Edge Intelligence for the Energized Home

Brandon Kanter
Systems Manager
Energy Infrastructure

Designing safer, more intelligent residential energy systems through advanced sensing, protection, and processing

At a glance

- Modern homes are shifting from simple power distribution architectures to dynamic, interconnected environments that require more intelligent monitoring and protection.
- Edge intelligence enables real-time fault detection and response in residential energy systems with solar, battery storage and electric vehicle (EV) charging.
- Advanced sensing technologies distinguish between normal electrical events and hazardous conditions to prevent unnecessary interruptions and improve system reliability.
- Integrated protection architectures combine precision measurement, local processing and connectivity for safer, more efficient home energy management.

Introduction

On a hot summer day in Texas, a homeowner arrives home and plugs in their EV. Solar panels generate more power than the house consumes, allowing excess power to charge the home's battery system or return power to the grid. Earlier in the day, the dishwasher ran as scheduled, and the air-conditioning system automatically ramped to full capacity.

Household systems such as solar installations, battery storage and EV charging stations may feel ordinary and familiar on their own. But when they interact, they create a different kind of home energy environment, shaped by higher electrification loads, variable pricing, energy storage, and bidirectional power flow. As higher-power systems become more common, homes increasingly need smarter energy management that supports electrically complex systems with connected appliances and distributed energy sources. These are energized homes.

Energized homes distribute more energy throughout the walls and roofs, which inherently creates more risk, because as electrification increases, the margin for errors in protection systems decreases. To help address these risks, engineers must design systems that can sense accurately, analyze conditions locally, and provide the connectivity needed for visibility and coordination. Such systems expose the limits of conventional protection and control technologies.

Engineering challenges

Threshold-based circuit breakers cannot adequately address the energy flow variability and context-dependent behavior characteristic of energized homes. Energy management systems must integrate multiple functional domains including sensing, signal conditioning, data conversion, processing, and communication, each of which must operate reliably in electrically noisy and high-voltage environments without false trips.

Advances in isolation and sensing make it possible for designers to manage high-voltage and high-current conditions safely, resulting in a lower risk of electrical hazards and improved system protection for homeowners. But overly sensitive protection is as disruptive as insufficient protection.

The challenge for engineers is designing protection systems that optimally balance sensitivity and selectivity. False trips, which occur when a protection device interrupts power in the absence of a true fault, can have significant downstream effects. Improving fault classification enables systems to distinguish more consistently between transient events and true fault conditions, resulting in fewer unnecessary interruptions and improved system reliability for homeowners and service providers.

Optimizing the energized home requires engineers to observe how power is moving through the systems. Figure 1 shows an example of a smart circuit breaker solution that provides remote load management, automation and control at the circuit level. High-resolution measurement technologies can provide detailed data about voltage, current and system behavior across loads and distributed energy sources. That visibility helps engineers improve fault detection to make more informed protection, control and energy-management decisions.

Figure 1. *A smart panel solution provides remote load management, automation, and control at the circuit level*

Intelligent protection architecture

At a system level, protection systems for energized homes operate in a continuous loop of these three actions:

- Detection – High-resolution sensing captures voltage, current and system conditions in real time.
- Analysis – Embedded processing evaluates electrical signatures to identify patterns and anomalies.
- Response – Protection mechanisms act based on context, either isolating faults or maintaining operation as appropriate.

Continuous sensing and detection

At the detection stage, protection systems in highly dynamic environments must operate continuously to gather real-time measurements of voltage and current across a wide dynamic range. Reducing latency is important, because detection systems must capture and relay information with sampling and processing sometimes measured in milliseconds.

Analysis through local intelligence

Embedded processing enables protection systems to interpret electrical behavior instead of simply responding to fixed thresholds. This distinction matters because in energized home environments, electrical signatures can be difficult to describe with deterministic rules alone. Performing pattern-based analysis locally at the data's source enables greater precision in order to improve both responsiveness and reduce the dependence on connectivity for core safety functions. Design tools such as CCStudio™ Edge AI Studio from Texas Instruments (TI) can help streamline the progression from data capture and labeling to model evaluation and deployment.

Adaptive protection and system response

The final stage is response. In a conventional binary system model, the system trips when a measured value exceeds a specified threshold. But energized home environments require nuanced responses that go beyond simple interruption. They require intelligent protection systems that can evaluate context by distinguishing transient inrush currents from sustained faults, while also recognizing when power is flowing in different directions across solar, storage, and EV charging systems (**Figure 2**). This enables more selective intervention and can help coordinate load balancing across the home, managing safety and system performance together.

Figure 2. *An intelligent monitoring system ensures that bidirectional energy flows seamlessly while protecting the home from faults and hazards*

System integration: From sensing to visibility

Visibility beyond the physical system is now foundational for reliable operation in energized homes, where sensing, processing and communication operating together determine system performance. Individually, these technologies enable critical functions, but fragmented designs limit system performance, scalability, and reliability. Their full value emerges only when an engineer integrates them into a cohesive, end-to-end architecture.

TI supports this architecture across the entire signal chain, including sensing, isolation, data conversion, edge processing and connectivity. In the sensing path, precision analog and metrology technologies help designers capture voltage and current accurately across wide dynamic ranges. Then, isolation and signal-chain devices help maintain the integrity of signals traveling between high-voltage domains and low-voltage processing electronics.

Designers can also use data-conversion and signal-conditioning technologies to turn electrical behavior into usable system data, and use embedded processing at the edge to support local analysis for protection and control functions.

How an intelligent protection architecture works

In **Figure 3**, the flow starts at the sensing layer, where the system captures physical parameters such as voltage and current and converts the amounts into electrical signals that represent what is happening in the system.

These signals then move into signal conditioning, where the front end amplifies, filters and isolates them so that data stays accurate and usable even in electrically noisy, high-voltage environments.

Once the signals are conditioned, the edge processing layer converts the data into real-time system understanding by running local analysis to detect patterns, classify events, and flag abnormal conditions.

The communication layer then passes the processed information between subsystems and, when needed, out to external interfaces so that the system can support coordination, diagnostics, and control.

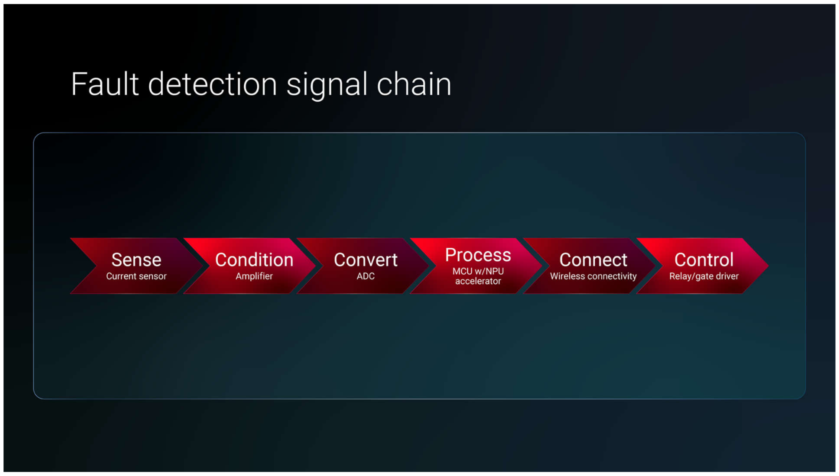

Figure 3. *Stages of intelligent protection architecture*

Building blocks for intelligent protection

- Precision **analog-to-digital converters** and **isolated modulators** for capturing electrical behavior as usable system data.
- Instrumentation amplifiers and signal-chain devices for accurate measurement in noisy, high-voltage environments.
- Embedded processing devices such as TI's **MSPM0G5187 microcontroller with the TinyEngine™ neural processing unit** for local protection and control analysis.
- Wired and wireless connectivity technologies for diagnostics, visibility, and energy management across subsystems.

Finally, wired and **wireless connectivity technologies** help move relevant data between household energy subsystems or cloud-based interfaces for use in areas such as diagnostics, visibility, and energy management.

Why intelligence at the edge matters

Engineers must design energized home systems to make important safety decisions locally and in real time because protection functions cannot depend on connections to cloud resources or tolerate delays from potential network latency. Engineers therefore design systems to analyze measurements and interpret electrical behavior at the edge for immediate and appropriate action.

As residential energy environments grow more dynamic, the growing accessibility of artificial intelligence (AI) is making edge processing more practical and more powerful. Normal operating events such as appliance start-ups, motor activity and transient current changes can at times appear similar to fault conditions. Edge AI helps address this by evaluating multiple characteristics of an event in parallel instead of relying on fixed thresholds alone. This improves the system's ability to determine whether the event reflects expected behavior or a condition that requires intervention.

In applications such as arc fault detection, added context can help distinguish hazardous events from benign ones. This can reduce the occurrence of unnecessary interruptions, resulting in a system that can respond more accurately and support better user experiences.

Intelligent protection in residential energy systems

Interactions between systems define energized homes, and the architectural principles designers follow are not purely theoretical. They already shape the design of residential energy systems, where designers must enable safety, efficiency, and reliability in increasingly complex environments.

Smart circuit breakers

The electrical panel is becoming an intelligent control point rather than a passive distribution node. Smart circuit breaker panels can function as a system's central control point, supporting remote diagnostics and reset capabilities for system components.

Advanced smart meters

Energy measurement is shifting from periodic reporting to continuous system insight. Earlier generations of smart meters focused primarily on automated meter reading, but newer ones offer more granular insight, enabling detailed analysis of energy usage across different appliances and time periods.

This increased visibility supports both operational and user-facing benefits. Utilities can better manage grid demand, while homeowners gain a clearer understanding of how and when their household systems consume energy.

Safer, simpler energy management

For homeowners, the value of intelligent monitoring and protection is simple: greater peace of mind. In energized homes, where solar, battery storage, EV charging, and connected loads all interact, protection systems need to sense accurately, interpret context, and respond appropriately so that the home stays safer and more reliable without unnecessary interruptions.

For builders and system designers, those same capabilities can help support compliance goals and more predictable system performance as residential energy systems grow more complex.

And when designers have greater confidence in how a system monitors and protects itself, they can move more confidently toward features such as higher charging speeds, better coordination across energy assets, and more advanced home energy management.

Conclusion

The trends driving the energized home – electrification, integration of renewable energy generation, and increased system intelligence – will continue over the coming decade. As residential energy systems become more complex, manual management will become less practical, reinforcing the importance of integrated architectures and reliable, responsive automation. Because energized homes are both highly dynamic and connected, the ability to sense accurately, respond locally, and integrate intelligence across the system will be foundational not only to building safer, more resilient, and more efficient energized homes, but also to giving homeowners greater confidence and control.

Additional resources

- Read the company blog, "**Smarter breakers, safer home: The hidden technology within your energy-abundant house**."

About the author

Brandon Kanter is systems manager for TI's energy infrastructure, where he focuses on innovation in sustainable energy, including solar, EV charging and smart grid systems. Previously, he was business lead and applications manager in power-management integrated circuits, focusing on industrial and automotive. Brandon earned a bachelor's degree in electrical engineering and a master's degree in business administration for the University of Kentucky.

IMPORTANT NOTICE AND DISCLAIMER