Communications with the Grid Edge

Unlocking Options for Power System Coordination and Reliability

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Part of a series of white papers on
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Introduction: What is the *grid edge,* and how is it evolving?

Grid edge has a fluid definition. In this document, we define the grid edge to be the boundary zone where the utility ends and customer premises equipment (CPE) starts. Specifically, the grid edge begins at the meter interface (the utility demarcation point). The grid edge contains all equipment, software solutions, and controls owned by the customer. Customers could be homeowners, businesses, and industrial or commercial facilities.

The grid edge is evolving faster than the bulk power system in integrating new technologies. Virtual power plants (VPPs), rooftop solar systems, electric vehicle charging stations, and energy storage solutions are examples of some of the new technologies that are becoming increasingly popular. Until a decade ago, power engineers viewed the grid edge as mostly a load-draining system. Generation and energy storage at customer sites were simply viewed as "negative" load. There was little, if any, need to interact with these loads when maintaining stability and control of the grid. The need for communications with the grid edge itself was—and remains—a relatively low priority. Utilities would consider grid edge loads as part of their seasonal and annual planning processes but would rarely involve them in day-to-day operations (beyond some blunt demand-response programs).

Today, the situation is changing, and interest is increasing to integrate edge devices into grid operations. First, the magnitude of these edge loads (both positive and negative) is increasing. Distributed solar has reached a level that has completely reshaped the daily net load curve in some regions,[1] while the growing number of electric vehicles (EVs) has the potential to similarly affect demand. The size and behavior of these loads add complexity to grid management—and, unaddressed, may harm grid reliability. This risk leads to the second driver of interest in bridging the interface between the grid edge and the bulk power system: these are "smart" loads, potentially capable of being coordinated and controlled, and thus capable of providing additional options and flexibility to grid operators.

While the grid edge has evolved rapidly, the distribution utility power and communications networks have not. To grow with the changing customer landscape, the distribution operators must evolve not only their power networks, but also their communications infrastructure to enable increased visibility and superior coordination with the grid edge. The next section explains why.

How can a secure, efficient, reliable communications infrastructure leverage the grid edge to improve system operations?

The sophistication of CPE continues to grow, both for commercial/industrial (CI) and residential customers. CI and residential customer on-premises equipment and associated software hold a wealth of information, such as energy production, consumption, and energy health. Distributed energy technology (DER) equipment enables consumers to put energy back into the grid, making them energy partners as described in FERC Order 2222.[2] Power utilities, unfortunately, do not have access to this wealth of customer data. If they did, they could use this new information for improving resiliency, reducing costs, providing better response during emergency scenarios, and forecasting loads more accurately. This vision of integration between the grid edge and the distribution utilities requires a secure end-to-end communications network that is robust, interoperable, and resilient. Without such coordination, grid stability may be at risk.

[1] California ISO. (2016). *Fast Facts: What the duck curve tells us about managing a green grid* [White paper]. https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf.

[2] Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, Docket No. RM1809-000; Order No. 2222 (2020). https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf.

Imagine a future scenario similar to what occurred in the western United States in September of 2022: a heat wave makes it challenging for transmission and distribution (T/D) utilities to meet demand. Surplus energy available for import is low, all the transformers in the T/D system are already running at peak levels during the middle of the day, and anticipated peak load is not forecasted to occur until the late afternoon or evening. A VPP provider, anticipating high demand in the late afternoon hours, commands the energy storage devices under its control to start charging to maximize capability. Unfortunately, the VPP has no knowledge of this strained state of the T/D system, which its actions will exacerbate.

On the other side, the distribution utility has no knowledge of why many of its customers suddenly flipped from net generation (via rooftop solar) to net load (at roughly 10 kW per battery). The transformers reach their thermal limits, and the power flow is interrupted causing wide-scale outages.

This type of an outage is preventable with increased visibility, and visibility requires secure communications: the ability to deliver trustworthy data between T/D utilities, grid edge devices, and intermediaries in near real-time while protecting confidentiality where necessary.

Managed EV charging presents a similar scenario: direct current (DC) fast chargers for heavy duty transportation charge at rates that exceed 1 MW; DC fast chargers for light duty transportation charge up to 350 kW per port. A typical six- to twelve-car light duty charging cluster by itself may require as much power delivery as an entire feeder or more. A similar supply requirement also applies to multifamily dwellings: if all the vehicles in the parking structure charge simultaneously at 19.2 kW (100A), the load placed on the utility may be in the order of multiple megawatts. Grid reliability will be adversely affected during extreme conditions without clear, direct communications between managed EV charging providers and distribution utilities.

Integrating these grid edge assets with the distribution system requires a robust, interoperable, and secure communications network that enables the types of coordination utilities will need. While the customers have access to monitor and interact with their assets, the utilities are mostly blind to the capabilities and resources on customer CPE.

In addition to its value enabling grid coordination during the sorts of scenarios described above, increased visibility promotes safety and cooperation between utilities and consumers during “black sky” events, wherein crises originate external to the system, as in the event of a hurricane. Typically, when meteorologic forecasting predicts large impacts, utilities forward-deploy assistance. After the event, the response to outages is managed according to available information, attempting to coordinate recovery efforts to ensure that critical loads are addressed in a safe, timely, and priority-based manner. As balancing authorities work together during this time to better understand the needs, T/D utilities can provide a limited picture of impact. With CPE data in hand—enabled by robust, resilient communications—this picture of impact is better understood, and the response can be fine-tuned.

Finally, while “black sky” events rightly receive a lot of attention, the visibility enabled by communications with the grid edge promotes safety and cooperation between utilities and consumers even under normal, “blue sky” operations, such as identifying and mitigating ordinary daily or seasonal effects, such as those from pollen, pollution, or a cloudy day on solar photovoltaic generation.

All of these cases deliver increased value to both utilities and consumers. All also require an end-to-end secure communications architecture coupled with data-producing grid-edge equipment to enable rapid data acquisition, coordination, fault location, and outage detection.

What are the barriers to planning and investing in secure communications between the grid edge and the bulk power system?

What should that communications architecture look like, and how can it be instantiated on the grid? There are both engineering and policy issues that must be resolved. On the technical side, a coherent, interoperable architecture must be defined with support from a variety of vendors and a diversity of devices and standards.

As CPE becomes more prevalent and the vision of operational coordination between the grid edge and the bulk power system comes to fruition, security takes on increased importance. More interconnectedness between critical operational technology and edge devices—which are often exposed to information technology networks—increases complexity and risk, unless security is built in. Utilities must begin to consider communications security to address an expanding set of threat vectors at the grid edge. Managing these risks in a densely interconnected environment will require cooperation between utilities, communications vendors, government, and customers.

Aside from the technical coordination and security challenges, socioeconomic factors, regulatory regimes, and geographies differ greatly among states and utility service areas. Some utilities do not (yet) face deep penetration of grid edge assets, and so they may not prioritize adopting modern communications technologies in advance of seeing this evolution take place on their systems. In addition, regulatory frameworks designed for the bulk power system, the patchwork of asset ownership across the grid edge, and misaligned incentives lead to friction in deploying interoperable communications infrastructure. Grid edge asset owners may optimize for their needs, leaving distribution utility requirements unaddressed, while utility-built communications infrastructure may not meet grid edge stakeholders' expectations for speed, flexibility, and accessibility.

Investing in enhanced communications technologies brings about system visibility that—in addition to the operational and response/recovery improvements described above—enables smarter, more efficient spending better targeted at documented needs. A robust, interoperable communications link with the grid edge allows utilities to bring data-driven analysis to decision makers and improve mission success, suggesting that communications investments should not take a back seat to other priorities.

Conclusion

Communications between the grid edge and the bulk power system is critical for a reliable, resilient, and secure energy future. The goal of this paper is to motivate a discussion on this topic between T/D utilities, grid edge asset vendors, communications companies, the federal government, and local jurisdictions on the need for secure, enhanced communications between the T/D operators' facilities and customer-owned, data-driven systems. This white paper is part of an effort by the Department of Energy Office of Electricity to bring stakeholders together to discover gaps, identify needs, and explore how secure communications can enable new capabilities for the electricity system of the 21st century.

Please consider participating in a series of Department of Energy-sponsored webinars, workshops, and conferences in 2024 and beyond to drive consensus toward an innovative, cost-effective, and secure solution for grid communications.

References

1. California ISO. (2016). *Fast Facts: What the duck curve tells us about managing a green grid* [White paper]. https://www.caiso.com/documents/flexibleresourceshelprenewables_fastfacts.pdf.
2. Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, Docket No. RM1809-000; Order No. 2222 (2020). https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf.