Investing in Transmission to Enhance the Reliability and Resilience of the Energy Grid
OUR SOCIETY DEPENDS ON A RELIABLE AND RESILIENT ENERGY GRID

With every advancement in technology, Americans are using electricity in more ways than ever. Our ever-increasing dependence on electricity underscores how vital the energy grid is to our nation’s security and prosperity and reinforces the important role that electric companies play in improving the lives of all Americans.

A reliable, resilient transmission system is the backbone of the energy grid and enables electric companies to deliver energy where it is needed, when it is needed. A robust transmission system is also critical to helping our industry continue its clean energy transformation.

The Edison Electric Institute’s (EEI’s) member companies—our nation’s investor-owned electric companies—are making significant investments in the energy grid to make it smarter, cleaner, stronger, more dynamic, and more secure. These investments help to increase the integration of renewable resources, power the rapid increase in electric vehicles, and facilitate the adoption of a broad array of smart technologies to better serve our customers and our communities.

In addition, investments in smarter energy infrastructure help to protect the energy grid from extreme weather and cyber-attacks; help predict and prevent outages; and help electric companies respond to and restore power faster when outages do occur.

While improving security and reliability is a priority for our members, providing an energy grid that is also resilient against all hazards is an increasing focus for our sector. At EEI, we think of resilience as the ability to operate normally under abnormal conditions, particularly in an increasingly dynamic threat environment. In short, it’s about preparedness and planning for the purpose of successfully responding to, and recovering from, adverse events.

As the examples herein demonstrate, EEI’s member companies are committed to delivering safe, reliable, affordable, and clean energy—and are making investments in the energy grid to meet their customers’ needs today and tomorrow.

THE VALUE OF ELECTRIC TRANSMISSION

Our nation’s energy grid has been called the most complex machine in the world. It efficiently delivers reliable and safe energy, so customers always get the power they need. The energy grid’s value often goes unrecognized because of its amazing reliability and its contribution to resilience. According to the North American Electric Reliability Corporation (NERC), even with all the changes underway in the electricity sector, the bulk power system remains highly reliable and resilient, showing improved reliable performance year over year.

NERC’s annual “State of Reliability Report” for 2018 was released on June 19, 2019, and notes that, “in 2018, firm load was served on the bulk power system 99.92 percent of the time.” While extreme weather events continue to be the leading causes of power outages, we are seeing quicker restoration times and reduced outage severity. According to NERC, “transmission recovery during the extreme weather events in 2018 was evidenced by quick restoration times and statistically significant reductions in transmission outage severity.”

Transmission serves such a vital role because it provides optionality, like a robust system of highways for transportation. A robust transmission system alleviates costly congestion, provides access to lower-cost generation, increases the reliability and resilience of electricity delivery, and can flexibly adapt to changes in public policy and sources of electricity generation. This optionality value comes at a surprisingly small cost: on average about 13 percent of the total amount of a customer’s total electricity bill.

Electric companies plan electric transmission projects in ways that consider the long-term needs of all customers and other stakeholders, as well as the need to maintain reliability of the energy grid. Customers’ needs and expectations are changing, increasing the importance of reliable and resilient power supplies, as well as the need for additional investment in our nation’s electric transmission system.

INVESTING IN TRANSMISSION RESILIENCE: CASE STUDIES

Over the past decade, there have been several record-breaking storms, from Superstorm Sandy to Hurricanes Dorian, Florence, Harvey, Irma, Maria, Michael, and so many others. Every storm and natural event creates new challenges, while reinforcing the need to invest in the energy grid to mitigate extraordinary impacts.

Since Superstorm Sandy in 2012, our industry has invested more than $340 billion to enhance the energy grid. As the following examples illustrate, these hardening and resilience measures include reinforcing transmission infrastructure, raising vulnerable substations above flood levels, using fiber optics for real-time transmission performance monitoring, and employing wildfire prevention mechanisms on transmission lines.

HARDENING TOWERS, POLES, AND WIRES

EEI’s member companies are dedicated to hardening transmission lines, poles, and towers as the first line of defense in preventing disruptions to power delivery. As shown in Figure 1, PPL Electric (PPL) in Pennsylvania has taken several steps to rebuild its transmission lines to enhance reliability and resilience.

Similarly, Florida Power & Light (FPL) has spent $2 billion in transmission and distribution hardening since the devastating hurricane seasons of 2004 and 2005, which hit Florida with seven named storms within an 18-month period. By 2016, FPL had incorporated steel or concrete construction materials in 85 percent of its transmission poles. The value of these hardening investments was evident when Hurricane Matthew made landfall as a Category 4 Hurricane along the Florida Panhandle in October 2016: no transmission poles were lost.

American Transmission Company (ATC), with service territory in the Midwest, has taken similar proactive measures based on design codes and application criticality and has adopted weather-resilient transmission line design practices and specifications to operate in extreme temperature ranges of +/- 40°C.

Measures include: disconnect switches for ice loading requirements above the National Electric Safety Code (NESC) minimum; easement acquisition standards to

Figure 1: PPL Electric Pole and Wire Hardening

EXAMPLE 1: REBUILDING TRANSMISSION LINES PROVIDES SAFE, RELIABLE ELECTRICITY.

1. Dual overhead ground wires added to reduce outages caused by lightning. Fiber is also added to provide a communication path across our grid, enhancing cyber security and improving reliability.
2. New insulator design and materials provide greater reliability.
3. Higher capacity, steel reinforced conductor allows for more efficient power flow and reduces electrical losses.
4. Greater clearances between electrical lines reduces outages caused by animals and provides safer working conditions for our crews.
5. Sturdier steel poles improve resiliency during storms, provide longer life expectancy and lower maintenance costs.
6. Improved grounding provides better lightning performance and safer operation of our system.

Source: PPL Electric
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Prevent tree outages; dual insulator strings at all 345-kilovolt (kV) dead-end assemblies for redundancy; resilient foundation designs; NESC Grade B construction for all new transmission construction; a 100-year return period for wind and ice events; steel and laminated wood structures that can withstand a single broken wire; and critical lines designed with more stringent standards than service conditions warrant, including double circuit 138-kV structures designed to withstand a once every 1,400-year wind speed.

Structures supporting twisted pair conductors are designed using larger phase spacing to mitigate outages from extreme wire oscillations due to high wind (“galloping”). In addition, fiber splice boxes are designed to withstand debris damage from tornadoes that rate up to 3 on the Enhanced Fujita (EF) scale in order to make ATC’s communication systems inherently more resilient.

Eversource, which serves customers in Connecticut, Massachusetts, and New Hampshire, has adopted standardized steel as its preferred material for transmission structures. Steel transmission structures either can have a weathering steel or galvanized steel finish. Eversource’s use of “light-duty” or “wood pole equivalent” steel has increased dramatically in recent years due to its resilience, longevity, and cost-efficient qualities. Eversource’s anticipated life expectancy for steel poles is approximately 50 percent longer than for wood poles. Steel poles have replaced the use of natural wood in most Eversource transmission applications, and Eversource is implementing several programs that ultimately will replace more than 6,000 wood transmission structures with more resilient and longer-lasting steel structures.

Of course, weather is not the only natural phenomenon to impact grid reliability and resilience. In PacifiCorp’s Pacific Northwest service territory, a transmission line experienced an abnormally high number of trips and recloses (around 20 per year). It was assumed that the insulators were insufficient and, thus, were replaced. Despite these replacements, trips and recloses kept occurring even on insulators not even a year old. After further inspection, PacifiCorp determined that the interruptions were caused by avian interference, requiring the unique installation of bird guards to cut down the number of trips and recloses. Since completing the project, PacifiCorp has not yet experienced another occurrence of trip and reclose on a modified insulator string.

Substation Hardening

Flooding can create tremendous issues for transmission substations. In the southern United States, for example, Duke Energy (Duke) experienced two storm events in recent years (Hurricanes Matthew and Florence) that exceeded the 500-year flood zone. Following Hurricane Matthew, Duke identified 10 substations vulnerable to flooding and began investing in both temporary and permanent hardening measures to protect those assets from future flood risk.

At these most vulnerable substations, Duke is installing sheet pile flood walls that are constructed of composite material to resist decay and rust and that are placed 18 feet below ground and up to nine feet above ground to prevent flood waters from reaching critical components of the substations (see Figure 2).

In addition, before Hurricane Dorian struck in 2019, Duke installed “fast barriers” consisting of metal frames draped with fabric barriers (see Figure 3) around seven vulnerable substations, which successfully protected those assets from water intrusion.

Similarly, Eversource built a new substation to serve the growing demand in the South Boston Waterfront. Due to its susceptibility to floodwaters, Eversource elevated the substation 15 feet above ground with mini-piles driven 80 feet into existing bedrock.

Figure 2: Duke Energy Sheet Pile Wall

Source: Duke Energy
Public Service Electric and Gas (PSE&G) had a Transmission Hardening Program in its New Jersey service territory that included raising all substation facilities to one foot above Federal Emergency Management Agency-designated flood levels and rebuilding the infrastructure to be less susceptible to damage from extreme wind and flying debris.

Because of these raised, relocated, or protected transmission switching and substations, PSE&G estimates that if another storm as powerful as Superstorm Sandy were to hit again, about 490,000 fewer PSE&G customers would lose power and those who did lose power would be restored more quickly. Further, additional circuits were made available to 260 critical facilities (police, fire, hospitals, etc.) to improve resilience, benefitting an additional 412,500 customers.

PSE&G’s investments proved valuable during Tropical Storm Alberto in May 2018, when floodwaters covered the site of the Ewing Township substation in New Jersey but did not reach the newly raised equipment (see Figure 4). As a result, none of the customers served by this substation lost power due to flooded equipment.

In addition to raising substations, FPL installed flood monitors on 223 substations located in areas susceptible to flooding. These monitors alerted operators to rising water levels at the St. Augustine substation in Florida during Hurricane Matthew, which allowed the company to take the substation offline proactively. While more than 6,000 customers lost power, the proactive shutting of the substation preserved the equipment and limited the duration of the outage.

While flooding is a major concern for coastal regions, electric companies in the Midwest must protect substations from other severe weather, such as extreme cold and...
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Figure 5: PPL Electric Upgraded Substation Design

Source: PPL Electric

tornadoes. ATC has begun utilizing a 1-in-100-year frost depth for substation ground grid design, which is even more stringent than the design standards required by the Institute of Electrical and Electronics Engineers (IEEE). Additionally, all new ATC substation control houses now are designed to withstand a direct hit from an EF3 tornado with back-up control houses available on short notice.

Recognizing not only the threats from severe weather but also physical threats, PPL has changed the design of the perimeter fencing on its substations from legacy chain-link metal fences to engineered perimeter barriers surrounding the entire substation complex. These barriers have varied in design over the past six years to meet evolving efficiency and resilience criteria (see Figure 5).

FIRE PREVENTION AND DETECTION

Severe weather impacts differ among the various regions within the United States. In California, years of drought conditions, coupled with high winds and other factors, have resulted in an increased number and severity of wildfires that can devastate natural habitats and communities.

Roughly one-quarter of Southern California Edison’s (SCE’s) service area, covering about 9 million acres, is considered high fire risk area. SCE has initiated its Wildfire Mitigation Plan in order to monitor weather and equipment that could exacerbate wildfire spread and upgrade transmission infrastructure to mitigate wildfire impacts should they occur.

Pursuant to this plan, SCE is enhancing and accelerating inspections of all overhead power lines in high fire risk areas. In order to check for needed repairs and preventive maintenance to reduce risks of ignition, SCE completed aerial scanning of 6,932 miles of transmission lines using infrared and corona detection technology. SCE recently exceeded its 2019 goal of replacing at least 96 miles of overhead power lines with insulated wire, with a combined total of 371 miles in 2018 and 2019. This also includes installing current limiting fuses that interrupt current more quickly to boost reliability by segmenting circuits to isolate problems.

SCE is hardening the design of its transmission by increasing the use of fire-resistant poles, composite crossarms, and covered conductors in select high fire risk areas to reduce the risk of ignitions from sources such as windborne debris that is blown into overhead lines (see Figure 6).

Wildfire mitigation extends beyond inspection and maintenance of equipment. As part of SCE’s Wildfire Mitigation Plan, the company has installed 147 high-definition cameras that enable fire agencies to observe potential fire activity in high fire risk areas 24 hours a day. By 2020, SCE plans to install up to 160 cameras, providing approximately 90-percent coverage in high fire risk areas. In addition, SCE is installing hundreds of weather stations in high fire risk areas with multiple sensors to provide real-time weather data that is publicly accessible. The goal is to install up to 850 stations across SCE’s service area by the end of 2020. These weather stations provide data to SCE’s state-of-the-art weather modeling computer software that can forecast high fire risk conditions within a two-mile area.

As part of PacifiCorp’s wildfire mitigation plan, all transmission lines in a wildfire risk area were reviewed to determine if wildfire risk mitigation was needed. Scheduled projects consist of replacing old wood poles with
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either new fire-resistant mesh-wrapped wood poles or steel poles, conductor replacements due to age, and the installation of transmission spacer cable. The ability to install new access roads and increase line rights-of-way also are being evaluated to determine if they would be beneficial in areas that present a wildfire risk.

SMART GRID AND ENHANCED COMMUNICATIONS

Our industry’s investments in smart meters have been the foundation for today’s customer-facing, modern energy grid. As technology advances, the possibilities continue to grow. Today, electric companies are finding new ways to create value from the data and capabilities that smart meters enable. In 2009, about 13 million smart meters were installed. As of year-end 2019, that number is projected to be more than 98 million, meaning more than 70 percent of U.S. households have a smart meter. Smart meters and other smart grid features are beneficial in both mitigation of power outages due to faults on the energy delivery system and recovery from outages because they allow the system to detect outages and remotely reroute electricity to undamaged (unfaulted) circuits and feeders. Through automated distribution technologies that utilize reclosers and automated feeder switches, faults can be isolated for greater system reliability and fewer affected customers.

Included as part of its $2 billion in infrastructure investments, FPL installed 2,830 automated feeder switches. When Hurricane Matthew hit in 2016, these hardened feeders experienced 31 percent fewer outages, resulting in the prevention of 118,000 customer outages and restoration of 98.7 percent of FPL’s impacted customers at the end of two days.

As part of its Wildfire Mitigation Plan, SCE is using artificial intelligence, machine learning, and predictive modeling with real-time data to identify both early warning signs of potential equipment failure as well as downed wires, which enables a quicker restoration response. Deployment of equipment and device configurations, such as fast-acting fuses that deactivate immediately upon detection of a power surge to protect critical components, can react more quickly to reduce fire risk. Infrared scanning technology helps identify equipment before it fails.

SCE continues to develop technology that leverages smart meter data and advanced analytics to quickly detect downed, energized wires, thus mitigating fire risks. As referenced, SCE is enhancing its meteorological monitoring and forecasting capabilities with added high-resolution weather data maps and new modeling capability to identify extreme conditions. These tools assist SCE in strengthening its current prevention strategies and increase coordination with first responders and affected communities when a wildfire starts.

Several EEI member companies have focused on hardening critical communications in order to defend against disruptions. Deployment of company-owned, private, closed networks allows greater control and security of vital communications and greatly reduces vulnerabilities around unwanted cyber intrusions.

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American Electric Power’s (AEP’s) fiber network build-out is dedicated to transmission data needs associated with real-time monitoring and control along with the use of advanced analytical tools. This build-out supports AEP’s efforts to enhance situational awareness associated with both the transmission system and its assets.

ATC has pursued similar efforts by supporting control house communications with a redundant fiber optics system, which is backed up by satellite links that offer adequate performance during an emergency in critical locations throughout its Midwest service territory.

Similarly, ITC Holdings Corp. (ITC) embarked on a five-to-seven-year project beginning in 2018 to construct a private fiber network across its Midwest and Great Plains service territory that will provide secure communication and connectivity between ITC’s primary and secondary control centers. The private network consists of a fiber optic network that will have dual paths for redundancy, have speeds up to 100 gigabits per second, and will be deployed using the most advanced routing technologies available. This project supports supervisory control and data acquisition (SCADA) traffic, telecommunications, video surveillance, relay network, digital fault recorders, substation monitoring, and ITC-dedicated voice services and enterprise access.

Other benefits of a smart grid network include the flexibility of managing advanced digital energy grid equipment, increased bandwidth for better physical security tools, and improved voice communications to each facility located on the network.

In addition to private networks, EEI’s member companies are hardening critical control facilities, including control centers, substation control houses, and critical communication hubs. For example:

AEP’s critical hardening approach includes shielding, filtering, and grounding to protect the sensitive electronics needed to support the ongoing operation and control of the energy grid.

ATC designs fiber splice boxes to withstand debris damage from EF3 tornadoes in order to make its communication systems inherently more resilient. In some densely populated urban locations, ATC has installed new EF3 resistant pump houses for its underground cable systems. Emergency generators with onsite fuel are installed at key locations to maintain critical communication paths during a local outage or a black sky event.

Recognizing the importance of coordination, ATC also has installed a National Incident Management System - Incident Command System that allows all levels of government, non-governmental organizations, and the private sector to work together to prevent, protect against, mitigate, respond to, and recover from incidents. In this vein, ATC has formed public/private partnerships with Wisconsin Emergency Management, the Wisconsin National Guard, and other first responders and governmental entities in its service territory.

**THE BENEFITS OF RELIABILITY AND RESILIENCE INVESTMENTS**

The investments EEI member companies are making in transmission infrastructure benefit customers by reducing the severity and duration of power outages. For example, in 2016, Hurricane Matthew, the first Category 5 storm in the Atlantic since 2007, left approximately 3.2 million customers without power; 95 percent of those customers had their power restored in less than a week.

Irma, a Category 4 hurricane when it made landfall in Florida in 2017, was the most intense storm to hit the United States since Hurricane Katrina. Irma impacted more than 7.8 million customers in Alabama, Florida, Georgia, North Carolina, and South Carolina. At its peak on September 11, 2017, 64 percent of electricity customers in Florida experienced outages. As with Hurricane Matthew, 95 percent of customers experiencing outages were restored within one week. As a point of comparison, the U.S. Energy Information Administration (EIA) noted that, in 2005, Hurricane Wilma caused 36 percent of Florida customers to lose power; although Irma caused a higher percentage of outages, the rate of electric service restoration was more rapid. EIA reports:

Five days after Irma’s landfall, the share of customers without power had fallen from a peak of 64 percent down to 18 percent (a recovery rate of about 9 percent of customers per day). Power outages during Wilma declined from 36 percent of customers to 16 percent by the fifth day after landfall (an average recovery rate of about 4 percent of customers per day).6

EIA credits the improved restoration to the investments made by electric companies in Florida and other affected states, including upgraded electric infrastructure and smart grid technologies.\(^7\)

Because of PPL’s investments, some of which are noted in this paper, its transmission system is now more resilient. For example, a major winter storm that impacted the East Coast in 2018 had comparable wind gusts to Superstorm Sandy. During Sandy, PPL had 13 transmission line outages and more than 57 million minutes lost; by comparison, there were only two transmission line outages and 200,000 minutes lost during the 2018 winter storm.

**SUPPORTING INVESTMENTS IN SMARTER ENERGY INFRASTRUCTURE**

As demonstrated, transmission system investments are critical to maintaining an overall resilient energy grid, since even the most robust distribution system cannot function if the transmission system fails.

Building and maintaining electric transmission are multi-billion dollar and ongoing long-term commitments, which is why EEI continues to advocate for policies that recognize the value of—and support investments in—the energy grid and to work to secure regulatory approval for grid modernization investments that enhance reliability and resilience.

Since EEI member companies are regulated by state and federal commissions, thoughtful public policies that encourage, enable, and support resilient infrastructure investments are essential to promote reliability and to keep energy affordable for all customers.

EEI’s member companies are committed to investing in the energy grid and to continuing to make it smarter, cleaner, stronger, more dynamic, and more secure. We look forward to working with policymakers to help achieve these goals.

\(^7\) Id.
The **Edison Electric Institute** (EEI) is the association that represents all U.S. investor-owned electric companies. Our members provide electricity for about 220 million Americans, and operate in all 50 states and the District of Columbia. As a whole, the electric power industry supports more than 7 million jobs in communities across the United States. In addition to our U.S. members, EEI has more than 65 international electric companies with operations in more than 90 countries, as International Members, and hundreds of industry suppliers and related organizations as Associate Members.

Organized in 1933, EEI provides public policy leadership, strategic business intelligence, and essential conferences and forums.

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