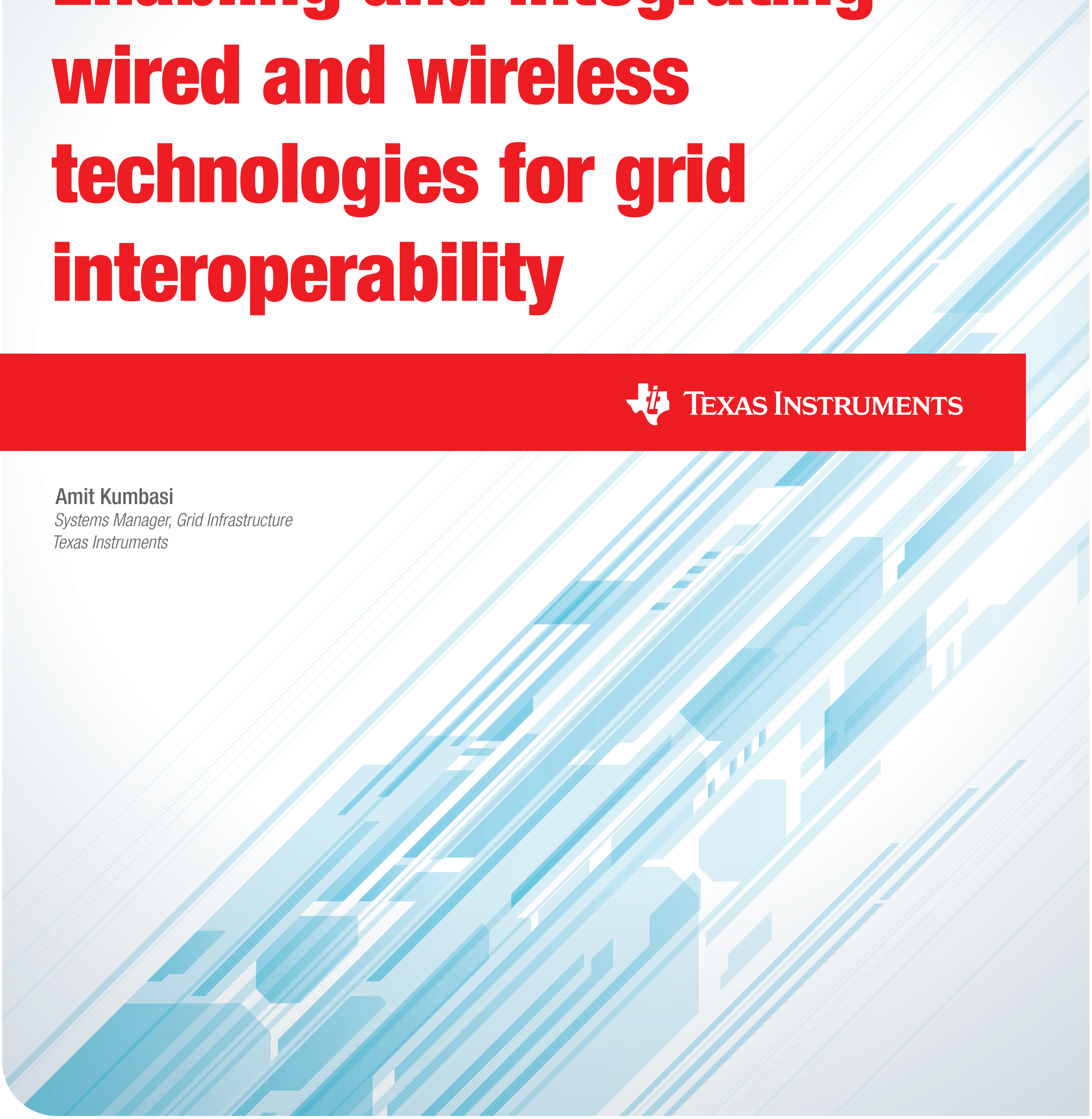
Enabling and integrating wired and wireless technologies for grid interoperability

Texas Instruments

Amit Kumbasi
Systems Manager, Grid Infrastructure
Texas Instruments



If you want to know how old a tree is, you count its rings. If you want to know how old a power distribution grid is, find its oldest component – it's likely been there for decades.

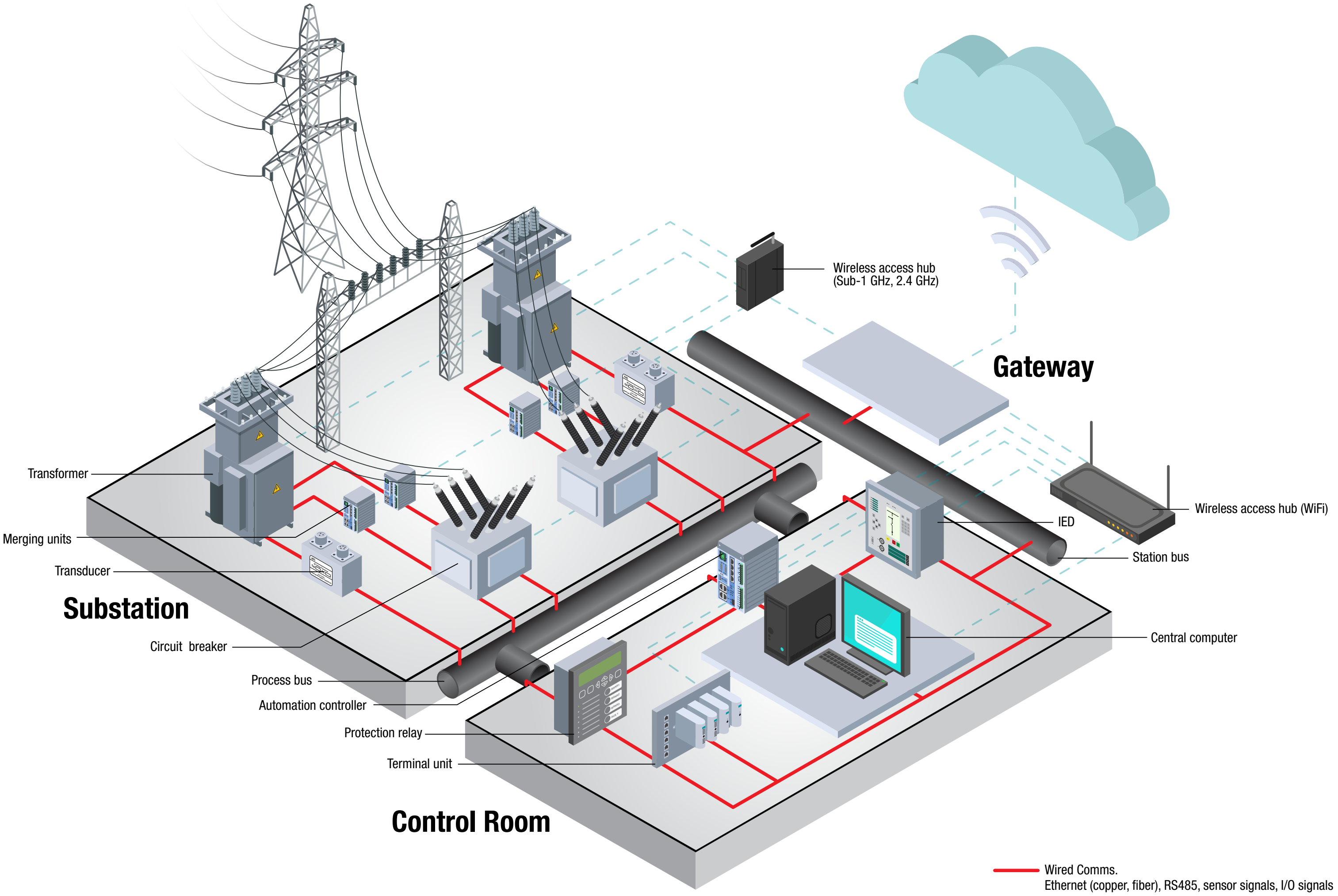
In fact, many grid components go back farther than 50 years. Some of these original mission-critical pieces still work, and thanks to an "if it ain't broke, don't fix it" philosophy, a key challenge in grid evolution is how to achieve interoperability. How do you incorporate tried-and-true technologies such as the RS-232 and RS-485 wired connectivity while continuing the transition to the latest Ethernet technologies and adopting wireless technologies such as Sub-1 GHz, ***Bluetooth***® and Wi-Fi®? As the Internet of Things (IoT) in grid evolves, most of the underlying wired and wireless technologies necessary for creating a smart grid are well established. What's needed is a framework to bring them all together.

What's between where we are and where we want to go

Most power distribution networks today are a patchwork of technologies that support monitoring, protection and control of primary grid assets. They are cumulative entities in that they've expanded over time to meet demand. Even if you use modern connectivity technologies, they must still interact with stalwart legacy equipment.

Today's large grids are stitched together with regionally established best practices. The International Electrotechnical Commission (IEC) 61850 is an international standard that attempts to standardize the communication protocols for intelligent electronic devices at an electrical substation level. As towns and cities started expanding, the grid infrastructure with transmission lines, distribution lines and substations proliferated to connect power generating stations to consumers. The equipment in a substation required a safe and reliable method of communicating with each other so that there was an exchange of information for protection and control across the substation. Running hard wires using RS-232 and RS-485 was the best practice for decades until the 1990s when wired Ethernet, with its much greater bandwidth, gained more prominence. While wireless connectivity was limited to fault monitoring equipment in the transmission and distribution space, the transition to low-power radio frequency (RF) for asset monitoring in power distribution is only just starting to evolve.

Both the grid assets and the monitoring equipment are built to the last for 20-30 years. The older cabling still provides a reliable connection when equipment needs to talk to each other. While wireless technologies can be less expensive to integrate, it doesn't make financial sense to replace an entire network infrastructure that is a few decades old when it can still do the job. On top of that, security is always a concern with any wireless technology. Eventually, it might get swapped out for newer wireless technologies, but those successors are still going to have to communicate with equipment that's decades older.



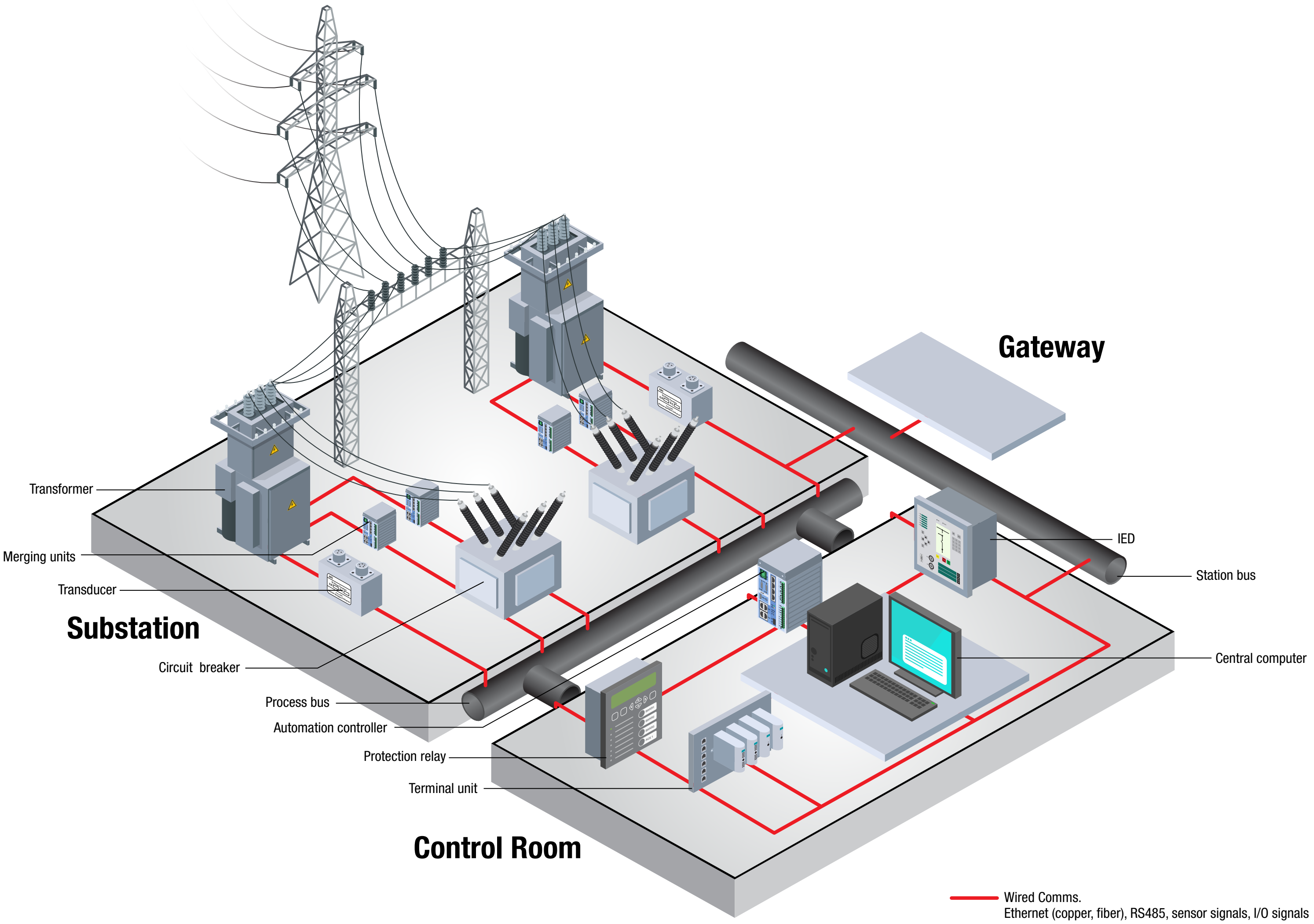
Like U.S. highways, the underlying wired grid network may add a new exit ramp or two, but never be completely replaced. Even if you were to add a new solar-based power plant or a micro grid with the latest wireless connectivity technology, it's still going to need to interoperate with an infrastructure that's decades old. Older equipment will only be replaced when it stops performing its primary function.

Because of its European roots, IEC 61850 is more prevalent in European countries and regions where European manufacturers sell their equipment. Although this global connectivity standard has influenced substation design for the collection, management and movement of data, there remain incompatibilities because each addition to the grid is designed based on the maturity of the available technology. A station built in an older part of the town might hardly be gathering any data from assets compared to a newer substation servicing a newer part of the town because there is no mandated standard. As these power distribution networks merge, it becomes a challenge for interoperability because the underlying infrastructure that connects equipment for each substation was designed differently.

Along the same lines, while the oldest substation may have only a few breakers, transformers, regulators and other protection and monitoring equipment, bringing in new lines means adding new circuit breakers and modern protection relays that should talk to those put in place 20 years ago. Everything works, but it all works differently, which creates both the impetus and challenge for the realization of the smart grid and IoT-connected grids that can scale data up and down as needed.

An advanced power distribution grid is an electricity network that can self-heal during faults. It allows scalability and interoperability between grid assets and the end equipment. This grid supplies electricity – ideally from as many renewable sources as possible – using a two-way flow of power. A smart grid aims to overcome the challenges of traditional grids and enables monitoring, analysis, control and communication to help improve efficiency, reduce energy consumption and cost, and maximize transparency and reliability. The IoT-enabled power distribution grid takes this further by providing data on demand with the integration of more ultra-low-power sensors and wireless communication nodes.

Wired technology isn't going anywhere, however, and makes up the backbone of modern smart grids, although there is an argument to be made for retiring legacy technology regardless of how functional and reliable it is.



The whys and why-nots of wired technologies

The hard-wired grid infrastructure goes back a long way – as far back as 50 years. It's still in place because it works and because of the prohibitive capital costs of replacing it with something better.

Many older communications protocols, circuits and wiring remain part of today's grids. The stalwart universal asynchronous receiver transmitter (UART) uses only two wires to transmit data between devices. The RS-232 protocol dates back 60 years and at one point was the only available standard for data exchange. RS-232 defined voltage levels that made it immune to noise disturbances and reduced errors in data exchange. It can be found in most computers today.

RS-485, meanwhile, is one of the most versatile communication standards, widely used in data-acquisition and control applications in which multiple nodes communicate with each other. Unlike the single-ended signaling of RS-232, RS-485's differential signaling isn't sensitive to the signal-line noise that limits both the maximum distance and communication speed.

The PROFIBUS standard for field-bus communication can trace its inception back to the mid-1980s and is still one of the most popular technologies for instrumentation connectivity.

Despite their age, these standards and protocols still offer benefits in part because of their simplicity and reliability, as well as security: unlike modern Ethernet or Wi-Fi networks, they can't be as easily hacked. They're also very cost-effective if you're exchanging only limited amounts of data. This can be a significant constraint, however, when you're looking to add flexibility and functionality to the electrical grid. The slower speed and lower bandwidth limitations opened the door to Ethernet, which supports data rates of megabytes per second.

The Ethernet MAC and PHY interface today supports dual ports, allowing redundancy, higher bandwidths and speeds, and the ability to add more functionality.

TI's reference designs for wired technologies

Texas Instruments (TI) has developed reference designs that outline not only how a specific communication technology can be woven into grid equipment in a manner that makes the most of its inherent benefits, but also how it talks to other technologies, including legacy protocols.

TI has several reference designs to address the RS-232 and RS-485 protocols. The isolated RS-232 with integrated signal and power reference design provides a compact solution capable of generating isolated DC power while supporting isolated RS-232 communication. It consists of a reinforced digital isolator with integrated power combined with an RS-232 communication transceiver.

For RS-485, TI has two reference designs. The communication module reference design for functional isolated RS-485, CAN and I2C data transmission is a low-cost, high-efficiency communication module solution designed for industrial systems, including energy storage banks that need isolated communication and isolated power. This design is suitable for electrical grids in part because it's tested for robust data transmission in harsh environments. The isolated RS-485 with integrated signal and power reference design, meanwhile, is a compact solution capable of generating isolated DC power while supporting isolated RS-485 communication. It consists of a reinforced digital isolator with integrated power combined with a RS-485 communication transceiver.

For Ethernet, TI's high-availability seamless redundancy (HRS) Ethernet for substation automation reference design provides a framework for high-reliability, low-latency network communications for substation automation equipment in smart-grid transmission and distribution networks. It supports the HSR specification in the IEC 62439 standard and the Precision Time Protocol specification in the Institute of Electrical and Electronics Engineers (IEEE) 1588 standard and can support the popular IEC 61850 standard without requiring additional components.

The EMI/EMC compliant 10/100 Mbps Ethernet brick with fiber or twisted pair interface reference design eliminates the need to have multiple boards for a copper or fiber interface. It uses a small-form-factor low-power 10-/100-Mbps Ethernet transceiver to reduce board size, enabling a cost-optimized and scalable solution with reduced power consumption in high-temperature environments.

Of course, Ethernet does still have some of the same drawbacks of older cabling. You still need to put fiber into the ground just as you would copper. It's not an insignificant capital expense to dig trenches and lay fiber in the ground, which is why a modern smart grid includes wireless technologies such as Sub-1 GHz, Bluetooth® and Wi-Fi as an extension to wired technologies.

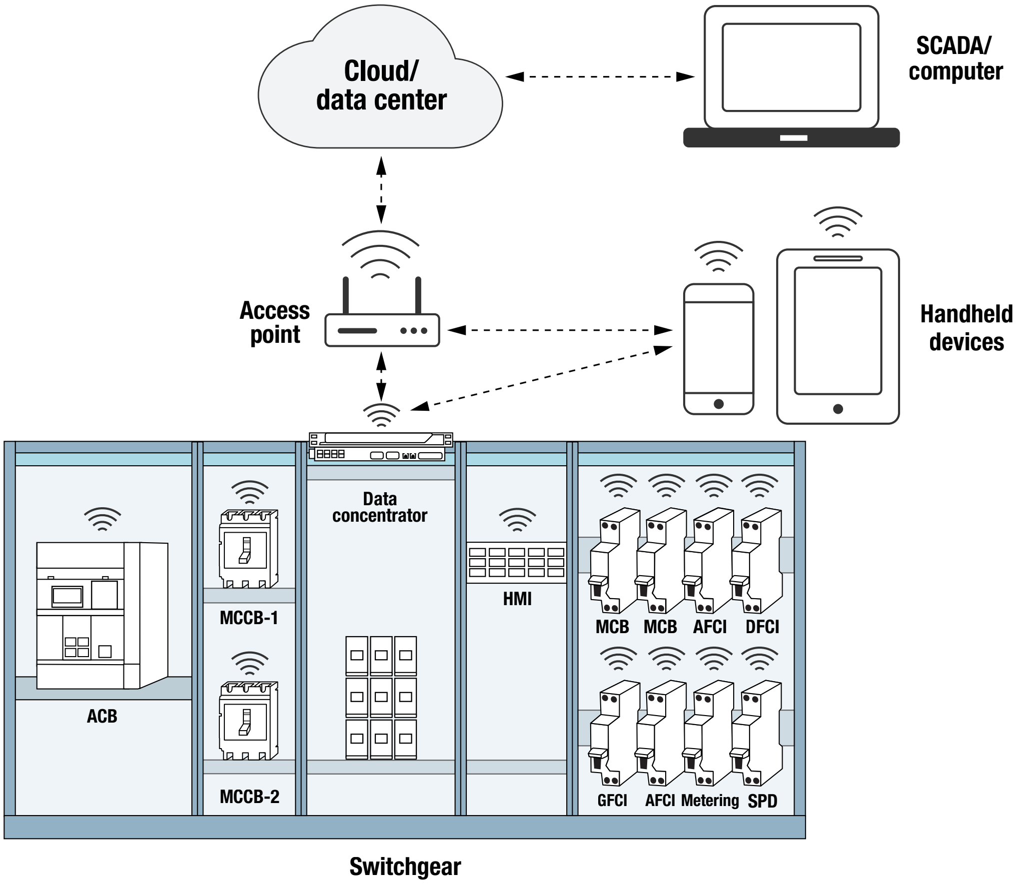


Figure 3. *Wireless connectivity to protect and monitor devices in a switchgear.*

The whys and hows of wireless

Wireless communication adds redundancy and resiliency to networks. Depending on the application, wireless technologies such as Bluetooth low energy, Sub-1 GHz and Wi-Fi are available with trade-offs between distance, bandwidth, power consumption and noise sensitivity.

TI's grid IoT reference design for connecting circuit breakers and sensors to other equipment using Wi-Fi demonstrates setting up a Wi-Fi network, schemes for data transfer and minimizing power consumption. It integrates Wi-Fi capability to enhance connectivity in grid equipment for asset monitoring using TI's SimpleLink™ CC3220 wireless MCU with an integrated network processor and applications processor.

If the equipment is further apart, with data transmission distances over a few miles or kilometers or in the absence of Wi-Fi network, then wireless spectrums (Sub-1 GHz and 2.4-GHz) are available. TI's grid IoT reference design: connecting fault indicators, data collector, mini-RTU using Sub-1 GHz RF offers Sub-1 GHz wireless communication in a star network between multiple sensor nodes and a collector. This design is optimized for low power consumption and short ranges using an overhead fault passage indicator and data collector.

These wireless technologies add a great deal of flexibility with grid interoperability. They can help gather large amounts of data on demand, almost instantaneously, from the grid to better monitor the health of an asset. Wi-Fi, Bluetooth low energy and Sub-1 GHz allow for faster deployment of primary and secondary equipment in a smart grid without the time and expense that comes with modern wired technologies such as Ethernet.

Plotting the path to a wireless smart grid

Digital and IoT-enabled grids are inevitable, but they're going to have to accommodate legacy protocols and modern wired technologies.

Modern technologies will enable better resource management of older assets. Wireless sensors will be able to monitor a decades-old transformer and make proactive changes to manage its health. Data analytics are driving the need to share more information about the state of the grid more quickly.

Because legacy equipment has such a long shelf life, it's going to be a long transition, and the nature of grids means that the age of various functional components will span decades. TI's reference designs and products provide a framework to manage the transition. Over time, more wireless technology will displace the hard-wired, legacy infrastructure. But today's smart grids are still a mix of old and new technologies that need unification and harmonization.

Important Notice: The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

The platform bar and SimpleLink are trademarks of Texas Instruments. All other trademarks are the property of their respective owners.

© 2019 Texas Instruments Incorporated

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale (www.ti.com/legal/termsofsale.html) or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2019, Texas Instruments Incorporated