Wildfire Mitigation – System Hardening with Aerial Covered Conductor

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Introduction

Electric utilities in the US and around the world have been increasingly grappling with wildfires over the last couple of decades. Of particular concern are wildfires caused by power lines. These are especially troublesome in light of public safety concerns as well as from a property loss standpoint. As such, a fundamental goal in designing power lines for operation in wildfire prone regions is to ensure they are hardened against the potential to ignite a fire. The emphasis here is not about wildfire survival, but rather preventing wildfire ignition in the first place. While there are numerous techniques to harden a system for surviving wildfires, such as brush clearing, prediction, monitoring, Smart Grid, pole changeouts, and Public Safety Power Shutoffs (PSPS), they are not to be discussed here as the goal is ignition prevention via system design.

Power Lines and Wildfire Ignition

As little as 5-6 years ago, data showed that power lines caused only about 10% of recorded wildfires but were responsible for around 20% of the damage and loss. These statistics went out the window after 2018 when the Camp Fire in Paradise California destroyed 19,000 structures and resulted in 85 deaths. Wildfires in remote areas can start quickly, and with high winds and dry terrain, can spread just as rapidly.

The leading cause of powerline-related ignition is contact with trees during high wind events. A tree branch spanning two phases of a power line may become ignited and fall to the ground, igniting dry brush or grass on the ground, as demonstrated in the photo below.

Power lines can also be knocked to the ground by high winds, and, unfortunately, depending on the conditions on the ground, there may not be enough current to operate a protective device (fuse/recloser/relay). This phenomenon is referred to as a high impedance fault. If the ground is dry, or there is dry brush available, it is very possible that the available current is sufficient to cause ignition. Even if the fire is noticed and someone calls authorities, it is often too late as the fire has already spread out of control.

High winds can also cause what is known as “Conductor Clashing” or “Conductor Slap.” In this scenario the high winds cause one conductor to blow into another, producing high temperature plasma particles which inevitably fall to the ground and are a potent source of ignition.

Another source of ignition is the use of mylar balloons, technically known as "foil balloons", commonly used at birthdays and celebrations. The balloons are made of nylon, but are covered with a metallic coating, making them conductive. They are often released into the air (accidentally or negligently), and can become lodged between energized powerlines and cause a massive explosion when they fault phase to ground or phase to phase. San Diego Gas & Electric recorded over 700 outages and 28 fires due to mylar balloons from 2015 to 2021, while Southern California Edison had over 1,100 outages caused by balloons in 2021 alone. Pacific Gas & Electric reported 376 outages caused by mylar balloons in 2023.

Legislation in the state of California (Assembly Bill 847) will take effect in 2027 after the IEEE finishes writing standard IEEE 2845 to require mylar balloons to be nonconductive. With noncompliant balloons phased out over 4 years, (2031) and violators facing fines, the proposed changes hold some promise to reduce wildfires from mylar balloons, although not any time soon.

Bare Wire Lines

Wildfire ignition incidents connected with power lines have been exclusively tied to bare wire lines. Bare wire lines are fundamentally susceptible to being a source of ignition. Bare wire lines can make contact with trees or fall to the ground and start a fire. Note that they may also fall to the ground de-energized, come into contact with a stone or hard object, throw a spark and cause ignition. Some novel protective relaying schemes have been devised which anticipate a line falling to the ground and de-energizes the line before it hits the ground. While this is a valuable additional tool, if bare metal hits a rock and throws a spark, ignition will possibly still occur.

Some utilities have chosen to utilize interphase spacers on bare wire lines which pose a risk of conductor clashing. The interphase spacers are installed between the phase conductors, mid-span, and prevent the conductors from touching during high wind events. A more recently introduced strategy is to use Flame Retardant (FR) insulators. It is known that wildfires can reach temperatures of 1,100°F – 2,000°F, while the high density polyethylene (HDPE) used in distribution insulators can ignite at much lower temperatures (~650°F), so a passing (or static) wildfire can still ignite the insulator at the top of the pole. In contrast, with FR insulators, if the insulator is ignited, it will self-extinguish when the flame is removed, and will prevent flaming drips of polyethylene from dropping down onto ignitable material which may be lying on the crossarm or the ground below.

Undergrounding of Powerlines

Undergrounding has become a standard go-to strategy for wildfire mitigation. Popular among residents and regulators alike, underground lines are aesthetic, can't throw a spark onto dry brush, and aren't bothered by vegetation contact. The first and perhaps insurmountable obstacle is that underground lines often cost five to ten times the cost of bare wire construction, and are even more costly to install in locations with legacy infrastructure. So, while undergrounding is a technically viable and extremely attractive option for wildfire mitigation, it also comes with a cost structure that may be difficult to justify systemwide.

Aerial Covered Conductor – Spacer Cable and Tree Wire Systems

Spacer Cable Systems consist of three heavily covered, but unshielded, phase conductors. The conductors are usually AAC when in a spacer configuration, since there is no tension on the phase conductors, but can be ACSR or AAAC when installed in a self-supported or "Tree Wire" configuration.

In Spacer Cable construction, the phase conductors are attached to a messenger by spacers, installed every 30 ft. (10m.) along the messenger. The messenger is a high strength, alumoweld (AW) or alumoweld-aluminum (AWA) conductor which has several functions. The first is that the messenger is the mechanical strength member, holding the phase conductors up. The messenger can also be used as a system neutral, is a lightning shield, and provides a mechanical protection function by protecting the phase conductors from any items (leaves, branches, trees) which can fall onto the bundle from above. The spacers are made of High Density Polyethylene (HDPE), as are the pin or line post insulators used on the angles, to ensure dielectric compatibility with the phase conductors.

Tree Wire systems, on the other hand, look more like bare wire construction. They utilize the same 3-layer covered conductor design, but the phase conductors are usually either ACSR or AAAC (since it is fully self-supported and tensioned). Tree Wire systems are strung in an open wire configuration on crossarms with polyethylene insulators. The photo below left shows a spacer cable system, while the photo on the right shows a tree wire configuration.

There are many differences in operational effectiveness between Spacer Cable and Tree Wire. Our purposes here are to simply review their efficacy as wildfire mitigation tools. There are three attributes of covered conductor systems that directly help mitigate the risk of powerline-related ignitions in wildfire prone areas:

1. If a covered conductor line blows into trees or branches, there is not enough contact current to cause ignition.

2. If a covered conductor line is impacted physically and falls to the ground, there is not enough current to ignite dry brush or other fuel which may be present.

3. If a covered conductor line falls to the ground and hits a rock, the polyethylene covering will not cause a spark to be thrown (unlike a bare wire, where a spark and subsequent ignition of dry brush would be possible.)

There are a few differences between Spacer Cable and Tree Wire Systems with respect to wildfire mitigation effectiveness. If a Tree Wire configuration is used, there is the possibility that an overhead tree could fall onto the line, abrade the conductor covering over time, and result in a failure. That would seem to reduce the attractiveness of Tree Wire in abundantly treed wildfire prone areas, in favor of Spacer Cable.

Additional differences arise in relation to the presence, removal, and trimming of foliage, since spacer cable uses less Right-Of-Way (ROW) than Tree Wire.

Tree Wire

Spacer Cable

The illustrations above show the differences between Tree Wire and Spacer Cable with respect to tree trimming. For the Spacer Cable configuration, even with fully compliant clearances, much more of the tree remains intact. Note that the reduced ROW (and hence additional remaining foliage) does not increase the risk of ignition when the Spacer Cable configuration is utilized. If branches become weighted down with wind or rain and touch the power bundle, they will be supported by the high strength messenger, which is suitably grounded at every pole, or every other pole. This is one fundamental and vital function of the overhead messenger: to protect the phase conductors beneath it from objects which may fall on the powerline from above.

Not all powerline-related wildfires initiate with branches falling from above. A significant part of the wildfire prone landscape consists of dense scrub, tangled bushes, and what is more commonly known as chaparral. These plants don't threaten powerlines from up above but are a potent source of fuel for wildfires from below. Further, there are cases of palm fronds being ignited by fire and travelling with the wind hundreds of yards. Should a palm frond fly between two phases of a bare wire system, this can be a concern. Note that fire is plasma, and conducts electricity, since it is essentially an ionized gas consisting of ions and free electrons. If the ignited palm frond gets between the two bare wire phases, a flashover is likely. This could create a new wildfire location beneath the power line. The use of a covered conductor would prevent this scenario.

As such, when there are no trees, it is viable to use covered conductor in a Tree Wire configuration. Conversely, when trees are present, Spacer Cable is recommended since it will prevent ignition and protect the phase conductors from objects which threaten the power line from above and below.

Covered Conductor and Operational Strategy

Utilities can design power lines with covered conductor to minimize the potential for wildfire ignition. However, can this have ramifications for electric utility operational strategies during wildfire season? Common to wildfire prone areas is the aforementioned Public Safety Power Shutoff(PSPS), whereby the utility can turn off the power if conditions (high winds, dry climes, high fuel load on the ground) suggest a wildfire is a possibility. At least one utility has stated that in addition to its wildfire mitigation benefits, covered conductor has some PSPS benefits as well, raising the threshold for PSPS to higher wind speeds than those used for bare wire systems.

Summary and Conclusions

The threat of wildfires being ignited by power lines is a reality for electric utilities. While bare wire, underground and covered conductor line designs each have mitigating strategies available in the design stage, those strategies also have their own costs and effectiveness (or lack thereof). Covered conductor systems, both Spacer Cable and Tree Wire, are proven and cost-effective design tools for wildfire mitigation.

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