BATTERY CHARGER OPTIONS OF STATIONARY APPLICATIONS
WHY DO WE NEED THIS STUFF?

Matthew Theriault
Designer
HindlePower Inc.
1075 Saint John Street
Easton, PA 18042

SCOPE AND PURPOSE OF THE PAPER

Throughout my work with the utilities and users of stationary batteries I have developed many options and features that have been employed in the battery charger enclosure. Most of these options are needed to power and monitor the DC bus. Some extra features will perform duties that are just related to the DC bus while others are dedicated entirely to the battery. These features are remote in function from the charging process of the battery. These extra features, such as sirens, input metering, and battery disconnect contactors were added to the battery charger enclosure to reduce cost, footprint, and to allow one-stop shopping. The end user or buyer may want to add their own special desires to the DC bus equipment to meet the needs of specifications developed for their application. Each utility has their own favorite features, and over time some of the options developed have been named after the utilities that created them.

Although most of the paper is written as an editorial about the ancillary equipment that is married to the battery charger, I do not go into any detail of the statistical analyses or probability of failure due to these added options. Keep in mind the key function of the battery charger is maintaining the DC bus while keeping your battery at optimum health and state of charge. What I hope to show is the description of the options, their function and what relevance those options have to the battery charging process. I will let you decide whether you think it is better to include specific features inside the battery charger enclosure. As I write the paper I know that this will have little impact into curtailing the specification requirements of the options described. Cost will always sit in the driver's seat when it comes to the DC system.

The DC system being used by the utilities and process control industries consists of a battery charger, battery, rack (or enclosure), spill containment of some sort or other, and the distribution center. The stationary battery charger is float charging the battery while providing the current for the DC loads. The battery is standing-by for loads that demand larger currents then the battery charger can provide or supplying the DC bus while the battery charger is offline.

Below is a list of common features that I have separated into three categories that are installed in a standby battery charger: There are certainly more features available that I have not included, but this gives us a good start for explaining the differences between them.

The first list of features is needed for the charging/process, and supports the loads which I call *Critical Drive Circuits*

- I/O protection
- Conversion style
- Current and voltage control
- Filter requirements
- Float / equalize controls
- Metering
- Temperature compensation
- Enclosure types or environmental controls

All these items are needed to perform the fundamental task of charging the battery and providing user controls.

The second tier list is the alarms for the DC bus: I'll call these *The Fault Circuits*
The alarms can provide a local and or remote indication of the condition of the battery and charger's health.

- High and low DC voltage monitoring
- Low or zero DC current
- AC failure or phase failure
- Battery charger failure
- Over temperature

The third category are features inside the battery charger enclosure that are either non-critical options or features associated with the AC feeds or the DC bus and are only slightly related to the battery charger. Extra Frills:

This is the category of options and features that the rest of the paper will address.

- AC ammeter and AC voltmeter
- Circuit breaker options such as breaker aux contacts, bell alarms and indication lamps
- Large KAIC rated breakers where there is a feeder breaker of the same rating upstream
- Transformer or bridge fusing
- Ground detection circuits
- Battery/Load current direction indicators and detectors
- Load distribution breakers built into the battery charger
- Battery charger voltage and current transducers
- High voltage/current relays for remote indication
- Enclosure features that do not agree (like NEMA 1 with doors that need a gasket)

Although the paper is written to utility power generation and distribution of electricity, it can apply to any stationary application where the DC bus voltage is 48V or higher. So these same issues can translate to process control, communications, UPS, and other kinds of battery charger applications.

Let's take a look at what is in a basic battery charger so you can understand their parts and functions.
The first is the AC input stage that provides some kind of protection, with fuses or a circuit breaker feeding an AC to DC conversion circuit. This conversion could be accomplished by a switching power supply, a Ferro-resonant transformer with a diode bridge, or a standard isolation transformer with an SCR/diode bridge. There is a filter section for reducing AC ripple and protective devices on the output. The charging process of the battery is provided by controls that limit the voltage and current depending on the battery type or charging needs. Output meters are added to monitor the output and adjustment controls are added to set the output voltage float and equalize setting.

Now to my objections to the list of options and features of the Extra Frills category listed above.

- I have a general rule when designing a reliable DC system: "keep it simple". Less switching, less metering, and less protection ensures that the equipment will have less to fail and less to maintain.
- Adding extra options in the battery charger box, like the load connections, shifts the DC bus focus from the main source of power, the battery, to the battery charger. This can result in a much more difficult job for the maintenance crew of ripping the entire DC bus apart in order to remove the battery charger.
- Some features are really related to the battery and the DC loads and these features may be more useful external to the battery charger enclosure.
- This list of features requires very custom equipment being produced in such small numbers that the cost for this custom work is expensive (?), engineering-intensive, and generally has little track record. Often these features are designed anew each time by the utility.
- Utilities need to invest in training personnel on usage and maintaining the custom equipment. This then becomes more extensive and expensive.
- When commissioning equipment there is not only the wringing out of the charging process, but deciding who is responsible for the function of the overall DC bus operation that may be unrelated to the battery charging process. Is it the fault of the specification writer, installer, or battery charger manufacturer when the whole system is not working to a customer's expectations?

GROUND DETECTION:
I want to start with one of the most common and perplexing features in standby battery chargers: DC bus ground detection alarm. This is a group of circuits that measures the imbalance of the DC bus to the building ground connection. Some customers wish to have a voltmeter or ammeter that displays the amount of imbalance. I rank it as one of the poorest ways to measure ground fault, because what is read on the meter is often misunderstood and always needs interpretation to determine the impedance of the fault.

The common problem with all ground detection circuits built into the battery charger enclosure is that if a ground fault occurs in the DC bus you need to isolate the problem by removing the separate parts. The first is the battery charger itself. This is done by removing the DC leads or opening a DC feeder breaker. If the ground detection circuit is installed in that enclosure you have just removed the tool that measures the fault to continue checking the rest of the DC bus. I have seen simple ground detection circuits mounted externally on the battery or distribution that is now in parallel with the battery charger's ground detection circuit. All of this adds what we are trying to avoid: an electrical connection to ground and the DC bus.

AC METERING:

The second is specifying AC metering. We are adding connections and components to the AC input of the battery charger often after the protection device. We need to weigh the need to read the feeder voltages and input current on the door of the battery charger with a possible fault that might cause the AC input breaker to trip. This would result in the battery no longer being charged. I always wondered why a utility that is monitoring the AC feeds throughout a substation or power plant would have someone wanting to monitor the AC power to the battery charger. Most battery chargers are installed in a place where personnel are restricted from observing operation. In most battery chargers an AC Failure alarm is added for remote and local indication, and is a more useful, cheaper and simpler option. Sometimes this gets worse and we add expensive digital metering and transducers for remote communications of the AC voltage and current.

BREAKER OPTIONS:

Circuit breakers are designed with many built in options, such as an auxiliary switch or a bell alarm. These two are remote indications of the position or whether the breaker was tripped due to over current. These options are usually built in by the breaker manufacturer. Most battery charger option sets provide an alarm if the AC fails or the DC bus voltage has fallen to a low alarm level. These indicate something has opened including the breakers or fuses that are included in the battery charger. The end user may want to know if a breaker is opened, but this becomes extra cost without much benefit. One of the added issues is the power that is monitoring the breaker is being fed through the breaker enclosure frame.

Another common breaker feature is a shunt trip breaker option. This is where a voltage can be applied to a breaker to activate the tripping mechanism and open the breaker. These are used to prevent over charging in case the output voltage becomes too high. It is a nice fail safe technique for shutting down the charger, but in some cases the customer asks for some strange actions to activate the trip circuit. I have seen specifications to use a DC low voltage alarm to activate the AC breaker shunt trip. The result of the low voltage alarm which could occur during an AC power outage would shut off the charger! Once AC was restored the batteries would not be charged. This event could also occur if loads were added that drove the battery charger into current limit. The next problem is how you choose to trip the AC breaker. Should you use the DC bus to open the AC breaker or the AC power to shunt trip the breaker? If I use the most reliable power, the DC, I am running the DC bus into the frame of the AC breaker. If I use the AC power how do I turn the battery charger on once my alarm has occurred? Most of this just makes designing, building, and using the battery charger much more complicated.

KAIC RATINGS IN BATTERY CHARGER BREAKERS

A breaker has three important ratings: two are voltage and current that the breaker opens during a fault, but it also has a rating of the amount of current that it can handle without exploding or melting. KAIC stands for Kilo Amperes Interrupting Capacity. This is important when a battery charger breaker is being fed by a power source that can provide many thousands of amperes from a power plant. In most cases there is a series feeder breaker at site that is connected and rated at the needed KAIC, which then feeds the battery charger just a few feet away. We now have paid for two breakers within 25 feet of each other doing the same job. Some of these breakers are hundreds of dollars spent needlessly.

The DC breaker is also sized for a KAIC rating to handle the short circuit current of a battery. This makes some sense, but when we look at the DC bus we see the battery is the source of the power. The battery charger circuit breaker is only protecting the wiring inside the battery charger. It does little good to protect against a fault to the I/O or the battery cabling. If you want to protect the DC bus it is at the batteries that we need to add the protection.

INTERNAL FUSING OF POWER COMPONENTS

I also see from time to time a requirement for fusing the bridge or transformer of a battery charger. These fuses are expected to open if there is a short to the bridge or a short to the transformer. These in–circuit fuses are often preceded by a circuit breaker. Not only are we adding the fuse holder wires and connections, but are adding a possibility that the connection may open power to the conversion circuit and prevent the battery charger from doing the job intended.

BATTERY / LOAD CURRENT DIRECTION OPTIONS

This was added into the battery charger many years ago and is a family of options that provides an indication of which way the current is flowing: in or out of a battery. The options include zero center ammeters along with alarms that activate as soon as current starts to flow out of the battery into the load. Since the battery charger is producing one of these currents it makes sense to place the electronics or metering into the battery charger enclosure. One of the drawbacks is that the load and the battery both need to be attached to the battery charger. If one wants to replace the battery charger the load has to be broken from the battery to unwire the trio. This requires the load to be shut down completely to do the reconnections. To improve the design we would want the current measuring device to be moved into the battery leads. But we need to move this away from the acid as well as enclose the measuring equipment in a separate enclosure. This drives up cost.

LOAD DISTRIBUTION BREAKERS/FUSING

This combines the battery charger with the load breaker panel board. It seems to make sense if you have only a few load connections and mount the breakers in the battery charger door. But again we may want to upgrade the battery charger and replace the battery charger and we would need to bring down the entire DC bus to do this work.

TRANSDUCERS:

Transducers can provide a group of voltage and current measurements connected to the communication port known as SCADA (supervisory control and data acquisition). This option uses a device that translates a voltage or current in the battery charger and converts it to a proportional signal, often isolated and remotely powered. The most common in the utility industry is transmitting a 4 to 20 milliamp signal. This option is a great way to remotely monitor the output voltage or current of the battery charger. It is a worry that we need to power the transducer with stable reliable power. The operational power to the SCADA system is the best choice but this needs to be defined and coordinated with the utility. Some would decide on the battery to power the devices and some would use a 120V AC source derived from a UPS. There is no real standard for this and so there are a lot of custom designs developed on each battery charger. Some customers want to monitor other voltages and slide these transducers into a battery charger enclosure. A list below shows some that I have seen:

- AC input voltage, current and frequency
- Battery current flow and direction
- Battery temperature
- Charger temperature

HIGH CURRENT AND VOLTAGE RELAYS FOR REMOTE INDICATION

Below is a section of a specification about relay contact capabilities:

"An AC power failure relay shall be provided with each battery charger purchased. It shall be designed to control a monitoring system, an alarm system, or both systems simultaneously. The relay contacts shall be sized to carry the following loads: 0 to 50 VDC at 10 amps 51 to 125 VDC at 5 amps"

Alarms built into the battery charger usually provide non-wetted (dry) contacts from a relay closure to signal a fault. Most of the time the contacts are wired to the SCADA system for remote monitoring. Some customers want to power something that is added externally like a siren, a flashing light, or an auto-dialer to the local fire department. When this is required they often use the DC bus that is present, and wire the loads through the battery charger.

Although the excerpt from the specification uses the words "sized to carry the following loads… 51-125VDC," what this relay really needs to do is to switch what could be an inductive load at 5 Amps with the DC bus at 145VDC. To do this job one needs a very expensive, fairly large relay. I might find a relay that meets the specification, but rated for switching only resistive loads. The possibility exists that the switch portion of the relay might break down during switching and cause arcing or fire in the battery charger. It would be safer to move these kinds of relays outside the battery charger enclosure.

OPERATIONAL CAPABILITIES

Although the specifications for a battery charger may include a list of options and features that can be isolated into the categories that were described above, there are other features that are defined rather loosely per expected operation.

> Spec excerpts:
> "B. The battery charger shall be capable of supplying DC load with the battery disconnected."

In the excerpt above it describes the battery charger being capable of operating a DC load with the battery removed. In the standby application it is important to be able to start the battery charger without the battery, but the wording about the load is too broad a term when trying to operate equipment that depends on the battery. The battery charger is not a battery and in some cases damage to certain loads could occur if the loads are being operated just by the battery charger.

This brings us to the feature of the Battery Eliminator. The name itself creates some misconceptions. First it does not eliminate the battery and the performance does not match the battery characteristics. The bus can be supported by the battery charger but in most cases the reason the battery is required is to handle high current loads or loads that need power while the AC has been removed from the battery charger. This question often arises when a substation wants to operate while the batteries are being serviced or folks want to start testing a new site without the batteries.

Now that the tour of the options in battery chargers is coming to a close, I step away with some final thoughts about the options ordered in the battery charger. I do not expect that requirements for these kinds of options are going away in the near future. Each utility does not like to be the first to embrace new designs or the last to use an outdated technology. The stationary battery charger is sold in such small numbers that new development investment is scarce, but I expect the world will want to have better ways to communicate via some kind of digital network. It is being done today and this reduces the amount of individual alarms and features. Think about adding options to the power supply that is powering the battery, and supporting large value turbines, high tension wires and the like may reduce the reliability of the critical source power.