Scope

ATevo Battery Chargers (1 PH & 3 PH)

Summary

Since November 2022, the ripple voltage allowed on the dc output of stationary battery chargers, including HindlePower's ATevo Series single- and three-phase chargers, has been specified by IEEE standard 2405.2022. Prior to this date, ripple was specified by the legacy standard NEMA PE5. This document aims to clarify any confusion that may have arisen during the evolution of these standards and answer FAQs related to ripple sources and measurement.

IEEE Standard 2405 Ripple Specification

According to IEEE Standard 2405.2022, "the charger's output rms ripple voltage limits shall not exceed those specified in" the [Table 1 below] and shall apply for the full range of the charger's output.

Table 1: IEEE Standard 2405.2022 Ripple Voltage Limits

Nominal Charger Voltage (volts)	Condition	Limit
12/24/48	Filter Level 0 - Unfiltered[a]	N/A
	Filter Level 1 - Filtered	2% Vrms[b]
	Filter Level 2 – High Filtered	30 mVrms
125	Filter Level 0 - Unfiltered[a]	N/A
	Filter Level 1 - Filtered	2% Vrms
	Filter Level 2 – High Filtered	100 mVrms
250	Filter Level 0 - Unfiltered[a]	N/A
	Filter Level 1 - Filtered	2% Vrms
	Filter Level 2 – High Filtered	200 mVrms

Notes:

[a] Filter Level 0 is not recommended. ATevo Series Battery Chargers are not sold unfiltered. One should never operate an unfiltered charger without a known good battery connected to the dc bus as ripple voltage can be high enough to damage equipment connected to the dc bus.

[b] mVrms = millivolts root mean square
The term 'rms' is the effective or representative value of an ac voltage. Therefore, the ripple voltage is the value of the ac voltage that can be measured at the battery terminals or at the output terminals of the battery charger.
Where the ripple voltage is shown as a percentage in the table above, this is the percentage of the dc output voltage. For example: a filtered charger operating without a battery at 132.0 Vdc would have a maximum rms ripple value of 2.64 Vac.
The 1996 version of NEMA PE5 is ambiguous about the rating of the battery used to qualify a battery charger for this specification. We use the PE5-1983 requirement for a battery whose Ampere-hour (AH) rating is four (4) times the output current rating of the charger.

Frequently Asked Questions (FAQs)

What causes ripple?

The input power for a battery charger is obtained from an alternating current (ac) power utility. Voltage and current change polarity sixty (60) times a second, a frequency of 60 Hertz (Hz). A battery charger changes alternating voltage to direct current (dc) voltage with a rectifier circuit. The output of the rectifier circuit still has some of the alternating voltage left in it, so it's normally passed through a filter, which makes it look and act more like pure direct current (a "pure" dc voltage is like what you would get from a battery).

Can ripple cause damage to the battery?

Yes. When you want to charge a battery, you need to deliver pure direct current to the battery terminals. Anything other than pure dc doesn't charge the battery. In fact, if the ripple is large enough, it can cause unnecessary heating in the battery, in some cases reducing the life expectancy. In fact, the high ripple voltages, and resulting high ripple currents to the battery, may also require use of larger wiring between the charger and the battery.

Can ripple cause damage to equipment on the dc bus?

Yes. The ripple voltage at the output of an unfiltered charger can be very high, with high peak voltages (up to 200V or more for a 130V charger). This is especially true for single phase chargers. Unfiltered chargers depend on the battery to provide filtering and limit the peak output voltages. Powering the dc loads without a battery connected can apply excessive peak voltages to sensitive equipment. We have experienced dc relays being destroyed when the charger was turned on without a battery connected.

What lessons can we learn from this?

- Lesson 1: Never use an unfiltered battery charger.
- Lesson 2: If you must, never operate it without a battery.
- Lesson 3: If you must, it is better to never energize the charger.

Why do ATevo Chargers always reduce ripple to at least Filter Level 1?

All HindlePower ATevo Battery Chargers make use of a 3-stage filter consisting of 2 inductors and 1 capacitor and meet IEEE Standard 2405 Filter Level 1. With Filter Level 1, ATevo maintains ac ripple below 100 mVrms when the battery is connected. When the battery is disconnected, Filter Level 1 limits ac ripple to 2% Vrms; so, for a 130V charger, this would be 2.6V. Such filtering is always sufficient in reducing the heating affects that can reduce battery life, and it may be sufficient to prevent damage to equipment on the dc bus should such equipment consist of less sensitive equipment such as motors or resistive loads. Of course, high-amplitude transients and sources of ripple other than the battery charger must be controlled as well to guarantee the safety of equipment on the bus.

What filtering level do I need if I have sensitive equipment on the dc bus?

The better the filter is, the lower the ac ripple voltage is. If you need to disconnect your battery for maintenance and want to be assured of the lowest ripple value, you should use a charger that meets Level 2 (high filtering). ATevo with Filter Level 2 makes use of a 4-stage filter consisting of 2 inductors and 2 capacitors; the second capacitor helps to keep ripple at 100 mVrms when the battery is disconnected, just as it would be when the battery is connected. At such low levels of ripple, even sensitive electronic communication equipment on the dc bus will not be damaged by ripple caused by the battery charger. As stated before, high-amplitude transients and sources of ripple other than the battery charger must be controlled as well to guarantee the safety of equipment on the bus.

Are any ATevo chargers sold with “battery eliminator filters,” and does this mean that I can operate dc equipment without a battery?

ATevo chargers are available with Filter Level 2 as an option to keep ripple at 100 mVrms when the battery is disconnected. The term “battery eliminator” that was used in NEMA PE5 has been retired by IEEE Standard 2405-2022 because it has led to this misconception for decades. See the FAQ-Can switchgear be operated by a battery charger without a battery connected? for more information.

How do I measure ripple?

You measure the ripple voltage using an ac voltmeter connected to the battery terminals. If the battery is disconnected (of course, only if you have a sufficient level of filtering in the charger as discussed earlier to protect equipment on the dc bus), measure the ripple at the output terminals of the battery charger. An analog voltmeter, like the old Simpson 260, is best, because the reading on a digital voltmeter might be too jumpy to get a good measurement. If you do use a digital voltmeter, it should have a 'true rms' measurement range.

I have a filtered battery charger. Ripple shouldn't be higher than 100 mV, but I measure a much higher voltage. What's wrong?

Of course, there is always the possibility that one (1) of the filter components in the battery charger is defective (usually capacitor 'C1' or 'C2'). These may need replacing after about ten (10) years. Before replacing components, check the other equipment on the dc bus. Some equipment (especially inverters, or instruments with switching power supplies) can increase ripple on the dc bus, even when measured at the battery terminals.

References

Additional information is available from the following sources:

- IEEE 2405-2022, IEEE Standard for the Design of Chargers Used in Stationary Battery Applications
- Charge! – Everything You Always Wanted to Know About Stationary Chargers
- FAQ-Can switchgear be operated by a battery charger without a battery connected?

Version History

Date	Firmware Version	Changes
05/05/2024	3.2.0+	Date document originated.