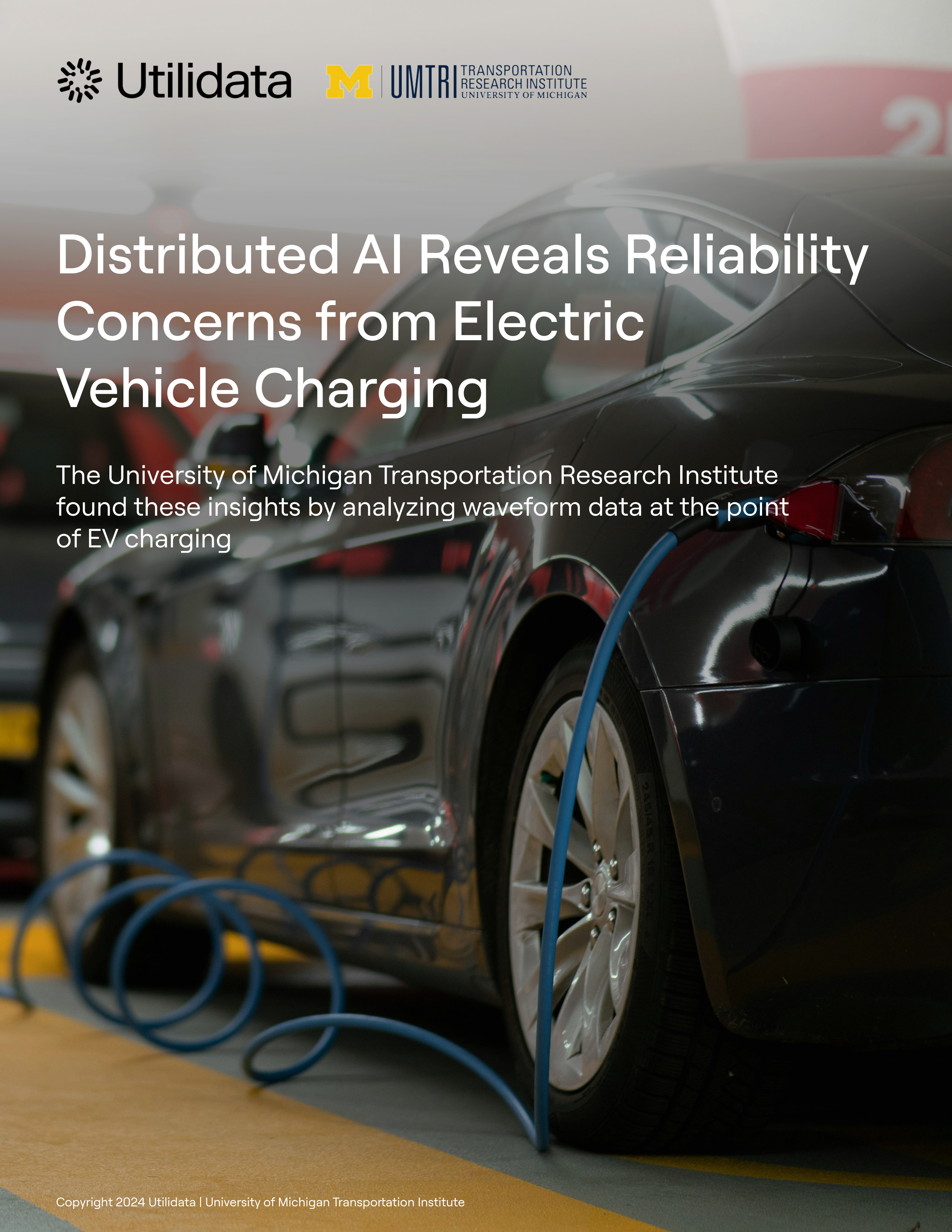
Distributed AI Reveals Reliability Concerns from Electric Vehicle Charging

The University of Michigan Transportation Research Institute found these insights by analyzing waveform data at the point of EV charging



Executive Summary

Using a distributed AI platform to analyze real-time waveform data at the edge of the power grid, the University of Michigan Transportation Research Institute (UMTRI) identified rapid swings in current draw, voltage drops and harmonic impacts that could lead to potential reliability concerns, including power outages.

For this study, UMTRI utilized a distributed AI platform built by Utilidata and NVIDIA, called Karman, that gives utilities and researchers the ability to use AI to analyze high volumes of electric waveform data in real time. Karman is powered by a custom NVIDIA module built specifically for the edge of the grid to analyze electricity data. Using this tool, researchers found:

1. EV charging can cause unexpected rapid swings in current draw.
2. EV charging lowers local voltage significantly.
3. EV charging causes variability in local voltage.
4. EV charging lowers power quality by introducing current harmonics generated from the conversion of AC to DC power.
5. EV charging in the presence of a grid fault showed potential to support voltage recovery.

The Karman platform revealed that at times EVs and EV chargers exhibit inconsistent power draw, including "short cycling," meaning a continuous stop/start draw from chargers even after the vehicle was fully charged. This type of inconsistent power draw can result in inefficient energy consumption, overheating wires, power loss, transformer stress, and possible outages.

UMTRI recommends that industry stakeholders, policymakers, and regulators support further research into the potential reliability impacts of EV charging, including the value of granular grid edge data and AI models to manage power quality and potential grid upgrade costs.

The Challenge

The rapid proliferation of electric vehicles (EVs) presents both opportunities and challenges for electric distribution companies. EVs are projected to make up more than 50 percent of all car sales in the US by 2030.[1] Without the proper insights and tools, EV adoption at this scale will require significant investments to upgrade the grid to manage this new load. In California alone, one study estimated that unmanaged EV adoption could require $50 billion in distribution grid investments by 2035.[2]

Utilities currently lack visibility into when and where EVs will charge, and by what rate. Some drivers may choose to charge their vehicle when the battery is half full, some may charge it based on infrastructure availability, and extreme weather conditions can impact both battery performance and driver charging behavior. These factors can create sudden surges in charging demand and lead to unpredictable fluctuations throughout the day. In addition to this unpredictability, utilities lack real-time actionable data about both charging events and the state of the grid, which creates significant challenges to managing the grid with two-way power flow due to EVs, solar, and batteries at the edge.

Granular data is needed to design programs that fully capture the potential benefits of managing EVs. Most programs focus on using EVs as a resource to serve system-wide generation and capacity needs while failing to capture the additional value of managing local distribution grid constraints. Utilities also lack real-time visibility of the charging process to offer dynamic pricing and charging management, which could be more beneficial for participating customers and have less impact on their charging preferences.

> Granular data and real-time visibility unlocks significant value for utilities and all customers by reducing costly infrastructure upgrades and utilizing EVs to support grid reliability.

Project Objective

The University of Michigan Transportation Research Institute (UMTRI), a global leader in transportation research with over 1,000 research projects, in collaboration with Utilidata, a leading AI-powered technology company, conducted a pilot research project leveraging distributed AI to study the relationship between EV driving and charging behaviors to better understand how those behaviors impact the electric grid. This area of research can aid utilities, EV manufacturers, and policymakers as it explores new ways to manage EV demand, ensuring drivers can reliably charge their EVs with minimal disruptions to the grid while also serving as a resource to the grid.

Methodology

To measure grid performance, UMTRI installed Utilidata's distributed AI platform, Karman, via electric meter adapters at six EV charging stations on the University of Michigan campus. To measure driving and charging behavior, UMTRI installed vehicle monitoring devices on 10 EVs of drivers who charge their vehicles at one or more of the selected charging stations. Data collected from the EV monitoring devices includes start and stop time for charging, location of charging, trips taken, and acceleration/deceleration.

Utilidata's Karman platform computes real-time voltage, current, power and other power system properties such as harmonics, allowing researchers to analyze and detect EV charging patterns and anomalies. Karman

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[1] Bloomberg: More Than Half of US Car Sales Will Be Electric by 2030
[2] CPUC Electrification Impacts Study Part 1: Bottom-Up Load Forecasting and System-Level Electrification Impacts Cost Estimates

bridges the gap between EV manufacturers and utilities as well as other companies that operate at the edge of the grid by capturing granular data at the source, processing it in real time, and using local AI models to understand and predict charging behavior and the impact to the grid.
Data for this pilot study was collected from March 3 - June 27, 2023. This project was intended to be an initial analysis to explore how to design a broader and statistically-reliable research project that can answer key questions about EV use and grid impacts.

Findings

While it's widely known that EV charging behavior is unpredictable, the specific impact that a given charging event will have on the grid is even more unpredictable than previously understood and can cause various reliability issues. Large amounts of granular data that can be processed and analyzed at the edge in real-time is critical for identifying these reliability issues, and then providing grid operators with actionable recommendations to maintain reliability while integrating EVs, and potentially use EVs to support the grid without affecting customers' charging preferences.

Preliminary findings include:

1. **EV charging can cause unexpected rapid swings in current draw.** Inconsistent power draw when an EV is charging can result in inefficient energy consumption, which could lead to overheating wires, power loss, transformer stress, and possible outages. Distributed AI models would enable utilities to quickly identify these anomalies and notify charger operators/customers to adjust the charger behavior, or inform OEMs to modify their charger design. (Figure 1)

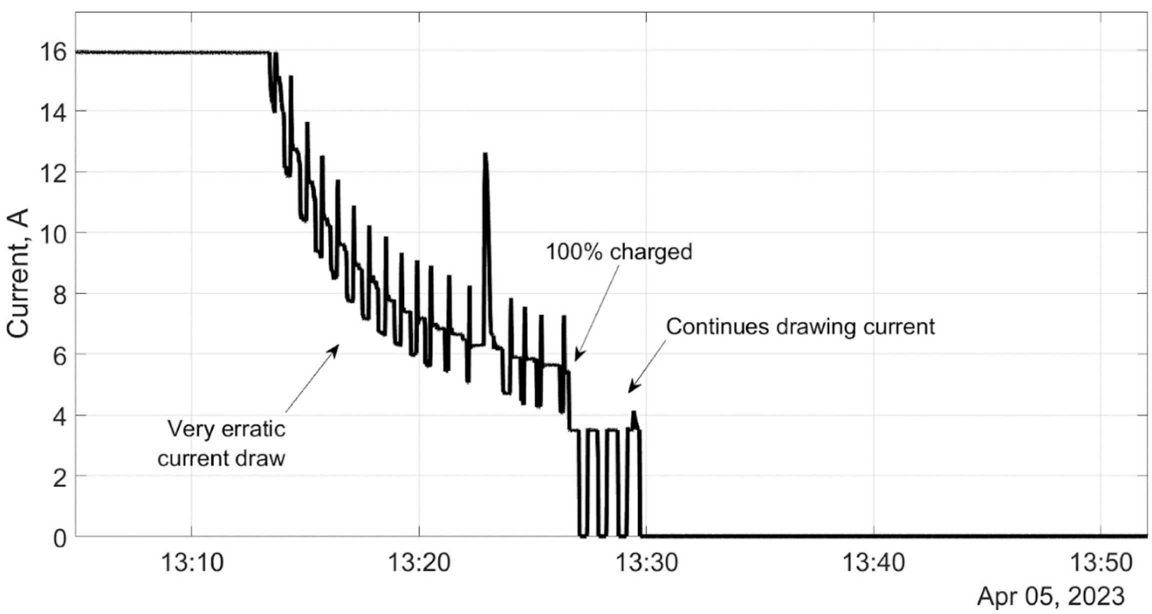

Figure 1. EV charging causes large, rapid swings in current draw, which could cause overheating power lines, power loss, and outages.

2. **EV charging lowers local voltage significantly.** Areas with high concentrations of unmanaged EV charging are at risk of more-frequent power outages driven by these low voltages. (Figure 2)

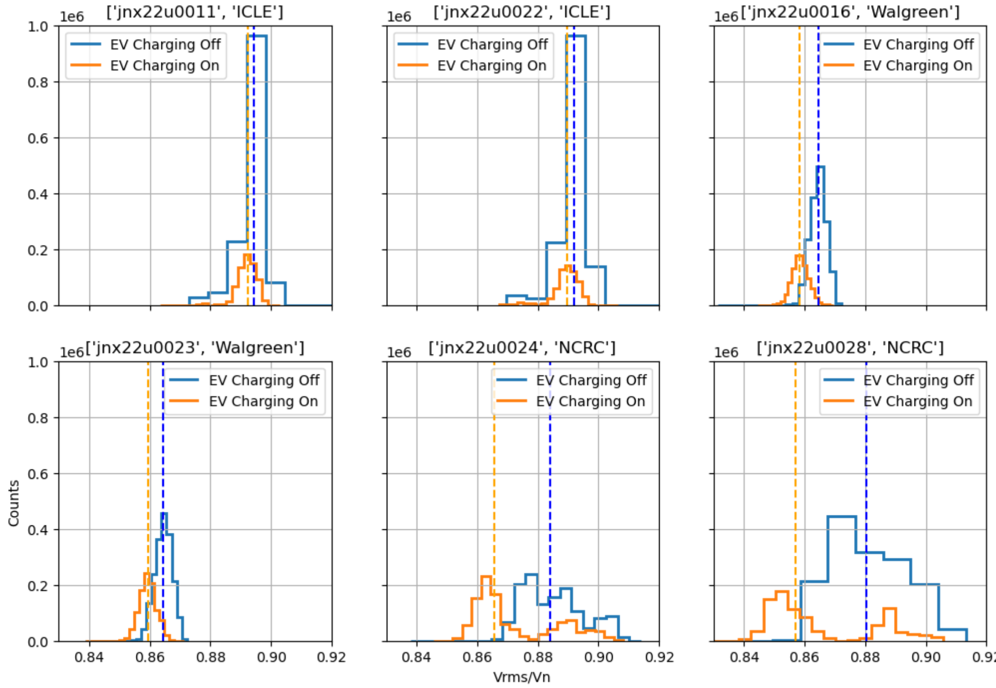

Figure 2. Data from six locations shows EV charging lowers local voltage, which creates risk of outages.

3. **EV charging causes variability in local voltage.** Voltage stiffness at individual locations was calculated using high-resolution measurements. Calculation of high resolution measurements with local computing at individual locations revealed local voltage stiffness. This information helps identify which locations can accommodate EV charging and where to implement managed charging and grid service programs. (Figure 3)

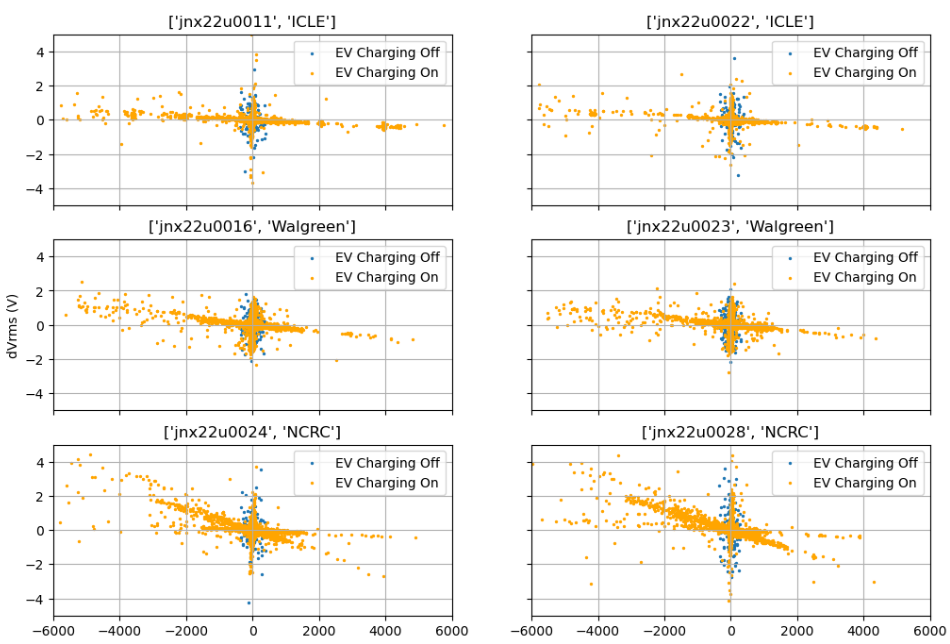

Figure 3. Data from six locations shows EV charging causes variability in voltage which differs by location, which must be understood to plan for future EV charging.

4. **EV charging lowers power quality by introducing current harmonics generated from the conversion of AC to DC power.** Low power quality causes equipment degradation and failure for both utilities and consumers, including flickering lights and excessive motor wear and tear on home appliances, causing premature failure; also including transformer overheating, causing faster transformer degradation. (Figure 4)

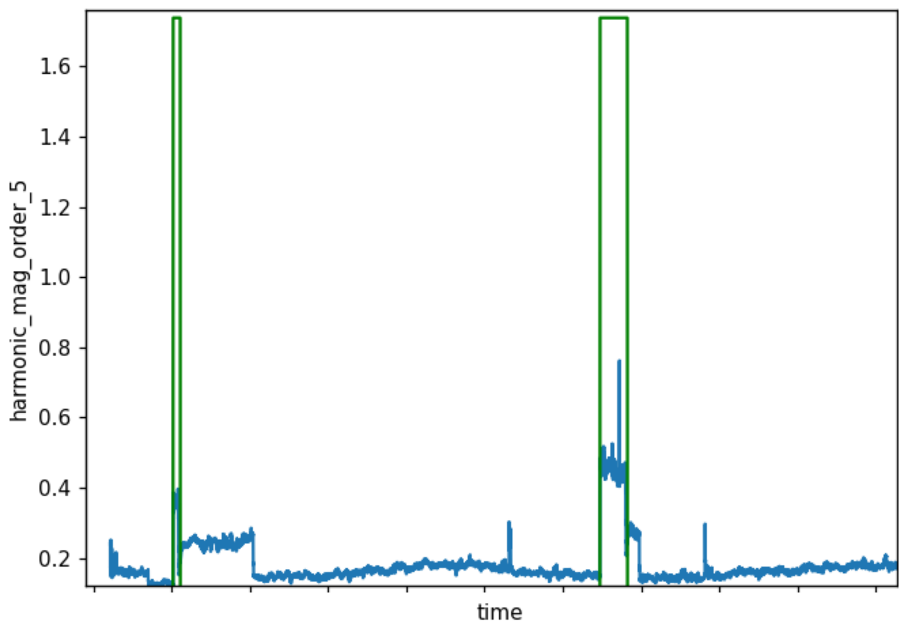

Figure 4. EV charging lowers power quality by introducing current harmonics generated from the conversion of AC to DC power, which causes utility and customer equipment degradation.

5. **EV charging in the presence of a grid fault showed potential to support voltage recovery.** With granular real-time data, utilities can manage EV charging in the presence of faults to mitigate the fault impact and facilitate faster recovery. (Figure 5)

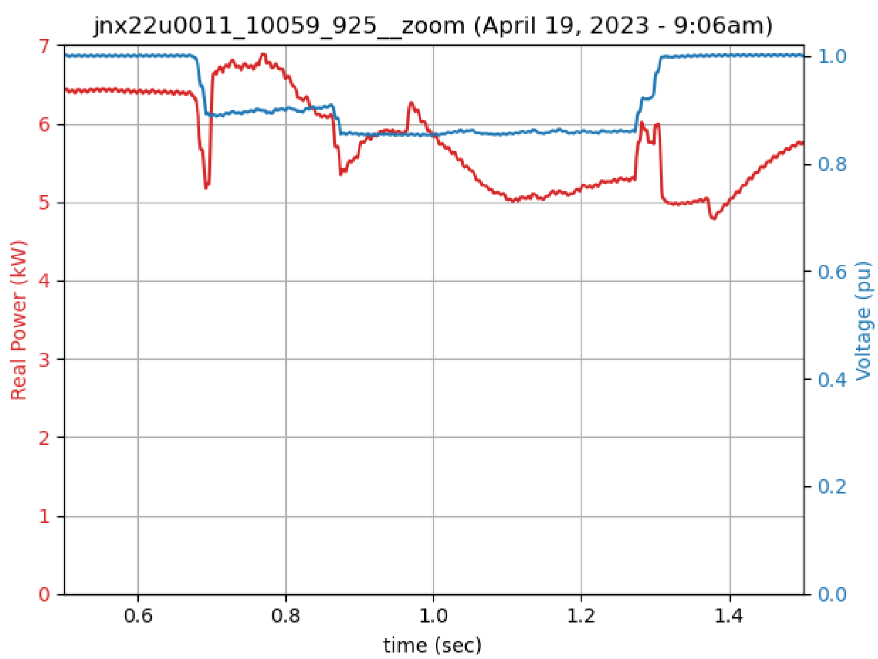

Figure 5. EV charging in the presence of a grid fault showed varied conditions to support voltage recovery.

About Karman

Karman leverages advanced machine learning algorithms to accurately identify EV charging events. Initially trained on the cloud with data collected from real world scenarios, Utilidata's model is then deployed at the edge with local computing to ensure real-time processing, analysis, and prediction. Karman continues to self-train at the edge, refining its accuracy by learning from local features and nuances.

Karman analyzes 32kHz waveform data with on-chip digital signal processing and detects the start and stop of an EV charging event, while analyzing the power quality. Recorded metrics are compared to data from when the EV is not charging to understand the impact. Karman identifies power quality issues in real-time and sends that data to the cloud-based platform. The detection model is multifaceted, encompassing models tailored to recognize higher-order features such as harmonics and voltage transients. This comprehensive approach enables precise identification of EV charging events, even amidst complex grid dynamics.

Once EV charging events are identified, Karman enables local optimization to efficiently manage charging behavior. By integrating grid signals into automated load and distributed energy resource (DER) management programs with dynamic pricing, and considering constraints such as voltage thresholds, Karman ensures optimal utilization of DERs while maintaining grid stability. The local optimization capabilities empower utilities to offer customer programs to dynamically adjust EV charging schedules in response to fluctuating grid conditions, thereby maximizing grid reliability and minimizing operational costs.

Conclusion

These preliminary findings indicate the potential risks to the grid from large-scale unmanaged EV-charging as well as the opportunity for EVs to provide value to the grid and improve service for all customers. Utilities need local computing, analysis, and predictions to be able to manage and coordinate EV charging demand and charger dynamics. Technologies that capture and analyze granular data locally, like Utilidata's Karman platform, are critical for effectively managing EVs to the collective benefit of consumers, auto manufacturers, and utilities. This study by UMTRI serves as the foundation for additional research to more fully explore ways in which distributed AI can be used to understand and manage the effects of EV charging on the grid.

About Utilidata

Utilidata is an AI-powered technology company providing utilities with robust, real-time insights to operate a connected grid. The company's distributed AI platform, Karman, is built on a custom NVIDIA module, and provides unparalleled processing power at the grid edge to accelerate decarbonization and better serve people. For more information, visit utilidata.com.

About UMTRI

UMTRI is a global leader in safe, equitable and efficient transportation research innovation. With partners across academia and sponsors in government and industry, UMTRI remains at the forefront of research innovation to help shape the evolution of a global transportation and mobility system. UMTRI experts focus on large scale data collection, driver behavior, human factors, engineering systems, injury and biomechanics, and are committed to data-driven changes in legislation that will ensure all individuals experience safe, equitable and efficient transportation and mobility options. For more information visit umtri.umich.edu.