WILDFIRE RISK REDUCTION METHODS

Executive Summary

Electric companies' commitment to consistently deliver safe and reliable power regardless of conditions has been challenged in recent years by the growing prevalence of wildfires. Many factors have contributed to increased wildfire impacts in the U.S. and around the world, including the changing climate and increased development in high-fire-threat areas. As the impacts have grown, so has the desire to better understand risks associated with the electric power system infrastructure and its relationship to potential wildfires. Within this context, it is useful to evaluate approaches and technologies that may contribute to a reduction in fire ignition risk potential.

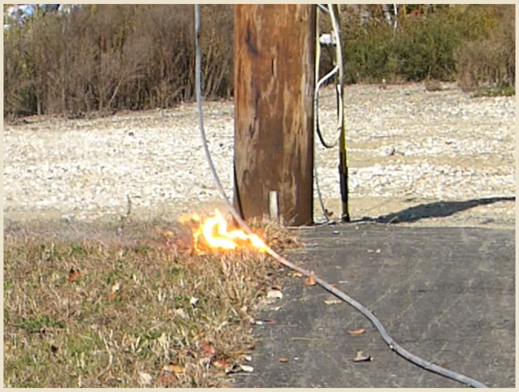
Because the electric power system is designed to allow service providers to tap into power lines at any point to establish electric services for customers, this (normally energized) system has inherent challenges from occasional contacts with trees, animals, and other external objects and forces. The result of these inadvertent contacts is typically an unintended electric current flow (or electrical fault) that can create brief energy bursts in the form of electric arc energy and heat.

The fundamental goal of the power system is to safely deliver electricity while minimizing the potential for external contact and unanticipated electrical arcing—with a specific focus on the highest-fire-threat days. These occur when the chance for the ignition of a wildfire is the highest and most consequential—usually days with dry vegetation, strong winds, hot temperatures, and overall conditions supportive of fast fire spread. An example of an ignition risk created by an electrical arcing fault from a downed power line is shown in Figure 1.

The overarching objective is to lessen ignition risks by reducing the likelihood of faults, with additional focus on limiting the duration and energy associated with any arcing that occurs. Simply put, electrical faults (i.e.,

What is a High-Fire-Threat Day?

A high-fire-threat day is one when the climate, ground fuels and other vegetation are in a state of elevated threat for the ignition and fast spread of a wildfire. This generally is associated with dry, windy days in areas with dead or dying vegetation that is prone to ignition.



disturbances in the electrical current) caused by vegetation, animals, lightning, and equipment failures can each create an unintended arcing fault. As the fault current flows, it can create burning and electrical arcing until the circuit protection detects the condition and opens the circuit. The amount of arc energy increases based on the duration of the fault current, with a longer fault current presenting a greater likelihood of developing enough arc energy to ignite nearby vegetation, poles, or structures on a high-fire-threat day.

Given the power industry objective to lessen the risk of power system ignition incidents on high fire threat days, this document summarizes some of the potential mitigation strategies and technologies available today. Some of the described approaches may create a more resilient electric power system to better manage weather-related damage and simultaneously reduce the likelihood of future wildfire threats.

The strategies and technologies consider:

1. Fault Reduction Methods
   - Table 1 outlines approaches that may reduce equipment faults and decrease corresponding ignition risks.
2. Fault Protection Strategies for Reduced Arc Energy
   - Table 2 outlines a mix of leading practices and emerging technologies that could reduce arc energy and ignition potential.
3. Enhanced Situational Awareness Technologies
   - Table 3 presents emerging tools and approaches designed to help provide a better understanding of ignition risk.

While each of the technologies and approaches discussed herein may play some role in reducing ignition risk or improving power system resilience, none of the technologies is a standalone solution because of the diverse set of geographic and power system configuration challenges facing each electric service provider. Further, some of the technologies are applicable to just power distribution circuits (and not to transmission circuits), while others apply only to certain types of distribution system configurations.

Before determining which set of solutions is most beneficial (toward the given resiliency and ignition risk reduction objective), it is important to understand power system assets and their respective failure and fault probabilities, as well as inspection and maintenance practices that may reduce the probabilities. While it is a challenge to have such a comprehensive understanding of the assets and their behavior, it could provide value by better informing retrofit decisions, as well as helping establish more consistent fault and arcing event reduction expectations.

The following is a high-level overview of the technologies at their present state of development, including proposed research needs for each category. Such research could produce better understanding of the capabilities and potential tradeoffs of each listed technology or approach. The symbols next to the descriptions generally indicate whether the technologies are an emerging or early development opportunity, a partial solution, a capital-intensive solution, or one facing certain implementation challenges. These tables are derived from detailed EPRI research. Note that the list is not all inclusive and any vendor-specific products have been grouped into their generic functional categories to focus on the technology application rather than the brand.

Table 1. Fault Reduction Methods

Approach	Applications and Benefits	Implementation and R&D Considerations
Covered Overhead Conductors and Covered Accessories	Conductors with insulating covers can reduce faults from external sources, such as tree limbs and animals. In conjunction with insulated connectors and other insulated accessories, a system could become less prone to faulting due to external sources. The overhead line's improved fault performance is comparable to that of an underground system.	**Pros**: Mature technology. Reduces risk of faults commonly associated with bare conductors, such as animals, vegetation and flying debris. **Cons**: More susceptible to burndowns and conductor damage from arcing. More mechanical loading, including ice loading, which may require redesign. Significantly changes mechanical performance for tree impacts. Changes thermal system loading limits. Field personnel require retraining. Changes to supply chain and warehousing associated with design standards. Harder to detect live downed conductors. **Research Needs**: Determine optimal materials selection. Connections that limit arcing damage. Mechanical and aging tests on connectors, insulators, and accessories to assess performance and life expectancy. Advanced inspection and assessment techniques to identify high-risk and end-of-life assets. Best practices in deployment with wire-down sensing technology.
Strategic Undergrounding	Underground lines are unlikely to trigger wildfires unless a manhole or an underground access enclosure has a cable splice failure. Strategic undergrounding considers that the first priorities for undergrounding start with the areas of highest risk and/or those with greatest load density.	**Pros**: Virtually eliminates fault causes that can ignite wildfires (aside from splice failure events). **Cons**: Depending on location, can be three to ten times more costly than overhead bare conductor designs. Undergrounding customer service drops or connections is difficult and requires building owner coordination. Mainline connections are more difficult. **Research Needs**: Less expensive undergrounding options, for service drops, diagnostics and sectionalizing.
Enhanced Vegetation Management (EVM)	Targeted vegetation management can reduce limb- and tree-caused faults, reduce physical damage to poles and wires, and minimize ground fuels. Approaches include cyclic vegetation management, hot spots, cylindrical and dimensional targeted trimming, and hazard species management.	**Pros**: Because vegetation is the source of many ignition scenarios, this directly targets a root cause. **Cons**: EVM over a circuit lifecycle can be costly. It is impractical to fully eliminate vegetation-caused faults. Managing vegetation outside of the right-of-way which may impact performance under high wind conditions is difficult. **Research Needs**: Optimizing maintenance strategies by risk, including vegetation at risk, growth rate analytics, and vegetation strategy efficacy.
Fault Count Reduction Construction Practices	Construction practices geared toward fault reduction consider options not specifically identified in the approaches described above. Examples of hardening animal guards, tree wire, spacer cable, and conductor slap limiting line separation and tensioning.	**Pros**: Improved designs that can reduce downed live conductors resulting from impacts of trees and large limbs. **Cons**: Requires pole retrofit. Running more than one circuit on a pole is more difficult due to the complexity of attachment devices. **Research Needs**: Mechanical and aging tests to evaluate long-term performance and fault reduction benefit.
Alternatives to Undergrounding	Some utilities have considered surface-based options, as opposed to traditional overhead or fully underground solutions.	**Pros**: Reduces fault counts by limiting line exposure to trees, winds, and animal contact. **Cons**: No historical performance data. Must be people- and tamper-proof. May not be suitable for all high-fire-risk threat areas. **Research Needs**: Design and construction practice documents, fault count reduction analysis, cost analysis, mechanical performance, and aging testing.

KEY CONSIDERATIONS:

Emerging or Early Opportunity	**Capital-Intensive**	**Implementation Challenges**	**Partial Solution**

Table 2. Fault Protection Strategies for Reduced Arc Energy

Approach	Applications and Benefits	Implementation and R&D Considerations
Reclose Blocking	Preventing the automated reclosing of protective devices after a fault avoids the risk of additional arcing if the protective device would have been programmed to reclose into an uncleared fault.	**Pros**: After the initial fault, the circuit is de-energized, removing further ignition risk. Reclose blocking can be implemented on high-fire-threat days. **Cons**: Customers experience longer outages while the circuit is patrolled. Non-communicating reclosers do not have dynamic programming ability. **Research Needs**: Curated metrics on ignition risk reduction and enabling communications and settings management practices.
Protective Device Coordination	With communicating and microprocessor-controlled protective devices, opportunities exist to fine tune circuit protection.	**Pros**: Faster fault clearing and less associated arc energy. **Cons**: Requires tuning and customization for each circuit. **Research Needs**: Demonstrations and documentation. Additional modeling tools.
Expulsion Fuse Retrofits with Non-Expulsion Fuse Designs	Fuses that are designed to contain arc energy and not emit molten particles onto vegetation when they operate could reduce the likelihood of an ignition incident.	**Pros**: Reduced ignition chances due to less molten particle emission. **Cons**: The replacement technologies need to be proven over time to be reliable and not create peripheral ignition concerns. Coordination of non-expulsion fuses for full feeder deployment is limited. **Research Needs**: Industry consensus on how to test new designs for ignition potential and lifecycle performance. Demonstrations and testing on the broad array of implementations of varying maturity.
Materials Fabrication	Components made of materials that are flame retardant or self-extinguishing and that animals are averse to chewing.	**Pros**: Non-flammable materials reduce ignition opportunities. **Cons**: The replacement materials need to be proven over time. **Research Needs**: Insulation, aging, and flammability testing. Inspection and assessment practices to identify high-risk and end-of-life components.
Resilient Wire (also applicable to Table I)	Stronger wire and connectors (i.e. larger sized and/or more steel cores) are less susceptible to breakage, resulting in fewer live downed conductors and, by extension, fewer ignition opportunities and improved public safety for electric shock-related hazards.	**Pros**: Mature and proven way to reduce downed conductor events. Added layer of safety for human shock prevention. **Cons**: Only reduces the conductor on ground arcing issue, but not the in air-related fault and arc. If not well coordinated with stronger poles and crossarms, more tree-related pole breaks may occur. **Research Needs**: Optimization of overall pole, wire, crossarm, and connections for mechanical coordination.
Resilient Poles (also applicable to Table I)	Resilient pole design includes stronger pole and crossarm materials with special design methods to promote strategic and controllable points of failure with fewer incidents of live downed conductors.	**Pros**: Less pole damage equates to fewer live downed conductors and faster restoration times, as well as reduced likelihood of pole top fires. **Cons**: Implementation costs. **Research Needs**: Mechanical coordination and optimization of overall pole, wire, crossarm, and connection construction. Advanced pole design (e.g. composite poles) have unknown performance and life expectancy. Third-party attachment issues.
Fault Current Limiters	Fault current injection and fault current-limiting technologies are designed to restrict current flows at the point of the fault and reduce the amount of resulting arc energy.	**Pros**: Ignition risk is reduced without the need for insulated cable. **Cons**: Only applicable to certain distribution system configurations and certain specific fault types. **Research Needs**: Demonstrations and analysis to understand application issues and ignition reduction probability for different circuit types. Life-cycle management consideration of a new asset class.

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Table 3. Enhanced Situational Awareness Technologies

Approach	Applications and Benefits	Implementation and R&D Considerations
Imagery	Imagery refers to all technologies capable of capturing a spectral representation of terrain or assets. This includes visible stills and video, and invisible spectrums, such as infrared and ultraviolet. Key applications for wildfire ignition risk include: 1. Asset inspection technologies that can distinguish between normal and anomalous conditions. 2. Vegetation inspection technologies that can identify ignition risk concerns, such as proximity and fuel density. 3. Geographic surveillance technologies that can quickly provide near-real-time situational awareness.	Ongoing asset inspection and vegetation inspection pilot projects are documenting the benefits and potential to expand these efforts with new ideas and additional spectral analysis. The geo-surveillance use case is less mature and provides an opportunity for satellite data curators to collaborate with western U.S. utilities to document one or more ignition detection use cases.
Geospatial Tools	Geospatial representation of relevant data layers is the most emergent approach for ignition risk analytics by far. Key topics for advancing wildfire ignition risk understanding include: 1. Display of fuel density and moisture for risk zone metrics. 2. Fire spread modeling based on wind speed and fuel layers. 3. Geospatial display of historical fault locations.	The use cases for fuel condition and fire spread modeling are in early pilot stages and require detailed documentation on resolution and data specifications. The historical fault location use case is not underway due to a lack of available data. There is a need to confirm the value of this use case for both storm and wildfire mitigation.
Grid Sensors	Grid sensors include a broad category of power monitoring and diagnostic devices. For fault and ignition awareness, the most beneficial or promising use cases include: 1. Detecting live downed conductors. 2. Continuous online monitoring for incipient failure signatures. 3. Sensors that aid in determination of fault location.	All three use cases are in pilot or deployment stages and have shown limited success. None of the technologies is a standalone solution for situational awareness or ignition mitigation. However, each could add a useful layer to the overall awareness objective.
Environmental Sensors	All technologies that provide real-time awareness of climatological, weather, or current fire status are beneficial. The most beneficial use cases today include: 1. Implementing weather sensors with the intent of gleaning more localized awareness of climate and weather. 2. Leveraging right-of-way cameras for real-time video to detect smoke, flames, ignition, or vegetation issues.	The weather sensor use case is highly beneficial from a resolution standpoint and can help identify locations where proactive power shutoff or fault hardening could be necessary. The right-of-way camera use case could benefit from imaging technology that looks at invisible spectrum to alleviate confusion between smoke and clouds.

KEY CONSIDERATIONS:

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