How-To Series

Understanding Charging Option for Heavy-Duty Electric Vehicles

LION ELECTRIC

thelionelectric.com

One of the biggest questions every operator looking to transition to electric vehicles (EVs) will have is **what charging options are available on the market, what the terminology means, and most importantly, which solution is right for their specific application.**

With new terminology such as AC and DC fast charging, kilowatt (kW) power ratings and voltages, just to name a few, it can be easy to feel a bit overwhelmed even for those familiar with consumer EVs vehicles, who aren't used to much difference in fuel stored energy aside from octane ratings.

However, the learning curve is not nearly as steep as it initially may seem – and the good news is, unlike traditional internal combustion engine (ICE) vehicles, EVs offer a broad range of possibilities for delivering energy to the vehicle. With many charging options available for fleet electrification, it is often difficult to navigate the full range of solutions, and there are certain schools of thought within the industry where philosophies clash. In short, your infrastructure needs to match your fleet needs if you want to derive maximum benefit from your EV leet.

This article presents the various vehicle charging options that are available or are currently the subject of research and development, which could make them viable solutions in the future. We present the options with their advantages and disadvantages. It is important to understand their capabilities and, in some cases, the context in which they were introduced. A final summary table allows you to compare the options and find the best fit for you. This will give you the knowledge to ask the right questions to your vehicle manufacturer, supplier or charging partner. Certain manufacturers may provide all of these services, which is worth taking into consideration when choosing a vehicle.

Table of **contents**

02 Introduction

03 Table of contents

04 **Direct Connection**

05 Level II – AC charger

06 Level III – DC charger

07 **Battery Swapping**

09 **On-Demand Charging Systems (overhead)**

11 **Induction Charging**

12 **Charging Option Comparison**

13 **Understanding Recharge Time**

15 Summing it Up

Direct **Connection**

Direct connection refers to when the electricity is carried from the EV charger to the vehicle by a cable. The vehicle will be connected to the charger and the charging time may vary according to several criteria: the most important being the capacity of the battery and the power level of the charger, expressed in kilowatts (kW). Obviously, the vehicle needs to come back to the charging station to recharge the battery. The charger will be installed at the depot where the vehicle resides as in most private fleets, at a specialized charging center or at a public terminal.

There are three levels of chargers, designated simply Level I, II and III. Level I involves plugging into a standard 120-volt wall outlet. This is not an option for a heavy-duty vehicle due to the immense size of their batteries, but is common for home EV charging. We will therefore focus on Level II, which uses alternating current (AC), and Level III, which uses direct current (DC). These are two separate technologies. The most important differences for the fleet operator are the potential charging speed and the price of charging infrastructure.

Level II – AC Charger

Figure 1. Standard Level II home charging station

A Level II charging system consists of a small charging station which delivers power, by alternating current, to an internal charger installed in the vehicle. The reason being batteries can only charge and store energy in direct current form, so the onboard charger must invert the power from AC to DC which the battery can accept. A Level II charging station is economical (typically less than $5,000) but the vehicle must be equipped with an internal charger, which will have an impact on the purchase price of the vehicle. Installation is relatively simple, as many Level II stations can be plugged into a 208/240-volt outlet, similar to a drying machine plug. However, higher powered Level II charging stations typically associated with heavy duty fleets are usually hardwired directly into a panel.

This charging system is also less powerful in comparison to Level III. The maximum power available is currently around 20 kW. Thus, it will be useful for vehicles with smaller batteries, relatively speaking, and which have a long enough period to recharge, such as vehicles parked overnight (see the guide on charging time later in this article).

AC/Level II Advantages:

- **LOW acquisition price** for the charging station
- Generally **EASY to install**
- **LOTS of availability** in public terminals

AC/Level II Disadvantages:

- **SLOWER recharging**
- **May impact vehicle price**

Level III – DC Charger

As with AC charging, DC charging requires the truck to be plugged into a charging station. The main difference is that the inversion of current from AC to DC – the current used in the battery - is included in the charging station and thus there is no on-board charger (or inverter) installed on board the vehicle. This will generally save a few thousand dollars on the vehicle cost and a bit of weight in the vehicle. DC charging is commonly referred to as fast charging, especially in the context of public EV charging networks.

Figure 2. Level III charging station

DC charging is typically faster because it is more powerful, but there is a wide range of DC charging powers available, from a little over 20 kW to several hundred kW. Thus, it is possible to charge the batteries of the vehicle in a very short amount of time and get back on the road quickly. However, the more powerful a charger is, the more it will demand from your electrical installation. It is advisable that you contact your electrician as well as your local utility to understand their rate structures and potential demand charges.

When it comes to DC fast charging speed, the sky is not the limit for a few reasons. If you are planning to acquire an electric heavy-duty vehicle and a charger, you really need to check with your truck supplier to find out what is the greatest charging power that the vehicle can safely accept – manufacturers have different limits based on several factors, but ultimately aimed at not overly stressing the battery as charging has the potential to create a lot of heat. It is unnecessary to equip yourself with a very powerful (and more costly) charger if the vehicle cannot receive the maximum power the charger delivers. In that case, the vehicle will only accept its maximum charging power – for example, a 150 kW charger attached to a vehicle that can only accept 100 kW will charge at 100 kW, and no higher.

However, one consideration is that it could make sense to get a more powerful charger to accommodate future models of vehicles with higher charging power limits. In addition, some charging station models are equipped with two connection sockets. When two vehicles are plugged in, the charger supplies 50% of its capacity to each vehicle, but when only one is plugged in, it receives 100% of the power. This turns out to be a great alternative that can serve two vehicles today and a more powerful one in the future. It is important to discuss with your energy charger supplier and vehicle OEM.

DC/Level III Advantages:

- **SPEED** of charging
- Potential solution for routes with **FASTER turnaround times**
- **LESS expensive** and lighter vehicle

DC/Level III Disadvantages:

- **HIGHER energy demand** for your electrical installation
- **Typically a HIGHER purchase price** than AC charger
- **Likely HIGHER utility costs,** depending on your utility and charger power level

Battery **Swapping**

Battery swapping involves replacing a depleted battery with a fully charged battery. The concept behind battery swapping is for it to be done quickly so that the vehicle is ready to hit the road again. It sounds simple and convenient.

In reality, however, battery **swappings quite complicated** both technically and operationally.

A heavy-duty vehicle battery pack weighs several hundred kilograms/pounds and typically a heavy-duty vehicle has a minimum of two battery packs, often more. Specialized handling equipment is therefore necessary for battery swapping, however there are robotic solutions being tested. In addition, most modern batteries are cooled with a liquid or gas coolant. Thus, not only must the electrical connection to the batteries be disconnected, but also the tubing which carries the coolant – and any coolant lost in the process must be replaced. In addition, consider the size of compressors / heat exchangers and fans that surround this type of battery. You can imagine the technological issues linked to the swapping of batteries, however convenient it may sound. There are companies exploring this space, but it is clear that easily swappable modular technology will need to be developed and perfected, along with standardized specifications and form factors.

Consider also the operational or logistical challenge. Battery exchange centers would need to be located along heavily-trafficked highways in order to enable long distances to be reached conveniently. Like going to a gas station, the truck driver must exit the freeway and go to the battery swapping center. The work would need to be done quickly so as not to interrupt the driver's shift dramatically. Such a center must also be able to recharge the batteries quickly in order to be effective. Consider that the truck driver must make this type of stop, with today's technology, every 400 kmor 250 miles, which effectively means less time on the road per shift. Many truckers will be reluctant to accept this type of route, which undermines the likelihood of electrifying the route – no one wants to build a truck stop on a road with no meaningful truck traffic. For an operator using only one brand of truck and exchanging their own batteries, swapping would be more feasible but still brings several complications and compromises.

The more likely solution for long-distance EV trucking is very high-speed charging. The time it takes to fill a truck with a tank of diesel today is still the gold standard that truckers expect and factor in as they plan their time behind the wheel – getting as close as possible to this time-frame is the goal. Experts agree that electrified long-distance runs will be possible in the near future when the fast charging capabilities of both chargers and trucks will result in charging times of 30 minutes or less.

Figure 3. Robotic Battery Swapping Test Center

On-Demand Charging Systems

On-demand (overhead) charging consists of charging the batteries in small doses several times throughout a route. This technology was developed in Europe in the early stage of heavy-duty vehicle electrification when batteries had little capacity. In order to travel a certain distance, charging had to be done often, so the solution was to recharge the vehicles whenever there was a stop via an overhead charging mechanism. Applied to buses, this technology offers a certain consistency because the buses travel the same route and must stop often on their route.

However, each overhead charging station is very expensive because it must input a large amount of energy to the vehicle in a very short time. Furthermore, the physical footprint of each charger is also an important issue in cities where space is in high demand. The advantage of this technology lies mainly in the fact that the vehicle requires smaller batteries (which tend to cost less), and is less bulky and less heavy.

Catenary system or **electric road**:

Moving this concept further would result in a system where the vehicle is constantly connected to the electrical network. This is what catenaries offer as a solution. The catenaries are reminiscent of the first rail trams that circulated in several city streets, but they are also used for heavy-duty vehicles – most commonly buses. The cities of Vancouver and San Francisco, for example, have sophisticated networks of electric buses powered by catenaries. The route of the vehicles is limited because they have very little autonomy without their connection to the catenary network.

Some studies are currently underway in Europe to explore this type of link for trucks transporting goods on roads. However, the volume of vehicles on these road sections must be very high to justify the installation of a catenary system. Such systems are expensive; a UK study estimated the cost of construction to be around $ 1.5 million USD per km or over $2 million USD per mile. In addition to the pantograph (the piece attached to the vehicle) required to reach the power line, vehicles must also be equipped with an electric motor and battery (albeit small in comparison to an EV) to go from the terminal to the electrified route road. The empty mass of the trucks is therefore pretty similar to a battery powered truck and the price of the trucks is at best only slightly reduced.

Catenaries also impose many logistical constraints and of course, it is nearly impossible to overtake a slower vehicle. Vehicle failures, infrastructure integrity and power supply on such a network could all cause potential shutdowns. Groups continue to support this type of infrastructure, but the limitations are significant when it comes to trucking.

Figure 4. Autobus avec caténaire *Source photo: Flickr "VBSG - Hess lighTram 25 DC" par Kecko*

Induction

Charging

Induction charging allows the battery to be charged without direct connection, or even without physical contact. Some smart phones and watches are now equipped with this type of recharging, but consider that their batteries and power needs are very small.

Induction charging offers a practical element which is very interesting because the driver only has to bring their vehicle to the source of energy and charging begins immediately – for example turning a parking space or garage into a charger, with no need to plug in, which for fleets would take a step out of the process. After all, neglecting to plug in a truck will have a major impact on operations. Several studies are currently underway in this area. For the moment, the power that can be transmitted safely by induction remains relatively low, which limits its use in the world of heavy-duty vehicles.

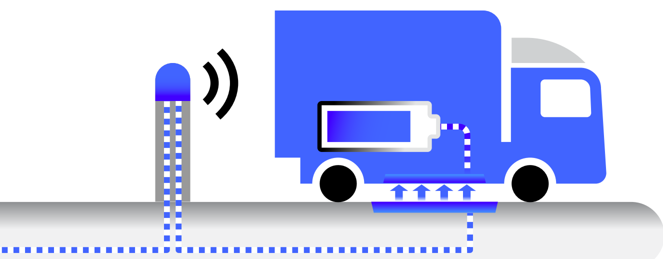


Figure 5.Induction charging parking space

Charging Options **Comparaison**

	Speed of charge	Cost	Impact on logistics
AC charger		$	
DC charger		$$	
Battery swapping		$$$	
On-demand (overhead)		$$$	
Catenary / electric road		$$$$$	
Induction		$$$	

Understanding Recharge Time

The recharging time varies considerably depending mainly on the type of charger used, the battery capacity, the protections installed to protect the integrity of the battery (vehicle charging power limit) and the outside temperature. Remember that high power charging has the potential to create a lot of heat, which can damage the battery.

To estimate the recharging time, the following rule of thumb can be used:

Battery capacity in kWh / charger power in kW = Charging time.

A 100 kWh battery will be recharged in about 5 hours with a 20 kW charger.

Recharge **curve:**

Manufacturers often report charging times for 80% of the capacity of the battery. For instance, 80% battery will be charged in 2 hours. The reason is that the first part of the recharge is always faster than the last 20%. It's a bit like when you fill a glass with water to the brim, you will start by turning the tap on all the way at first and then reduce the flow to a trickle of water to complete the filling. This is done to protect the battery from potential damage.

In the case of the battery, it is the internal battery system, also called the battery management system (BMS), that protects the battery against overheating (See figure 1).

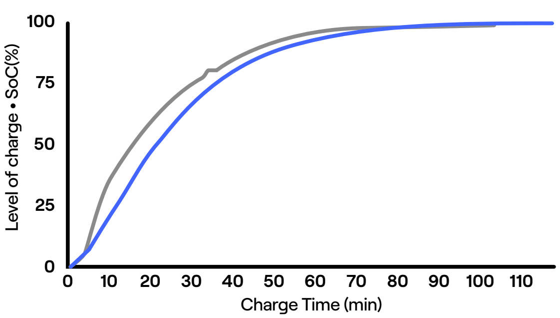


Figure 1. Typical Cooldown Curve

Impact of charger power:

Using our example of a glass of water, simple math could lead us to believe that by using a fire hose to fill a glass with water, it could be filled in fractions of a second. The reality is that most of the water will just splash out, due to the high pressure, or the glass could even break. We can draw the same parallel with a charger too powerful for a battery.

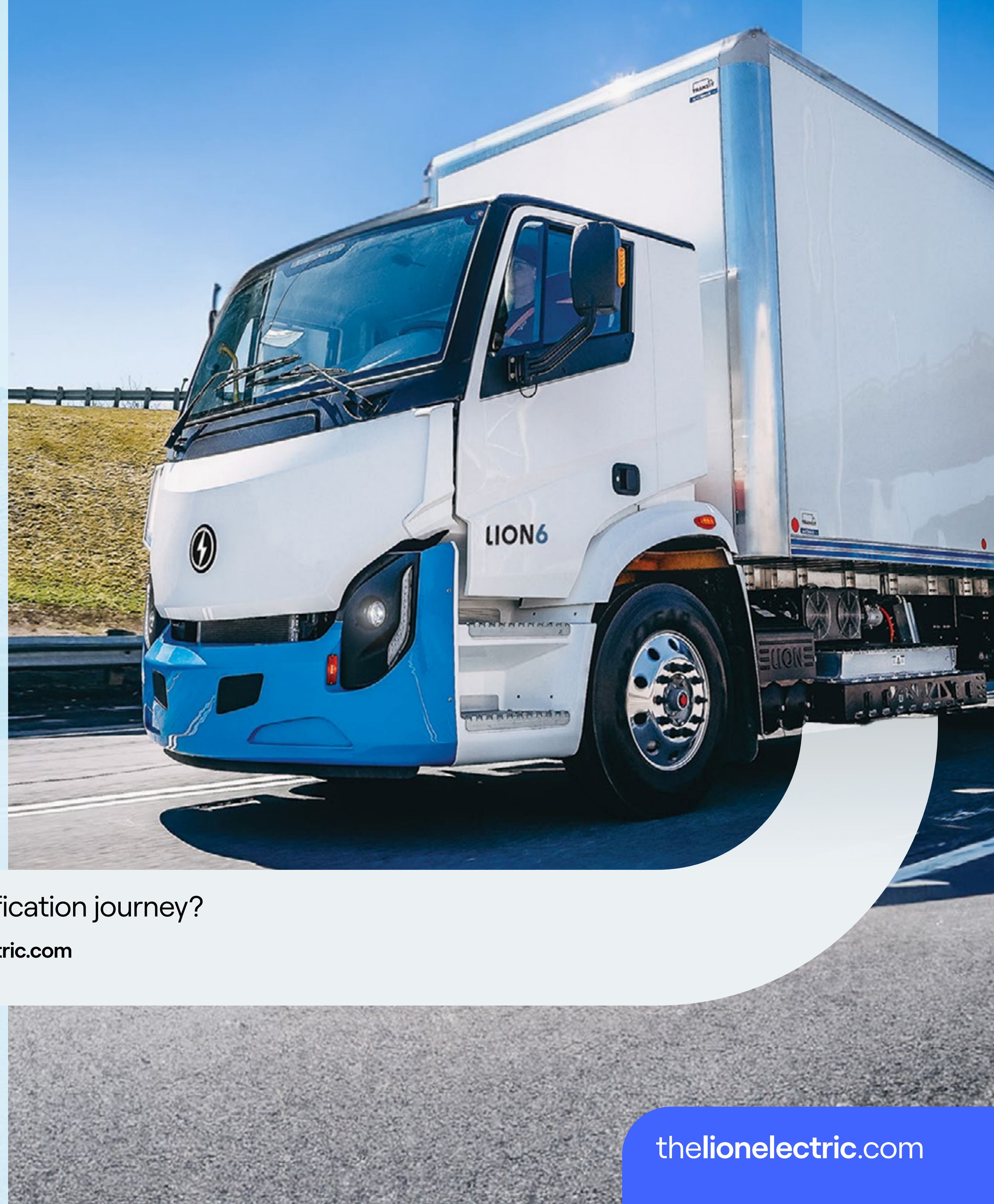
Charging a battery with a charger that is too powerful is like a fuel station suddenly announcing that it offers a diesel filling service with a flow rate of 500 gallons per minute. This would certainly be very fast, however it would be impossible to get that fuel into the vehicle's tanks at that rate.

Imagine a driver wanting to optimize their time to better serve customers comes to the pump. The driver takes the filler from the pump and inserts it into the tank (and hopefully holds it firmly with both hands!), and starts filling. The flow generates a real storm in the tank, the internal turbulence causes the fuel to splash everywhere, it even comes out through the filler hole. Quickly the tank begins to overflow. Satisfied, the driver puts the filler back and climbs into his truck, not only noticing his tank not full, but hardly any fuel transferred to the tank on the opposite side of the truck!

This is exactly what happens with over-charging your batteries. The BMS (Battery Management System) will protect the battery. Even if the charger can deliver 250 kW, if your 500 kWh battery can only take a flow of 100 kW, it will protect itself and it will not take 2 hours to charge the battery but 5 hours.

Summing it Up

When it comes to heavy-duty charging, the most important thing to consider is what solution available today is right for your needs. If you have shorter turnover times between routes, DC charging may be the way to go, while for vehicles which are parked overnight, AC charging may be sufficient. There are some interesting alternative options which may become viable in the future and some solutions may prove well-matched to certain niches. By working with a vehicle manufacturer who can evaluate your fleet needs and assist in implementing the proper charging technologies, you will ensure the right infrastructure fit for your fleet.



Ready to get started on your electrification journey?

Discover more valuable information at **www.thelionelectric.com**
or email us at **info@thelionelectric.com**!

LION ELECTRIC

thelionelectric.com