CREATING THE GAS STATION OF THE FUTURE WITH GALVANICALLY ISOLATED DC:DC CONVERTERS

How Implementing Galvanically Isolated DC:DC Optimizers Can Facilitate the Transition to a Faster, Safer and More Cost-Effective Infrastructure for Large Scale Charging of Electric Vehicles

Abstract

This white paper explains both the basics of EV charging as they stand today as well as the challenges involved in scaling up the faster charging approaches we will need to implement to meet the current Administration's EV penetration goals. This white paper introduces a novel approach to charging EVs faster at scale based on Alencon's unique, galvanically isolated DC:DC converters, a concept we call "The Gas Station of the Future." Fortunately, it is a concept that is here today. Read on to learn more.

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Creating the Gas Station of the Future with American Made, Galvanically Isolated DC:DC Converters

In case you missed it, the recently announced [$2 trillion dollar federal infrastructure bill] from the Biden administration includes an ambitious plan for the expansion of electric vehicles and electric vehicle charging infrastructure including installing 500,000 EV fast-charging stations across the country. In this white paper, we are going to take a deep dive into the ramifications of this goal, including explaining what EV fast charging is all about, some of the fundamental challenges in implementing this goal and how an American manufactured, galvanically isolated DC:DC converter technology might just hold the secret to achieving this ambitious vision while doing so in a manner consist with a [recently issued executive order] on doing so with American manufactured products.

Where We Are with EVs Today and the "Fast Charging Challenge"

The reality of the situation today is that all electric vehicles, also referred to plug-in electric vehicles or PEVs, including models from Tesla, account for less than 2% of vehicles on the road. That is a far cry from the ambitious goals laid out in Biden's plan.

To increase the penetration of electric vehicles and move them from niche to the mainstream, we need to address the issue of charging them faster. Efficient, safe, cost effective and readily available EV charging represents one of the greatest obstacles to large scale EV adoption. To get more Americans to adopt electric vehicles, it is critical that PEVs be at least nearly as fast and convenient to "fill up" (or recharge) drivers have become used to with internal combustion engine (ICE) vehicles. That is a tall order since gas stations today are ubiquitous and filling up even a large, gas guzzling SUVs does not take more than 15 minutes typically.

As a bit of background, let's explain the different types of EV charging available on the market today.

Level 1 Chargers: Level 1 chargers typically come with new electric vehicles and can be charged with a standard 120-volt wall outlet in your home. Challenge is, this level of charging is incredibly slow, typically taking tens of hours to fully charge a PEV, meaning it could take upwards of 40 hours to give you 250 miles of range. Ouch.

Level 2 Chargers: Level 2 chargers can be installed in your home by a qualified electrician and require a 240-volt electrical service. They will charge your vehicle anywhere from three to seven times as fast as a level one charger, which is a big step in the right direction. With a Level 2 charger, you can typically charge a PEV in about 7 – 10 hours, so you can reasonably achieve 250 miles of range by plugging in your vehicle overnight. Better, but still a far, far cry what ICE vehicle owners are used to. Many public charging stations are Level 2 chargers. If you have a level two charger at work, you can conceivably charge up at work (once your office opens up after COVID that is).

Level 3 Chargers: Level 3 chargers are the fastest way to charge a PEV today. Some public stations are level 3 chargers. These are also known as DCFC or DC Fast Chargers and get you fully charged in about an hour. Still not as good as the gas stations service ICE vehicles, but much better. With this approach, you can at least go to the grocery storage and get your car mostly charged while you do your shopping.

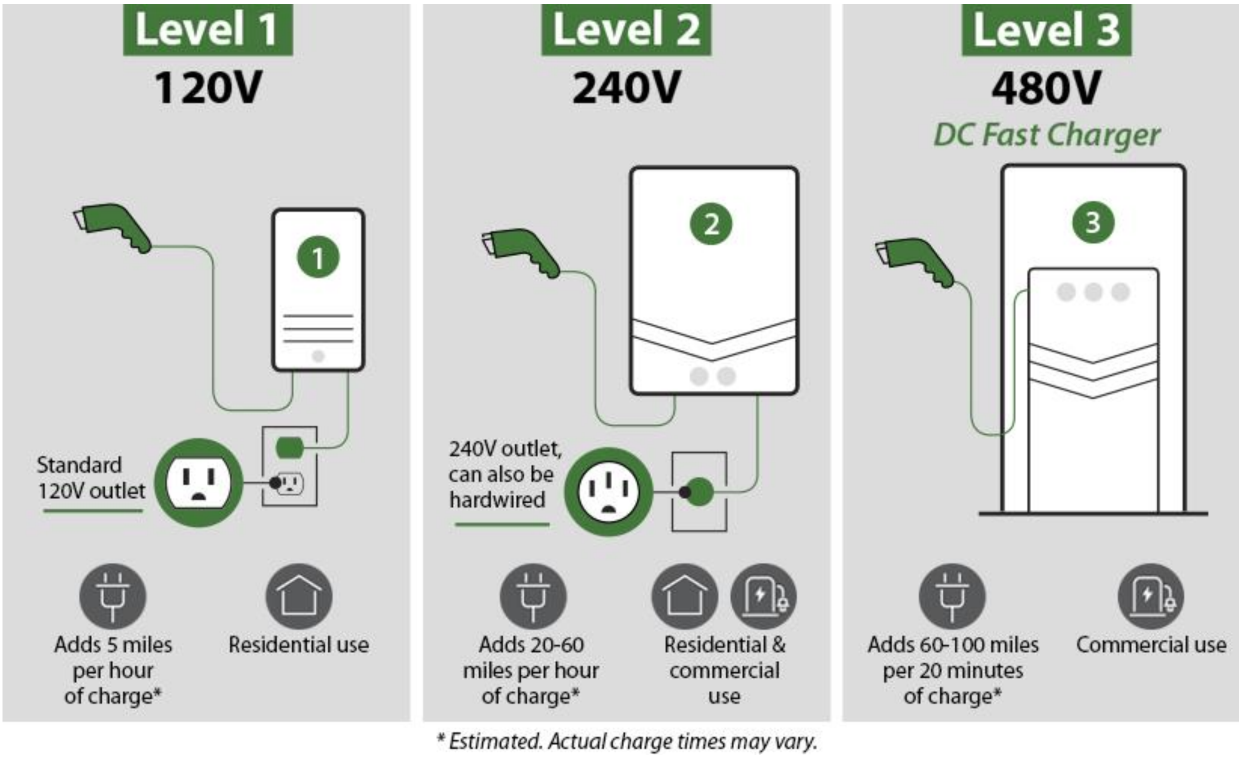

Figure 1 The info graphic above shows the various levels on PEC chargers on the market today. Graphic courtesy Central Hudson Gas & Electric Corp

The Challenge of Fast Charging

Given the options above, clearly Level 3 charging will be the most preferable for the typical driver. Alas, if only it was so easy. The speed of EV charging is directly correlated to the amount of current the vehicle draws. Current dictates the rate at which an electrical load like a PEV charges. Current, in electrical terms, has a direct correlation to rate of flow of gasoline from the pump into your ICE vehicle. If a gas pump merely trickled gasoline into your engine, even an ICE vehicle would take hours to charge. This is essentially what is occurring in Level 1 and Level 2 charging. Voltage (electrical potential) is being delivered at lower current to the PEV, which is to say slowly, which explains why Level 1 and Level 2 charging takes longer.

The challenge that faster EV charging presents is that it commands a tremendous current draw. That current has to come from somewhere. Today, that source is typically the utility grid. Unfortunately, our grid is already overtaxed. It was not designed to handle the unpredictable and sudden current draw the Level 3 charging requires at scale. What this often means in practical terms is that when developers seek to build new, Level 3 charging facilities, they are faced with expensive grid infrastructure upgrades which can be costly and time consuming to implement and can be even be the death knell of such projects.

The Gas Station of the Future

As mentioned above, today, EVs by and large rely on the utility grid for providing the power for their charge. To draw an analogy to the conventional gas station of today, imagine if the gas station where you filled up your tank was connected directly to the refinery. That would be ridiculous! Of course, the way gas stations work is that there is a large tank under ground which is refilled by a tanker truck from time to time. As vehicles pull up, they draw gasoline from that tank underground.

Fortunately, a parallel to recreating the filling stations we are all used to can be replicated with battery energy storage (BESS) systems. In such an approach, an on-site battery can act as the power reservoir for the vehicles. One of the major benefits to this approach is that battery can be charged with clean renewable energy in a predictable, cost effective manner – just the sort of approach grid operators like. The battery even can be programmed intelligently to perform energy arbitrage. For example, if the charging station with an onsite BESS is near a wind farm where power could be very inexpensive, or even have negative pricing at night (when most people would not actually need to be fast charging their cars), the battery can charge up at a moderate rate inexpensively with minimal strain on existing grid infrastructure. Of course, this also works well with solar.

Why the Galvanically Isolated DC:DC is So Critical to Building the Gas Station of the Future

While this approach to EV fast charging seems so delightfully obvious, like so many new technical applications, the devil lays in the details of implementation. One of those particularly devilish details is the fact that voltage at which BESS discharges will typically vary wildly from the voltage a vehicle needs to charge itself. The voltage of large-scale BESS typically varies between anywhere from 700 – 1400, though any one battery would not typically have such a large voltage range. A BESS could have a voltage range of 700 – 950 volts or 1100 – 1400 volts. A typical passenger PEV like a sedan or SUV will require a voltage between 200 – 500 volts, though larger electric vehicles like trucks and buses will have voltages ranges between 700 – 900 volts.

What this means is that voltage from the "reservoir" must be manipulated to match the voltage of the vehicle. This matching process is achieved by a device called a DC:DC converter.

DC:DC converters are built in different "topologies" – meaning they can use different electrical construction and power conversion schemes. The most commonly found DC:DC conversion scheme is referred to as "buck boost" conversion. While more commonly found in the marketplace, this scheme is highly limited and largely inappropriate for use in the gas station of the future where the DC:DC converter sits between the BESS and the vehicle. In the gas station of the future being described here, at least one terminal of the BEES is directly connected to the PEV. If several vehicles are charging at the same time, if a traditional buck boost converter is used, it means that your EV is connected directly to all other vehicles being charged at that same station. This potentially can harm your car, the BESS and other cars being charged while being quite dangerous.

The much-preferred approach is the galvanically isolated topology of DC:DC converters. Galvanically isolated DC:DC converters safely isolate the BEES and all other EVs. The energy is transferred from the battery to the vehicle by noncontact means.

Here at Alencon, we have commercialized the market's leading suite of galvanically isolated DC:DC converters that can work in both a uni-directional and bi-directional manner. Our products achieve galvanic isolation between DC source and loads by using a high frequency a transformer between input and output. Uni-directional charging is ideal for standard EV charging, whereas bi-directional charging allows for vehicle to grid applications (V2G).

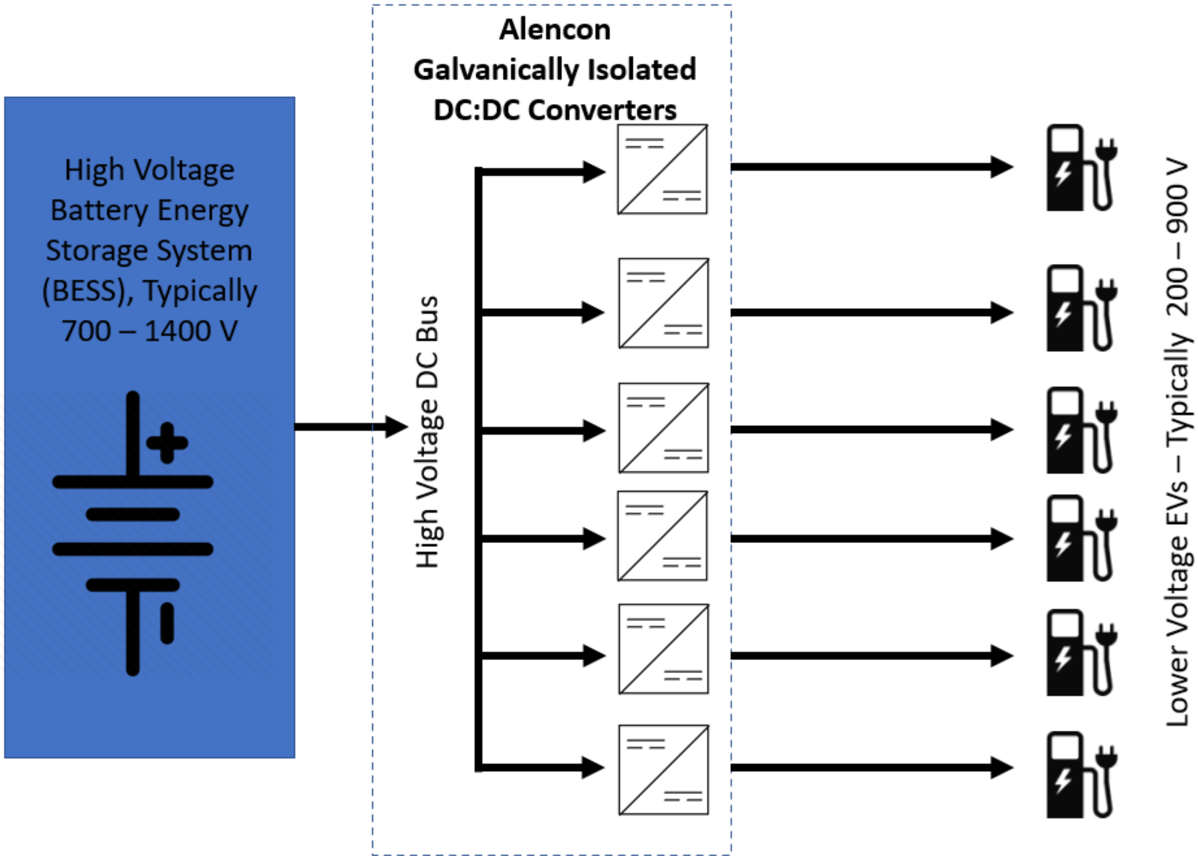

Figure 2 The graphic above shows how Alencon's galvanically isolated DC:DC converters can provide the lynch pin between a large, higher voltage battery energy storage systems and lower voltage PEV's being charged from it. The graphic above shows unidirectional charge from a BESS to an EV. Alencon devices also allow for bi-directional charge, which can facilitate vehicle to grid charging (V2G).

Having a galvanically isolated DC:DC converter for EV charging applications is critical for the following reasons:

1. **Safety:** In EVs and HEVs, when the grounds of two distinct circuits are at different electrical potentials, galvanic isolation is necessary to prevent the triggering of dangerous ground loops, which can generate noise that could compromise the safety of the vehicle. The currents flowing in these types of vehicles can be lethal to humans, so it is essential to ensure the highest degree of safety. In many jurisdictions it is a requirement to have galvanic isolation between the vehicle and the charging source.

2. **Large Voltage Differences:** The galvanically isolated topology also easily supports large differences in voltage between the BESS and the vehicle through easily adjustable dynamic and static voltage ranges without any loss in conversion efficiency even if voltages are far apart from one another.

The high frequency, galvanically isolated approach has other benefits for EV fast charging as well. By operating at frequency, Alencon can make its devices very small and compact, which makes them ideal for inclusion as the "engine" for DC fast chargers where space is at a premium. Also, the isolation and high frequency also further improves fast charging system safety by shielding the vehicle from the potentially high fault current of the BESS. You can learn more about [BESS and fault currents from this article](#).

Fault current is the electrical current which flows through a circuit during an electrical fault condition. A fault condition occurs when one or more electrical conductors short to each other. On the BESS, the isolation of the Alencon device prevents any "shoot through" fault current from the BESS into the vehicle. On the vehicle side, the high frequency allows for the use of small output capacitors on the devices (typically about 12 microfarad per 100 KW of charge) which means the fault current contribution of the Alencon device to the vehicle is minimal and can easily be handled with small, fast acting fuses, which come integrated into Alencon's devices.

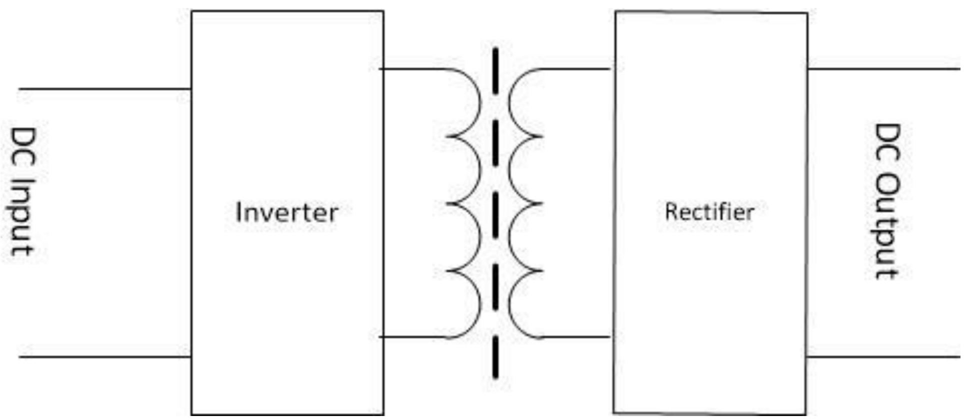

Figure 3 Alencon's DC:DC converters achieve galvanic isolation through the placement of a unique, high frequency transformer between the input and the output. This isolation allows EVs to be charged from larger BESS safely through contactless means while providing myriad of other benefits. This approach also makes it easier to handle large voltage differences between the BESS and the vehicle.

American Made Clean Tech

Alencon's successful implementation and commercialization of its unique, patented galvanically isolated technology is directly related to its roots and deep commitment American based R&D and manufacturing. We spent seven years in R&D, part of which was funded by a grant from the Department of Energy's Sunshot program, developing our products before deploying our first products in the field in 2017. Building a cost-effective, galvanically isolated DC:DC converter took a novel approach to power conversion design, one which uses next generation silicon carbide-based power electronics as opposed to the traditional silicon IGBT based approach found in most other buck-boost DC:DC converters on the market today. This more commoditized approach is often found in products made in overseas, most typically in China. Alencon's approach, which holds several U.S. and global patents, could only be perfected through a unique balance of U.S. based engineering and manufacturing. By building our products domestically in our Philadelphia-area factory, we were able to close the loop quickly between engineering and manufacturing as we perfected both our technology and production process. This close feedback loop could have never been achieved if we had chosen to outsource our manufacturing to a lower cost area. Arguably, one could state choosing to build our products in the U.S. costs us more. However, ultimately, we believe the trade off in higher quality and more rapid innovation and response to customer demands more than offsets this arguably higher labor cost base. As the U.S. moves to achieve this Administration's vision for a carbon free transportation sector, we will scale up to meet these challenges while adding numerous high quality domestic jobs in areas as diverse yet integrated as manufacturing, hardware engineering, software development, sales, business administration and customer service.