Modernizing the grid to make it more resilient and reliable through technology

Henrik Mannesson
Grid Infrastructure Sector General Manager
Texas Instruments
Prompted by the need to comply with environmental and societal concerns, electric power generation and distribution systems are undergoing an unprecedented transformation.

The U.S. electric grid comprises more than 9,200 electric generating units, with more than 1 million MW of generating capacity, connected to more than 600,000 miles of transmission lines.

The distribution network connecting generating plants to factories, businesses and homes is in the midst of a much-needed upgrade designed to make it more reliable and resilient. By employing advanced sensors in generation, transmission and distribution, grid operators can monitor health, optimize old (and expensive) assets, detect faults, and restore power more quickly.

This will have little impact on consumers but will help asset owners manage reliability: New data from grid assets gives operators greater insight into infrastructure performance so that they can respond more quickly to changing grid conditions based on shifting generation mixes, extreme weather events or security issues.

Smart grid sensors enable the remote monitoring of equipment such as transformers and power lines and facilitate demand-side resource management. Smart grid sensors can also monitor weather conditions and power-line temperatures, which can be used to calculate the line’s carrying capacity.

On the load side, meters will help consumers ease the migration toward more renewable energy as well as electric vehicle (EV) charging. What’s more, smart meters enable consumers to engage and make better choices based on their energy needs.
What was once a network of electromechanical systems with minimal feedback and passive loads has become highly automated and driven by intelligent devices and modernization strategies. The result is a more interconnected power delivery network – from generation to transmission and distribution to end use – integrating distributed energy resources and ensuring greater grid reliability and resiliency.

Grid modernization is a broad term, referring generally to actions that make electric systems more robust, responsive and interactive. Specifically, however, this paper will summarize developments in four key elements of grid modernization:

- Digitalization, specifically in intelligent meters, sensors and device nodes widely deployed across the grid.
- Communications and control technologies for managing distributed energy resources of all kinds.
- The impact of EVs and the EV recharging infrastructure.
- Real-time data management for enhanced protection and control.

Next up: Connected battery-powered gas and water meters

Although connected meter deployments started initially with electricity, the adoption of automatic meter reading (AMR) and smart meters within the flow meter market (gas, water, heat) is also gaining momentum.

To reduce mechanical failures, improve accuracy and add intelligence, gas and water meters benefit from:

- Ultrasonic flow measurement, with high accuracy and low energy consumption.
- Wireless communications, with long ranges to assure connectivity.
- Intelligent power management, to maximize efficiency and provide at least 10 years of battery life.

Powering electric meters is obvious – since measurements are taken from a power line, there is power where the electric meter sits. But battery-powered technology is the norm in gas and water metrology, which makes it a lot more challenging because the power budget is much lower. There is also a commercial challenge: In many regions gas and water are handled by smaller entities than electric providers. In the same area, you might have one organization owning the electric meter network but multiple companies supplying water to residents.

Water or gas utility providers who wish to add AMR capability further face the choice of replacing all of their existing meters or installing an electronic add-on module to accurately measure the flow rate and wirelessly transmit the results. Such add-on modules offer an inexpensive solution to provide AMR features to consumers, as shown in the Low-Power Water Flow Measurement with Inductive Sensing Reference Design from Texas Instruments (TI), which is enabled by the CC1350 SimpleLink™ wireless microcontroller (MCU) and FemtoFET™ metal-oxide semiconductor field-effect transistor (MOSFET).
In a gas- or water-meter network, the smart meter is the sensor responsible for collecting usage data and reporting it to upstream control nodes. Accurate ultrasonic measurement helps reduce mechanical failures and leads to greater system reliability. Ultrasonic measurement eliminates mechanical wear and tear by using a solid-state sensor architecture with no mechanical components. The introduction of ultrasonic flow-measurement system on chips (SoCs) has greatly reduced the cost of transitioning to this technology.

TI’s industry-leading integrated circuits and reference designs for smart gas, water, and electricity meters help original equipment manufacturers (OEMs) meet key design challenges of greater measurement accuracy and extending battery lifetime.

The Ultrasonic Sensing Water Meter Front-End Reference Design helps engineers develop an ultrasonic water-metering subsystem using an integrated, ultrasonic sensing analog front end (AFE), which provides superior metrology performance with low power consumption and maximum integration. The design is based on the MSP430FR6047 ultrasonic sensing SoC. The MSP430FR6047 offers an integrated ultrasonic sensing subsystem AFE, which provides high accuracy for a wide range of flow rates through a waveform capture-based approach. Additionally, the MSP430FR6047 SoC helps achieve ultra-low-power metering combined with lower system cost due to maximum integration requiring very few external components.

Similarly, the Battery and System Health Monitoring of Battery-Powered Smart Flow Meters Reference Design enables highly accurate power measurement and state-of-health projections, which forecast battery lifetime. The monitoring subsystem also protects against overcurrent conditions, which can dramatically reduce battery life.

Distributed energy resources as an integral part of the grid

Traditionally, the power grid has been a “one-way street,” with power flowing from utility-owned centralized generation, transmission and distribution lines toward consumers. As solar and wind energy start to make up a greater share of the electric grid, dynamic management will become more prevalent. Utilities will come to view the electric grid as more of an interconnected web, with a small but growing number of consumers generating electricity with small-scale, distributed systems. In other words, homes will alternately be consumption units and generation units.

Solar and wind energy have zero carbon emissions, and unlike fossil fuels are not affected by price volatility. More and more regions (especially those with abundant sunlight or wind and a high cost of electricity) are starting to see grid parity – the point at which renewable energy is equal to or cheaper than the cost of fossil fuel.
Solar microinverters are an emerging segment of the solar power industry. TI’s comprehensive selection of isolated and nonisolated gate drivers, current sensing signal chain, voltage monitoring devices and MCUs can handle digital control loops targeted at all sizes of inverters, both grid-tied and off-grid, to maximize system efficiency and extend product life spans.

**Bi-direction EV charging to help balance the grid**

In the near future, EVs (cars, buses and trucks) will replace vehicles powered by fossil fuels. And while the electric distribution system was originally designed and built to serve peak demand and passively deliver power through a radial infrastructure, a smart grid not only facilitates more customer choice but can be managed locally, remotely or automatically. The smart grid enables utilities to keep up with changes in consumer behavior (for example, most EV battery charging at home will likely take place at night during off-peak hours).

The highest-performing electric cars feature onboard chargers that are in the 10 kW range. That may soon move to 15 kW or 20 kW to reduce recharging time, even though there are very few other things in a home that need that much power – not even air conditioners.

The idea of bidirectional chargers brings along with it the possibility of using an EV as a battery storage element. Let’s say that the EV in the garage can go 400 miles on one charge. But through communications, cloud computing and the modernized grid, the car “knows” that the owner is not going to drive more than 50 miles tomorrow. The battery does not technically have to be full at 7 a.m., so energy could be pulled out of the car overnight for local consumption or put back into the grid during peak hours.

Additionally, improving grid power quality and reducing the drawn harmonic currents requires power factor correction, as many of the forward loads are DC. For example, in an off-board fast EV charger operating at 20 kW, the input is a three-phase AC connection from the grid and the output to the battery is DC.

Many topologies exist for active three-phase power factor conversion. The Three-level, three-phase silicon carbide (SiC) AC-to-DC converter reference design is a good fit for the task, capable of bidirectional power conversion and using SiC MOSFETs with higher switching frequencies to improve efficiency and shrink the size of magnetics to reduce overall system size. This topology is scalable to higher-power smart grid applications like EV charging and solar inverters. SiC MOSFETs with lower switching losses ensure higher DC bus voltages up to 800 V and a peak efficiency of >97%.

**Real-time data management**

Electric utilities are starting to face important challenges in key aspects of their business as a result of the ongoing and rapid transformation of the grid.
Conventionally, grid networks in cities relied on above-ground distribution via wires. This system will yield to power conduits dug down into the ground, because there isn’t space for more overhead lines in big cities and because people don’t like to see power lines over or in front of their homes.

In the past, utilities had fairly simple ways to find faults above ground: they sent out a maintenance truck to drive along the power line to discover a fallen power line, a tree hanging on a line or too much snow on a line. In all of these instances, the cause of a power outage is pretty obvious. But grid modernization demands real-time communication, measurement and surveillance, because you cannot visually see underground failures.

Thus, the use of real-time data management has become more important than ever when it comes to connecting the utility grid system. The goal is to place data in the hands of those who can make the best use of it. Modern mobile devices are a readily available platform for data delivery and control of the smart grid, as well as the multiple energy sources incorporating the solar photovoltaic panels that make up a microgrid. Wi-Fi® and Bluetooth® are obvious methods for grid connectivity, or if necessary, using an intermediate gateway can be another option.

TI’s Grid IoT Reference Design: Connecting Circuit Breakers and Sensors to Other Equipment using Wi-Fi is designed for real-time asset monitoring in the smart grid. The main benefits of the design include:

- Real-time asset health monitoring (monitoring current, voltage and temperature levels via Wi-Fi communications).
- Adding redundant, variable-data-rate transfer capability for critical applications.
- Backup for wired communications within the substation.
- Improving response times for detecting faults.
- Reducing power downtime.

The design shows how integrating Wi-Fi is a viable solution for substation equipment and residential breakers where high data rate and large bandwidth is required. Additionally, Sub-1 GHz connectivity is another applicable wireless technology when data has to be transmitted over a long range with low power consumption for substation and distribution automation. This is useful when multiple nodes (i.e. fault indicators) need to transmit data to one data collector where a star network has to be formed. Both technologies are available via the SimpleLink™ family of ultra-low power Arm® MCUs based on the foundational SimpleLink™ Software Development Kit (SDK), promoting 100% code reuse and seamless transition between multiple wireless connectivity technologies.

The Grid IoT Reference Design: Connecting Fault Indicators, Data Collector, Mini-RTU Using Sub-1 GHz RF has wireless Sub-1 GHz communication in a star network between multiple sensor nodes (in this case, fault passage indicators [FPIS]) and a collector using the TI 15.4 stack. This design is optimized for short-range (< 50 m) low power consumption using overhead FPIS and a data collector in distribution automation as an application scenario.
It employs the CC1310 from TI's SimpleLink™ family, which incorporates a Sub-1 GHz radio frequency (RF) transceiver and an Arm® Cortex®-M3 MCU. The TI 15.4 stack configures beacon-mode communication over the U.S., European Telecommunications Standards Institute (ETSI) and China frequency bands. Current consumption data is available for a single-packet data transfer of 1 to 300 bytes at a 50 Kbps data rate by optimizing transmit power levels (0 to +10 dBm) and beacon intervals (0.3s-5s).

**Summary**

Across the country, states and utilities are busy building the grid of the future, transforming the transitional passive, electrical and electromechanical grid into an active electronic grid with dynamic control. The technology drivers for grid modernization include:

- Bringing electronic technologies and semiconductor devices to meters at the edge of the grid.
- Integrating distributed renewable generation resources.
- Adapting to electrical transportation systems and their charging infrastructure.
- Making improvements in grid monitoring, protection and control.

Modernizing the grid and the controls that communicate and work together to deliver electricity more reliably and efficiently will greatly reduce the frequency and duration of power outages, diminish the impact of storms and restore service faster when outages occur. Updating an aging system won’t be easy, and it won’t be accomplished quickly, but it will ultimately prove beneficial to society and the economy for decades to come.

TI, a company founded on energy, has the technology and system expertise to help you engineer efficient power delivery and smarter solutions for the grid infrastructure that meet global compliance standards and future load patterns for long-term reliability and future-proofing. For more information about TI grid modernization technologies, see [ti.com/grid](http://ti.com/grid).

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