ELECTRICI
NEW REA

THE BALANCING ACT

It's one of the simplest things a child learns when she gets tall enough: Flip the switch, and the lights turn on. As she grows, she might begin to fathom the scope of what it takes to get the power to that switch. Even adults may not always understand the complex network of technology, infrastructure and markets required to deliver reliable electricity in the U.S.

The power delivery system is the largest, most complex machine ever built, and the world has transformed around it. Now, an ongoing revolution in renewable energy sources and distributed generation options is changing the structure of that machine. Grid modernization is how power delivery is adapting to new realities.

"The distribution systems that serve the 'last mile' of the grid are increasingly the subject of major investments that are addressing the dramatic changes we see underway in the power industry," says Ken Gerling, a vice president at Burns & McDonnell.

Those investments take a multitude of forms.

"We're seeing initiatives to change nearly every aspect of the way we plan, construct and operate the distribution system," says Lucas McIntosh, who is leading grid modernization consulting and distribution planning at Burns & McDonnell. But the essential mission for the power delivery infrastructure is unchanged. It must get electricity from the points of generation to the points of consumption, instantaneously balancing supply and demand.

"The system or the business model was not designed with the idea that consumers and businesses might one day have an alternative to getting their power from centralized infrastructure," he says.

The power distribution grid is undergoing tremendous change as it evolves from a centralized, unidirectional system pushing power out from large-scale generation facilities to a multidirectional system that can distribute generation from an ever-increasing variety of resources and locations, says Matt Olson, projects director in the Networks, Integration & Automation department at Burns & McDonnell.

The grid's transformation is in part a response to the rising utilization of distributed generation (DG) in all its forms, from wind farms to residential and commercial solar panels and more. DG is just one leg in the distributed energy resources (DER) triad along with storage and demand response. A host of other factors also are driving the changes, including grid automation, customer expectations, communications, electrification of transportation, microgrid implementations, breakthroughs in large-scale energy storage, and sweeping technological improvements.

Curious about the breakthroughs in energy storage? Read about them on page 16.

When anyone can be a producer of energy — say, by installing photovoltaic (PV) panels on a roof, or by keeping electric vehicles plugged into the grid when not in use — how does that affect the power delivery system and associated business models?

"Power has always been delivered to homes and businesses," Olson says. "Now you can put it back into the grid, but the existing grid wasn't designed for that.

"Even without the expected growth of interconnected DERs, the grid requires continuous improvements to maintain the reliability and resiliency of the system and services that customers increasingly depend upon every day."

A two-way grid becomes essential to provide the flexibility needed to balance loads in a more dynamic marketplace.

"The wires don't care which way the electron goes; most of the other electrical apparatus does not either," Olson says. "But the system was designed — for example, sizing the wires — assuming all power originated from the substation, and the protection and controls were configured for power just to flow one way."

MULTIPLE CHOICE

As utilities ponder their options to improve the grid, potential projects run the gamut from simple to complex, and from physical to digital.

There are many layers to grid modernization, and every initiative can span multiple layers or focus on one. Those layers include software upgrades and intelligent devices on the grid that can perform a lot of functions they couldn't in the past, like automated switches.

"Then there are the actual poles and wires that must be paired and matched to facilitate new, intelligent equipment, communications and coordination, and also the back-office software that monitors and controls all of it," McIntosh says. "And that's without mentioning the people, whose roles will change drastically in the next decade."

Asset replacement might not sound high-tech, but it can represent thoughtful investment in the physical backbone of the grid.

"Aging infrastructure is an ongoing issue," says Meghan Calabro, distribution modernization director at Burns & McDonnell. "The expected life cycle for most distribution equipment is about 40 years, but the rate at which utilities are currently replacing assets on the grid in the U.S. represents closer to a 100-year cycle.

WE STILL HAVE A LONG WAY TO GO TO IMPROVE THE INFRASTRUCTURE AND SUPPORTING OPERATIONAL TECHNOLOGIES ACROSS THE GRID.

MEGHAN CALABRO

“Infrastructure and asset renewal are going to be hugely important over the next several decades.”

Other tactics that can play an important role in enhancing the grid include strategic undergrounding of lines and intelligent management of vegetation and other threats.

“Vegetation management is typically considered an operations and maintenance cost, but it shouldn’t be downplayed — data-driven vegetation management can have huge impacts on reliability,” Calabro says.

This is not to discount the role of technology in modernizing the grid. From automation in substations to advanced technology on distribution lines, improvements in the grid can result in better outage management analytics, tighter isolation of faults, and speedier transferring of loads to minimize the number of customers impacted by an event.

Combining advanced metering infrastructure (AMI) with vastly upgraded communications networks and data management will give the grid the agility to adapt to the challenges of intermittent and distributed generation and storage.

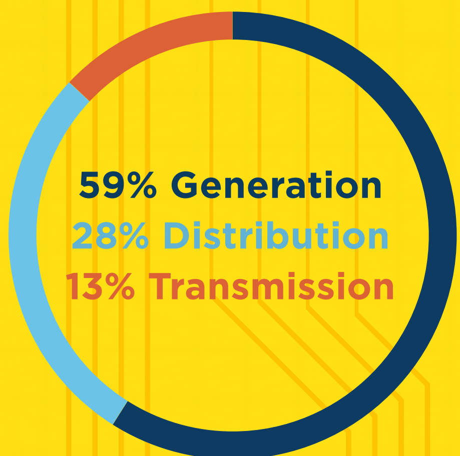
“Grid modernization is the mixture of three attributes: strong, smart and sustainable,” McIntosh says. “You can’t have a smart grid without an underlying strong infrastructure. Otherwise the optionality that the smarts can choose from is limited. Our mantra: Build it strong first, then add the smarts. Then we’ll have the opportunity to optimize and achieve a sustainable grid configuration that can weather the uncertain future of DERs and load growth.”

It is essential to recognize the need for a diverse approach.

“Over the past 15 years, utilities have invested a lot of money in technology, such as AMI, which helps a lot, but we still have a long way to go to improve the infrastructure and supporting operational technologies across the grid to truly optimize the way we manage power flow to customers, especially in a distributed energy future,” Calabro says. »

THE PRICE OF POWER

Distribution costs represented more than a quarter of the average price of electricity in the U.S. in 2017.



Electricity prices vary by customer because of varying costs to deliver power. Serving bulk consumers generally is more efficient and less expensive. Average price per kilowatt-hour of electricity in the U.S. in 2017:

Overall: **10.54** cents

Residential: **12.90** cents

Commercial: **10.68** cents

Transportation: **9.67** cents

Industrial: **6.91** cents

Source: U.S. Energy Information Administration

UNEVEN DISTRIBUTION

In a world with increasingly distributed generation, often based on intermittent renewable sources, the challenge of maintaining the balance between supply and demand is complex.

"If everyone in an area starts producing solar power at one time, or if everybody starts consuming energy to charge electric vehicles at one time, you overload the system," Olson says.

And that forces utilities to try to influence customer behavior.

"If too much solar power comes on in the middle of the afternoon, for example, we can only push so much power through the wire before the voltage gets too high," he says. "To prevent that, we have to curtail that production, add load or rebuild circuits to handle the increase. But that means sometimes we can't take full advantage of the generation capability.

"Conversely, if there's too much load, the voltage will get too low, and the utility has to curtail load to balance the system. We have to build a system that's more flexible and has ways to accommodate those scenarios."

Modernizing the distribution grid is part of the solution. Another aspect depends on developing appropriate incentives to adapt behavior and maintain balance.

"In the old paradigm, demand is what it is, and we built infrastructure to meet that demand," Olson says. "That resulted in infrastructure we don't use very often. Now we have to figure out ways when we have intermittent renewable supply sources to change the net demand to match."

The cost to provide electricity fluctuates from day to day, minute to minute, dependent also on localized conditions. In some locations, the real-time cost of energy has even gone negative at times. This is caused when there is an excess supply of uncontrolled energy — such as solar power during midday or wind power at night — and the utility needs to raise demand to balance the system, while due to operating costs or tax

NETWORKING THE PROBLEMS

As smart technologies from the transmission system get pushed out to the distribution grid, it is important to be aware of the different data and communications requirements and functionalities involved.

"In order to keep the distribution system properly balanced, we need real-time communications and control of the distribution grid," says Meghan Calabro, distribution modernization director at Burns & McDonnell. "We need lots of intelligent electronic devices spread out along the distribution grid, and those devices need to communicate with each other and with centralized systems. In order to communicate, we need sensors, and those sensors need a communications infrastructure."

Those capabilities have differing needs. Consider video security in substations.

"It's very bandwidth-intensive, but signal latency is not a big deal. It doesn't have to have 100 percent uptime," she says. "When it comes to capacitor banks performing voltage regulation, the communications don't have to be super-fast or incredibly reliable. If we're doing protective relaying with reclosers, however, communications must be very fast and very reliable, but we don't require as much bandwidth."

Different applications will have varying capabilities and divergent communications requirements. Grid improvement projects have to take these sometimes conflicting, sometimes complementary needs into design consideration.

"We're also helping push the technology vendors in the direction the industry needs them to go," Calabro says. "Many of our vendors work across industries, so they aren't just selling to utilities. They don't always understand why a particular utility wants them to add a feature or make an enhancement to a product.

"Because Burns & McDonnell works with so many clients across the electric utility space, we can explain to the vendors that we've seen multiple utilities having the same challenge, and we can encourage the vendor to add the necessary feature to its road map."

> **IF EVERYONE IN AN AREA STARTS PRODUCING SOLAR POWER AT ONE TIME, OR IF EVERYBODY STARTS CONSUMING ENERGY TO CHARGE ELECTRIC VEHICLES AT ONE TIME, YOU OVERLOAD THE SYSTEM.**
>
> *MATT OLSON*

incentives, the producers have a marginal operating cost that is negative.

"Traditionally, utilities offered special rates for electric vehicles to charge overnight. There was excess capacity available in the system, so that was the most cost-effective time," Olson says. "Now, with rooftop solar, maybe that time shifts to daylight hours to take excess energy from solar PV off the grid."

California utilities plan to implement time-of-use tariffs in 2019 that offer lower rates during daylight hours and higher prices in the evening. This is a reversal of traditional models.

As the marginal cost of producing energy approaches zero — as new technologies are developed that move toward converting sunlight into electricity in real time, for example — the fixed costs of building and maintaining the infrastructure still must be addressed.

"We have to separate the cost of the energy from the cost of the infrastructure," Olson says.

Historically, utilities have been vertically integrated. They have produced, transmitted and distributed power all the way to the customers, collecting revenue to support all those expenses: fuel for generation, fixed costs for the generation and wires, and variable costs for maintaining the wires, McIntosh says. »

"When people start producing their own electricity or paying very little because the bill is based on reduced consumption from the grid, we end up with a subsidization effect," McIntosh says.

The fixed costs of the infrastructure must be met, but when rates are based on usage, individuals and businesses that can afford to become power producers will contribute less — or even get compensated for selling electricity back to the grid. That leaves the rest of the connected customers to foot more of the bill for keeping the infrastructure in place, and they could see rates go up as a result.

"Many agree that today's business model is not conducive for the future grid we envision, with distributed generation playing a larger role," McIntosh says. "As customers increasingly adopt behind-the-meter distributed generation, they often reduce or eliminate financial contributions for maintaining the grid, and those who remain using it without distributed generation pay more. This creates an even greater incentive for them to adopt distributed generation or leave the grid. It's a cascading effect that can have significant social impacts."

BEYOND TECHNOLOGY

Solutions might include a shift from basing rates on usage to selling access to the improved grid and connectivity, similar in part to how cellular providers have shifted from selling minutes to selling access.

"Mobile providers realized it's a fixed cost to construct and maintain the infrastructure, and as long as you're not overloading it, there are safeguards — and that's why they can throttle access when needed — but ultimately they don't care how much you use as long as you pay a fair fee to support the fixed cost to support the infrastructure," McIntosh says.

The regulatory landscape similarly has a role to play, as investment incentives often are regional or tied to the regulatory environment in a geographic area. Public regulators aim to look after all grid users and try to make sure the system is fair, but pressures from the evolving market will pose new challenges that vary from place to place.

The political and operational issues are going to be much harder than the technical, Olson says: "There are plenty of technical issues, but we excel in solving those problems." The regulatory and operational challenges can be resolved as well with time and effort.

Given the rapid development of emerging technologies and expanding services from electric utilities, the power industry faces challenges similar to those of the industry's early days. Back in the late 1800s, leaders made choices about how to make and move electricity. As applications grew, the industry had to adapt both its delivery methods and how it charged customers for service.

Today, nearly everyone is already connected to the grid; the World Bank estimates over 87 percent of the world had access to electricity in 2016. The issues to resolve today, like then, include building and maintaining a safe, reliable, affordable and sustainable electric grid amid evolving and expanding market requirements. Like the electric grid itself, regulators, utilities and their partners are all pursuing balance.

More and better data is transforming the approach to optimize the distribution grid. Learn more about holistic, data-driven planning methods at burnsmcd.com/DataDist.

DISTRIBUTION MODERNIZATION COMPONENTS

- Infrastructure and asset renewal
- Strategic undergrounding
- Vegetation management
- Substation automation
- Distribution automation
- Grid management systems
- Advanced metering infrastructure (AMI)
- Distributed generation
- Distributed energy storage