POWERSIDE®

Power Quality:

THE FIRST MILE IN EV CHARGING

How to build grid resilience and equipment uptime into EV charging station planning and management

In 2021, when the U.S. announced plans to triple its public EV charging capacity, it was surely music to the ears of millions of EV owners and the companies supplying this massive new market.

But some may only be cautiously optimistic, with good reason.

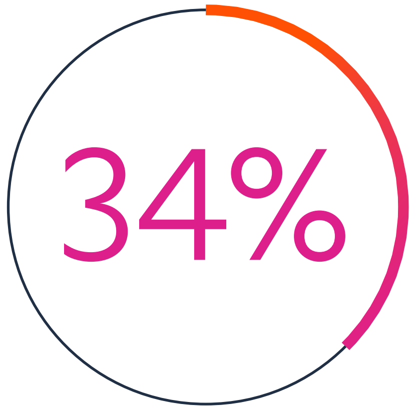
CHARGE ANXIETY
is the new range anxiety.

Charging station availability — in terms of both local penetration and uptime — has long been a deterrent to EV adoption. EV drivers are growing evermore frustrated by failed charging due to equipment malfunction or damage.[1]

Out of 26,000 public Level 2 and Level 3 charging attempts examined by J.D. Power **in all 50 states, downtime was as high as 39%.**[2]

The U.S. infrastructure plan mandates 97% charger uptime. But it's not that easy.
The science of EV charging can be tricky. Inverters that convert the AC power system voltage to the EV battery voltage create power quality challenges — most notably harmonic distortion. High harmonic currents contribute to distribution circuit losses, voltage fluctuations on power distribution networks — and ultimately, faulty EV chargers.

Stakeholders need to account for and incorporate power quality measures on the front-end of charging station infrastructure planning.



of fast-charger users said broken chargers were at least a "moderate concern[3]"

To get a sense of scale,

LET'S START WITH THE BASICS.

The 2021 Bipartisan Infrastructure Law appropriates $7.5 billion to establish a nationwide network of 500,000 public EV chargers by 2030. Key requirements:

Public charging stations must offer at least 4 working ports with Level 2 Alternating Current (AC) or Level 3 Direct Current Fast Charging (DCFC) or both, with a 600 kW total minimum power capacity. Locations along certain national highway corridors require a minimum of 4 Level 3 ports capable of up to 150 kW power delivery.

Level 2 chargers are the most frequently used type, often found in retail centers, public parking lots, office buildings and multifamily developments. They a require a 240-volt electrical source and take several hours to fully charge a vehicle.

Level 3 chargers, which require a much larger grid connection, are usually reserved for high-traffic locations or those where speedy charging is paramount (e.g., highways and medium-duty fleet depots). DCFCs require a 480-volt or 600-volt grid connection and can deliver a complete charge in roughly 30 minutes, depending on vehicle and battery type.

These fast chargers operate differently from Level 2 chargers in several ways. Charging power is higher, resulting in a shorter charging time. Also, as the name implies, the fast charger features a direct current converter. These are just a few of the characteristics that make fast charging especially susceptible to severe power quality issues.

How many chargers does it take to serve a community?

The U.S. Department of Energy created a nifty tool to calculate estimated capacity in local areas. Check it out.

Kinetic energy:

The Interdependent Drivers of **EV Charging Infrastructure**

Until recently, the process of adding EV charging stations has largely been market driven. That's changing. The nation's mission to lead the world in e-mobility brings a new shape to supporting EV infrastructure as it serves crossover interests: **transportation, energy, land use policies, customer experience and economic development.**

The EV Stakeholder Ecosystem At-A-Glance

Electric Vehicle Supply Equipment (EVSE) Manufacturers
Produce & deliver charging station equipment and payment devices

Utilities
Power supply and equipment investment

Charge Point Operators (CPOs)
Site selection and charging station equipment, management & maintenance

State & Local Government
Permitting, site approval and funding

Site Hosts
Provide space & access to free or paid charging via contracts with charging station network operators

Contractors & Installers
Install and energize the EV charging station

Automakers
Meet consumer demand for energy-efficient, reliable EV vehicles

SO, WHO HAS THE WHEEL?

No single entity has sole responsibility for overseeing EV charging infrastructure. It's a collective effort of stakeholders with discrete objectives that often overlap. Communication and coordination are key.

Where do charging stations
AFFECT THE POWER SYSTEM?

As mentioned, the process of converting power from AC to DC can generate harmonic distortion and voltage imbalance at levels that can disrupt charging, distort utility supply voltage and damage equipment. Here are a few of the issues harmonics can have on distribution assets encountered by researchers who modeled Level 2 chargers and Level 3 DC fast charge (DCFC) stations.[4]

Transformers

Increased harmonics can cause current losses that elevate temperatures and accelerate insulation and oil deterioration within the transformer. This results in higher real power consumption; reduced efficiency; and equipment degradation due to abnormal temperature increase. Transformers must be designed with adequate K-factor to withstand anticipated harmonics.

Power cables

Rapid flow of electricity during peak times causes extra heating from I^2R losses; voltage stress and corona due to system resonance, with possible dielectric failure.

Capacitors

Harmonics introduced by a nonlinear load may interact with nearby capacitors and cause very high voltages and currents and resonant frequencies. This can lead to catastrophic failure or shortened asset lifetime.

System imbalance

Nonlinear loads create imbalances that can produce excessive currents and conductor heating. Unbalanced loading can result in currents within the neutral line, leading to overheating in extreme cases. Chargers connected to a common service are subject to imbalance because chargers are engaged stochastically.

Driver's charging state

MATTERS TOO.

Consumer demand drives designs toward Level 3 DC fast charging to reduce the wait time along major routes. As the battery nears full charge (usually at 80%) the controller adjusts to "trickle charging." This increases the relative harmonic magnitudes, which can negatively affect distribution assets. For this reason, various states of charge should be included in EV charger power quality modeling. Designers and installers should consider all the different load states — not just full load — to properly assess the system harmonics.

In today's evolving grid, also consider that grid-originated harmonics generated from nearby inverter-based resources, like solar or wind farms, may impact the EV charging location.

THD variations in a Level 3 charger at various charging periods:[5]

	Harmonic Order	Charging Times (t_i, minutes)	
		7	17
$\frac{I_h}{I_1}(\%)$	3	2.84	6.61
	5	2.96	6.27
	7	1.81	4.75
	9	2.28	4.65

What can be done to

IMPROVE POWER QUALITY?

Engineers can take preventive measures to ensure proper function of EV charging equipment.

Power quality monitoring

Sophisticated power quality analyzers can be affixed to chargers and medium voltage power distribution lines to identify, measure and record data and power dynamics relevant to system reliability, energy consumption and component health.

For example, the ultra-precise Powerside PQube® 3 detects and provides insight and visuals of voltage fluctuations, current disturbances, harmonics, impulses, frequency variations and interruptions. For a fleetwide view and analysis, Powerside's QubeScan power monitoring platform provides real-time power quality data for troubleshooting, reporting, sharing and strategic planning.

Supra-powers: PQube 3 is especially unique in its ability to detect supraharmonic frequencies between 2 kHz–150 kHz. EV chargers produce high frequency emissions in this range, at 15 kHz to 100 kHz, particularly due to the switching operations either at the start or the end of the charging process.

Problem resolution

If power analysis indicates harmonic distortion or other potential fault, active power filtering is a relatively easy and very effective remedy. Powerside's PowerAct low voltage active harmonic filter offers full correction capacity for harmonics, phase imbalance and power factor. It's also designed for small spaces and outdoor installations, making it a perfect fit for EV charging equipment that may be in a tight parking garage or at the curb.

Case Study: A high-traffic Level 3 DCFC charging station experienced frequent outages due to high THD from a combination of DC charging units plus adjacent solar energy on the grid.

The utility implemented Powerside's PowerAct active filter in voltage control mode, **reducing the harmonic distortion as much as 70%.**

To maximize successful EV charging operation, consider the following guidance before the dig.

EV charging stations in **industrial areas should be located based on data driven analysis of power quality and not just load,** and be outfitted with protective systems to ensure reliability and compliance.

EV chargers should be placed **in the electrical system in a manner that ensures optimal performance** and mitigates potential downtime risk.

EV charging **near large-scale renewable resources,** such as solar, should include harmonic filtering.

Consider incipient fault detection in EV installs. Underground cable is more susceptible to harmonic impacts and resonance than overhead transmission lines[6] due to the capacitance in underground cables.

Stakeholders are sharing learnings and best practices too. A few highlights:

Several communities have rewritten building codes to require or strongly encourage pre-wiring for EV charging on new commercial and multifamily housing builds. This not only helps with capacity planning but also streamlines siting and permitting.

Revising language in right-of-way ordinances can help utilities more efficiently work through approvals.

Consider including wiring upgrades to future-proof for DC fast charging as capacity needs increase.

Ready to hit the road on large-scale

EV CHARGING IMPLEMENTATION?

Let Powerside be your guide to ensure high power quality and equipment reliability.

Start a conversation.

powerside.com/ev-charging

Additional resources

[1] J.D. Power, 2022 U.S., Electric Vehicle Experience (EVX) Public Charging StudySM

[2] InsideEVs, "EV Charging Stations In The US Are Plagued By Reliability Issues: Study," February 13, 2023

[3] Plug In America, The Expanding EV Market: Observations in a Year of Growth, February 2022

[4] N. Woodman, R. B. Bass and M. Donnelly, "Modeling Harmonic Impacts of Electric Vehicle Chargers on Distribution Networks," 2018 IEEE Energy Conversion Congress and Exposition (ECCE), Portland, OR, 2018, pp. 2774-2781. doi: 10.1109/ECCE.2018.8558207

[5] Alame D, Azzouz M, Kar N. Assessing and Mitigating Impacts of Electric Vehicle Harmonic Currents on Distribution Systems. Energies. 2020; 13(12):3257. https://doi.org/10.3390/en13123257

[6] Y. Xu, Y. Xu, Z. Chen, F. Peng and M. Beshir, "Harmonic analysis of electric vehicle loadings on distribution system," 2014 IEEE International Conference on Control Science and Systems Engineering, Yantai, China, 2014, pp. 145-150, doi: 10.1109/CCSSE.2014.7224526.