DYNAMIC
Measurement & Control Solutions, LLC

« ELECTRIC VEHICLE »
Infrastructure

www.dynamicrep.com

CURRENT LANDSCAPE OF **EV INFRASTRUCTURE**

Electric Vehicle (EV) charging stations are typically described as electric vehicle supply equipment (EVSE); which is part of an electrical energy distribution system for recharging electric vehicles. The global demand for EV charging infrastructure will rise to $140.0 billion between now and 2030.

The pace of growth in this sector can be attributed to the ongoing innovation and R&D initiatives undertaken to develop EV charging technology. Level 1 and Level 2 type chargers are based on AC power feeding the vehicle. At Dynamic we concentrate our efforts on the higher voltage and current needed in DC fast chargers for eBus and fleet vehicles. DC fast chargers are moving towards 1000V @ 500A and charging power levels of 50kW, 75kW, 100kW and now even 175kW.

Also referred to as CCS quick charging stations these types of Level 3 fast chargers are more sophisticated, they take AC power and convert it to DC within the charger before delivering it to the vehicle. This also benefits the future of EV's since they will no longer need the conversion devices on board the vehicle. The weight savings may allow for a larger motor and increased performance. Also, a lighter vehicle in combination with ongoing battery efficiency and capacity improvements will make them go farther.

With less of the conversion devices like AC Power Electronics, AC/DC Converter, Inverter, etc. the overall EV could become less expensive to purchase.

EV **CHARGING MARKET**

The electric vehicle market continues to develop, and this evolution is bringing increased operational ranges. A battery-only passenger vehicle could be the key to increasing EV acceptance. The key requirements for this growth are not only lightweight high-performance motor drives and high-capacity vehicle batteries. But also national charging system with high voltage charging facilities in private and public parking lots, city centers, suburban shops, and parking spots. However, the ultimate goal to increase EV popularity and ease of use, is to make industrial electric charging stations that resemble and perform like or alongside a traditional "gas station."

AC VS DC **CHARGING PARAMETERS**

The maximum useable charging capacity of a 480V three-phase AC grid, due to the necessary fusing and other elements, is limited to 22kW (32A) or 43kW (63A). Charging with direct current (DC) does not have these limitations and thus favored for fast charge lithium-ion and lithium polymer type traction batteries.

TYPICAL **CHARGING POWER**

Battery packs are typically charged at high DC voltage levels of around 450V. It takes about 80 minutes to charge the batteries for a 250-mile journey. The average charging capacity is a maximum of 50 kW. Since the charge plugs presently have a fixed 200A continuous load, the existing 400V output can only be at a maximum of 80 kW. To cover a 250-mile trip, it is difficult to decrease the full charge time to less than 50 minutes.

DC FAST "FILL UP" AND SAFETY

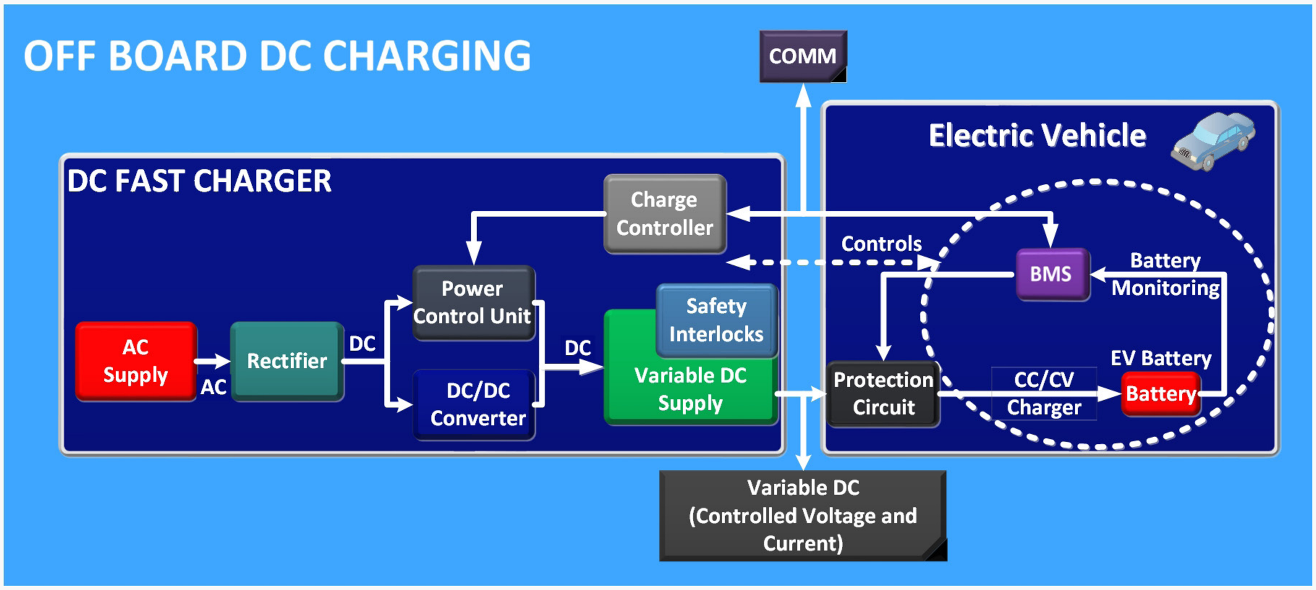
Charging an EV like a traditional gas power vehicle is an important objective of embracing long-distance all-electric journeys. When on the road the charging process will need to become just a few minutes to be "filled up". This demands an infrastructure as similar as possible to the current fossil-fuel filling station. To create this network a charging station must have multiple high voltage charging points. These High-Voltage consumer charging stations will require the utmost care in designing the electrical system.

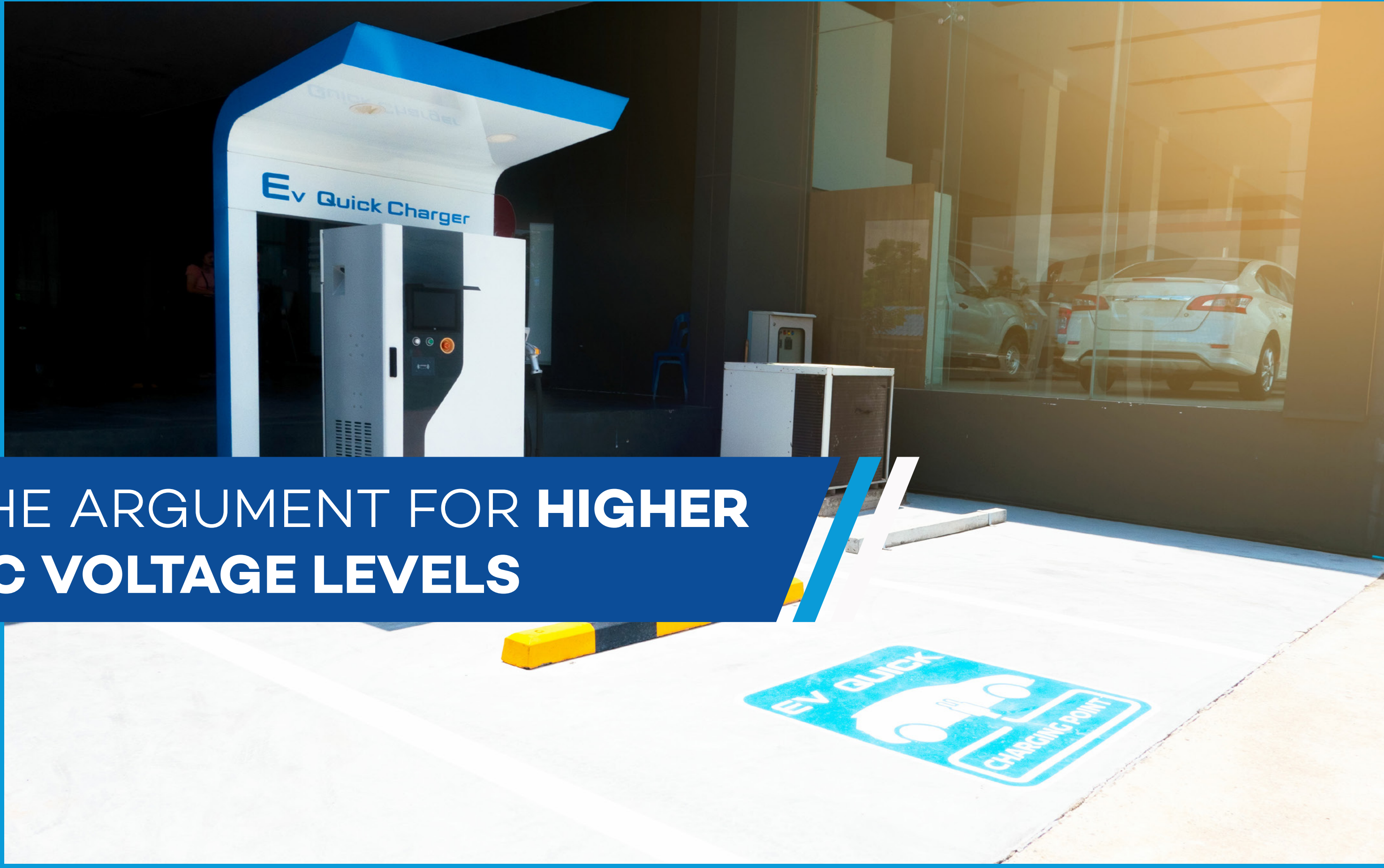
Having untrained people handling high voltage lines is quite an interesting proposition. However, with carefully thought out electrical architecture and considering these systems need to be designed with life safety in mind, we can make these charging points much safer. Any electrical components in contact with High Voltage DC will need to have strong isolation properties. To protect people there should also be special care when designing the safety interlock regarding leakage current. To de-energize the connector and cable in a fault condition you will need fast acting Ground Fault Circuit Interruption devices.

Because the charging current is limited in existing battery technology, DC fast charge points are primarily intended a for fast intermediate charge (extending the range of the vehicle) not to completely charge the battery. With today's battery technology charge currents of more than 150A are done at the expense of battery life.

This means the charging current strength must be reduced as the battery level State of Charge (SoC) increases. It limits fast intermediate charging to between 30% and 80%

of the battery capacity. Therefore, fast charging must complement and adjust the full load supplied during a long EV "fill up". This can also lead to degradation of some of the internal electrical components like power semiconductors due to the heat buildup. Other devices such as measurement instruments have the potential to be overloaded which causes drift. Also, at risk of wearing down, are the electrical contacts that make and break DC loads (i.e. = Pre-Charge Contactor). So again, an emphasis on safely designing the DC fast charger system with the proper electrical components will improve user safety, overall efficiency, lessen the charge time and lengthen the battery life.





THE ARGUMENT FOR **HIGHER DC VOLTAGE LEVELS**

In terms of developing DC infrastructure in the e-mobility sector, the aim is to change the electric vehicle charging station experience to that just like “filling up” a conventional gas car. The higher voltage levels of EV’s at 800V is already being deployed by automotive manufacturers such as Porsche.

With the existing infrastructure and battery technology, an improvement to 350A of charging current would be necessary for fast charging. That would require the development and acceptance of liquid-cooled charging plugs and cables.

The problem with increasing current in EV’s is that they would need larger and heavier electrical conductors and surrounding components to carry these loads. This will make the vehicles heavier and degrade the performance specifications. However, if the charge voltage were increased to 1000VDC an 80% charge could be reached within 11 minutes and cover an additional 250-mile operating range.

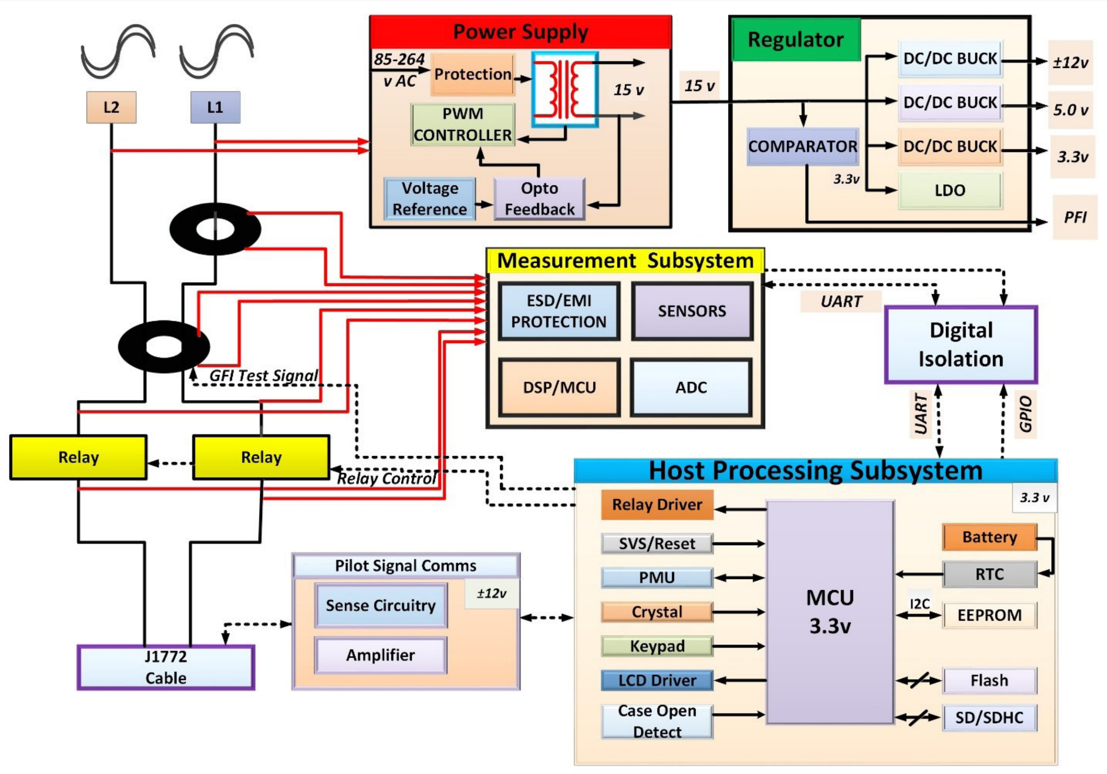
Raising the DC voltage in EVSE infrastructure allows for lower current levels and fast charge times. With that change an improvement in EV performance is possible in weight savings alone.

ELECTRICAL COMPONENT CONSIDERATIONS IN **DC FAST CHARGER DESIGN**

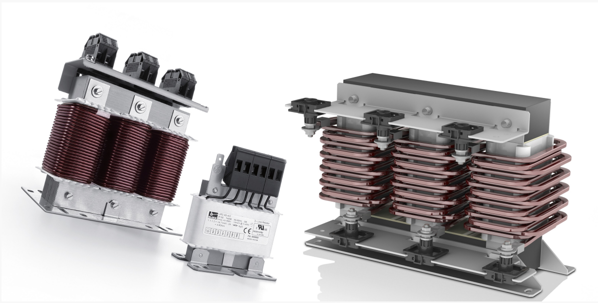
AC/DC conversion for lower wattages means the "on-board" recharge techniques, which are usually fed from a 3-phase network, cannot be used for fast loading (charging). The power level needed for fast charging would not be possible with the converters being on board the vehicle.

A charge power of 40 kW is required for a battery capacity of around 20kWh when charging times are short. Therefore, DC fast charging points will need a minimum of 480V AC at 100A to efficiently charge to the capacity of about 22 kW. When the appropriate AC grid power is available the DC voltage can be generated "off-board" (inside the DC charging station).

These fast charging points require excellent incoming Power Quality (PQ) so AC component selection is also important for increased charge efficiency.

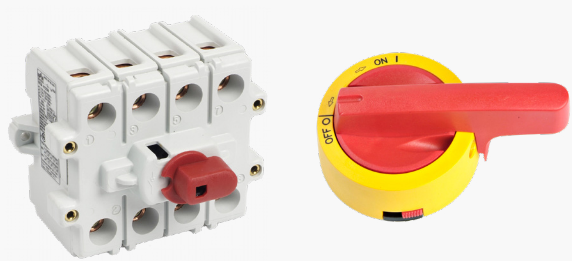


TRANSFORMER & FILTER FOR AC POWER QUALITY



In a charger with three-phase rectifier/inverter front end, one of the more important devices for power quality is high performance transformers. They are used mainly for isolation and voltage level adjustments. Another particularly important device for clean power is the inductors (also called line reactors in PQ applications). The inductor functions as a filtering device to smooth voltage rises and reduce EMC. Dynamic offers a wide range of robust high quality, transformers, and filtering devices both in standard and custom configurations. We know all about the need for power factor correction (PFC) and the manufacturing of DC fast charge equipment.

EMERGENCY ELECTRICAL DISCONNECTS

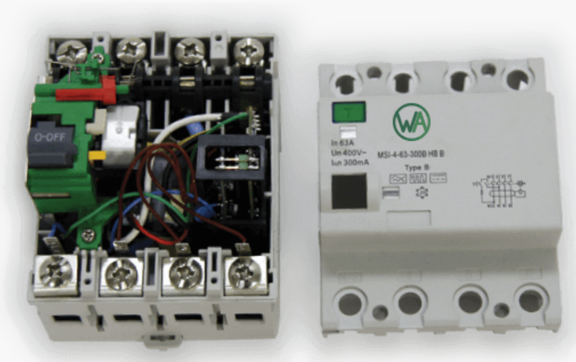


Sometimes referred to as an isolation or load break switch, electrical disconnects ensure power has been disconnected from all power, control, and signal circuits. As the NEC or NFPA 70 standard reads an electrical dispensing device must have the means to disconnect simultaneously from the source of supply, all conductors of the circuits, including the grounded conductor. Switches must be built to comply with either UL 60947 or UL 98. The rules can be tricky, but we are available for consultation to make them easier to understand.

ENERGY MEASUREMENT

DC fast charge point volumes are increasing every day because of the growing market of electric vehicles. Some will be tied directly to the utility grids and others to an enterprise or commercial building. In either case, monitoring the kWh energy consumed and pricing needs to be monitored very closely. Dynamic provides solutions for extremely accurate Current and Voltage Measurement when revenue metering and system monitoring is critical.

DC RESIDUAL CURRENT DEVICES (RCD AND GFCI)



There is a risk of electrical shock when it comes to high voltage DC fast charging and ensuring user safety. Dynamic provides customers with residual current detectors, ground fault circuit interrupters as well as transient and overload protection. Our devices are necessary when you put protection and human life safety above all else.

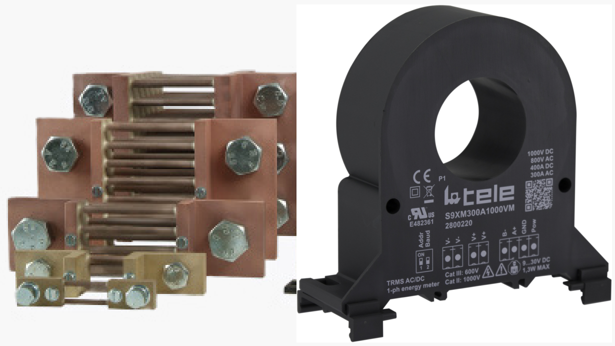
DC CONTACTOR/RELAY

Rugged high-power relays for switching DC under load. DC contactors quickly and safely quench the electric arc and have been proven for repeated use to minimize contact welding. Dynamic is providing electro-mechanical DC contactors that guarantee the electrical circuit has been physically broken.

VOLTAGE TRANSDUCER

DC fast chargers are high voltage instruments. There are two important voltage measurements when charging the EV. One is the battery voltage level, to lengthen battery life, the appropriate current and voltage levels must be continuously monitored. Second is the DC link voltage must be monitored in relation to the grid voltage. Measuring these high DC voltages safely and to minimize risk to the users, these components must have high electrical isolation properties. Dynamic is providing voltage transducers with best in class accuracy, speed, and precision. They come with standard pre-calibrated ranges or can be built to your custom specifications.

CURRENT MEASUREMENT (SHUNT RESISTOR OR HALL EFFECTS)



Shunt Resistors are one of the most accurate ways to measure DC current, couple these with a high accuracy transducer for revenue grade metering. DC shunt resistors from Dynamic provide a precise, long term stable measurement of DC currents up to 15kA. Hall effect sensors can also be used to measure the magnetic flux but are typically less accurate. The advantage of a hall effects device is they can have electronics built in that provide diagnostic information, detect faults, and have a variety of signal outputs.

EMC AND EMI REDUCTION

With the rising power levels in DC fast charge equipment, there is the potential for electronic devices to emit more RFI or interact adversely with surrounding devices. Anything carrying high current such as cables, bus bar, and solid cores will have a conductance increase. To mitigate some of the EMC risk proper circuit design (in regards to impedance) is a must, as well as proper techniques for shielding and grounding.

Other methods for noise reduction and limiting the magnetic field are isolation and filtering which are built to many of our other power devices. The use of grounding clips, EMI reducing cord grips, and EMC cable glands are great mechanical solutions for reducing EMC levels in high voltage DC power applications.

HIGH VOLTAGE DC POWER CONNECTORS

Connectors must ensure efficient energy transfer and power transmission when dealing with high voltages. Harsh environmental conditions are normal, especially when dealing in areas where fleet vehicles and UAV's are used. However, this creates concerns for oxide build up which can lead to increased contact resistance and potentially arcing or burning. High current DC connectors for industrial battery and fast charge applications must be precisely made. Withstanding these power levels requires the connectors to be made from quality materials, have large diameter pins, high tensile force, and utilize as much contact surface as possible.

TERMINAL BLOCKS (RING LUG OR STUD CONNECTION TYPE)

Choosing the correct terminal types is important for ensuring a secure connection in energy transmitting applications. In EVSE and fast chargers connecting the main charger cable is a tough task. Dynamic is providing customers with ring lug terminals and connectors which have a high pull strength, ideal for power cable connection points.

CABLE SEALS AND VENTING

In charging applications, it is typical to find power distribution systems or a high voltage junction box. When dealing with the thermal elements of DC current and voltage there will be a continual heating and cooling process. This combined with outside ambient temperatures can lead to condensation building up.

Likewise, a poorly sealed box where your cables are coming through the panel can also lead to ingress. DC fast charger enclosures need to be sealed to at least IP65.

Water inside of a high voltage junction box can lead to corrosion, mold, or worse an explosion. Proper pressure equalization, cable seals, venting and drains can help prevent this.

COMMUNICATION GATEWAYS AND ETHERNET SWITCHES

Electric Vehicles use a Communication Controller (EVCC) to “talk” between the charger and the vehicle. The communication protocol in the U.S. is still not standardized so the networking systems between interconnected chargers tend to be ethernet based communications. “Plug and Go” charging technology is currently being developed that allows information exchange, authentication, and billing via the charge cable. Dynamic supplies rugged, case hardened ethernet switches and gateways for industrial networking applications.

AIR CONDITIONING AND COOLING

CONTINUED

Liquids and electricity do not mix! DC fast charging stations create large amounts of heat especially at rush hour when multiple vehicles are lined up for charging. Since this heat can be harmful to the equipment, some sort of cooling solution must be attached. However, most charger manufacturers think a radiator style set up is the best option. At Dynamic we are providing advanced cooling technology that utilizes thermo-electric cooling, heat pipes and heat sinks that can be completely sealed from the outside environment. Our enclosure coolers are of highest quality and can run continuously to keep the internal electronics operating at optimal levels.

HIGHER POWER LEVELS **AND CHARGING FLEET VEHICLES**

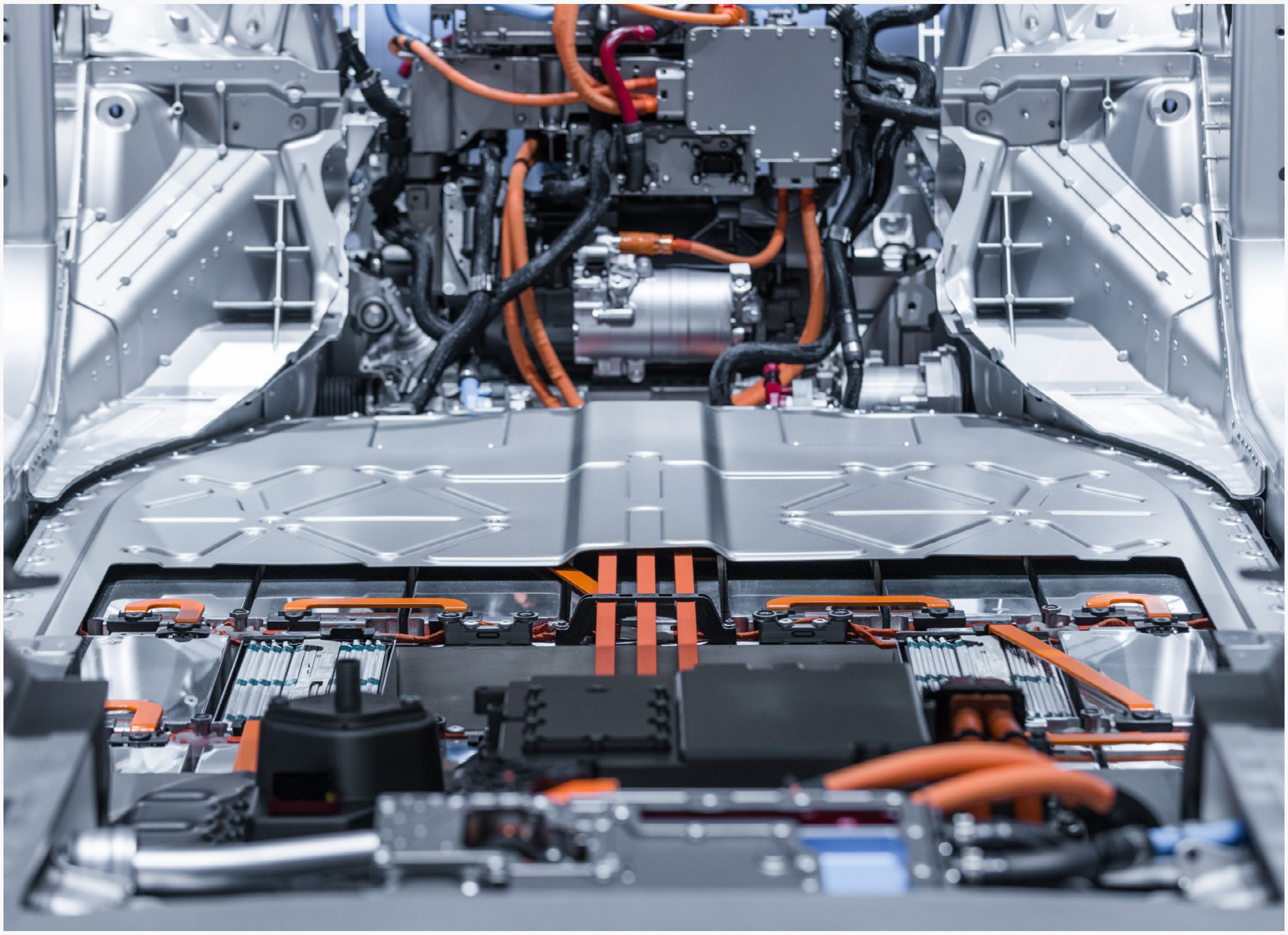
To reduce "dwell time" future super-fast charging points will offer up to 350 kW of charging power and ensure that various EV battery topologies are supported. Long-haul electric vehicles and mass transit fleets may have a variety of different battery voltages and capacities. These will require powerful multipoint charging stations. They will also need to draw this power from a nearby medium-voltage substation or have the means to provide their own energy source, i.e. = an energy storage system.

There is also discussion of Bidirectional DC fast charging infrastructure called Vehicle to Grid (V2G) technology. Bidirectional EV chargers will be able to pull power from the grid and feed it back to the charging station. These DC fast chargers will be able to convert DC back to AC and power your home, allow you to sell power back to the grid, or even for an emergency backup power source. In a fleet application this would be especially useful. Ideally your vehicles would store power that you could sell back to the utility provider during low demand times or use your own stored energy during peak times.

By flattening out your load profile you could avoid penalties or receive a credit back from the utility. Let us take for example the US postal service jeeps that deliver mail. If they were directly plugged in via the V2G format the energy storage amounts would be tremendous during off peak times (evenings and weekends).

This is when most individuals are at home and consuming power. You would also see gains in environmental impact and the USPS could be earning/saving millions of dollars by utilizing this technology.

In addition to the V2G benefits, EV charging infrastructure can turn to the integration of battery banks and solar power plants for a high degree of utility network friendliness. An energy storage option will help during peak charging management so not everyone is pulling from the AC grid at the same time. This would increase availability of EV driving and charging if there were a short-term power loss, like a black out. These types of vehicles would have Active Front End (AFE) systems. An AFE system is when the main rectifier is equipped with a negative feedback and communication system so the grid can retrieve the stored energy. This would be extremely useful for fleet vehicles of the future.



KEY ELEMENTS FOR THE **FUTURE OF ELECTRIC MOBILITY**

The biggest fear of EV manufacturers is failure of electrical infrastructure, it is a huge investment of capital to run the utility scale substations to remote areas. Faulty charging equipment, blackouts/brownouts, unstable power grid, maybe even "power supply stations" going out of business could potentially lead to abandonment of the EV. This would have a more dramatic impact than if gas or diesel fuel stations disappeared because energy reserves in an electric vehicle are lower and the charging station network is much smaller.

Sophisticated power electronics and electrical components represent a key technology for allelectric vehicles to ensure the mobility of the future. If designed thoughtfully a quick-charge outdoor station could run reliably and safely for 20 years. It is of the utmost importance that the electrical system components not only be designed to cover a wide temperature range for high accuracy and low losses, but also for a high degree of reliability (MTBF).

Dynamic has many years of experience with electrical components, EV's, and electrical infrastructure design. Do you have electrical issues or want to improve your design?

Our engineers will assist you with proper component selection and help you build an amazing end product. Get in touch now to discuss your DC charging application.

CONSULT A PRODUCT EXPERT TODAY!

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