Fast Charging Facts

Enhancing use of electric lift trucks, AGVs, and other motive electric vehicles

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Introduction

Fast charging of industrial batteries has become a main stream charging technology due to the operational savings, increased productivity and safety that this technology offers. Users have realized the benefits of fast charging and continue to realize the benefits at manufacturing plants and distribution centers throughout the US.

History

The concept of fast charging introduced in the 1970s focused on NiCad batteries for handheld products. By the early 1990s, fast charging had expanded to electric vehicles (on-road EVs) as a way to reduce charge time and make highway travel with an EV a reality. With the demise of the EV market potential by mid to late 1990s, the fast charging concept was further extended to industrial forklift truck batteries. Although many users and battery OEMs alike were quite skeptical of fast charging, extended field trials have demonstrated the viability of this technology and the durability of industrial batteries in such applications.

What's the difference between conventional, opportunity, and fast charging?

Conventional Charging

- Batteries are charged at rates of 16-18 A / 100 Ahrs
- Takes about 8-10 hours to fully recharge the battery
  - A battery is charged using the 8-8-8 rule: the battery charges over an 8-10 hour period, rests and cools down for another 8 hours, and is used (discharged) over an 8 hour shift.
  - This makes conventional charging ideal for one shift operations. For multi-shift operations (2 or 3 shifts), more than one battery per truck is needed. This means changing batteries every 8 or so hours, requiring labor, time and risk of injury.
- Conventional chargers always charge the battery to a 100% state of charge (SOC) on a daily basis, a process that involves considerable gassing to bring the battery to name plate specific gravity. This entails placing chargers in centralized charging areas to maintain hydrogen concentrations well below OSHA limits.

Opportunity Charging

- Batteries are charged at rates of 25 A / 100 Ahrs at every possible opportunity (i.e. lunch breaks, between shifts)
- Opportunity charging is a good choice for extended shift operations where battery changing can be eliminated.
  - In addition, opportunity charging extends the run time of aging batteries and recoups the lost capacity that comes with age. Note: the battery's end of life criteria is when the battery capacity reaches 80% of its new value.
- Due to the frequent charging and in order to limit battery gas generation, opportunity chargers are normally set to charge a battery up to 80%-85% SOC throughout the day and back to 100% only once a day (i.e. during night hours).

Fast Charging

- Batteries are charged at rates of 40+ A / 100 Ahrs at every possible opportunity. This includes breaks within and and in-between shifts, as well as lunch breaks.
- With brief and frequent charge intervals, a single battery per truck can be used thus eliminating the need for additional batteries as well as eliminating all battery changing between shifts.
- Batteries are charged to 80%-85% SOC on a daily basis thus eliminating any unnecessary gassing. The battery is required to be finish charged and equalized (100% SOC) at least once a week, which is normally done on weekends.

Benefits of Fast Charging

Conventional vs. Fast

Conventional charging in two and three shift applications—given that the required battery to truck ratio is 2 or 3 to 1 with battery use never exceeding 8-10 hours over a 24 hour period—the battery utilization (asset utilization) is 33% on average, a poor percentage for efficient asset use.

Fast charging, however, due to the higher charging rate and more frequent charging throughout the day, requires only a single battery per truck. This eliminates the need for additional batteries and greatly improves truck driver productivity because the time spent changing batteries in two and three shift applications is also eliminated. The battery utilization factor jumps to a full 100% (full utilization of the asset) with fast charging.

Return on Investment (ROI)

ROI and NPV of fast charging in two and three shift operations well exceed the return requirements of the most aggressive finance managers. Although the cost of fast charging equipment is higher than that of conventional chargers, significant operational savings as well as initial investment savings can be realized.

Lets consider the case of a manufacturing facility planning to acquire (or upgrade) a forklift truck fleet of 50 trucks. With conventional charging, assuming a ratio of 2.2 batteries per truck, 120 batteries are needed versus only 50 batteries with fast charging. In addition, with conventional charging, battery extraction and changing equipment will also be needed to change batteries between shifts. A simple run through the initial investment costs as well as the operational savings of conventional versus fast charging is shown below:

CAPITAL COSTS				
	CONVENTIONAL		FAST	
	No. of Units	Cost	No. of Units	Cost
Batteries	120 @ $4,000	$480,000	50 @ $5,000*	$250,000
Chargers	50 @ $2,000	$100,000	50 @ $11,000	$550,000
Changing Equipment		$50,000		$0
TOTAL		**$630,000**		**$800,000**

*NOTE: The additional cost of the fast charge battery is due to the extra construction requirements, as well as recommended accessories for equipping fast charge batteries (see Battery Requirements).

Additional Initial Investment = $170,000

ANNUAL SAVINGS			
Saving	Detail	Calculations	Annual Savings
Productivity (no battery changing)	• 100 battery changes/day (2 shifts, 50 trucks) • 20 min./change = .33 hrs • $25/hour labor rate (loaded) • 5 days/week => 250 days/year	100 x 0.33 x $25 x 250	$206,250
Battery Room Attendant can be utilized elsewhere	• 1 attendant/shift (2/day) • 8 hours/shift • $25/ hour labor rate (loaded)	2 x 8 x $25 x 250	$100,000
Floor Space Savings (no battery room needed)	• 4,000 Sq. Ft. @ $25/Sq. Ft.	4,000 x $25	$100,000
Additional Batteries Needed	• Battery life = 3 years in fast charging vs. 5 years in conventional charging (need new batteries by year 3)	3/5 x 50 x $5,000/3	($50,000)
		Total Annual Savings	**$356,250**

ROI = 0.47 Years

Fast Charging Requirements

Battery Requirements

The basic cell construction of a fast charge battery is the same as that of a conventional battery. What differentiates a fast charge battery from a conventional one is the final construction of the battery tray, as well as the accessories installed on the battery. Fast charge batteries are commonly equipped with dual intercell connectors and dual cables. In some instances, the batteries are also equipped with copper post inserts which tend to reduce the contact resistance of the post. Finally, some fast charge batteries are built with vents in between the battery cells to allow for improved cooling.

In addition to construction requirements, fast charge batteries need to be equipped with a number of accessories, which include a single point watering system with water level indicator, an electrolyte temperature sensor (thermistor), and an optional battery monitoring unit. Since temperature data (or battery monitor data) need to be fed back to the charger, connectors with auxiliary contact pins are required. Although SBX connectors incorporate auxiliary contact pins, Euro type connectors have more durable auxiliary contact pins that are molded within the connector housing.

Truck Requirements

There are minimal requirements to operate a truck in a fast charge application. Changes include permanent mounting of connectors on the truck, especially if using dual battery cables and connectors. If a single battery cable/connector is used, then no changes are required. Optional accessories include fans to cool the battery and reduce heat rise under the hood. Fans may also improve battery performance by lowering the battery operating temperature.

Another requirement, often overlooked, is the need for vents within the battery compartment. Many trucks have conventional designs where the battery is fully enclosed within the battery compartment. This can lead to higher battery temperatures during run time, as compared to trucks with exposed battery compartments, and may lead to interrupted charge cycles as the battery temperature might exceed the maximum allowable limits. Truck manufacturers ought to consider venting options to allow the batteries to run cooler or allow for added active cooling via on board fans to move air on top of the battery for a successful fast charge implementation.

Fast Charging

Fast chargers are quite different than conventional chargers in a number of respects. First, the power rating of a fast charger is 3-4 times that of a conventional charger. Note that fast chargers are available with charging rates of up to 600A. As such, fast chargers may be equipped with dual cables and dual connectors for charging rates in excess of 300A. Secondly, fast chargers incorporate advance controls that maximize battery acceptance and actively limit the battery temperature rise. As such, a thermistor is required on the battery side. In order to allow feedback temperature measurement to the charger, connectors with auxiliary contacts are needed. Available connectors with auxiliary contacts include the SBX and the Euro types, although the Euro type connectors have more durable auxiliary contacts.

Electrical Infrastructure Requirements

Since the power rating of a fast charger is higher than that of conventional chargers, the plant electrical infrastructure must be capable of powering the fast charger fleet. This also entails proper sizing of the electrical outlets for each charging position as well as distributing the power to various fast charging locations throughout the plant.

Charger Placement

Since fast charging entails charging at every opportunity possible, it is highly recommended that the chargers are placed very close to the work areas (distributed throughout the plant). This is contrary to conventional charging where chargers are installed in one area, namely the battery room. Careful review of the plant operation and the work flow throughout the plant will allow for better implementation of fast charging. Fast chargers are commonly placed near break areas, receiving and shipping docks, and work cells.

Fast Charging Battery Concerns

Although fast charging has become a main stream charging technology, there are still negative impressions about this technology. One of the most common misconceptions is that "fast charging is not good for the battery". Some claim that the higher temperature the battery experiences due to the high rate of charge leads to shorter battery life. In fact, many go further to conclude that the expected battery life in fast charging is three years or less as compared to five years in standard charging applications. At a first look, these comments are sound and reasonable given that some of these claims used to be true. Due to advancing technology, however, these claims are no longer accurate.

Operating Temperature

First, it is true that a battery experiences higher operating temperatures in fast charge applications. The only caveat is that the higher temperature is not due to the high charging rates but rather to the lack of cool down periods. Note that in conventional charging, the batteries on average get a rest or cool down period which reduces the battery operating temperature. In fast charging, since the battery is either in use or being charged, cool down periods are limited to weekends after an equalize cycle. As such, the average operating temperature of the battery increases throughout the week. Note that the temperature rise due to the higher charge rate of fast chargers is not much different that that of conventional chargers. In fact, most of the temperature rise during the charge process takes place during the gassing phase or finish charge phase (85%-100% SOC). The fast charge process is terminated at 80%-85% SOC, well before the onset of gassing, limiting the temperature rise of the battery. In addition, all fast chargers require temperature feedback from the battery and incorporate active controls to limit the maximum battery temperature during charge.

Battery Life

Many perceive that the average battery life should be 5 years (time based). This is true for conventional charging methods. With a fast charge application, however, battery life is generally 3 years or less. It's important to note that in conventional charge applications, the battery is used in one shift per day while in fast charge applications it is used in two or more shifts per day. Hence, a fast charge battery does the work of two or more batteries on a daily basis. As such, even if a fast charge battery lasts half the time of a conventional battery (2.5 years versus 5 years), it will still deliver the same amount of power that a conventional battery will deliver over a longer time period.

To present the point in a different way, if one would calculate the total amp-hour delivered from a conventional battery over its life time, the fast charge battery would deliver the same amp-hours or even more during a shorter time frame. A customer is still getting the full power he paid for out of both batteries. This in fact gives rise to a new warranty concept that is not time based but rather energy throughput based, or what we refer to as Warranted Amp-Hours. Converting a typical conventional battery warranty of 5 years where the battery is expected to deliver 1500 cycles with 80% depth of discharge, the resultant Warranted Amp-Hour value is: 80% x 1500 x Battery Rated Amp-Hour Capacity or 1200 x Battery Rated Ahr Capacity. For example, for an 850Ahr battery, the battery is expected to deliver 1.02 million amp-hours over its life time. As such, battery OEMs can offer an alternate warranty for the same battery of 1.02 million amp-hours or 5 years, whatever comes first.

Is Fast Charging for Everyone?

Not necessarily. First, there must be ample opportunities to charge the battery within each shift (or in between shifts) to recoup the amp-hour used. In some applications, and although there is ample time within the day to return all amp-hours used, most of the charge time available is after the end of the second shift, i.e. two shifts are operating back to back with minimal charge opportunities. Unless the operation can be modified to allow for more breaks (charge opportunities) within each shift, fast charging may not be the right application.

Secondly, one needs to allow for a finish/equalize charge cycle at least once a week, a process that may take up to 8 hours. Heavy three-shift or 24/7 usage may not be a candidate for fast charging if a finish / equalize charge cycle cannot be accommodated. However, hybrid opportunity/fast charge/battery changing solutions may be viable and may offer dramatic reduction in the number of battery changes per day, which can significantly improve productivity.

Are You a Fast Charge Candidate?

Well the litmus test is simple. If you operate (plan to operate) battery powered trucks at least 1.5+ shifts per day and do (or anticipate doing) at least one battery change out per day, you may be a candidate for fast charging. The next step is to fully understand the operational profile of the trucks and batteries to discern whether you can actually use fast charging. This can be established through a power study where the battery/truck operation is monitored throughout the week. For the collected data, one can establish whether there are adequate opportunities for fast charging through the shift or day as well as a weekly opportunity to perform a finish / equalize cycle.

Final Word

Fast charging is a technology that has many advantages that can allow users to realize significant savings. For the successful implementation of fast charging, one needs to consider a number of factors and develop a good understanding of what this technology can offer and what the limitations are.

Case Histories of PowerDesigners Charging and Monitoring Applications

Food Products Service Distributor Saves on Energy and Capital

The situation:

- Old charger technology burning energy and money
- Two batteries per truck, requiring change outs and excessive capital and labor costs
- A 12 truck fleet and low energy costs at 3 cents/kWHr

After implementing PowerDesigners' fast/opportunity charging:

- $2,600 per year in energy savings
- $56,000 per year in labor productivity savings

Global Third Party Logistics Company Optimizes Cost Savings

The situation:

- Battery change outs are time consuming and labor intensive
- Dropped batteries risk worker health and damaged equipment
- Truck accidents common near change out equipment

After implementing PowerDesigners' fast/opportunity charging:

- Reduced labor and capital costs
  - Eliminating battery change outs saves $4,500 per truck annually in change out labor
- Reduced risks
  - No chance of dropped battery
  - Truck accidents eliminated by removing need for trucks to converge at single point

Global Automotive Manufacturer Right Sizes Fleet to Reduce Capital Costs

The situation:

- Large manufacturer wants to get more out of less equipment
- Begins by gathering critical battery and charger data with PowerTrac SP+

After implementing PowerDesigners' fast/opportunity charging and battery monitoring system, PowerCharge.NET:

- Operations streamlined with rapid and opportunity chargers configured for any battery
  - Reduced number of batteries needed
  - Eliminated need for battery change outs
  - Eliminated charging rooms to free up space
- Capital costs greatly reduced
- Labor productivity improved as labor costs decreased

Large Distribution Center Establishes Battery Management Practices

The situation:

- Large, multi-shift distribution center routinely mismanages battery fleet
  - Lack of battery equalization
  - Lack of battery watering practices
  - Lack of battery preventative maintenance

After implementing PowerDesigners' fast/opportunity charging and battery monitoring system, PowerCharge.NET:

- Savings of $700,000 in reduced battery maintenance and replacement costs
- Battery tracking, automatic alerts, and customized reports simplify battery management
  - Batteries in need of equalization are automatically equalized
  - Under-watered batteries are flagged and held at battery rack for watering
  - Battery reports help determine overall usage of each battery

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