WHITE PAPER

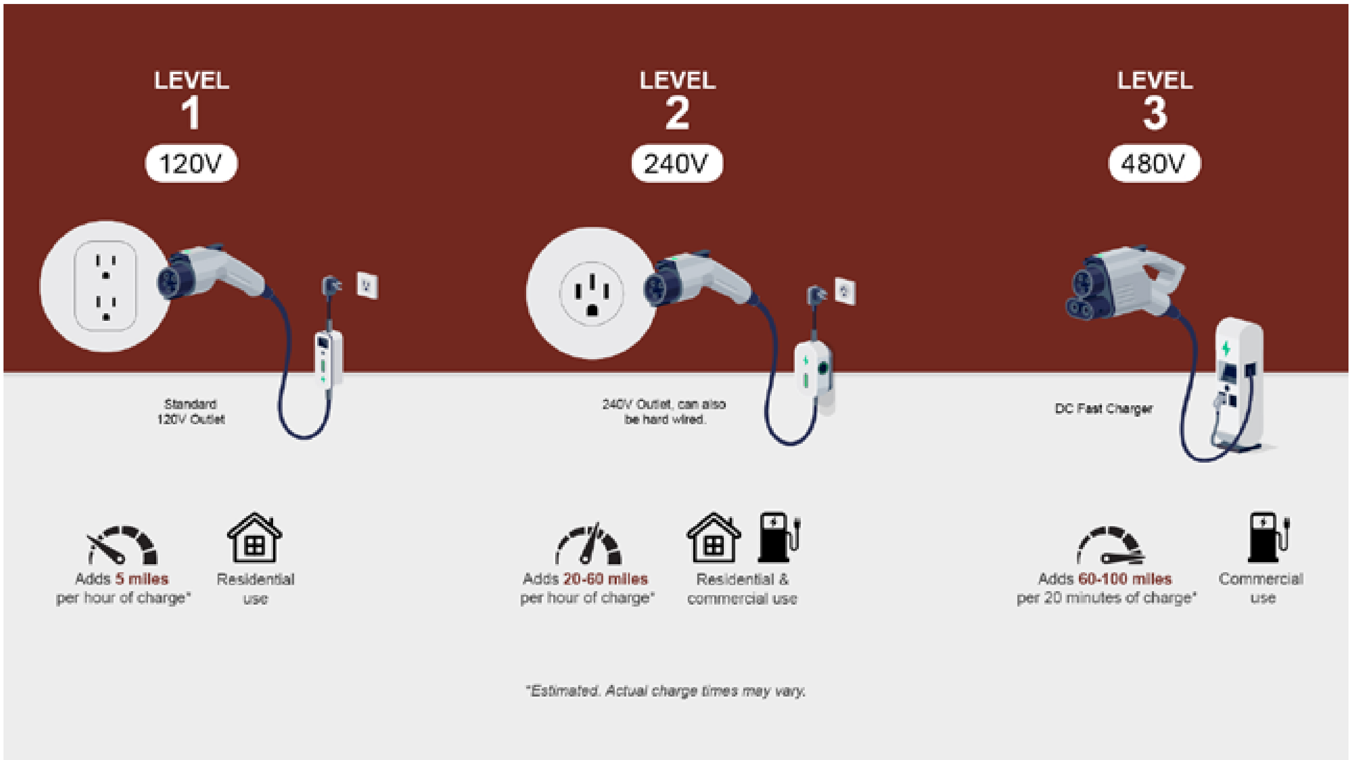
EV Charging Stations Uptime Challenges

Abstract

The rapid integration of public and commercial Electric Vehicle (EV) charging stations into the power grid, driven by legislative mandates and growing consumer demand, presents significant challenges to electrical grid infrastructure. Key issues include voltage harmonic distortion, inadequate grounding, and surge-related damage, which impact the reliability and uptime of charging stations. These challenges affect operational efficiency, customer satisfaction, and revenue generation. This white paper explores the technical and regulatory aspects of maintaining EV charging infrastructure uptime, including grounding best practices, surge protection strategies, harmonic filtering, and compliance with standards like NEVI and IEEE 519. By addressing these power quality and reliability issues, stakeholders can ensure sustainable and efficient EV charging systems, supporting the expanding electric transportation ecosystem.

EV Charging Stations Uptime Challenges

Integrating Public and Commercial Electric Vehicle (EV) charging stations into the power grid is accelerating, due to global and national legislative mandates, such as those outlined in the U.S. Infrastructure Investment and Jobs Act and increasing consumer demand for EVs. This rapid expansion poses significant challenges to the existing electrical grid infrastructure, particularly regarding power generation demands and electrical power quality events that can damage cars and chargers. Challenges with voltage harmonic distortion, improper grounding, and surge-related damage impact charger reliability, leading to failures and degrading the customer experience. These factors play a significant role in revenue generation. Addressing these challenges is crucial for maintaining availability and ensuring the efficient operation of EV charging systems.



EV Charging Infrastructure: Technical Overview

EV fast chargers are typically classified into two main types: Level 2 (AC fast charging) and Level 3 (DC fast charging).

- **Level 2 Chargers:** These chargers operate on AC power, typically at 240V, and provide a charging rate range of 3 kW to 19.2 kW. Residential Level 2 chargers commonly use a NEMA 14-50R plug, whereas public installations are typically hardwired for reliability.

  Level 3 Chargers: Also known as DC fast chargers, these systems bypass the vehicle's onboard inverter and deliver DC power directly to the battery at much higher power levels, typically ranging from 50 kW to over 500 kW. This allows for significantly faster charging (commonly 30-45 minutes for a full charge) times but introduces various technical challenges, particularly related to electrical grid stability and power quality.

National Electric Vehicle Infrastructure (NEVI) Formula Program Requirements

- Owners of EV charging infrastructure funded by the NEVI Formula Program should provide reasonable plans and guarantees for maintaining the chargers, related equipment, and overall charging locations in good working order.
- EV charging infrastructure should be maintained in good working order and in compliance with all requirements under Title 23 CFR (Code of Federal Regulations) part 680 of NEVI.
- Ensuring customer safety may require the addition of lighting, video surveillance, emergency call boxes, fire prevention, and devices that maintain payment integrity, all of which are susceptible to electrical power quality challenges and disturbances.

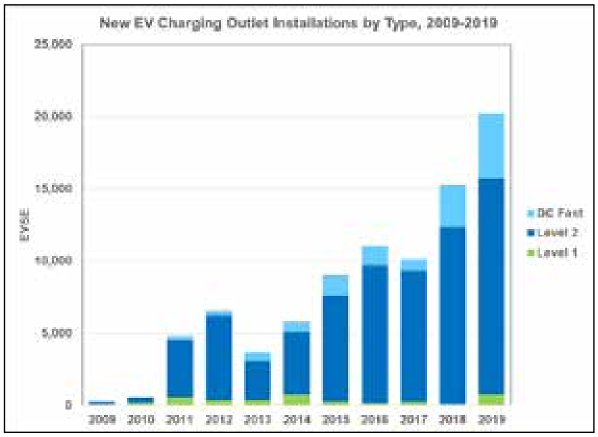


Chart source: US Department of Energy

- Charging-network-to-charging-network communication: A charging network must be capable of communicating with other charging networks so that an EV driver can use a single method of identification to charge at Charging Stations that are part of multi-location networks. Refer to NEVI part § 680.108 for more information about OCPI (Open Charge Point Interface) requirements.
- Minimum uptime. States or other direct EV charging station recipients/operators must ensure that each charging port has an average annual uptime greater than 97% NEVI part §680.116(b).
- A charging port is considered "up" when its hardware and software are both online and available for use or in use, and the charging port successfully dispenses electricity in accordance with requirements for minimum power level (see NEVI part § 680.106(d)).

EV Stations Electrical Power Challenges and Their Reliability Implications

- **Electrical power grid stability and lightning voltage transients** can further degrade the sensitive electronic components of the EV chargers if the installed electrical and communications cables are not protected by SPDs and properly grounded. Overvoltages due to electrical power disturbances and lightning strikes are a significant concern for EV charging stations, particularly those located in areas prone to thunderstorms. A robust grounding system, integrated with Surge Protective Devices (SPDs), is critical to protecting sensitive electronics from overvoltage and is critical to supporting the 97% NEVI uptime requirement.

- **Voltage Harmonic distortion** arises from the non-linear nature of the loads connected to the grid, particularly the power electronics used in Level 3 chargers. These chargers utilize high-frequency switching devices such as Insulated Gate Bipolar Transistors (IGBTs) or Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) to convert AC to DC. The rapid switching introduces harmonic currents at multiples of the fundamental frequency (60 Hz), which can propagate through the electrical network, leading to higher losses in conductors and transformers due to heat. This can cause overheating and reduce the lifespan of the electrical components, thus reducing the overall power capacity of the electrical service and nuisance tripping of breakers, particularly at the Point of Common Coupling (PCC) where the EV charging station connects to the Electrical grid,

Mitigation Strategies

Maintaining 97% uptime for EV charging stations requires a comprehensive approach to electrical power quality management. Over time, degradation of components such as capacitors, inductors, and semiconductor devices increases the likelihood of equipment failure. Protecting against external events to extend component reliability and life is critical to delivering charger uptime. To mitigate power quality concerns and ensure the reliable operation of EV charging stations, the following strategies should be implemented:

- **Grounding:** Proper grounding is critical in EV charging stations to ensure both safety and the effective operation of the system. A poorly grounded system can exacerbate electrical power quality issues and reduce the predictability of the uptime of EV charging stations. Equipment grounding of EV chargers ensures adequate bonding, especially for those handling high power. EV chargers, particularly Level 3 DC fast chargers, can generate significant fault currents. The equipment grounding system must be capable of handling these currents, ensuring a low-impedance path to prevent hazardous voltages from appearing on exposed conductive parts. Also, the grounding electrode system must be designed to handle ground fault currents to provide a low impedance path for electrical faults and lightning currents.

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- **Surge Protective Devices (SPD) Selection and Placement:** The selection of SPDs must be based on the specific requirements of the charging station, including the expected surge levels, voltage, and the criticality of the protected equipment. Surge solutions should fail open without tripping the main power breaker to avoid disrupting power and charger availability. Communication and security equipment should be protected with non-degrading technology, which provides the lowest VPL (Voltage Protection Level), ensuring best-in-class protection. For 480V power systems, MOVs (Metal Oxide Varistors) should be used to protect against surges. MOVs are most effective in clamping high-energy transients and preventing overvoltage conditions that could damage sensitive components. SPDs should be placed at critical points, such as the main service entrance, at each charger, and communication and control cables.

- **Standards Compliance:** Adhering to standards such as UL 1449, 5th Edition and UL497B, for the proper selection of AC power SPDs and Article 250 of the latest National Electrical Code (NEC) for the proper protection and grounding of the EV stations. Compliance with local/national codes and standards specifies acceptable levels of safety and protection for mitigating electrical power quality issues.

- **Harmonic Filters:** Harmonic currents generated by the non-linear loads in EV chargers can create circulating currents, causing additional heating in power cables; in some cases, this phenomenon may lead to nuisance tripping of overcurrent devices or the degradation of sensitive electronics over time. Recommended best practices, such as installing harmonic filters, either active or passive, can significantly reduce the harmonic content in the system. Active filters dynamically compensate for harmonics by injecting counter-phase currents, while passive filters use resonant circuits to absorb specific harmonic frequencies. IEEE 519 provides harmonic control guidelines, which outline equipment requirements such as EV charging systems. These guidelines are essential for minimizing the impact of voltage harmonics, which ensures charger uptime.

Quarterly Growth of Public DC Fast EV Charging Ports by Power Output

Chart source: US Department of Energy

Conclusion

The rapid deployment of EV charging infrastructure presents significant challenges to the electrical power system, particularly power quality concerns such as electrical grid overload, voltage harmonic distortion, proper grounding, and surge protection, causing equipment reliability and availability. By employing appropriate mitigation strategies and adhering to established standards and applicable codes, it is possible to integrate EV chargers into the electrical power grid while maintaining power quality and ensuring the longevity of the equipment. The EV station operator should also consider battery backup systems and maintenance contracts as essential parts of the EV charger network. As the adoption of EVs continues to grow, addressing these technical challenges will be a necessary part of the electric transportation ecosystem.

To learn more about Transtector's solutions for protecting EV charging stations, visit www.transtector.com or contact us at +1 (866) 679-4552.