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Wildfire Mitigation Through Advanced Monitoring – State of Texas Demonstration Project

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SUMMARY

The State of Texas has experienced over 4,000 power line caused wildfires in the past four years, including a major fire event in 2011 which resulted in hundreds of millions of dollars in property loss. Particularly in drought prone areas, power line ignition of wildfires poses a serious risk to safety and property for citizens, as well as a major potential liability for utilities.

Over two decades of field research, Texas A&M University has developed multiple advanced power line monitoring technologies which have the potential to detect electrical activity which can lead to wildfire ignition, notifying emergency crews of potential ignition events faster than conventional means. Additionally, advanced monitoring can, in many cases, give utilities notice of recurrent problems which pose an ongoing risk of wildfire ignition, enabling them to take corrective action.

The State of Texas Legislature, recognizing the potential public benefit, has funded a two year study to evaluate the effectiveness of advanced power line monitoring for wildfire risk mitigation. This paper describes the project methodology and goals. Preliminary results are expected to be available for publication next year.

KEYWORDS

Power system analytics; wildfire prevention; smart grid; advanced monitoring; vegetation management; fault anticipation; incipient faults

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Introduction

In September 2011, power lines ignited wildfires in Bastrop County, Texas, near the State Capitol of Austin. The fires eventually burned 139 km^2, caused over USD $300 million in property damage, and resulted in two deaths. [1] The Bastrop event brought a significant amount of public awareness within the state to a widespread problem: the State of Texas has experienced over 4,000 wildfires ignited by power lines from 2010-2014. Particularly in drought prone areas, power line caused wildfires represent a significant risk to both safety and property for the public, as well as a liability risk for utility companies. Since 2007, multiple wildfires ignited by power lines have destroyed billions of dollars in property, and resulted in hundreds of deaths in the United States and abroad. [2-5] Even though power line caused wildfires represent a small fraction of the total number of ignitions, fires ignited by power lines, on average, burn ten times the area of non-power line caused wildfires. [6] Increasing public awareness in areas affected by power line caused fires has encouraged policy makers to search for technical solutions to mitigate wildfire risk, where possible.

How Power Lines Cause Wildfires

Power lines ignite wildfires in a variety of ways: high-energy arcs can directly ignite vegetation or nearby flammable material; apparatus failures can expel burning insulating fluid; or molten particles expelled from faults, particularly burning aluminium, can fall on flammable vegetation. In some cases, more than one of these mechanisms occur simultaneously. [7] Downed conductors, caused either by component failure or physical teardown, are a particularly well known ignition problem within the industry. Downed conductors which do not operate system protection may stay on the ground in an energized state for minutes, or longer, arcing and expelling flammable material in the process, as shown in Figure 1. Studies have shown that as many as 30% of distribution lines which fall on the ground may remain energized. [8] In spite of this, many utilities do not have downed conductor detection technology installed or enabled on their protective relays. In such cases, the utility's first notification of an energized downed conductor is generally a customer call, or crew visit. In fire prone areas, this delay in detecting an energized downed conductor can result in an increased risk for a major wildfire event.

Figure 1: Energized downed conductor ejects molten particles

Figure 2: Transformer damaged by repetitive fault.

Temporary, self-healing faults can also pose significant ignition risk. Figure 2 shows a service transformer which was progressively damaged by vegetation-related arcing. Arcing eventually breached the lid of the transformer, which would have remained in service, had the problem not been detected. In this example, a breached lid can result in moisture ingress, which eventually degrades the insulating fluid in the transformer. In extreme cases, this behaviour can lead to an internal transformer fault, and an explosion, resulting in the expulsion of burning oil from the transformer tank. It should not be overlooked, however, that each individual arc which led to the progressive damage also had the capability to ignite a fire. Other short-lived faults such as bushing and insulator failures, conductor clashes, and vegetation contacts may be self-healing and temporary, in the sense that they may be cleared by system protection, but even in such cases, represent a competent ignition source which can ignite flammable material, should it be present.

Advanced Monitoring and Analytics

For over two decades, advanced waveform analytics have been used to detect a wide variety of incipient failure conditions, enabling utilities to take corrective action before pre-failures become catastrophic outages. [9] This technology has been used by utilities to improve reliability and operational effectiveness, as well as providing a wide variety of benefits through improved situational awareness. [10] Researchers at Texas A&M University have integrated two component technologies, Distribution Fault Anticipation technology, developed over a decade of research in collaboration with the Electric Power Research Institute and over a dozen utilities, and Texas A&M's patented high impedance fault detection technology (HiZ), to create a system capable of providing next-generation situational awareness of the real-time health of distribution circuits.

Many utilities have invested heavily in the installation of "smart-grid" technologies such as AMI and Fault Location, Isolation, and Service Restoration (FLISR) systems. These systems provide value to utilities and their users, but do not, in general, provide utilities with actionable information about components that are in the process of failing, including apparatus pre-failures and abnormal operations which might lead to an ignition event. By contrast, the DFA system provides utilities with a real-time snapshot of the health of feeder components, informing utilities when components begin to fail, and allowing them to take corrective action well in advance of a catastrophic failure. For events which do not have pre-failure mechanisms, for instance a line which experiences vegetation teardown, the DFA system gives utilities immediate notice of a problem, allowing faster response time in potential emergency situations.

The DFA system consists of a fleet of field devices, which monitor line currents and voltages 24x7, detect and analyse waveform anomalies, and communicate actionable information to a centralized master station. The master station aggregates reports from multiple field devices, and disseminates reports and alerts to utility personnel as events happen in real time on a user's circuit. Of particular importance for this paper, the DFA system provides automatic notification of events which are commonly regarded to have the potential to ignite a wildfire. Over a decade of field research with DFA and HiZ technologies has shown that utilities that have DFA installed on their systems can, in many cases, locate and correct pre-failures before they produce a catastrophic outage.

DFA field devices connect to traditional substation current and potential transformers (CTs and PTs), and have no communication with downstream devices, such as hydraulic reclosers or capacitors. Based only on monitored signals, the DFA system generates actionable line-item reports which allow utilities to take corrective action on failing devices and apparatus.

For many utilities, the DFA system provides the only notification that a problem exists on a circuit which, if left alone, will eventually lead to a catastrophic outage.

Wildfire Risk Mitigation Through Circuit Health Monitoring

A decade of field research has demonstrated the ability of DFA technology to detect multiple classes of events which, left uncorrected, have the potential to ignite a wildfire. [11] The use of DFA to mitigate wildfire risk falls into two broad categories: 1) prompt notification of power system events which are known to have the potential to start fires, particularly in areas that are known to be fire prone, and 2) prevention of repetitive ignition sources by identifying, locating, and promptly correcting the underlying problem before it can cause future ignition events.

Many wildfire ignition events are isolated, or have no precursors. Examples include conductor teardown from a hazard tree, or an animal standing across a transformer, which falls and ignites highly flammable vegetation. Because these are isolated events, predicting them through active monitoring of distribution circuits is not possible. In such cases, however, prompt notification to emergency responders is critical. In drought prone areas, particularly on days with high wind, even a few minutes of early warning of a potential fire ignition can be the difference between emergency crews successfully containing a fire, and the fire burning out of control. Some events without precursors, such as a vegetation-caused conductor teardown, would result in an outage, and as a result might be detected by a utility through AMI or FLISR systems. Many events which have the potential to ignite a wildfire, however, result only in a momentary interruption, which few utilities have the capability to detect on a real time basis. In these cases, the DFA system automatically detects the event, and informs the utility of a potential problem on their system, along with identifying information to aid in fault location. In fire prone areas, the information can also be relayed automatically to first responders, who can roll fire trucks to the affected area as quickly as possible.

Whereas some events have no precursors, many power system events capable of igniting a wildfire are the result of long-term failure modes, which produce detectable signatures days, weeks, or months in advance of a final failure. In these situations, swift remediation of the underlying problem can avoid ignition events entirely. It is easy to see how final, catastrophic failures, such as transformer explosions or conductors breaking due to damage caused by repetitive contact with other conductors could cause a fire. Importantly, however, each individual fault or arc which contributes to progressive apparatus damage also represents a competent ignition event, should flammable material be present. The DFA system detects faults and arcs which appear to be related based on electrical characteristics, and automatically informs utilities of a potential recurrent problem on their system. By locating and fixing the underlying problem, utilities avoid not only an eventual catastrophic failure event that may lead to a fire, but also multiple momentary interruptions and arcs, each of which might also ignite a fire.

State of Texas Wildfire Mitigation Project

Recognizing the potential benefits of DFA technology for wildfire risk mitigation, the State of Texas Legislature has funded a large scale demonstration project within the state. Details of the project, as well as a project timeline, are presented below.

Project Overview

The Texas Wildfire Mitigation Project is intended to bring together multiple stakeholders from utilities, emergency responders and state agencies for the purpose of combining sophisticated power line monitoring with advanced wildfire forecast models, to reduce the overall risk of wildfires in the state. The goal of the project is to demonstrate the suitability of these technologies to detect and avoid current and future ignition risks in fire prone areas, thereby reducing the adverse effects of wildfires.

From a technological standpoint, the project combines DFA technology to detect failure and pre-failure events on distribution circuits within the state, and advanced wildfire risk forecast models, developed by the Texas A&M Forest Service, which give an indication of areas within the state that are at elevated risk for substantial wildfire activity during a given day. By overlaying GIS circuit maps with Forest Service wildfire forecasts, the DFA system can determine 1) whether an observed event is a type of an event class that has a high probability of igniting fire and 2) whether that event occurred in an area with elevated wildfire risk. If either of these conditions are true, the DFA system can automatically notify emergency responders and utility personnel of a potential problem, so corrective action can be taken immediately.

Additionally, researchers monitoring DFA data and reports will work closely with utilities to locate and investigate potential repetitive problems which have not yet, but may in the future, result in an ignition event if corrective action is not taken. Even if an event occurs in an area where the wildfire risk on a particular day is not high, taking proactive steps to remediate the problem can eliminate the recurrence of the problem on a day when fire risk is elevated, and consequently reduce the overall risk of fire ignition on a given circuit. By detecting pre-failure signatures well in advance of a final failure, the DFA system allows utilities to act on potential liabilities, before they become actual liabilities.

Project steps and timeline

The project has been approved by the state legislature, and utilities are currently in the process of selecting which circuits on their system will be monitored, as well as performing any make ready work to install devices. The project will instrument nominally 100 feeders across the state at multiple utilities, for a period of nominally two years. DFA monitoring devices are currently scheduled to be delivered and installed in Q4 of this year. Results from the project will be presented in future papers.

Conclusion

The risk of wildfire ignition from power system apparatus is a significant problem for utilities, particularly those utilities in areas where environmental factors such as drought and high wind increase the potential for a major wildfire event. Over the past decade, wildfires ignited by power lines in the United States and Australia have resulted in hundreds of deaths and billions of dollars in property damage. These major wildfire events have increased public awareness of the role power lines play in wildfire ignition, and have encouraged policies aimed at finding technical solutions which mitigate wildfire risk.

In over a decade of field research, the Texas A&M Engineering Experiment Station has developed multiple technologies which have demonstrated the potential to detect apparatus failures and pre-failures on distribution circuits which have the potential to ignite wildfires. These technologies help mitigate wildfire risk by 1) informing utilities in real time about events which may have ignited a fire and 2) informing utilities about long-term pre-failures which, unless corrected, are likely to result in multiple future pre-failures and failures, each of which constitutes a potential ignition event.

Recognizing the potential for DFA and HiZ technology to reduce wildfire risk, the State of Texas Legislature has authorized a large scale demonstration project, which will instrument nominally 100 distribution circuits in the state for a period of two years. DFA devices are scheduled to be delivered and installed in Q4 of 2014, and preliminary results should be available for presentation next year.

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