DESIGNING CHARGING INFRASTRUCTURE TO MAXIMIZE ELECTRIC VEHICLE FLEET AND CHARGING NETWORK RELIABILITY AND AVAILABILITY

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Executive Summary

The availability and reliability of electric vehicle (EV) fleets is significantly impacted by the availability, reliability, and serviceability of the charging infrastructure that supports them. The severity of charging infrastructure outages on an EV fleet is significant – it can mean that vehicles are offline for days at a time. This can cripple the transportation needs of commuters and commercial deliveries.

Charger designs derived from Level 1/2 automobile chargers are not adequate for today’s high-power charging (Level 3/“fast charging” or greater) requirement, since these Level 1 and Level 2 chargers are not designed for the power requirements of Level 3/fast charging networks and fleet charging infrastructure. These Level 1 and Level 2 chargers are also not designed for continuous operation at rated power. Failure rates approaching or exceeding 100% per year are not uncommon for high-power charging solutions that are derived from auto chargers. Capabilities such as continuous operation at rated load and serviceability must be factored in to the design from the start to achieve the required reliability necessary to ensure fleet availability. Rhombus utilizes its expertise in high-power electronics to design high-power charging infrastructure solutions for DoT Class 1/2/3/4 electric vehicles that maximizes reliability and availability, and are customizable to meet the needs of Level 3 charging networks for commercial and fleet customers.

1 Background

Vehicle electrification is a rapidly-growing trend. Global sales of electric automobiles exceeded one million vehicles in 2017, with electric automobile shipments in the U.S. alone of nearly 200,000 vehicles. By 2025, most automobile manufacturers will produce more electric and hybrid vehicles than gas- or diesel-powered vehicles. By 2050, 65%-75% of new light-duty vehicles sold will be electric. This growth is not limited to just the vehicles themselves – it also includes non-residential charging infrastructure for these vehicles. Volkswagen will be building roughly 2,800 EV charging stations
in the U.S. as part of the settlement of its diesel emissions measurement violations, augmenting the estimated 22,000 Level 2 or DC fast charging systems that already exist in the US and Canada.

2 Charging Infrastructure – The Oft-Forgotten Piece of the Medium/Heavy-Duty Electric Vehicle Puzzle

For operators of EV fleets and charging networks, the charging infrastructure is one of the most critical pieces of vehicle electrification. While there are roughly 22,000 electric vehicle (EV) charging stations (typically with a single dispenser) in the US, there are roughly 150,000 public gasoline stations, nearly all of which have several dispensers. More to the point, the power and duty cycle capabilities of these chargers vary significantly based on the class of chargers. These factors also affect charging times, which in turn affect the total number of vehicles that can be charged in a given time period. This is one of the fundamental determinants of the profitability of a charging network, or the capital cost of fleet charging infrastructure.

The relevant features of the various classes of chargers are:

- **Level 1 Chargers**: These chargers run off of standard 120 VAC single-phase feeds, with a typical current draw of 15 amps and a total power of 1.8kW. Level 1 chargers can typically provide 75-80 miles of range with an 8-hour charge.
- **Level 2 Chargers**: These chargers are fed from a 240 VAC three-phase power feed, with a total power of up to 6kW. Level 2 chargers can typically provide 75-80 miles of range with a 4-hour charge.
- **Level 3 Chargers, DC Fast Chargers, or Simply DC Chargers**: These chargers draw significantly more power than either Level 1 or Level 2 chargers, with power draws of up to 50 kW. These chargers can typically provide 90 miles of range in a 30-minute charge.
- **DC “Superchargers”**: The highest power chargers today for automobiles and light trucks are the chargers in the Tesla Supercharger networks. These chargers run off of 480 VAC utility feeds. The Tesla Urban Supercharger can provide 72kW of power, while the next generation of Super Chargers (“V3”) utilize a 1MW power conditioning unit (PCU) to power four Super Charger dispensers.

Unlike privately-owned passenger vehicles, the impact of charger downtime on EV fleets is substantial. One recent study put the cost of downtime for a fleet automobile at $79.32 per hour ($31.25 was driver
salary and $48.07 was lost revenue), or $634.56 per eight-hour day. For companies that operate high-power charging networks, the lost profit from a high-power charger is even greater.

3 Designing High-Power Charging Infrastructure to Support EV Fleets

The thermal energy that has to be dissipated in high-power charging systems (Class 3 or superchargers) is significantly greater than that dissipated by Level 1 and Level 2 EV chargers. A Level 1 charger with that is 90% efficient has to dissipate roughly 180 watts of power as heat; a 90% efficient Level 2 charger has to dissipate up to 600 watts of power. Compare this to a 95% efficient Level 3 charger, which must dissipate 2500 watts of power as heat – nearly ten times the power provided by a Level 2 charger.

While all EV charging systems in principal simply convert AC power to DC power and then deliver it to the EV’s battery under the control of its battery management system, the differences between Level 1/Level 2 chargers and high-power charging solutions such as Level 3/Fast Chargers or the even more powerful “Super Chargers” is considerable. Simply “scaling up” Level 1/Level 2 charger designs to meet the needs of high-power charging solutions is not an option, though many suppliers have tried this approach. The result of this “scaling-up” is typically significantly reduced charger reliability. Similarly, buying commercial off-the-shelf (COTS) power conditioning systems and “adapting” them to high-power charging is also likely to be unsuccessful. Simply put, the difference between these classes of chargers is measured in orders of magnitude, and simply in percentages.

So what attributes should an EV fleet operator or OEM look for in charging system? There are four sets of factors that impact downtime: charger reliability, charger diagnostics, charger serviceability, and charger parts availability. The relationships between these factors and downtime cost are relatively straightforward: charger reliability is inversely proportional to the failure rate of the charger, while the time to repair and bring a charger online is the sum of the time to diagnose the problem, get the repair part to the site, and install the repair part. Issues such as a lack of built-in diagnostics (or limited
diagnostics coverage) and poor serviceability are typically the biggest issues impacting time to repair a charger (parts availability is typically a logistics issue that can be dealt with via smart spares practices).

The primary factor impacting charger reliability are somewhat more complex. For power electronics, there are several failure mechanisms that bear scrutiny:

- Thermal failure (overheating)
- Supply line overvoltage and power spikes
- Overcurrent (which can cause overheating)
- Lightning strikes and other environmental issues
- Incorrect installation and/or operation

The “industry rule of thumb” for power electronics is that every drop of 10° C in component temperature below 40° C doubles the mean time between failure (MTBF). Designing a high-power charger to keep component temperatures low, both by adequately cooling them and by utilizing redundant fans (fans tend to be one of the highest failure rate components in power electronics) is critical to reducing failure rates. The “non-thermal” factors are most affected by the application of the correct high-power design rules in the development of the charger, and are typically some of the more likely failure mechanisms that occur when a vendor tries to “scale-up” a lower-power design to into a high-power EV charger. Simply adding more fans to move the excess heat can adversely affect MTBF by making the fans the primary failure mechanism. Moreover, achieving efficiencies of 95% or more alone can be significantly challenging for vendors that do not have experience in the latest high-power design approaches.

4 The Rhombus Difference: Unparalleled High–Power Design Expertise

Since its founding, Rhombus Energy Solutions has had one mission: to design high-power solutions for a variety of commercial and industrial uses. By combining the latest digital signal processing techniques for power control, solid-state power semiconductors, as well as proprietary topologies and algorithms, Rhombus’ solutions optimize efficiency, reliability, thermal management, size, and cost. These capabilities are further combined with the latest software management technologies to deliver systems that are highly configurable, exceptionally reliable and highly serviceable. We have also utilized an open architecture that allows our charging systems to be easily integrated with energy storage and renewable power sources.
Our VectorStat software not only provides unparalleled control of our charging systems across a variety of deployment scenarios, it also provides the full diagnostics capabilities that are critical to identify failed components so that they can be replaced during repair actions. The combination of these hardware and software capabilities has allowed Rhombus to achieve annual failure rates at or below 1% for our deployed EV fleet chargers operating in real-world conditions.

5 Summary – Increase EV Fleet Availability by Choosing the Right High-Power EV Charging Infrastructure Vendor

As we have described, high-power EV charging infrastructure has a significantly impact on the reliability and availability of EV fleets and charging networks. Choosing a vendor with expertise in the design and manufacture of high-power charging systems is critical to achieving the level of system reliability necessary for the cost-effective operation EV fleets and EV charging networks. As a vendor with centuries of expertise in high-power design, Rhombus Energy Solutions can uniquely provide the high-power charging infrastructure design that not only maximizes the charging solution ROI, but also positively impacts the ROI of your EV fleet or charging network. Our charging solutions are also highly modular, simplifying customization and reducing time-to-market. Whether you are an EV fleet operator, an OEM of EV Class 1/2/3/4 vehicles, or a charging network operator, look to Rhombus to provide the right high-efficiency, made-in-the-USA charging infrastructure for your business.

Reference List


   https://www.greentechmedia.com/articles/read/how-vehicle-electrification-will-evolve-in-2018#gs.x1sxhu


   https://www.hybridcars.com/volkswagen-electrify-america-2800-ev-charging-stations/