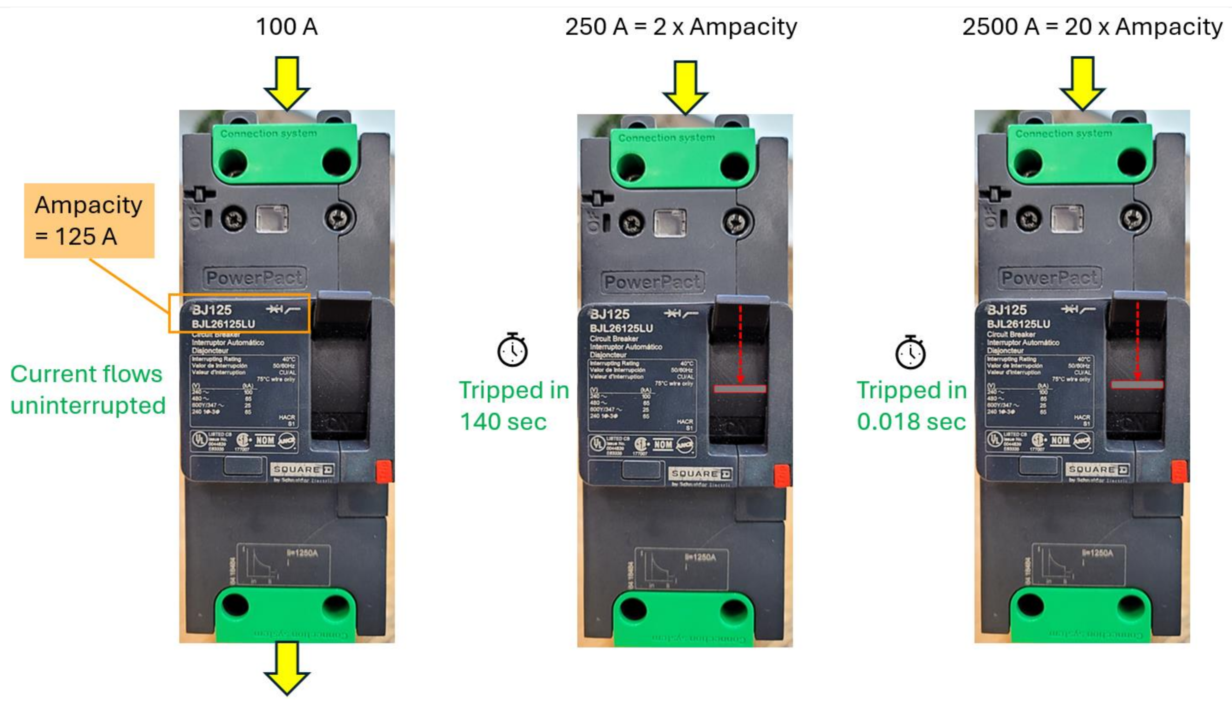

Figure 2 – Ampacity Rating: Minimum Current to Trip & Affect of Overcurrent on Trip Time

What determines how fast a circuit breaker will trip, and why is that important?

That depends on the current and the technology used to cause the circuit to open; various current sensing technologies exist such as thermal, magnetic, hydraulic and combinations of them. Regardless of the technology inside a CB, it will have a Trip Curve that plots the multiple of the rated current (where 1x = Ampacity rating) versus the time it takes for the CB to trip. Using the Trip Curve for the PowerPact B-Frame 110/125 A Thermal Magnetic Trip CB (see Figure 3 on next page), the trip time for the BJ125 CB in Figure 2, on previous page, is 140 seconds when input current is 250 A (2 x Ampacity) but reduces (almost by 8000x) to 0.018 seconds when input current is 2500 A (20 x Ampacity). As we know from Ohm's Law, power (or heat) created varies by the square of current, so a 10x increase in current results in a 100x increase in heat developed; to prevent damage, the CB must trip much more quickly.

What level of overcurrent may cause a circuit breaker to be damaged to where it won't trip or remain open after it does trip? How is this related to Ampere Interrupting Capacity (AIC)?

If you asked the first of these questions, you may have expected that if current flowing into a CB increases enough, the heat developed, and the arc created when the breaker is opened, may damage the CB. If the breaker is damaged, it may be unable to trip or unable to be reclosed once it has tripped.

Ampere Interrupting Capacity (AIC), measured in kA and often called kAIC, is a rating which specifies the maximum current that will open (or interrupt) the breaker without damaging it. If the current through the breaker exceeds the AIC rating, the breaker may fail and not be able to open the circuit and/or become permanently damaged while attempting to open the circuit.

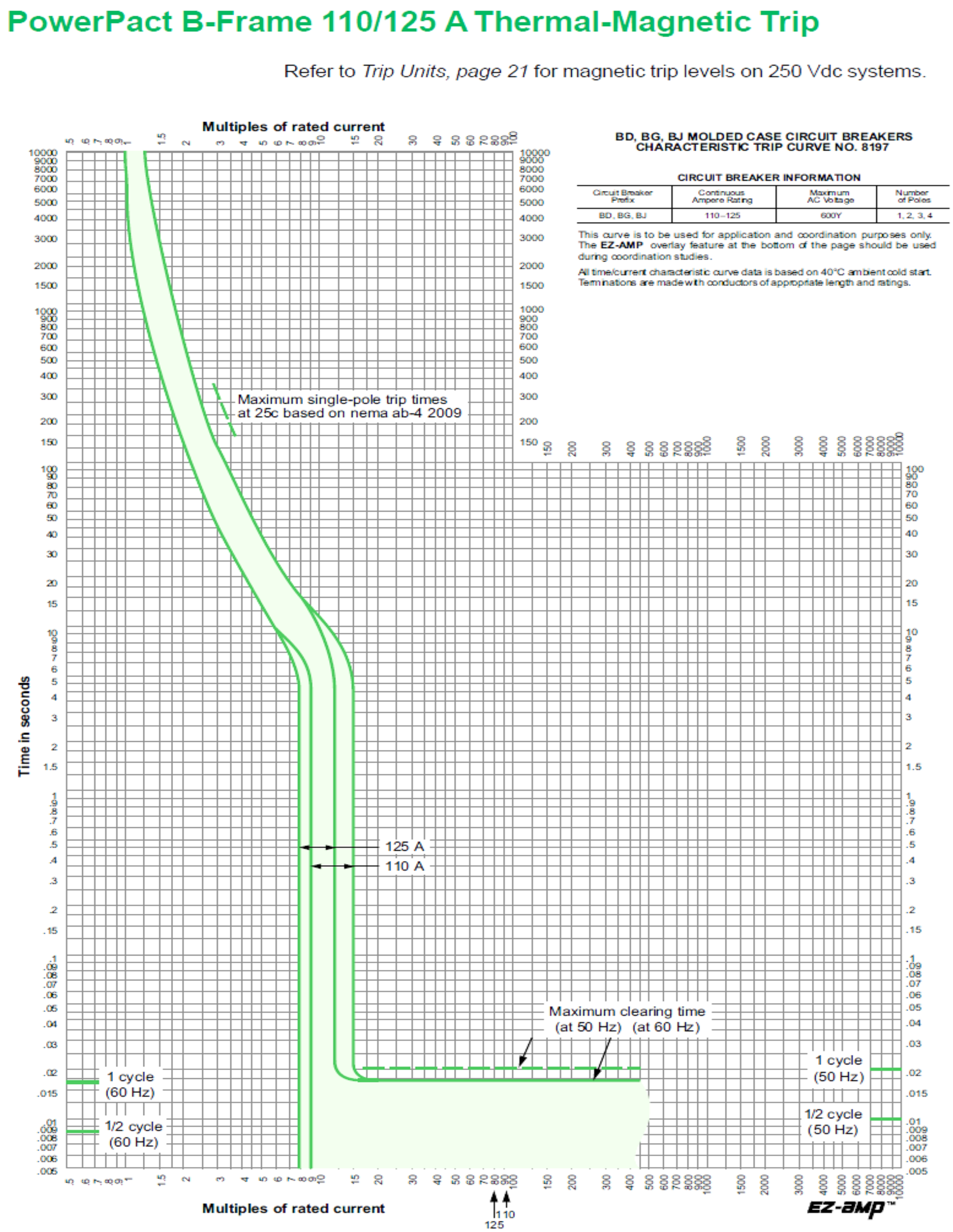

Figure 3 – Trip Curve for Example Circuit Breaker (source: Schneider Electric)

Ampere Interrupting Capacity (AIC) is explained further with Figure 4 which shows 2 scenarios with a PowerPact BJ125 CB: (1) current below AIC, and (2) current above AIC.

- The CB label identifies the "Interrupting Rating" or AIC as being 100 kA at 240 Vac. Notice that AIC current value decreases as ac voltage increases.
- A fault current of 75 kA (at 240 Vac), which equates to 600 x the breaker's rated Ampacity, will trip the CB in 0.018 seconds and not damage the CB.
- However, a fault current of 250 kA, equal to 2000 x the circuit breaker's Ampacity and 2.5 x the breaker's AIC (at 240 Vac), may create a continuous arc when the breaker tries to open the circuit. The arcing and heat may damage the breaker and any components or devices downstream from the breaker.

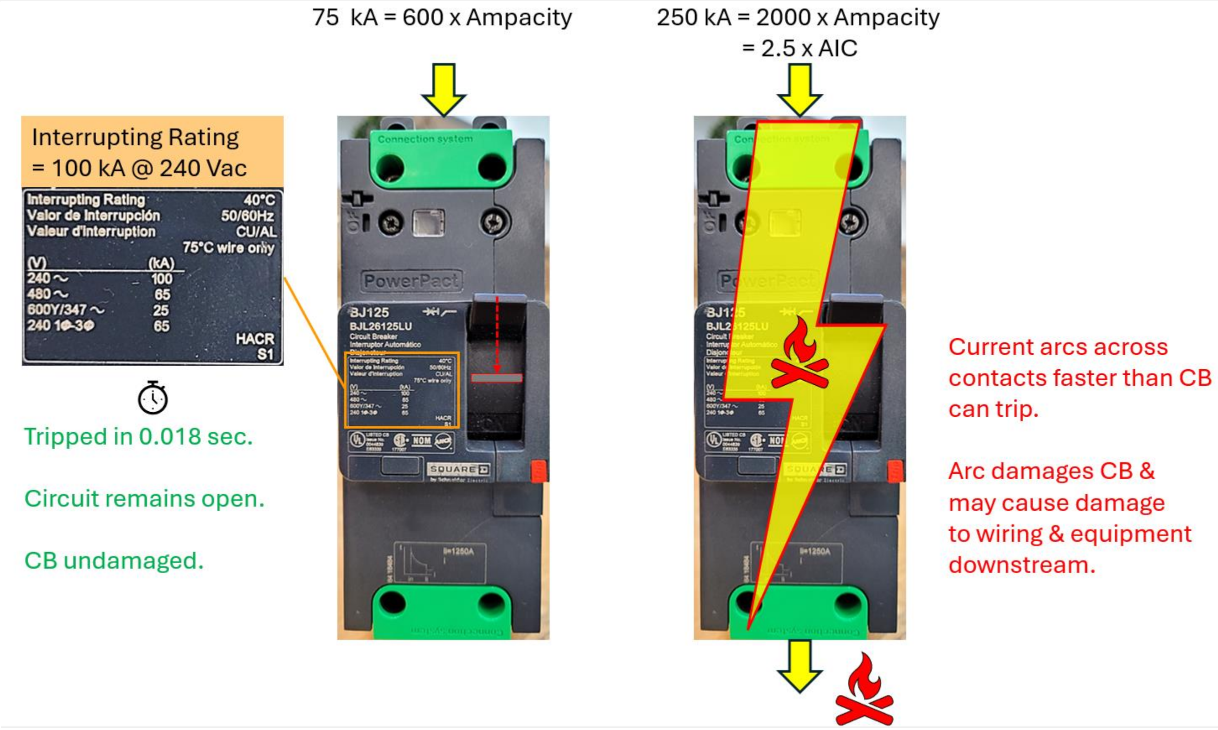

Figure 4 – Ampere Interrupting Capacity (AIC) Rating: Maximum Current That Will Open (Or Interrupt) Circuit Breaker Without Damaging It

Are Ampacity and AIC ratings different for ac and dc applications? Can the same breaker be used for both?

Breakers are rated for ac only applications, dc only applications, or both ac and dc applications. Breakers that are rated for both ac and dc have the same ampacity rating for both dc and ac, but typically have different AIC ratings for ac and dc.

The example CB in Figure 5, the SACE Formula A1A 100 is rated for both ac and dc applications. Notice from the image that the CB is rated to trip at 50A (for both ac and dc applications). However, its “Interrupting Ratings” shown are:

- 10 kA for ac voltage input between 120 V and 240 V.
- 5 kA for dc voltage input of 250 V.

The dc input current that can be interrupted will typically be lower than the ac input current at a given input voltage. The reason for this is that dc current is much more difficult to interrupt. The absence of a zero-crossing, when the current becomes zero, makes it harder to extinguish the arc. Although CB manufacturers make CBs that can be used for both ac and dc applications, usually they design CBs optimized for either an ac or a dc system.

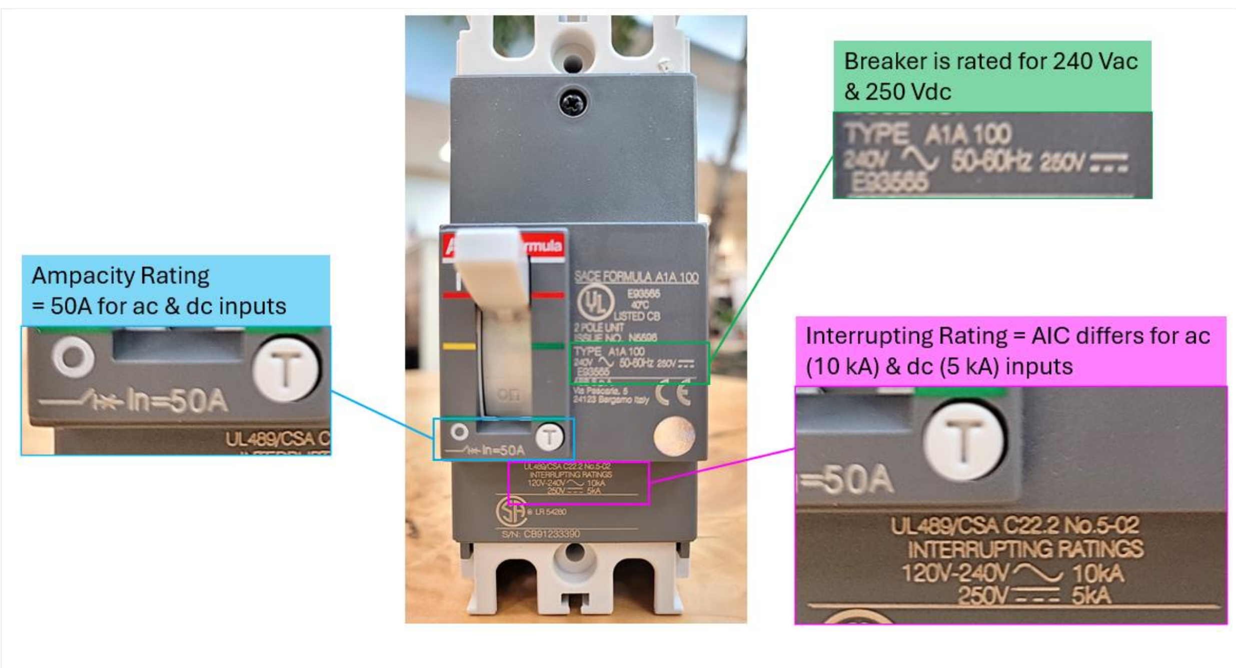

Figure 5 – AIC Ratings Differ for AC and DC Inputs

What 'Principles of Protection' must be followed when determining the AIC necessary for an ac circuit breaker (ACCB) in a battery charger?

AIC for the battery charger's ACCB must be > the maximum ac current that could supply the charger under a worst-case fault condition.

Figure 4, on page 6, illustrates this situation. An ACCB with AIC = 100 kA will open the circuit and safely clear the fault when the worst-case maximum ac current is 75 kA. Using an ACCB with AIC rating below 75 kA may result in damage to the charger and/or breaker.

HindlePower provides ATevo Breaker Tables (JF5072) to help you select a breaker that will meet your AIC requirements. With these tables, you do the following to select the ACCB for your ATevo:

1. Select table for single-phase or three-phase charger.
2. Under "DC Output Ratings", select row for your charger's "Voltage."
3. Within row for charger's "Voltage", select row for "Amperes."
4. Under "Maximum AC Input Current," locate column for your charger's ac input voltage. This lists the maximum ac input current expected to be required by your charger.
5. Under "AC Circuit Breaker Ampere Rating," locate column for your charger's ac input voltage. This is the required Ampacity Rating for your ACCB.
6. Under "AC Circuit Breaker AIC Rating," locate column for your charger's ac input voltage. This lists the "AC Breaker AIC Reference Key" you use to specify the ACCB. The "AC Breaker AIC Reference Key" table provides 4 choices for the maximum AIC rating.
7. Select your desired AIC level of protection.

- For example: If you have a single-phase, 130 Vdc, 30 Adc charger with 240 Vac input, then the table shows us that:
    - Maximum AC Input Current = 31 A
    - AC Circuit Breaker Ampere Rating (i.e., Ampacity) = 50 A
    - AC Circuit Breaker AIC Rating = "TYPE" A (reference key designation)
        - Standard Protection Breaker = 14 kA
        - Medium Protection Breaker = 25 kA
        - High Protection Breaker = 65 kA
        - Ultimate Protection Breaker = 100 kA

So, which of the 4 AIC protection ratings should you select? Choose the breaker with the lowest AIC rating that exceeds the maximum worst case fault current to the charger. As mentioned in our discussion of Figure 1, on page 2, if one or more upstream fuses or ACCBs protect against large fault currents, the charger ac breaker does not to be rated to clear the higher current fault. Having at least one branch CB or fused disconnect switch with lockout capability upstream of ATevo is recommended so that the ac input supply to ATevo can be deenergized for unit maintenance; see Section 2.4 of ATevo Operations Manual for further details.

However, if the upstream circuit does not have breakers or fuses that offer high current protection, and a worst-case scenario could lead to over 25 kA input current, then your charger should have an ac breaker with a Medium or High AIC rating.

What 'Principles of Protection' must be followed when determining the AIC necessary for a dc circuit breaker (DCCB) in a battery charger?

AIC rating for the dc circuit breaker (DCCB) must be > the maximum dc current that could flow into or out of the charger.

Since ATEVO charger's dc output current is always ≤ 120 A (for single phase) or ≤ 1200 A (for 3-phase), the AIC rating of every standard dc breaker used on ATevo will satisfy that condition. What is of greater concern is the possibility that a short could develop inside the battery charger that would let a connected battery feed a high level of dc current back into the charger through its output terminal. This unlikely, but potentially damaging scenario is pictured in Figure 6 on the next page.

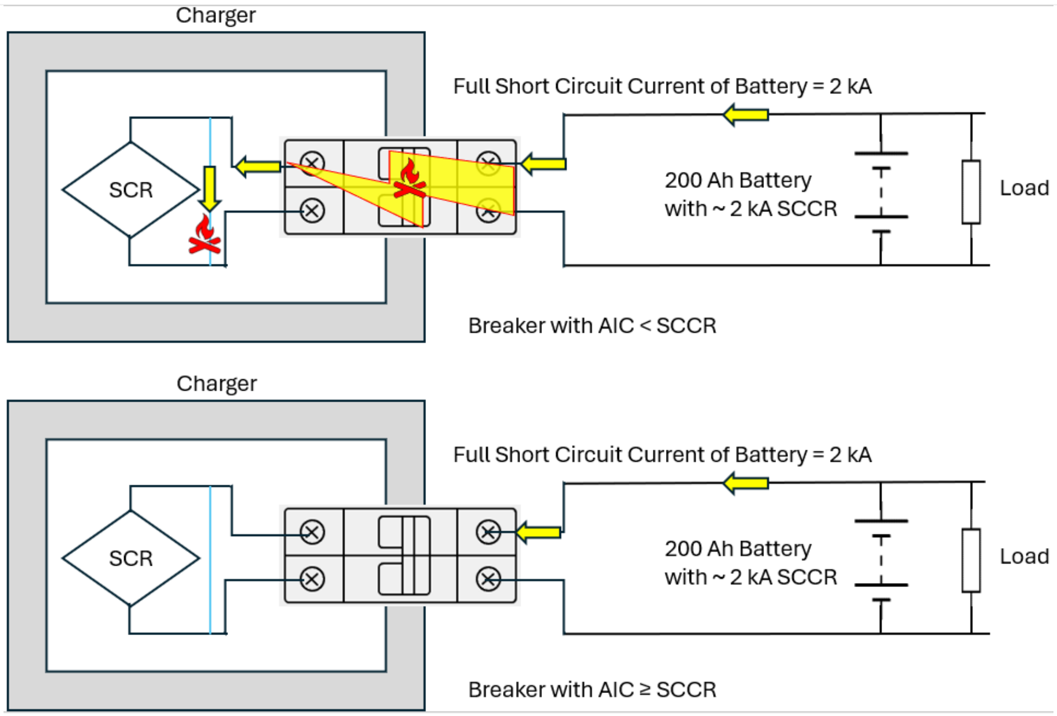

Figure 6 – Worst Case Scenario of Battery Short Circuit Current Flowing Into Charger Output: Breaker with Insufficient DC AIC Rating vs. Breaker with Sufficient AIC to Cover SCCR

The Short Circuit Current Rating (SCCR) is the maximum current a battery can source when it is fully charged. The SCCR is specified in the battery manufacturer's datasheet and for this example it can be approximated as being 10X the battery's Ampere Hour (Ahr) rating. A battery rated at 200 Ah would have an SCCR of roughly 2 kA. If an ATevo Battery Charger was connected to this battery with no intervening fuse or battery disconnect CB (as is recommended in Section 2.5 of ATevo's Operations Manual), then the charger's DCCB should have an AIC rating of at least 2 kA. The lowest rated AIC for a Standard Protection DC Breaker on ATevo chargers is 5 kA. Hence, the connected battery would need to be 500 Ah or have an SCCR of 5 kA before one would consider using a DCCB with Medium or High AIC rating.

HindlePower's ATevo Breaker Tables (JF5072), mentioned earlier, can also be used to select the DCCB for your ATevo:

1. Select table for single-phase or three-phase charger.
2. Under "DC Output Ratings", select row for your charger's "Voltage."
3. Within row for charger's "Voltage", select row for "Amperes."
4. Under "DC Circuit Breaker Rating," you will find the Ampacity.
5. Underneath "DC Breaker AIC Rating," you will find a letter. This tells you the "DC Breaker AIC Reference Key" you use to specify the DCCB. Within this you will have a choice of 4 levels of protection.
6. Select your desired AIC level of protection.

- For example: If you have a single-phase 130 Vdc, 30 Adc charger, then the table shows us that:
    - DC Circuit Breaker Rating (i.e., Ampacity) = 50 A
    - DC Circuit Breaker AIC Rating = "TYPE" J (reference key designation)
        - Standard Protection Breaker = 5 kA
        - Medium Protection Breaker = 10 kA
        - High Protection Breaker = 20 kA
        - Ultimate Protection Breaker = 50 kA

References

More information is available from these sources:

- Schneider Electric Catalog PowerPact B-Frame 15 to 125 A Circuit Breakers, 01/2017
- Section 2.4 Making AC Input Connections, ATevo Operations Manual
- Section 2.5 Making DC Input Connections ATevo Operations Manual
- ATevo Breaker Tables (https://www.hindlepowerinc.com/media/4v2dcekw/jf5072-00.pdf)