Bringing Artificial Intelligence to the Grid Edge

By Yingchen (Y.C.) Zhang and Marc Spieler

As the demand for energy increases along with the requirements for decarbonization, there is more complexity in which the world produces, moves, and consumes energy. The way we supply and consume energy is becoming increasingly complex and requires us to leverage technology and learn from the success of other industries. From the fuel that powers cars and planes, to the gas used for stove top cooking, to the electricity that keeps the lights on in homes and businesses, energy powers our daily lives. Oil, gas, and electricity are mature commodity markets, but as the mix changes at a rate never seen before, the industry must adapt at a similar pace. This includes leveraging artificial intelligence (AI), real-time analytics, and machine learning to create autonomous energy systems that can increase reliability and resiliency in a more complicated world. However, AI alone is not enough to transform the processes used to produce, transport, and deliver these resources.

Enter edge AI, deployed where decisions need to be made, where the data are being produced, where communications networks may not provide for the low latency required to make real-time decisions—such as on oil rigs, within power plants, along transmission and distribution grids, riding along utility trucks, and embedded in industrial facilities. As the grid edge becomes exponentially more complex, there is a massive opportunity for electric utility companies to use edge AI to improve operational efficiency, enhance functional safety, integrate renewable energy, increase grid resiliency, and provide reliable and affordable power.

What Is Edge AI, and How Does It Work?

Edge AI is the deployment of embedded AI applications in connected devices in the physical world. The “edge” component is a result of AI computation done near the user at the edge of the network, close to where the data are located, rather than centrally in a cloud computing facility or private data center.

Take the example of autonomous vehicles (AVs). Self-driving cars need AI to process large volumes of onboard sensor data from cameras, lidar, and radar to inform real-time driving decisions in split seconds, not minutes or hours. This requires continuous perception, mapping, planning, and driver monitoring capabilities. Imagine the consequences if an AV needed to wait for a response from a data center before applying brakes or swerving to avoid an obstacle in the road. Future electric grid infrastructure will leverage edge AI in a similar way to dynamically manage distributed energy resources (DERs), meet charging demands, balance the grid to avoid waste, and integrate more renewables, local production, and storage from increased rooftop solar and electric vehicle (EV) adoption.

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Top Benefits of Edge Computing

Edge computing and AI deliver real-time intelligence through model reasoning, live inference, and transmitting anomalies and results back to the cloud for future model training and data analysis. This workflow among the data center, cloud, and edge effectively handles the big data processing, response, and security needed to scale AI across an enterprise (see Figure 1).

Additional benefits of edge computing include the following:

1) Resilience: When an edge device fails or software has crashed, automated software can remedy issues without human intervention. Resiliency migrates the workloads of devices and systems to other systems on the same edge network, ensuring minimal application downtime and that insights are never lost.

2) Lower latency: Distributed infrastructure avoids sending unnecessary data back to the data center or the cloud. Enterprises can process data in real time through sensors embedded in IoT devices and edge servers, improving functional safety in industrial environments, building AVs, and more.

3) Scalability: Data processing at the edge avoids the need for high bandwidth for transmission, as data are transferred to the cloud only when necessary. This results in cost savings and avoids network constraints for weak and interrupted connectivity.

4) Remote management: Setting up and maintaining enterprise-scale systems at remote locations is challenging. A remote management platform allows IT teams to easily deploy, manage, and scale applications across the entire edge infrastructure from a single pane of glass.

5) Security: To protect sensitive data, edge devices can “desensitize” data at the edge first and then send the data to the cloud. Edge devices can also store and process sensitive data only locally, meeting the requirements for local data storage in multiple business scenarios.

How Edge AI Is Transforming Energy

Global energy leaders are using AI and machine learning to deliver a path to autonomous power plants and grids, optimize pipelines, and create intelligent forecasts of energy supply and demand. Industrial sites, such as oil rigs and power plants, require extensive monitoring for efficiency and safety because liquid, steam, and oil leakages can be catastrophic, costly, and wasteful. Energy
companies are training AI models using thousands of images and video streams from millions of onsite cameras and sensors to detect process anomalies. The models are deployed at the edge in power plants and use real-time inferencing to identify leaks. Rig operators are using computer vision, deep learning, and intelligent video analytics (IVA) to monitor heavy machinery, detect potential hazards, and alert workers in real time to protect their health and safety, prevent accidents, and assign repair technicians for maintenance.

Edge AI can calculate the optimal flow of oil to ensure the reliability of production and protect long-term pipeline health. Using IVA, these companies can inspect pipelines for defects that could lead to dangerous failures and automatically alert pipeline operators.

**Advancing Decarbonization and Grid Reliability With AI**

As companies and countries race to decarbonize and meet net-zero emissions goals, edge AI will play a key role in managing DERs, such as EVs, home batteries, solar panels, and wind farms, to enhance power grid resiliency and accelerate the energy transition. Edge AI can accelerate integrating DERs and EVs into the grid through distributed decision making. In a world where a utility distribution system has tens of millions of interactive DER devices, it will be critical to embed scalable IoT management within edge intelligence for in situ scheduling, condition forecasting, and proactive dispatch that will manage the entire power balance and system dynamics in real time. Real-time edge management will be critical to reducing and eliminating upgrade costs for DER interconnections, maximizing the existing grid capacity, and reducing the total cost of ownership of DERs.

Intelligent forecasting using grid simulations, accelerated by machine learning and AI models, combines historical data on energy usage and weather patterns to inform efficient generation, distribution, and management of energy resources to consumers (Figure 2). Climate simulations can predict the impact of extreme weather events and generate insights to save lives and reduce damage costs. AI helps manage the bidirectional flow of power in a grid, delivering reliable energy to residents and businesses, while automating the process for consumers to sell their additional energy back to the grid.

Edge computing can help monitor the estimated 185 million utility poles in the United States and reduce the tens of millions of dollars spent each year by utilities to manually track and maintain grid infrastructure. Fixed camera systems with edge computing capabilities can be secured to the roof of field service trucks to collect standardized high-resolution images of utility poles, power lines, and pole-mounted assets. The images can be analyzed at the edge to determine whether repairs or vegetation management are needed. With proactive maintenance, utilities can accurately detect defects and reduce unplanned outages to better serve customers.

**How to Deploy AI Intelligence at the Grid Edge**

As the edge of the grid becomes rapidly more complex with high penetrations of EVs, distributed solar, batteries, heat pumps, and extreme weather, utilities will need real-time visibility and decentralized decision making and control. Without distributed AI solutions, electric distribution utilities will struggle to support the clean energy transition and widespread electrification. Future smart grid edge intelligent devices will use distributed computing to
optimize power flow, detect grid anomalies, deliver more reliable energy at a lower cost, and unlock opportunities for end users to become active participants in energy applications.

A software-defined smart grid chip (Figure 3), developed by Utilidata in collaboration with Nvidia, will power next-generation edge intelligence to increase grid resiliency, decarbonization, and consumer value. The smart grid chip is an open source platform that collects and analyzes grid edge data in real time, using local rendering of machine learning algorithms to identify and classify problems, quickly resolve issues before they evolve into outages, enable greater efficiency through local operational decisions, and seamlessly connect and manage DERs. GPU-accelerated parallel processing can solve stochastic optimization problems with time-varying constraints and targets, enabling the management of tens of millions of DERs in real time while improving the reliability and resilience of the entire grid.

Let’s imagine a scenario where a storm took out a major part of the grid. Control centers lost communication connections to many parts of the grid, and repairing the centrally controlled network would take considerable time. If, however, a sufficient number of DERs remained functional and could be managed locally by edge intelligent devices, these DERs could be used to power the significant number of customers during the recovery time. Edge AI will ultimately shift the operational paradigm of power systems from centralized to truly distributed, software-defined, and autonomous systems.

**Figure 3.** The Utilidata smart grid chip powered by the NVIDIA Jetson edge AI platform.

**Figure 4.** Edge intelligence deployment.

**The Future of AI and the Electric Grid**

Digitizing the grid edge with open source AI is a key enabler to accelerate decarbonization and better serve utility customers. Distributed intelligence, powered by AI and edge computing, helps operationalize real-time data from every point on the distribution grid. To learn more, see Utilidata’s pilot smart grid chip deployment (Figure 4) with Lake Placid Municipal Electric (https://utilidata.com/lake-placid-smart-grid-chip-pilot-project/), and find out how Nvidia AI is powering a more sustainable future (https://www.nvidia.com/en-us/industries/energy/power-utilities/?ncid=progr-679351-vt31#cid=_progr_en-us).

**Biographies**

Yingchen (Y.C.) Zhang (yzhang@utilidata.com) is the Vice President of Product Solutions at Utilidata Inc., Providence, RI 02903 USA.

Marc Spieler (mspieler@nvidia.com) is the head of global energy business development at Nvidia, Houston, TX 77096 USA.