Thought Leadership
White Paper

Harnessing AI for wildfire prevention

The power to detect and prevent high impedance faults

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Executive summary

Fortifying the electric grid against the threat of wildfires has never been more important. Each year, wildfires cause an increasing amount of catastrophic damage. Over the last twenty-plus years, the reach of wildfires in the U.S. has more than doubled since the 1990s. On average, there are 61,410 wildfires and 7.2 million acres burned annually.[1]

Digital solutions for wildfire mitigation

According to recent research from the University of California, Berkley, powerline faults can be reduced upward of 72% through sensors already deployed at many utilities. Some of these powerline faults, such as high impedance (HiZ) faults, are incredibly difficult to detect. Today, there is no reliable technology to predict, detect and reduce the potential for these powerline faults. But that is about to change.

Our experts at Eaton Research Labs (ERL) and our Center for Intelligent Power (CIP) are leading our R&D efforts, working hand-in-hand with utilities, government agencies and industry organizations to develop site-ready solutions for fire hardening. Included in that work are projects to develop novel solutions using artificial intelligence (AI) to reliably predict and reduce the potential for powerline faults to initiate wildfires.

1 Source: Congressional Research Service, June 2023 update

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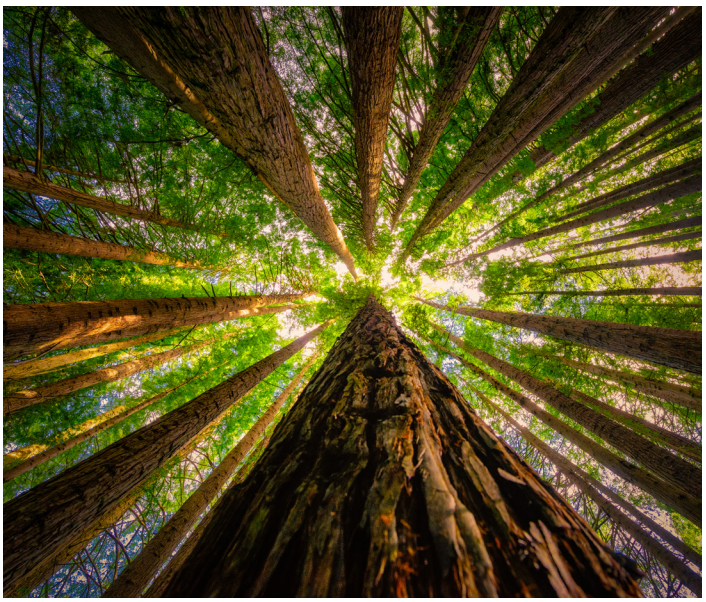

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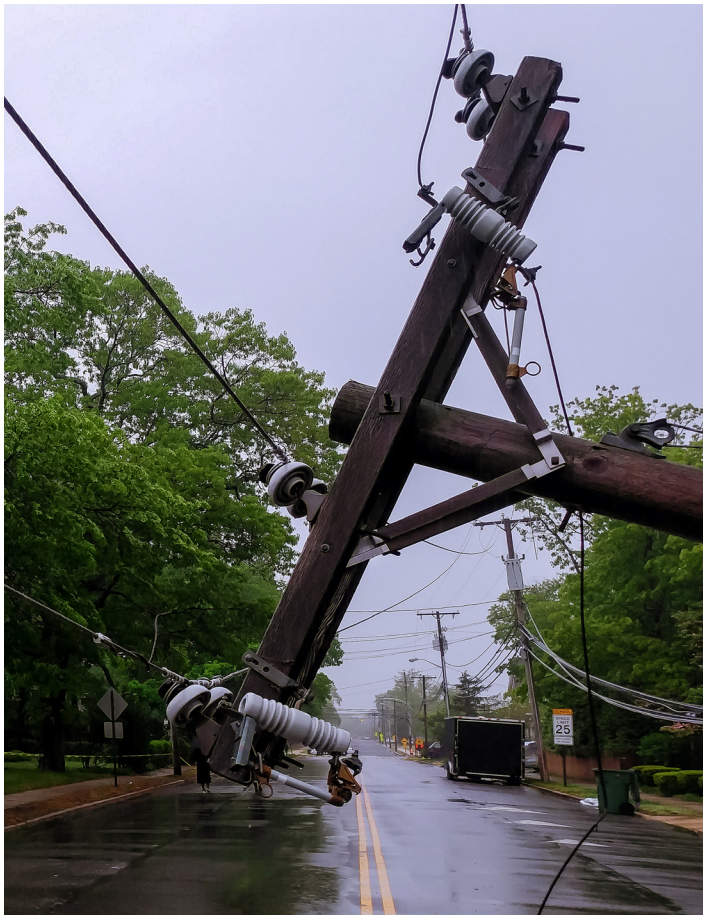


Detecting and addressing HiZ faults

HiZ faults are caused by trees falling on powerlines, downed powerlines and arcing through a failed insulator on a power pole.

When undetected, these public safety hazards may lead to arcing, which can start a wildfire when fuel such as dry vegetation is present.

These faults have small fault current traits that are similar in amplitude to normal loads on the grid. Unlike typical electric (short-circuit) faults that are generally cleared by protective devices (like circuit breakers or reclosers) within a few power cycles due to their high-fault current magnitude, HiZ faults are hard to detect.

The characteristics of HiZs depend on a variety of conditions, adding further complexity. Specific tree variety, utility grounding practice, soil conditions, humidity, power system topology, system voltage, weather conditions and load type impact the fault current and characteristics. For example, vegetation-related faults are known to develop gradually over time as the material slowly chars until it suddenly ignites.

As a result, utilities have resorted to public safety power shutoffs (PSPS), or temporary outages, to reduce risk. By turning the power off in an area during high-risk conditions, utilities can eliminate the risk of a HiZ during the outage, but that is not a long-term solution and it comes with its own challenges.

Military bases and critical infrastructure are also at risk of outages and wildfires. Military installations are dependent on uniquely long stretches of electrical lines in remote places. So, the Department of Defense (DoD) also needs to be able to quickly identify and de-energize powerlines at risk of spreading wildfires.

Government, industry and research labs team up to look for a solution

It is vitally important to identify powerline-initiated faults faster and far more accurately to prevent wildfires.

To develop a solution, Eaton, the U.S. Army Corps of Engineers and the National Renewable Energy Laboratory (NREL) teamed up to develop and demonstrate a data-driven HiZ detection technology that uses state-of-the-art sensing technology and advanced machine learning algorithms.

The team conducted hundreds of experiments and performed simulations to develop an understanding of the electrical signature of HiZ faults.

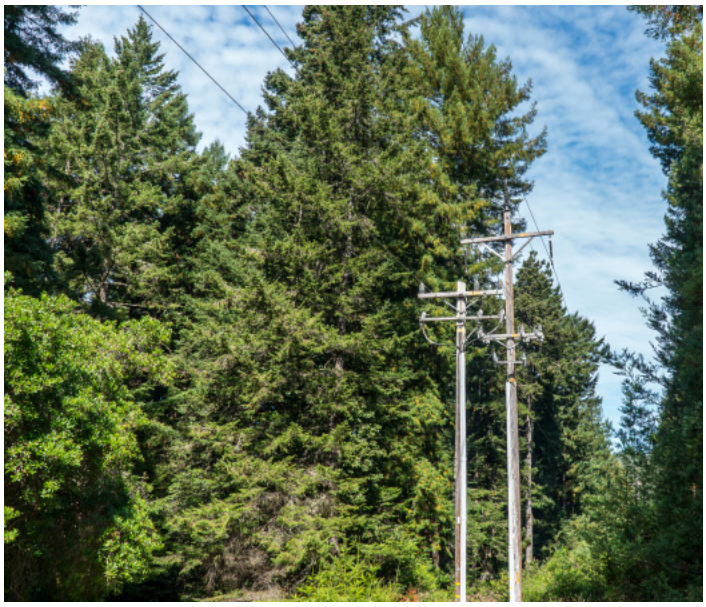
Extensive tests were performed at Eaton's Thomas A. Edison test center in Franksville, Wisconsin, which is one of only five short-circuit distribution class test labs in North America. The Eaton lab has high-power and high-voltage labs equipped with 8.3 kilovolt (kV) and 25 kV power feeders, along with a 500 megavolt-amperes (MVA) motor generator set. It is an accredited lab for electrical testing with special capabilities in high-fault current and load testing.

The team's tests included downed-conductor events on different surfaces (like concrete, dry grass, asphalt, sand and more) with varying levels of moisture and other external conditions. Additionally, the team tested tree contact to live powerlines for various tree species found in North America; these tests were vital to analyze unique fault characteristics that are specific to tree variety.

At Eaton, we used this data to develop a novel, AI-based comprehensive solution to detect and de-energize powerlines during these events using common edge devices on the grid, such as recloser controls. After testing and validating its HiZ solution on grid edge devices at the Eaton lab with high levels of accuracy, we are in the next stage of validating this technology.

Next, Eaton collaborated with multiple electric utilities in North America to further understand the unique opportunities and real-world nuances of wide-scale deployment of this wildfire mitigation strategy. We are getting feedback on our approach to ensure the development of a reliable solution. In these utility pilots, Eaton's solution is commissioned on utility distribution systems that are serving loads to customers using Eaton's Cooper Power™ series NOVA™ recloser and Form 7 control.

These pilots are providing opportunities for further validation of Eaton's solution and a deeper understanding of the corner cases (like false positives), helping further refine Eaton's technology. Once the utility pilots are completed, Eaton will proceed to commercialize the solution, aiming to solve a longtime challenge faced by electric utilities and help significantly reduce the risk of wildfires.



AI-based Eaton technology delivers on accuracy for HiZ detection

The AI-based technology currently being tested in the field is composed of three primary novel elements: integrated sensing, machine learning and edge-based implementation.

In lab-emulated tests, our novel analytics are detecting HiZ faults with greater than 90% accuracy at the Eaton high-power lab in Franksville, Wisconsin. Eaton is working closely with select utilities to deploy the technology on the grid and get more data, which will improve the reliability of our approach.

When it comes to integrated sensing, Eaton's apparatus and intelligent electronic devices support the integration of high-fidelity electrical measurements with current and voltage sensors. These sensors are embedded in the apparatus during manufacturing or integrated as a third-party product during field installation.

The fault detection algorithm is built on the latest advancements in machine learning technology that have recently solved long-standing challenges in AI and cognitive systems. The success of these approaches relies on a rich set of data to develop, train and validate the machine learning models. Therefore, Eaton and its project partners created a comprehensive library of the signature HiZ patterns by leveraging Eaton's laboratories and test facilities, NREL's grid simulation capabilities and field data from multiple utilities.

Because many powerlines are in remote locations with limited connectivity, the fault detection technology is being implemented within a field or edge device during the utility pilots without depending on communication.

Novel methods for reducing the complexity and optimizing the machine learning–based detection algorithm to run on low-cost, processing and memory constrained hardware have been created.

We believe this technology holds immense promise and versatility for utility and military applications, as it can be integrated into grid-edge monitoring and control devices with access to high-fidelity data. Currently, most utilities rely on traditional threshold-based protection, which lacks the necessary observability and protection capabilities to enable swift action by grid operators. Once this HiZ signature recognition and proactive protection solution is commercialized, it can be implemented across existing edge platforms—such as recloser controls, line sensors and capacitor bank controls—to significantly enhance grid visibility and bolster wildfire prevention efforts.

Industry collaboration is essential for the future of wildfire prevention

At Eaton, we are committed to solving the world's most difficult power management challenges, and fortifying the electric grid against the threat of wildfires is a top priority.

Our utility customers across North America are investing heavily to fortify their distribution systems to reduce the risk of catastrophic wildfires. We are helping the industry accelerate these efforts through our comprehensive approach to wildfire mitigation, which includes significant research and development investments.

In partnership with the U.S. Army Corps of Engineers, NREL and several North American utilities, Eaton is pioneering a new era of wildfire prevention technology. We are harnessing the potential of everything from digitalization and the Internet of Things (IoT) to advanced materials, additive manufacturing, power electronics and AI to meet the evolving power management needs of the world and our customers. Today, that means leveraging our technological advancements to build a safer electric grid and a more resilient future for our customers and communities.

INNOVATION AT EATON

At Eaton, innovation is about developing future-proof technologies that solve global power management challenges. By combining the best expertise, the right strategy mix and collaborative partnerships, we are focused on solving the industry's most difficult challenges.

Our innovation strategy relies on trusted partnerships across academia, national labs, research institutes, non-profits, suppliers, competitors, government agencies and industry specific organizations around the world. These partnerships allow us to give back to our communities through industry education and training, while generating unique opportunities for collaboration.

Together, with our customers and partners, we are breaking the boundaries of what electrical systems can do to advance safe, reliable electrical systems.

To learn more, visit **Eaton.com/wildfiremitigation**

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