# PROPERTY


COMMENTARY PAPER

## Electric vehicle charging stations: technology, reliability and loss considerations

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## Charging technologies

Electric vehicles (EVs) are a relatively new mode of transportation in mass production. Using electricity to propel themselves means a new infrastructure has been put into place – one which few are familiar with. Let's explore some high-level details about charging levels, charging duration and usage cost.

**Residential charging: Level 1**

The portable charger is sold with the vehicle. While it may be the slowest method of charing – it plugs into a standard residential 120V outlet.

- Typical power output: 1 kilowatt (kW)
- Charging rate: 3.5 - 6.5 miles/hour
- Charging duration: 30+ hours
- The monthly operating cost depends on the miles driven, the charging rate and cost of electricity. Assuming 1200 miles are typically driven in a month, a charge rate of 3.5 miles/hour and electricity at 15 cents per kWh, it would cost $52 per month to charge the EV.

**Residential and public charging: Level 2**

Chargers are not included with the EV, although often purchased at the same time. You get the slow charger with the car. For a faster charge, the owner can purchase a level 2 charger and have it installed in the garage. Professional installation is recommended for level 2 charges, as they are plugged into a 240V outlet – allowing for a charge that's 3 to 7 times faster, depending on the car and the charger.

- Typical power output: 7 - 19 kW
- Charging rate: 14 - 35 miles/hour
- Charging duration: 8 - 12 hours
- The cost to utilize a public level 2 charger ranges from $1 to $5 an hour.

**Public direct current (DC) fast charging: "Level 3" is not necessarily at that level**

Over a decade ago, when DC fast chargers were first introduced, EV enthusiasts and manufacturers incorrectly assumed they were qualified to be named "level 3". To date, the name continues to be wrongly used in advertisements and product specifications.

Direct current fast charging (DCFC) also known as fast charging stations, are far more powerful than level 1 (1 kW) and level 2 (7 - 19 kW) chargers. DCFC chargers range in power output from 50 kW to about 350 kW. Based on the Society of Automotive Engineers (SAE) J1772 charging standard, power levels up to 400 kW are still considered level 2.

- Typical power output: 50 - 350 kW
- Charging Rate: 3 - 20 miles/minute
- Charging Duration: 30 minutes to 80%
- The cost to utilize a DC fast charger ranges from $10 to $30 an hour.
- Most plug-in-hybrid-electric vehicles (PHEVs) cannot charge at DC fast charging stations.

**Commercial DC ultra-fast charging**

Ideal for electric buses and trucks, these types of chargers are capable of replenishing 186 miles of range in 30 minutes. Their typical power output is between 400kW - 900kW.

**Commercial megachargers**

In 2022, Tesla, the global EV manufacturer, begun installing megachargers for its electric semitrucks going into production in 2023. The chargers are capable of replenishing 400 miles of range in as little as 30 minutes. At 1.5 MW, the megacharger outputs 3.5 times more power than the most powerful level 2 charging station. The cost to utilize a megacharger has yet to be released.

## Public charging infrastructure

Mass adoption of EVs is unlikely to occur until a nationwide network of charging stations is installed, and a vehicle can be charged quickly enough to get travelers back on the road in minutes rather than hours.

The Joint Office of Energy and Transportation describes the current public charging infrastructure as follows: "Currently, there are no national standards for the installation, operation, or maintenance of EV charging stations, and wide disparities exists among EV charging stations in key components such as operational practices, payment methods, site organization, display of price to charge, speed and power of chargers, and information communicated about the availability and functionality of each charging station."

On June 9, 2022, the White House announced a plan to develop new standards for what they described as the "first-ever national network of 500,000 electric car chargers". The White House shared that, "The Department of Transportation, in partnership with the Department of Energy, is proposing new standards to make charging electric vehicles convenient, reliable and affordable for all Americans, including when driving long distances. Without strong standards, chargers would be less reliable, may not work for all cars, or lack common payment methods. The new standards will ensure everyone can use the network – no matter what car you drive or which state you charge in."

## Public charging station reliability

Similar to gas station pumps, charging stations are theoretically engineered to withstand years of harsh environmental conditions such as heat, cold, rain, snow and nearby lightning. Too often though, drivers face situations whereby charging stations charge at far slower speeds than advertised, are broken upon arrival and even fail to start charging when plugged in. The situation is similar across Europe and other major EV markets globally, where drivers face too many barriers to charge reliably. Even more worrisome, currently there are no safety statutes to which the chargers are required to adhere to once installed.

## Property loss examples

**2019** – At a public EV charging dispenser a vehicle was being disconnected from the charger when it blew apart, causing significant damage. Initial findings suggested that there was a fault within the charging unit, which caused its aluminum front panel to explode, creating a loud bang.

**2019** – After a supercharging station caught fire, investigators determined that the station was not responsible. In fact, the origin was a transformer that sends power from the utility to the charging station.

**2020** – Superchargers built next to a hotel, three restaurants and plenty of open space, experienced a loss after being installed in an area that regularly floods.


**2020** – After a fire broke out in an industrial park housing superchargers, investigators determined that a transformer — not the charging station — was the reason. The fire department said that it was the first case of an electric car charging station fire incident that they had encountered and suspect that a short circuit may have caused the fire.

**2021** – Fire-rescue units were dispatched after a neighbor called to report smoke visible in a garage. The operation required coordination of fire attack, ventilation, and search operations to confirm everyone had escaped. Investigators determined that the fire was accidental, originating from the charging system while it was charging a vehicle.

**2022** – While the exact cause of a parking lot fire remains unknown, according to investigators, the fire may have started as a result of a short circuit in one of the fast charging stations.

## Post loss considerations

The fire loss examples above, whereby the transformers were the cause of fire, perhaps provide an indication of what failures are on the horizon as charging stations age. The transformer failures were assumed to be a result of a short circuit.  Electrical short circuiting is a common assumption before forensic investigators determine what truly caused the equipment to malfunction.

Let's consider the makeup of the equipment that fast charging stations are typically comprised of, and then why transformers, as well as other outdoor electrical systems, commonly fail. The diagram below exhibits an example layout of a fast charging station. Very few stations are laid out the same way, although the electrical subsystems they are comprised of are similar.

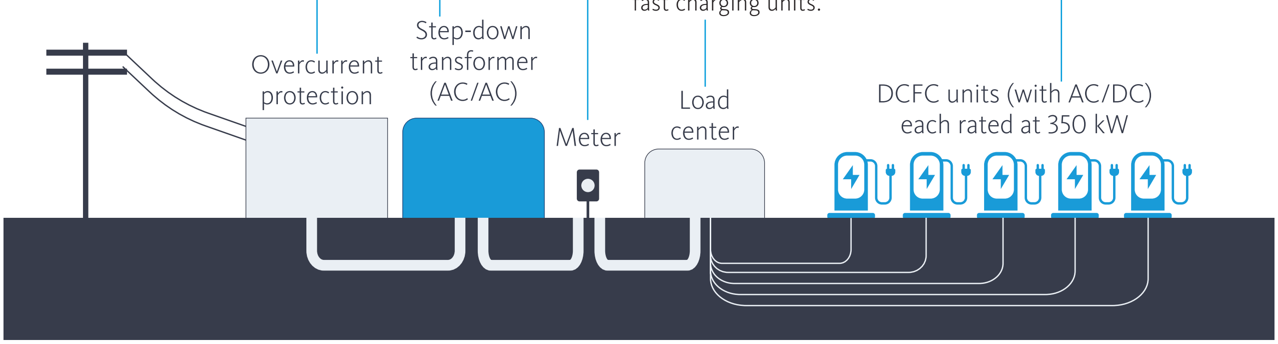
**Overcurrent protection**
The electric utility employs a high-voltage overcurrent protection device (fuse or circuit breaker) and/or sectionalizer (circuit-opening device) between the electrical distribution and the transformer.

**Step-down transformer**
A step-down transformer decreases voltage from the utility distribution voltage to the 480 VAC required by the chargers.

**Meter**
If the electric utility owns the transformer, the meter is positioned downstream from the transformer, as shown in the diagram. If the charging station owner owns the transformer, the meter is located on the grid side of the transformer.

**Load center**
The load center contains a circuit breaker panel that provides overcurrent protection and distributes power to the individual DC fast charging units.

**DCFC units**
AC to DC conversion, charger-to-vehicle communication, user interface and power delivery are all performed within the DCFC units. Depending on the design of these units and the power output requirements, a separate electrical cabinet may be required between the load center and the DCFC units, to house power electronic modules necessary for high-power charging. This may be done to minimize the bulk of the curbside units– to improve design aesthetics and reduce cost.



Below are fundamental causes of equipment failures for enclosed electrical systems that are housed outdoors:

**Transformer failures**

- Inadequate protection against factors such as power surges, over/under-voltage conditions or insufficient rating of circuit breaker protection devices.
- Operational overstressing or overloading that exceeds design specifications.
- Material defects, poor installation, inadequate maintenance, low quality repairs and normal wear and tear.

**Switchgear and power converter cabinets**

- Water intrusion – Hurricanes, tornadoes and accidents can lead to water intrusion, or even worse, submersion. Depending on the contaminants present in the water, exposure may cause instant short circuits. Exposure also compromises electrical insulation and susceptible metals, which develop surface rusting and eventually pitting. The function of electrical insulation is to separate electrical conductors and make electricity flow only where it is supposed to go, without deviating to other places.
- Glowing or loose connections – The National Fire Protection Association (NFPA) describes a glowing connection as follows: "When a circuit has a poor connection such as a loose screw at a terminal, increased resistance causes increased heating at the contact, which promotes the formation of an oxide interface. The oxide conducts current and keeps the circuit functional, but the resistance of the oxide at that point is significantly greater than in the metals. A spot of heating develops at that oxide interface which then becomes hot enough to glow. If combustible materials are close enough to the hot spot, they can be ignited".

  On June 16, 2022, Schneider Electric, a multinational company that specializes in digital automation and energy management, posted a recall on the U.S. Consumer Product Safety Commission site. Schneider recalled 1.4 million electrical panels due to thermal burn and fire hazards. The recall involves a loose neutral screw connection within a load center. It is estimated that 25% of all electrical failures occur because of loose connections.
- Breakdown of insulating materials – This type of breakdown can occur because of friction or tearing, and as a result of excessive electrical stress. Temperature fluctuations between extreme heat and cold cause mechanical stresses via differential expansion and contraction. There is a rule of thumb based on the Arrhenius equation, that states that for every 10˚C (18˚F) operating temperature rise, insulation's useful life is halved. This rule ignores factors such as moisture, vibration, chemicals and abrasives in the air that can attack insulating materials.

**Engineering design**

A product is considered to have a design defect if it can be shown that, under typical use, the product suffered systematic failure — injuring the user or property in the process or rendering the product unable to perform its intended function.

An article published in June 2022 by Energy Source & Distribution provides details about a lawsuit filed by South Australian electricity provider SA Power Networks. The utility is seeking $19 million in damages against Schneider Electric (manufacturer), alleging the company provided 1,500 pieces of vital equipment that prematurely rusted, melted and failed.

The utility stated that the manufacturers reclosers, sectionalizers and enclosed load break switches — intended to protect the network from catastrophic faults — were unfit for their purpose and incapable of handling Australian environmental conditions.

- **Reclosers** are an automatic high-voltage electric switch. Like circuit breakers in households electric lines, they shut off electric power when trouble occurs, such as a short circuit.
- **Sectionalizers** are protective devices that automatically isolates a faulted section of line from the rest of the distribution system. A sectionalizer should not be confused with a recloser; it does not interrupt fault current.
- **Load break switches** are devices used to open an electrical circuit by isolating the source from the consumer.

The utility asserted that the manufacturer was required to deliver items capable of withstanding temperatures of up to 122°F, wind speeds of 50mph and wind gusts of 99mph. It further asserted the devices were to handle 630A of electricity, be protected against corrosion and "have a service life of at least 30 years with minimum maintenance". After installation, the utility discovered the devices could handle only 450A.

"They were not suitable for the atmospheric conditions … they were, and are not, adequately protected against water, corrosion oxidization and heat," the utility said in its submission to the court. "The devices experienced premature oxidization and corrosion … resulting in arcing (of electricity) and overheating. The arcing causes the devices to experience 'hot joints' where the metallic connections overheat, melt and fail."

## Key takeaways

- Currently, there are no national standards for the installation, operation, or maintenance of EV charging stations.
- On June 9, 2022, the White House announced a plan to develop new standards for what they described as the "first-ever national network of 500,000 electric car chargers" stating that, "Without strong standards, chargers would be less reliable, may not work for all cars and lack common payment methods."
- Drivers often face situations whereby charging stations charge at far slower speeds than advertised, are broken upon arrival and even fail to start charging when plugged in. Even more worrisome, there are no safety statutes to which the chargers are required to adhere to once installed.
- Water intrusion during inclement weather, glowing or loose connections and breakdown of insulating materials, are common problems for equipment that is housed outdoors and not maintained on a regular basis.
- Equipment design flaws, even for safety devices, are not unusual.

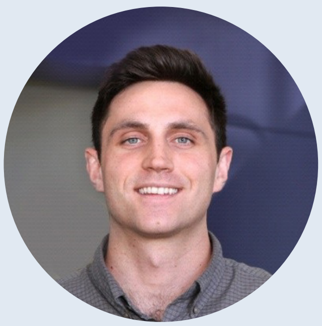
## About EFI Global

EFI Global, part of Sedgwick, is a well-established brand with an excellent reputation in the Americas, Africa, Asia-Pacific and Europe as a market leader in environmental consulting, engineering failure analysis and origin-and-cause investigations. Each year, EFI Global completes more than 45,000 projects worldwide for a wide range of clients, such as commercial, industrial, institutional, insurance, government, risk managers, public and private entities. EFI Global is one of the world's most respected emergency response firms, capable of providing practical solutions to the most complex problems. Our multidisciplinary team of first responders, project managers, engineers, geologists and scientists are selected for their technical proficiency and in-depth industry knowledge to aid clients in resolving technical problems. For more, see **efiglobal.com**.

## Get in touch with an expert

**Ward Arms**

With 25 years of experience in root-cause failure analysis, electrical engineering, electrical design & construction, and materials science, Ward serves as a forensic electrical engineer. Ward holds Bachelor of Science degrees in electrical engineering and materials science and engineering from the University of Minnesota (Minneapolis) College of Science and Engineering. He is a licensed professional electrical and computer engineer, as well as a licensed class A journeyman and master electrician. For more information, contact **ward.arms@efiglobal.com**.



**Wes Hansen**

As a forensic electrical engineer, Wes Hansen has over 7  years of combined experience in mechanical/electrical/plumbing (MEP) consulting, electrical design build construction, and forensic engineering. He is a licensed professional electrical and mechanical engineer, as well as a design engineer. With a background in construction, he has a clear understanding of subjects related to electrical, HVAC, plumbing, and building codes. Mr. Hansen's dual licensure provides value to customers in need of an expert. For more information, contact wes.hansen@efiglobal.com.

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