Genset Starting Education Module #5: How to Specify a Genset Battery Charger

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This module identifies and explains battery charger characteristics that are critical to success in genset applications, and includes the following specification areas:

- Battery charging performance, including compatibility with batteries of different technology
- Charger architecture
- Compatibility with the AC utility source
- User controls
- Ruggedness and reliability for the intended application
- User indications and alarms

Battery charging performance

The SENS Genset Starting Education Module #3: Solutions to Leading Causes of Battery Failure in Gensets identified some charger characteristics that can help overcome the inherent shortcomings of chemical battery technology. The complete list of demands placed on the charger by the battery is as follows. **The genset owner or maintainer must insure that**:

1. The battery charger **float voltage must be set to the correct value** recommended by the battery manufacturer. Different battery manufacturers recommend different voltage values because of different battery technologies (e.g. lead-acid versus Ni-Cd), specific gravities of electrolyte and different formulations of plates, grid alloy and active material. *The only reliable rule of thumb is to use the charging voltage recommended by the battery's manufacturer.*

2. **The charger must offer multi-rate (i.e. "boost", "high-rate" or "equalize") charging.** Automatic boost charging enables reduced charging time while minimizing electrolyte loss from excess charging voltage. Dual rate charging enables both fast battery recharge and low water consumption on float. Single-rate chargers, sometimes known as trickle chargers, only offer one charging voltage, so they cause either slow and incomplete charging or excess water use depending on their voltage setting. Because neither of these outcomes is acceptable in genset application, single-rate trickle chargers should be avoided except as temporary spares. More information on boost charging is in SENS Genset Starting Education Module #6: Battery Charging Basics.

3. The battery charger must be guaranteed by its manufacturer to **regulate DC output voltage to ±1% or better** of the correct value over all AC input and load conditions. This capability is essential to maintaining the battery's voltage in the narrow region between under- and overcharge.

4. Because the ideal charging voltage varies with temperature, the charger must **automatically temperature compensate its output voltage** so that charging voltage remains near the ideal value. All automotive voltage regulators are temperature compensated, and numerous chargers are available with this essential feature.

5. If a battery heater is used, the charger must be equipped with a **remote battery temperature compensation option, the remote sensing option** must be used, **and** the remote sensing probe must be physically connected to the battery's case or terminal post.

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6. **The charger's output voltage must be adjustable.** Different batteries might be paired with the charger during its lifetime. Battery manufacturers continue to innovate, and charging voltages sometimes change depending on the battery manufacturer and technology of the battery. Both the float and boost voltages must be readily adjustable to the battery manufacturer's specified values.

7. **The charger must be capable of charging a zero-volt battery.** In some cases batteries are sometimes discharged to complete exhaustion. Owners of rental gensets that are left disused for many weeks, for example, may attempt to recharge the genset's dead battery instead of replacing it. This requires that the charger recharge a zero-volt battery.

Battery charger architecture/topology

Battery chargers are available in several power conversion topologies, most of which have the potential to succeed in genset application. The corollary to this is that there are many chargers of all topologies that either fail prematurely or do a very bad job charging batteries. The outcome of either will be failure of the genset to start.

The job of the end user, consulting engineer or genset packager is therefore to correctly state the performance specifications the charger must meet, rather than specifying a specific topology. For example, if it is essential that a charger be electrically quiet, then users should specify the radio frequency interference (RFI) standards the charger must meet and require the supplier to prove with test data that its product meets the specified standard.

Battery charger topologies fall into two general groups based on mode of control and operating frequency:

1. **Mode of control - magnetic versus electronic:** Older designs of chargers including magnetic amplifier (mag-amp) and ferroresonant employ magnetic control systems to govern output voltage and limit current to a safe value. Although simple and very rugged, magnetic control is too imprecise to achieve the required regulation and temperature compensation functions specified above, under the heading *Battery Charging Performance*. Some magnetic amplifier type chargers are available with electronic controls that improve charging accuracy and functionality. Chargers using pure magnetic control deliver very poor output voltage regulation, causing both under- and overcharging of batteries. Therefore, chargers with pure magnetic control should never be used except as emergency spares. All silicon controlled rectifier (SCR) chargers are electronically controlled, as are all switch mode chargers.

2. **Operating frequency: line frequency versus high frequency:** Mature charger topologies including mag-amp, ferroresonant and SCR operate at twice line frequency – i.e. 120 Hz when operated on a 60 Hz AC grid. These technologies have in common the use of an iron core transformer that is, compared to switch mode technology, bulky and heavy. Switch mode topologies operate at high frequencies, e.g. >100 kilohertz (KHz). High level differences between the topologies are shown in the table below:

Table: Comparison of line frequency versus switch mode charger topologies

	Line frequency	Switch mode	Comment
Charging accuracy, features	Some accurate, some not	Some accurate, some not	SCR and switch mode designs are both electronically controlled. Accuracy and feature sets are determined by design specifications and engineering skill, rather than fundamental topology. Mag-amp and ferroresonant designs deliver less charging accuracy than SCR or switch mode types.

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Weight	Heavier	~ 20% weight of line frequency	Lower weight of switch mode topologies is enabled by high frequency of transformer operation. Mag-amp is heaviest of all types due to its use of a line frequency saturable reactor in addition to the line frequency power transformer.
Size	Larger	~ 50% volume of line frequency	Smaller size of switch mode topology is enabled by significant reduction in size of transformer and output filter.
Inherent electrical ruggedness	Better	Worse	The semiconductor power-switching devices in line frequency units are located on the secondary side of the charger's iron core isolation transformer. Because iron core transformers excel at filtering out high frequency signals, it is easier to design line frequency chargers with good inherent immunity against line-conducted transients such as lighting. In contrast, the power semiconductors of switch mode chargers are located on the primary side of the charger's isolation transformer. This increases the engineering skill required to provide immunity to electrical transients comparable to line frequency chargers. Any charger without published electrical transient resistance specifications should be regarded as a risky purchase.
Ruggedness	Some rugged, some not	Some rugged, some not	Both designs can be hardened to withstand shock and vibration, dirt, extremes of temperature and electrical transients. Consult manufacturer specifications to determine if the charger you wish to use is hardened to survive your environment.
Cost	Some cheap, some costly	Most cheap, some more costly	Consumer-grade switch mode designs can be extremely cheap because they are manufactured in large quantities and typically do not need to meet harsh the electrical and mechanical demands of genset application. Switch mode designs that are hardened against electrical and mechanical stresses are more costly than consumer-grade units. Chargers employing line-frequency power conversion of comparable specifications are generally more costly than switch mode topologies.

Compatibility with the AC utility source

Specifiers must insure that the charger is rated for the available AC supply. The following three types of AC input configuration are most common:

1. **Single input voltage**. The charger is rated for a single input voltage only – e.g. 117 volts AC, 60 Hz.

2. **Manually selectable input voltage**. The charger is equipped with an installer-operated switch enabling selection of different input voltages. Common inputs in North America are 120, 208 and 240 volts, 60 Hz.

3. **Autoranging input.** The input stage of some chargers can accommodate input voltage from 90 to 265 volts, meaning that they will operate on any common single-phase input supply.

Battery charger user controls

All adjustable parameters require easily understandable user controls. Controls commonly take the form of knobs, circuit board jumpers, keypad buttons or computer graphical user interfaces (GUI) connected to the charger via a data cable. Any of these adjustment systems is acceptable provided that the controls are reliable and easy to use. The requirement for high reliability rules out potentiometers (pots). Pots are undependable because they are subject to mechanical adjustment drift and contamination by dirt and

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moisture. Modern digitally controlled chargers completely eliminate pots, eliminating this particular reliability problem. Specifiers should forbid the use of pots in battery chargers.

Ruggedness and reliability for the intended application

Genset chargers are exposed to varying environmental challenges depending on method of installation in the genset, geographic location of the genset, and where the genset is located in the facility electrical system. To illustrate, a difficult genset environment is described below. This is followed by proposed solutions for each of the challenges identified:

1. **Charger mounting**: The charger is mounted without vibration isolators to a convenient genset surface that transmits considerable engine vibration to the charger. The charger is thus subjected to vibration of unspecified frequency and amplitude during genset operation.

2. **Geographic location:** The genset is located in central Florida. Humidity is high most of the year. Midsummer solar radiation heats the inside of the genset enclosure to 160 degrees F during the day.

3. **Power grid connection:** Central Florida is the lightning capital of the US, where electrical transients are frequent and severe.

4. **Installer skill:** The installer is inexperienced with battery charger installation.

Although no vibration, humidity or electromagnetic immunity standards are mandated for battery chargers in North America, the following approaches to increasing charger ruggedness are suggested:

- To address the vibration concern, require the charger supplier provide evidence of successful shock and vibration testing to standards applicable to gensets. The supplier may state the standards, but needs to provide a relevant link between the standard and real-world genset application.
- To address a highly humid environment, require that the charger’s **printed circuit cards be conformal coated** with suitable polymer material. Conformal coating reduces vulnerability of circuit boards to the effects of environmental pollution.
- To address concerns about lightning damage require that the charger supplier provide evidence that the charger **has passed electromagnetic immunity tests to at least IEC/EN 61000-6-2, “EMC Immunity for Industrial Environments”**. Products tested to this standard are more resistant to damage from electrical transients than untested products.
- To address concerns about installer experience, require that the charger be resistant to installation abuse such as reversed battery polarity and connection to incorrect battery voltage (e.g. 12 volt charger to 24 volt battery) and incorrect AC voltages. The charger needs to survive these events and provide visual indication that there is a problem.

In addition, users or specifying engineers should require the charger supplier to provide a complete statement of their product’s performance limits. Users and specifiers should then compare the published performance limits of competing products. Users and specifiers should always assume that **firms unable to supply performance documentation do not understand the limitations of their products,** and that such **products are not suitable for genset duty.**

Finally, users and specifiers should describe the operating environment in detail and require that the supplier warrants the charger will continue to meet its full specifications in the intended environment.

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User indications and alarms

The battery charger's electronic control system and permanent connection to the battery make the charger an ideal platform as a battery system health monitor. The requirement for meters and alarm systems is driven by standards bodies and by specific user needs. National Fire Protection Association (NFPA) standard 110, for example, requires that the battery charger provide metering of the charger DC voltage and ampere output. NFPA 110 also requires that the genset control panel provide certain alarms. Users thus have a choice to use a combination of control panel alarms or battery charger alarms to meet the alarm requirements of NFPA 110.

A typical battery alarm package may monitor the following conditions:

1. **AC failure alarm** to indicate when AC source has failed or is out of specification for the charger to function.

2. **Battery charger fail alarm** to indicate that although AC power is present, the charger is unable to deliver output.

3. **Low battery voltage alarm** to indicate that the battery has fallen below a predetermined, adjustable DC voltage. This alarm can be useful in detecting a gross failure in the battery, such as a shorted cell.

4. **High battery voltage alarm** to indicate that the battery's voltage exceeds a predetermined, adjustable DC voltage. The purpose of this alarm is to indicate battery charger runaway voltage.

Some chargers also monitor and alarm on incorrect connection of the battery and charger, such as reverse polarity battery, or connection of a 24-volt charger to a 12-volt battery, and vice versa. These alarms are helpful to installers in troubleshooting installation problems.

Safety agency certification

OSHA regulations require most electrical equipment connected to the power grid to be UL listed. The UL standard for gensets, UL 2200, requires that genset battery chargers be listed to UL 1236.

Seismic compliance

Seismic compliance: Earthquakes are a fact of life for most of the United States. International Building Code (IBC) seismic standards govern critical mechanical, electrical and plumbing equipment including gensets and genset subsystems such as battery chargers and batteries. Chargers and battery immobilization systems should be **certified by an accredited certification agency** as fully compliant with the latest release of IBC seismic standards.

The state of California imposes additional seismic requirements for gensets and genset subsystems installed in health care facilities. California OSHPD[1] requires either pre-certification to OSHPD seismic standards or lengthy review of submittal documents for each project.

Radio frequency interference (RFI)

Because many battery chargers include microprocessors, they are classified as computing devices by the Federal Communications Commission (FCC) and are required by law to comply with CFR Title 47, Part 15 regulations related to RFI.

[1] Office of Statewide Health Planning and Development.

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Battery charger power conversion efficiency

Certain jurisdictions such as the California Energy Commission either are enforcing, or have proposed battery charger power conversion efficiency standards in an effort to reduce national consumption of electric power. Depending on location of the genset installation, users may be required to prove that the charger meets the relevant efficiency standards.

Summary of key points

1. **Battery charger performance:**
    - Float voltage must be set to the correct value recommended by the battery manufacturer.
    - The charger must offer multiple charge modes (i.e. “boost”, “high-rate” or “equalize”) in addition to float, and selection should be automatic instead of manual.
    - Charger voltage regulation must be ±1% or better.
    - The charger must include automatic battery temperature compensation.
    - If a battery heater is used, the charger must be equipped with a remote battery temperature compensation option, the remote sensing option must be used, and the remote sensing probe must be physically connected to the battery’s case.
    - The charger’s output voltage must be adjustable.
    - The charger must be capable of charging a zero-volt battery.

2. **Battery charger topology:**
    - Many battery topologies can be made to achieve the above performance requirements.
    - Chargers with pure magnetic control (i.e. with no electronic control) should only be used for emergency spares.

3. **Battery charger user controls:**
    - Digital (jumpers or keypad) are easiest, as they allows precise adjustment of parameters.
    - Potentiometer (pot) adjustments should be avoided. Pots are susceptible to contamination by dirt and moisture, and they are vulnerable to mechanical adjustment drift.

4. **Battery charger alarms and metering:**
    - Gensets required to comply with NFPA 110 must be equipped with alarms for battery charger failure, AC failure to the charger, low battery voltage, high battery voltage and low cranking voltage.
    - Depending on capabilities of the genset’s control panel, some or all of these alarms and related alarm contacts may be required in the battery charger.
    - Battery charger meters for DC voltage and DC current are also required by NFPA 110.

5. **Ruggedness and reliability for genset applications:**
    - The charger supplier must provide evidence of successful shock and vibration testing to standards applicable to gensets.
    - The charger must be either fully encapsulated or have its circuit cards treated with a suitable polymer conformal coating.
    - The charger must include evidence that it has passed electromagnetic immunity tests to at least IEC/EN 61000-6-2, “EMC Immunity for Industrial Environments”.
    - The charger must include resistance to installation abuse including reversed battery polarity, connection to incorrect battery voltage (e.g. 12-volt charger to 24-volt battery) and connection to incorrect AC voltages. The charger needs to survive these events and provide visual indication that there is a problem.

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6. **Battery charger supplier specifications:**
    - The charger supplier must provide a complete statement of product performance limits.
    - Users and specifiers should compare the published performance limits of competing products.
    - Users should assume that suppliers unable to supply complete performance documentation do not understand the limitations of their products, and that such products are not suitable for genset duty.

7. **Agency certifications:**
    - *Safety*: genset battery chargers in the United States must be listed to UL 1236; in Canada they must be listed to relevant Canadian standards.
    - *Radio frequency interference*: As with all digital devices, chargers must comply with CFR Title 47, Part 15, Class A or B.
    - *Seismic:* Chargers weighing more than 20 lbs must be labeled by an accredited certification agency as fully compliant with the latest release of IBC seismic standards.
    - *Battery charger power conversion efficiency:* Depending on location of the genset installation, e.g. California, users may be required to prove that the charger meets the relevant efficiency standards such as the California Energy Commission.

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