Article for Fire Engineering

Understanding Contributing Factors of Electric Utility Causation of the California and Maui Wildland Fires

By Raul Angulo

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California is the state most prone to wildland fires. But this year, the Great Maui Wildland Fire of Hawaii, which started on August 8, 2023, and destroyed the town of Lahaina, has dominated the national news. As of this writing, there are officially 114 people confirmed dead, with over 1,000 still missing or unaccounted for, making it the deadliest fire in U.S. history in over a century. The Great Peshtigo (WI) Fire occurred on October 8, 1871, killing 800 residents of Peshtigo, and claimed as many as 2,500 lives, making it the deadliest fire on record in North America. The Cloquet (MN) Fire of 1918 killed 453 people and destroyed 38 communities making it the second deadliest wildland fire. The Great Maui Fire of Hawaii currently ranks #3.

The wildland forest fires in Canada also made national news for months due to the large smoke plumes which spread across much of the Northeast United States affecting air quality. Though this article primarily deals with California wildland fires and the problems associated with the electrical utility grid, much of the same equipment and industry-standard practices, are used, shared, or followed in other states with wildland interface regions and national forests. This means these same problems that occur in California, will most likely present themselves elsewhere around the country, including Hawaii.

Wildland Fire Facts

According to the 2021 U.S. Fire Administration (USFA) report on *Firefighter Fatalities in the United States , 18* wildland firefighters were killed in the line of duty (LODD) in 2021, the highest number in the previous eight years. Two of the 2021 LODDs involved aircraft accidents. In 2020, six wildland firefighters were killed in accidents involving aircraft.

According to the National Wildfire Coordinating Group (NWCG) *Report on Wildland Firefighter Fatalities in the U.S.: 2007-2016*, 170 firefighter LODDs occurred – an average of about 17 per year. Between 1990 and 2016, 480 LODDs occurred during wildland firefighting operations. The top five causes for wildland firefighter fatalities are:

1. Heart attacks
2. Vehicle accidents
3. Aircraft Accidents
4. Entrapments
5. Falling trees and rolling rocks

Two of the most famous wildland fires are the 1994 South Canyon Fire which killed 14 firefighters on Storm King Mountain in Glenwood, CO, and the 2013 Yarnell Hills Fire in Arizona, which killed 19 Granite Mountain Hotshot firefighters. Movies and documentaries have been made of these two fires. In both incidents, the tragedies were primarily attributed to an extreme and sudden shift in weather patterns, causing the fire to intensify, cutting off the firefighters' route as they were escaping. The firefighters were unable to outrun the blaze and were killed by the intense heat and flames of the fire.

The largest California wildland fire to date was the 2020 August Complex fire which burned across seven counties, consumed 1,032,648 acres, destroyed 935 structures, and killed one person. The second largest was the Dixie fire which claimed the life of one firefighter. The Dixie fire burned across five counties, destroyed several towns including Greenville, burned 963,309 acres, and destroyed 1,329 structures. The 2018 Camp fire in Butte county destroyed the town of Paradise. Both these towns were literally burned off the map.

The Main Causes of Wildland Fires

According to the civilian population in California, two of the most commonly accepted reasons for the cause of wildland fires without further question are climate change (global warming), and drought. These are theories and opinions that are scientifically hard to prove. The public has been misled to believe that global warming causes combustion that starts fires. In every fire incident, there has to be an ignition source caused by an event that sparks a fire. Whether that be a discarded cigarette, lightning, or some other form of ignition. Using global warming as an excuse just confirms the lack of understanding in the media and why the training of fire investigators is critical in bringing accountability and resolution to the public outcry.

If you’re a firefighter, it is a sure bet that someone will ask you what causes wildland fires. Why are there so many? Why can’t we put them out? Why aren’t there enough aircraft available to drop water and fire retardant onto the fires like the one in Maui? You’ll have the burden of answering. They are:

- Humans – intentional or accidental
- Arson
- Unattended campfires
- Fireworks
- Cigarettes
- Vehicle sparks
- Electrical power lines
- Lightning
- Poor forest management of old-growth trees and ground cover

After a windstorm, many fire investigators and elected officials are quick to blame the cause of wildfires on downed electrical power lines that spark brush fires, or arcing power lines running through trees. But it’s a little more complicated than that.

Electrical Utility Engineering Expert

After reading about all the destruction caused by the Maui fires, I reached out to Mr. Ed Clark, an electrical utility engineering expert who I had met when I inquired about the cause for the 2017 Napa Fires on the Pacific Gas & Electric (PG&E) system. I wanted his opinion and help in understanding whether the Maui fires were caused by the utility company, Hawaiian Electric, or were in fact caused by the environment (i.e. Hurricane Dora).

Mr. Clark has a BS degree in Electrical Engineering from Long Beach State University and spent part of his career working as an Electric Utility Transmission/Substation Division Engineer with Southern California Edison (SCE). With specialized training from SCE and years out in the field, he has extensive experience in electrical utility operations, engineering, design, and construction. He is an expert utility engineer at understanding the cause and effect of electrical disturbances that happen within a utility power grid, with heavy emphasis on relay protection systems required to protect the public. One of his primary responsibilities following a storm, or major interruption event involving multiple location starting points, was to understand and determine how, and if, each separate event was linked to each other. After 10 years with SCE, Mr. Clark started his own high-voltage electrical construction company, ELC Electric. Mr. Clark has been retained and has testified as a forensic utility expert for over two decades on all types of utility related explosions, accidents, and operational errors.

Though there are many common denominators, Clark cautioned against comparing the cause of the Maui wildland fires directly to the causes of the California wildland fires. In the 2017 Napa California fires, he found eight different fires that started simultaneously over 300 miles apart. The common link was the earth and the power lines, and they occurred all within the PG&E electrical grid system. However, there are several different factors to consider in the Maui fire. It may have been started by forces that exceeded the design criteria of the utility poles due to the storm and high winds. Clark stressed the importance of understanding how to find the initial ignition point of the fire. The key to making a determination if the fire was caused by natural forces, or by the Hawaiian utility, is concentrating on the actual cause of ignition (source of ignition), not simply the location of origin. Equally important is whether that initial event caused other simultaneous ignition sources, giving the illusion the fire was quickly spreading because of the winds.

Though there is the possibility that the initial Maui fires were caused by the hurricane winds, there is also the possibility that inherent design flaws in the electrical utility could have contributed to the spreading of fires, in addition to other causative factors, like drought conditions, dry grass, and dry brush. Clark emphasized the importance of training fire investigators on how to approach utility companies. Fire investigators, who are often firefighters themselves, are typically trained to discover one reasonable source of ignition. Multiple sources, and multiple locations, are usually attributed to arson. Fire investigators will start where the fire was reported, then pinpoint what wasn't on fire, to what was on fire, in other words, they will go from the uninvolved to the involved. The point of ignition will usually start as a "V" pattern and spread from there. The origin of the fire gets identified, but often, not its actual cause.

When the origin of the fire is the fault of the utility company, the cause can be from transient voltage spikes that exceed the basic insulation level (BIL), or impulse level of a pole-top distribution transformer, causing it to fail internally. Depending on the geographical location of the transformer, where it is installed in the line, the length of the line, and how it is protected with relays or fuses, it can become a source of ignition that starts a fire. This is something the fire investigator cannot see, and most likely doesn't understand, unless they have an electrical engineering and specific utility background, and have experience with electrical system analysis, along with relay protection expertise. The usual conclusion that satisfies all parties was that the fire was started by electrical wires in the trees, or by downed powerlines causing a spark.

However, the root cause for how so many fires start all at once is well-known within the "utility world," it's not that complicated, but because of the legal liability, it is rarely discussed or revealed to outsiders. Understanding, the electric utility companies have the right to defend themselves due to the magnitude of potential liability, and considering the public's first response is to blame the utility, it is imperative that fire investigators proceed with caution, as they will find the utility may not be willing to share what they know, unless the right questions are asked during discovery, or the investigation process. If the utility is cooperating with fire investigators, answers may be vague with the hopes that complete understanding of how electricity really works is beyond the comprehensive level of the average fire investigator.

The key to understanding the root causes of wildland fires like the ones in Northern California, and in Maui is to ask:

- Were there multiple fires reported by witnesses?
- What is the geographical location of the fires?
- Where was the actual point of ignition?
- What do these fires have in common?
- How can so many fires start at the same time?
- How did all these fires spread so quickly in so many areas?
- Is it really likely that all of these fires can start with trees falling on power lines at the exact same moment at all the different multiple locations?

For The Great Maui Fire:

- Determine if the initial ignition factor caused other events within the utility system's equipment and design.
- Did the Wind forces exceed the design criteria of the poles?
- If not, what caused the poles to fall over?
- Was it a tree blowing over on to the power line? Or was the pole rotten?
- Did a fault on the utility grid cause a transient voltage spike that resulted in pole-top transformers to internally blow, causing other problems, like an energized line burning down before the fuses blew, causing dry grass to ignite?

The starting point for fire investigators is to obtain the following information. [Note: Since fire investigators are dealing with an island with minimal substations, they should request all information, starting at the generating plant, then from all corresponding substations.]

1. Request a copy of all substation logs on the day of the fire.
2. Request a copy of any fault recording information on the electrical utility the day of the fire.
3. Ask what the line name, voltage, and location of the first relay operation was, then from all subsequent relay operations on the day of the fire. (i.e. line names, voltage, locations, substation name, time of event).
4. Ask for circuit breaker counter reports from all affected substations that had relay operations on the day the fire started.
5. For any poles that fell down, ask for the date of installation of the pole.
6. On the poles that fell down, ask for all maintenance records to determine any dates the poles were tested for their integrity.
7. For all distribution pole top transformers that failed, determine the dates transformers were installed, and ask for all maintenance records.
8. Obtain all nameplate data for transformers that list the BIL rating (basic insulation level) of the transformer.
9. Determine if the fires affected transmission, sub transmission, and distribution lines on the island, or just distribution lines.
10. Request and obtain any, and all on-line digital fault recording information available from the utility.
11. Obtain a 911 call log from the fire alarm center, or the phone company to determine the time frames the fires were being reported by witnesses,

The Northern California Fires

Since 2017, Northern California has experienced devastating wildland fires every year. The question is, why so many fires and how do they all start simultaneously? In his effort to determine the root cause of the California fires, Clark, along with a seasoned fire expert, visited eight counties and 13 of the 2017 fire locations: Atlas, Tubbs, Nuns, Cherokee, Sulphur, Redwood, Potter, Patrick, Adobe, Narbonne, Banger, La Porte, and Cascade fires. The fires had a 250 mile radius. The first point of interest was that the Atlas, Tubbs, Nuns, Cherokee, Sulfur, Redwood, Patrick, Adobe, and Banger fires all started on the evening of October 8, 2017. The calls into the 911 centers varied slightly, but were all reported at approximately the same time. Callers reported similar observations: flickering lights in their homes, fallen trees, downed power lines, and transformer failures. This information was also shared over social media and the internet. Although each location was heavily forested, it just doesn't make sense to the average person that falling trees would be the cause of simultaneous ignition points for 13 separate fires, hundreds of miles apart. The only explanation for simultaneous ignition for all these fires are found within the electric utility, in this case PG&E, and the earth. Any utility engineer with a relay protection background who has experience in physically installing settings on relays, and has an understanding of ground current and relay protection will understand the following explanation. To understand Clark's findings, you have to understand what an electrical fault is.

What is an Electrical Fault?

An electrical fault is the interruption and deviation of voltages and currents from a normal state of operation to an abnormal state. A fault occurs when a piece of equipment fails, explodes, or lightning hits a pole. The types of equipment that can typically fail are transformers, circuit breakers, capacitors, line switches, insulators, and generators.

Similar to circuit breakers in your house, when an electrical fault occurs, the affected circuit breaker at the source substation will sense the fault and open up (separating the connection), de-energizing the line feeding the electrical fault. Electricity cannot flow through an open circuit. It is that small duration in time – from the moment a fault occurs, to the time a circuit breaker opens and de-energizes the circuit, where excessively high electrical current flows from location of fault, through the earth, back to the source substation that is delivering the electricity. A fault is similar to slamming shut the nozzle of a fire hose flowing a straight stream of water – the sudden interruption results in a water hammer. When a fault occurs, the electrical current flowing back to the source is called *ground current*. During that short duration of time, excessive high voltage spikes can occur, causing transient voltages that can cause other equipment connected to the power grid to fail simultaneously.

The Earth

What does the earth have to do with the electric utility and a utility fault? The earth plays a very important role with electrical utilities and their electric power lines in that the earth acts like one big wire or conductor to give electricity a path to flow during a system fault or interruption as discussed above. The electrical ground current caused by the fault travels back to the source transformer delivering the electricity. People don't feel this or know when ground current exists because everything around us is grounded. This is the reason a bird can stand on a wire without getting electrocuted. As long as both feet are on the same wire, there is no difference in electrical potential. Earth acts the same way; it's one giant wire for us to stand on. When equipment is not grounded properly during a system fault, arcing (sparks) can occur – creating an extremely hot ignition source that can easily start a fire.

Electric Utility Lines

It is quite common for an electrical utility company on their system grid to experience and record a large number of pole-top distribution transformer failures during a lightning storm or after a major interruption (immediately following a fault). This is caused, or can be caused during normal utility operations from switching, from a utility system fault or disturbance, from capacitor switching, or from a capacitor failure, all which create *transient voltages* i.e. (impulses or electrical spikes – very short in duration,) that sends out an electrical impulse on the electrical system via the power lines. This impulse sometimes exceeds the basic insulation level (BIL) rating on a piece of equipment. The BIL is also referred to as a lightning impulse level. Impulses that exceed the BIL rating of electrical equipment, like transformers, can often fail.

The only way a utility company can have multiple transformers fail in so many different locations simultaneously is to have a major event somewhere on their transmission or sub-transmission grid. Such failures would have sent out a *transient impulse voltage pulse* out over their system, causing the effected transformers to fail at the same time. During a storm, lightning strike, or from a system disturbance, it is a common occurrence in an electrical utility to suffer an event that causes several distribution transformers to fail – often many miles away. Other events that can cause transient voltage spikes on utility lines can come from: system faults on the utility grid, equipment failures, a car hitting a power pole, 69 kilovolts (kv) capacitor switching, and switching in general.

The First Ignition Source Problem Identified

For pole-top distribution transformers out on remote radial-fed lines, once the transformer fails, the wire feeding the faulted transformer can act like a fuse, thus burning open and falling to the ground. Still energized, this can easily start dry brush on fire. This occurs because the wire feeding the transformer is only sized to carry normal-load current for residential occupancies. The wire feeding the transformer is not usually sized to carry high current (fault current) generated when a transformer fails. Therefore, the line melts, opens, falls to the ground onto dry grass and vegetation, and starts the fire.

Ladder fuels spread to the trees and the trees start to burn, giving the appearance that the trees into the power lines caused the fire. By the time most people sense, smell, and see the fire, the trees are already on the ground. So you can understand why there are so many reports of trees falling into power lines. In high winds, trees can fall, but in these 2017 California case studies, are we to believe that falling trees at all the locations spanning eight counties, several hundred miles apart – at exactly the same time, started these fires? It's very difficult to believe; there has to be a more reasonable and scientific explanation.

Solution

According to Clark, one solution for this problem is for the utility company, in this case PG&E, is to install primary wire of large enough gauge to carry fault current strengths so that if a transformer fails, the wire will not melt (or burn open) before the primary fuses on the transformer can blow, thus clearing the fault and preventing the energized line from falling down into dry grass or brush. Changing out the wire to a beefier gauge on power poles out in remote areas would no doubt be an expensive retrofit, but consider the annual dollar loss from wildland fires like the ones that burned in California. It's in the billions. This retrofit would be necessary to mitigate and prevent wildland forest fires from starting due to failed transformers.

For the technical reader: In 1988, Clark personally ran tests on equipment and captured graphically transient impulse spikes that exceeded equipment BIL ratings by more than two times (2x) their rating. The impulse lasted for a quarter of a cycle which is 1/240th of a second, too fast for most recording equipment to capture. He was able to capture this data by closing-in 69 kv capacitors on the sub-transmission system utilizing equipment that recorded data 3-cycles before an operation was triggered. PG&E became fully aware of the effects of transient voltage spikes and how it can affect equipment over a large geographic area, and this was the reason PG&E started installing reactors on all of their 69 kv capacitors – to cut down the impulse to an acceptable level, caused by daily switching of capacitors.

At each of the post-fire locations Clark visited during his investigation where only distribution lines were present, it revealed that power lines were spliced back together, and reattached to a new pole-top transformer, which had been replaced resulting from the failure. Each of these new pole-top transformers were found at the points of origin where the fires started.

The Second Ignition Source Problem Identified

The second distinct electrical system design problem that Clark discovered in his investigation of the California fires igniting in multiple locations simultaneously, and contributing to the fires spreading so quickly, is that PG&E and San Diego Gas & Electric (SDG&E), has been using the wrong cable design to anchor and hold in place sub-transmission wooden poles that suspend the 69 kv power lines. The tensioned cables, called down-guys, are attached to the wooden power pole to resist and maintain their vertical position during high-wind conditions and storms. The installation placement and procedures are covered in General Orders 95, put out by the California Public Utilities Commission. In Section D, (3), b), 1) Anchor Guys, the order basically states where two (down guys) are attached to the same pole…*they shall be separated at the pole by a vertical distance of at least 1 foot (.3 m).* For example, if you took a wooden vertical power pole with a down guy attached at the 9 o'clock position, the second down guy at the 3 o'clock position would have to be attached either 12-inches above, or 12-inches below the first connector at the 9 o'clock position – at minimum. This requires two separate connecting bolts into the pole [Photo 1].

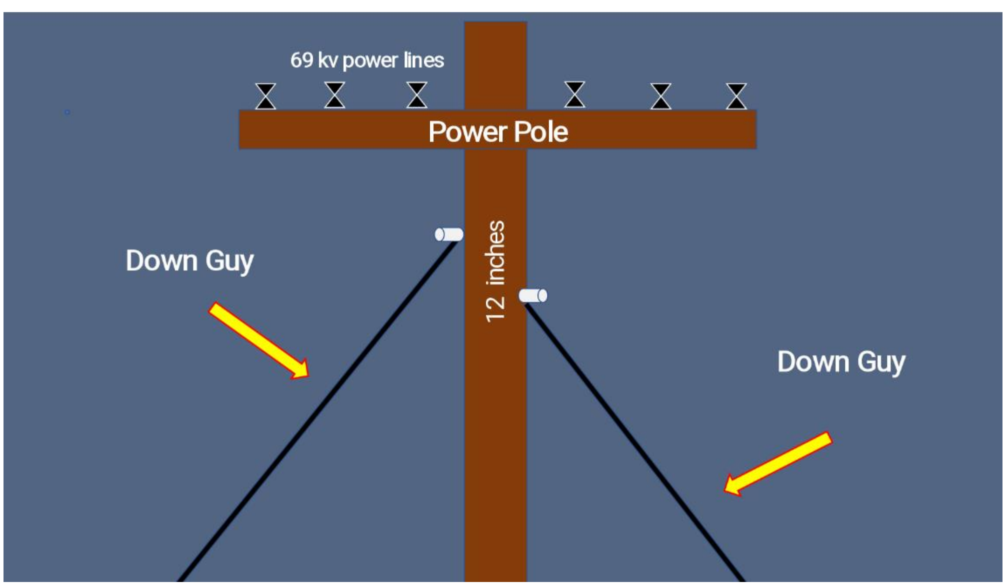

Photo 1

General Orders 95 states when two down-guys are attached to the same pole, they shall be separated by a vertical distance of at least 1 foot (as shown). PPT photo by author.

However, in Section D, (3), b), 3), the order states: *the provisions of this rule do not apply to guys which act in different directions from the pole.* Therein the wording lies the problem. #3 can be interpreted that when two down guys are used to support a pole going off in two different directions, the 1-foot (.3 m) vertical separation is not necessary. When you consider the hundreds of wooden power poles needed throughout the state of California, and the cost and labor required to install them, it is faster and cheaper to drill a single hole through the pole and use a single horizontal bolt to attach the down guys at the 9 and 3 o'clock position. The diameter width of wooden power poles range between 12 to 18 inches (30 cm to 46 cm). Many utility officials (incorrectly) interpret this width measurement as meeting or exceeding the 12-inch spacing requirement listed in General Orders 95 [Photo 2]. But that's not how electrical science works – and many utility officials are not electrical engineers. So it's up to the California Public Utilities Commission to rewrite General Order 95 so it is clear without confusion, or leaving room for misinterpretation – this can be done by simply omitting #3 from the order.

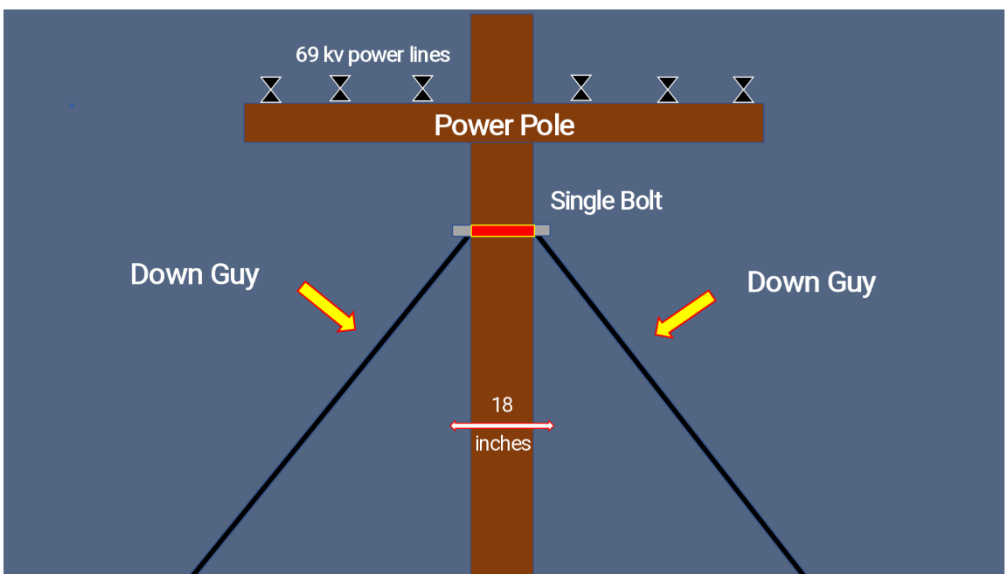

Photo 2

Often, General Order 95 is misinterpreted by using the diameter width measurement as meeting the 12-inch spacing requirement. PPT photo by author.

Here's how the science works: the down guy cables are fastened to giant anchor bolts and plates called *ground rods* that are buried ~ 8 to 10 feet (2 to 3 m) into the earth [Photo 3]. Then the cables are tightened down and tensioned to hold the power pole in place to resist the forces of nature [Photo 4]. In theory, if all the down guys remain tightly tensioned, there shouldn't be a problem when ground current is encountered. But after years of seasonal environmental impacts from wind and other sources, the down guy cables stretch, and loosen up from the eye bolt of the ground rod connectors. As stated, when a fault occurs, the 69 kv electrical ground current will flow through the earth taking the path of least resistance, back to the source substation that is delivering the electricity. The dirt, soil composition, and rocks all act as resistors to this ground current, and it is the only path available back to the source. However, metal is an excellent conductor with zero impedance. When the ground current encounters the ground rods, it jumps to this new path of least resistance, up the down guy, through the bolt, down the other down guy, and back on its way through the earth. The single horizontal bolt provides electrical continuity, so there's no separation – this is why two separate bolts would need to be installed to actually achieve the 12-inch vertical separation of the down guys as required in General Orders 95. This separation would create an open circuit disrupting the ground current flow of electricity – there would be no path for the electrical current to flow (an electrical dead end). This is the same way a light switch works. Flipping a light switch on connects the circuit which lights the bulb. Flipping the light switch off breaks or opens the circuit, preventing the electricity from flowing to the light bulb, so the light turns off.

Photo 3

Ground rods are buried 8 to 10 feet (2 to 3 m) into the earth. Photo by author.

Photo 4

Down-guy cables are tightened and tensioned to hold the power pole in place against the wind.

Photo by author.

This is the design error Clark found both on the PG&E system and the SDG&E system in many of the point of origin fire locations. The ground current from a fault encountered a ground rod, it allowed current to flow up a down guy anchor, to the single horizontal bolt through the pole providing electrical continuity, then down the other down guy to ground. If the down guys are loose at the anchoring connection to the ground rod, the wind, which shakes the pole, can cause the ground connection to *make and break* contact, causing electrical arcing when ground current is present at ground level. The temperatures are equivalent to those produced by arc welders, which produce sparks as hot as 10,000 to 15,000° F (6,000 – 8,000° C). With high winds and low humidity, in and around dry grass and brush, the super-hot temperatures of the sparks can start fires fast! [Photo 5]. Carbon deposits caused by the electrical arcing were also found on plastic covers and metal sleeves protecting the down guys. The cables also showed signs of carbon residue and damage from the high-temperature sparks. This problem is in addition to the transformer problems previously discussed.

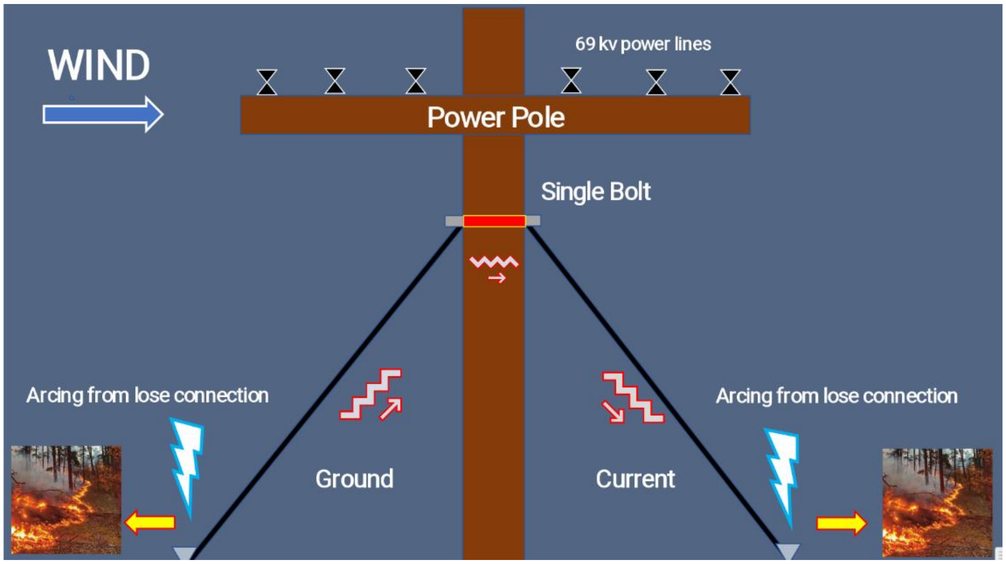

Photo 5

If the down-guy connections are loose, electrical arcing occurs when the wind shakes the pole. The sparks start the fire when ground current is present. PPT photo by author.

The Quick Fix

The easiest, fastest, and most economical solution is installing a small two-foot (.6 m) section of jumper cable, called a shunt, to each down guy at the anchor bolt in the ground. The diameter gauge of the shunt should be the same as the down guy. One end of the shunt is connected to the ground rod and the other is connected to the down guy. Because the shunt is not tensioned, nor does it serve any function in securing or holding the power pole in place, it isn't subjected to the forces of nature or impacted by the wind. Remember, the arcing only occurs when the down guys are loose at the anchoring connection to the ground rod. The movement of the power pole from the wind causes the ground connection to *make and break* contact continuity when ground current is present. Since the shunt cable is never stressed, the connections remain tightly secured providing contact continuity, so the down guys remain grounded, even if they're loose [Photo 6]. It is also the safest solution because a single employee can connect the shunt at ground level. There is no climbing of the pole or reconfiguring the down guys, so a line crew with their equipment is not necessary. It's also a cost-effective fix – the shunt cable and connectors cost about $30.00. Also, if the California Public Utilities Commission were to add the installation of the shunt cable to all 69 kv power poles into General Order 95, this would solve the problem without any more pole modifications. From Clark's investigation, it is the 69 kv power poles that pose the greatest potential for starting fires.

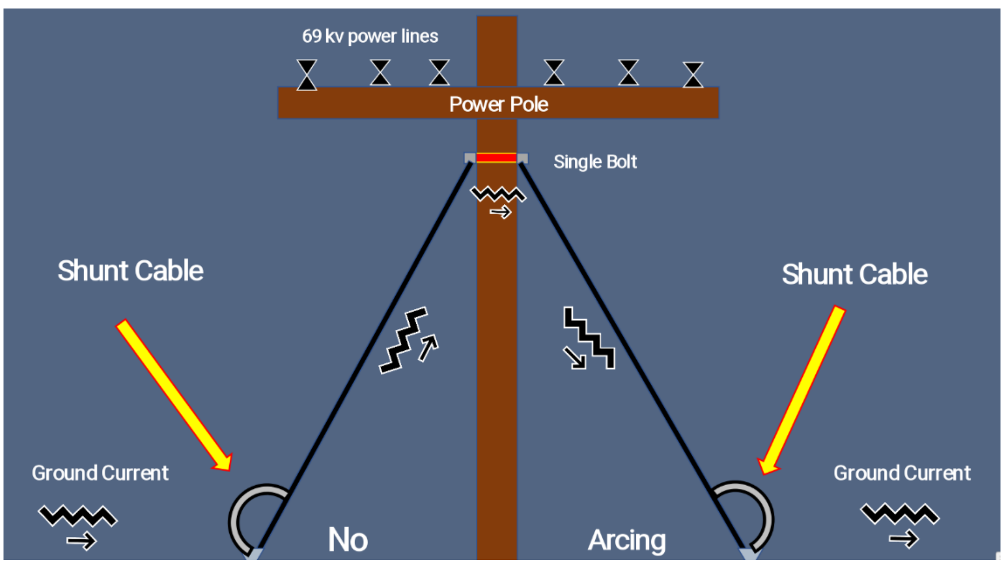

Photo 6

Applying a shunt provides contact continuity so the down-guys remain grounded, even when the connectors are loose. PPT photo by author.

Seeing is Believing

After numerous explanations, I finally understood what he was talking about. So when Ed Clark showed me his demonstration video, everything made sense [Photo 7]. He created a miniature model of a power pole with two down guys secured in opposite directions, connected to the pole with the single horizontal bolt. One ground rod was covered with twigs and dry grass clippings [Photo 8]. The other ground rod was left uncovered in order to see the arcing [Photo 9]. One of the ground rods underneath the table was connected to a 12-volt battery to energize the model, simulating the ground current. The connections to the ground rods had play in them to indicate they were loose. As Clark shook the pole, arcing was immediate. The connectors, making and breaking continuity, emitted sparks from the base of both down guys [Photo 10]. Within 10 seconds, the dry grass clippings and twigs started emitting smoke [Photo 11]. Within 20 seconds, the twigs and dry grass burst into flames [Photo 12]. In this demonstration, he had ignition of fuel in 20 seconds using a 12-volt battery. You can imagine the speed and energy behind 69 kv. The ignition of dry grass and brush with low humidity happens much faster with extremely high temperatures. It was this scenario that played out in the start of the 2003 Cedar fire, the 2003 Paradise fire, and the 2007 Witch Creek fire – the second-largest wildland fire of the 2007 California wildfire season. Interesting to note, the first 911 call to report the Witch Creek fire came in 15 minutes after the triggered fault was recorded by the utility equipment.

Photo 7

Photo evidence of the single horizontal bolt. Photo by Ed Clark

Photo 8

Left ground rod covered with twigs and dry grass clippings. Photo by Ed Clark.

Photo 9

Clark indicating the direction of travel for the electric ground current heading back to the source. Photo by Ed Clark.

Photo 10

Arcing starts immediately with movement of the pole. Photo by Ed Clark.

Photo 11

Smoke is generated within 10 seconds of arcing. Photo by Ed Clark.

Photo 12

Fuel ignites within 20 seconds of arcing. Photo by Ed Clark

When the shunt is applied across the connection points, the cable puts the same electric potential between the down guy and the grounding rod [Photo 13]. This continuity ensures the down guy remains grounded even if the connector is loose. The down guy to the right with the shunt is no longer sparking, while the down guy to the left without the shunt continues to spark as the connector makes and breaks contact [Photo 14]. Out in the field, a shunt would need to be applied to every down guy securing the 69 kv poles.

Photo 13 Shunt applied to down-guy and ground rod. Photo by Ed Clark

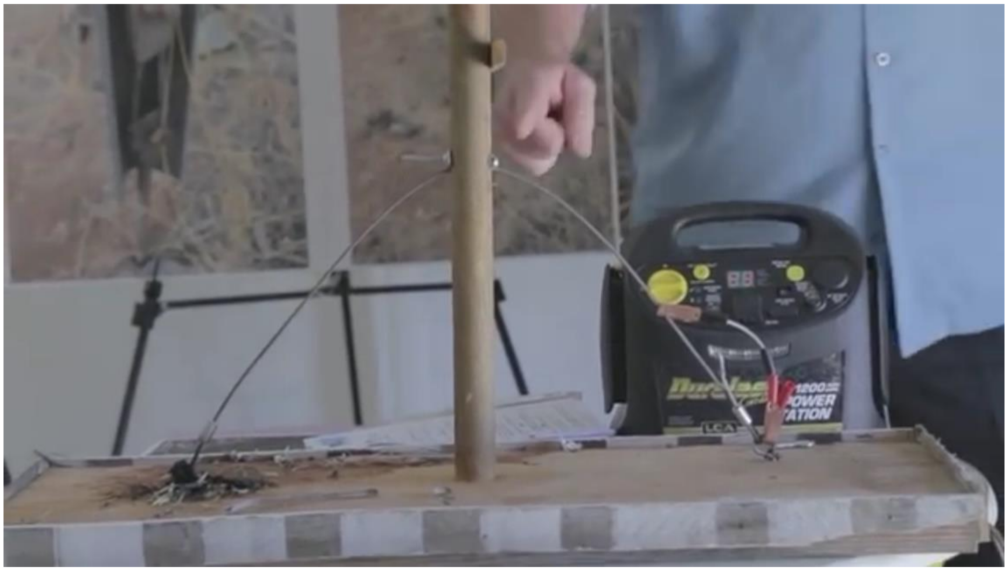

Photo 14

Down-guy with the shunt is no longer arcing. Down-guy without the shunt continues to arc as the loose connection is made and broken with pole movement. Photo by Ed Clark.

The Third Ignition Source: Smoke

The last factor to impact the spread of wildland fires, beyond the obvious fire spread of wind-driven flames with ample ground fuel are the large smoke plumes generated by these massive fires [Photo 15]. As the fire spreads, the smoke blowing downwind contaminates the insulators of uninvolved power poles. Insulators are glass or porcelain units with high-resistance qualities that when clean, efficiently insulate energized wires of all voltage levels from the crossarms of the power poles they are affixed to. When they become dirty with gritty particulates of smoke, their resistance drops. The smoke particles which include soot and carbon become conductors of electricity, eventually allowing current to track across the insulator causing them to flash over, triggering yet more faults. Additional faults means more arcing at ground level on down guys, resulting in more fires starting. The crackling and buzzing often heard on overhead power lines, especially in the evening or early morning when the moisture content in the air is higher is actually the sound of electrical current flowing across the surface of dirty insulators.

Photo 15

Smoke blowing downwind contaminates insulators of uninvolved power poles lowering their resistance and potentially leading to flash over and an additional fault. Photo by Mike Meadows

Conclusion

The gigantic steel towers that carry high-voltage 220,000 volt power lines are rarely the problem, though they have been known to cause fires. The design flaws within the electrical grid system Clark is talking about are centered around the sub-transmission lines carrying 69,000 volts, and the transformer failures on residential distribution lines.

The California Department of Forestry and Fire Protection (Cal Fire), which also includes the Office of the State Fire Marshal, is a state-wide fire department that serves 36 of the 58 counties in the state. In addition to fire suppression, their mission statement includes *protecting life and property through fire prevention,* *engineering programs, law and code enforcement, and education.* So Clark's forensic investigation evidence and findings are right up their alley. Cal Fire has placed blame on PG&E for multiple fires in the past, claiming their electrical equipment is responsible for starting fires like the 2018 Camp fire which killed 85 people, burned down 18,800 structures – 14,000 of which were residential homes, burned over 150,000 acres, destroyed the town of Paradise, was fought by over 5,000 firefighters, and caused over 8.4 billion dollars in damage. The California Public Utilities Commission has also placed blame on other utility companies like San Diego Gas and Electric for causing the 2007 Witch Creek fire by not trimming back trees that had grown into the power lines.

Under California state law, utility companies are required to keep vegetation a certain distance away from power lines (approximately 15 feet [4.6 m]). The accusations claim that when electrical power lines come in contact with trees, it causes sparks which fall into dry vegetation and starts a fire. That seems to be the accepted logical cause for ignition by fire officials. However, the utility companies like PG&E come back by stating their operational practices meet the state's high standards, and every electrical overhead transmission line is effectively monitored each year. This is why the California Public Utilities Commission needs to rewrite and clarify the standard. Utility companies do a pretty good job at trimming vegetation and trees back away from power lines, and though it is true, it can cause fires, Clark believes the majority of fires caused by the electric utility are primarily due to the ground faults triggered by the transformer failures and loose down guy connectors. These are the issues that are being misunderstood, overlooked, or ignored by all the governing parties involved. Politics and legal liability at the top state level is complicated. There will always be finger pointing and shifting of blame. No one wants to accept responsibility; that's the nature of politics in any organization. But certainly there must be a group of people within all the effected organizations who can come together in order to fix solvable problems to improve the safety of the overall system.

The reason Clark's findings are so important for the fire service to understand is because there are still hundreds of these power poles in service throughout the state of California, which can create the fault scenarios explained above. There's really no way to tell how many of these poles exist unless the California Public Utilities Commission or Cal Fire demands a complete survey from the utility companies so they can be modified.

Drought conditions, hot temperatures, low humidity, and an abundance of dry fuel in the form of dry grass, brush, and trees are all the factors for extreme fire danger. Once a fire starts, the wind kicks up and spreads the fire. The radiant energy preheats uninvolved fuel downwind, quickly ignites, and continues to grow out of control. Burning embers are carried into the thermal column for miles, land in remote areas and ignite fires beyond the fire perimeter. This explanation is accepted by all the agencies for why these wildland fires grow so fast. But what appears to be wind-driven fires quickly spreading ahead of the fire lines, may actually be grid system faults triggering arcing, starting fires in multiple locations simultaneously, miles apart from each other. <u>It's all about ground faults and ground current.</u> It is a misunderstood, unrecognized, and unaddressed error in the utility grid system that is creating a chain-reaction of faults within the grid, caused by the fire, but mistakenly attributed to explosive rapid fire growth. This may be a key component to why after all the hands-on, ground-level, and aerial fire suppression operations, we still can't get ahead of these fires. Clark has presented a scientific simple fix by applying electrical shunts to the down guys of power poles, and though it won't prevent all fires from starting, this easy inexpensive solution can surely put a major dent into the problem.

This is not just a California problem anymore. Resources in the form of firefighters, apparatus, equipment, and aircraft are deployed into California from all regions of the country. Though it helps California, it depletes emergency resources from their home states while incurring an economic cost in the form of supplies, logistics, back-fill, and overtime wages. As stated, since many industry-standard practices are shared or copied, it's very possible that this design error in the electric grid also exist in other wildland interface regions, state, and national forest areas elsewhere around the country. We also have to ask: Who benefits financially from the loss associated with these devastating wildland fires? Who is awarded contracts to rebuild these communities? How are insurance rates adjusted for these companies to recoup their payouts? Are there financial incentives to do nothing? There's a lot of money involved at every level in these annual disastrous events…but how many more firefighters need to die in the line of duty? How many more civilian lives need to be lost? How many more families will be devastated with the continued loss of their homes, valuables, and vehicles? How many more communities like Lahaina, along with other natural resources will be burned off the map? The need to train fire investigators on what to look for with electrical utilities is critical to force future remedies that would prevent fires from starting, and from spreading so fast. A recent headline read "The California Wildland Fire Season Will Most Likely Extend Through December."

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Raul Angulo is retired from the Seattle Fire Dept. and is Captain Emeritus of Ladder Co. 6 with over 40 years of experience. He is on the Editorial Advisory Board for Fire Apparatus and Emergency Equipment magazine and has authored numerous articles for Fire Engineering. He is the author of the new textbook *Engine Company Fireground Operations 4th Edition*, (NFPA and Jones and Bartlett Learning) and has been teaching at FDIC International since 1996.