Journal of the National Academy of Forensic Engineers®

NATIONAL
ACADEMY OF
FORENSIC
ENGINEERS

http://www.nafe.org
ISSN: 2379-3252
DOI: 10.51501/jotnafe.v41i2

Vol. 41 No. 2 December 2024

Forensic Engineering Analysis of a Residential Fire Caused by an Open Neutral

By Steve Pietropaolo, PE, DFE (NAFE 769S) and Yoandi Interian, PE, DFE (NAFE 1260M)

Abstract

An open neutral or floating neutral is a condition that occurs when the electrical current passing through the neutral conductor in a multiwire circuit is not balanced. This condition can occur when there is a break in the neutral wire, resulting in a loss of continuity in the neutral. As a result, an imbalance in electrical voltage is created in the electrical system. This paper will discuss the forensic engineering analysis of a residential fire caused by an open neutral. It will discuss in detail how a large tree fell on power lines near the house, fractured a nearby residential utility pole, caused a failure of the neutral service splice, and resulted in the separation of the neutral portion of the service line. It will further discuss how the open neutral resulted in a power strip overheating and caused the fire.

Keywords

Forensic engineering, open neutral, floating neutral, electrical fire, utility pole, neutral service splice, relocatable power strip (RPT), power strip

Introduction and Background

A structural fire broke out in a single-family residential house in Westchester County, New York, resulting in significant damage to the house. The house was a two-story wood-framed structure, approximately 1,800 square feet in size and 103 years old (**Figure 1**).

Based on a review of available documents, on the day of the fire, the following sequence of events was established:

Figure 1
Front view of the subject two-story single-family residential house. Photo taken by utility company on the night of the fire.

- Before 2:24 p.m.: A tree falls across the street from the subject house.
- 2:24 p.m.: The electrical utility company was notified by the local police department of fallen tree and downed wires.
- 2:25 p.m.: The utility company sends a technician to the scene.
- 2:58 p.m.: A technician from the utility company arrives at the scene and reports a broken utility pole in front of the subject house, but no downed wires were reported.
- 4:38 p.m.: The utility company was notified by the local fire department of a structural fire at the subject house and requested the utility company shut off all utilities to the house.

Upon arrival, the utility company found no evidence of any downed wires. The utility pole directly in front of the house had fractured as a result of the nearby fallen tree and strained the service lines extending to the house. The

---

Steve Pietropaolo, PE, 7 Reservoir Rd, North White Plains, NY 10603, (914)-670-0208, steve@lgiforensic.com

utility hypothesized that the neutral wire had pulled out of the connector near the weather head.

At the time of the fire, no one was present inside the house, and no injuries were reported. However, the house sustained severe structural damage as a result of the fire. Following the reported fire, the authors were engaged to evaluate the circumstances that led up to the structural fire, identify the cause of the fire, and determine whether the utility contributed to the cause of the fire. Various discovery documents were reviewed, and a site inspection of the scene was conducted. A lab examination of the evidence collected from the scene was also performed.

Scene Examination Post-Fire

A joint-scene examination of the property was conducted several days after the fire. **Figure 2** provides an aerial view of the house and the surrounding property.

A triplex service drop from utility pole #1 (located directly in front of the house) extended toward the service entrance of the house near the northwest corner of the house. Note: A service drop is a set of electrical cables that connect a utility company's power to a customer's building. The term "triplex" refers to the three wires in the cable that are twisted together in a set.

A service mast and weather head were mounted on the northwest corner of the house. The service mast (a rigid metal conduit extending vertically from the electrical meter box up toward the roof line) and weather head (a protective fitting placed at the top of the service mast) protect the electrical system and ensure a safe entry point for the utility power. The triplex service drop cable contained two aluminum insulated conductors and one bare conductor. The two insulated conductors serve as the "hot" legs of the service, while the bare conductor serves as the "neutral" leg of the service. The bare neutral conductor also served as the messenger wire and will be referred to as the "messenger neutral conductor." Note: A "messenger wire" is a wire that is run along with a cable to provide mechanical support for the cable.

The two insulated conductors were connected to the two insulated service entrance conductors with a utility connector and were intact at the time of the fire (**Figure 3**). The neutral service entrance conductor was also connected to the end of the neutral messenger conductor and was intact (**Figure 3**). Note: A neutral service entrance conductor is an electrical conductor that forms part of the service entrance wiring to a building. The role of the neutral service conductor is to provide a return path for electric current back to the utility's distribution system.

The opposite end of the messenger neutral conductor was found lying on the roof in front of the weather head. The messenger neutral conductor contained two splice connectors (**Figure 4**). A section of the messenger

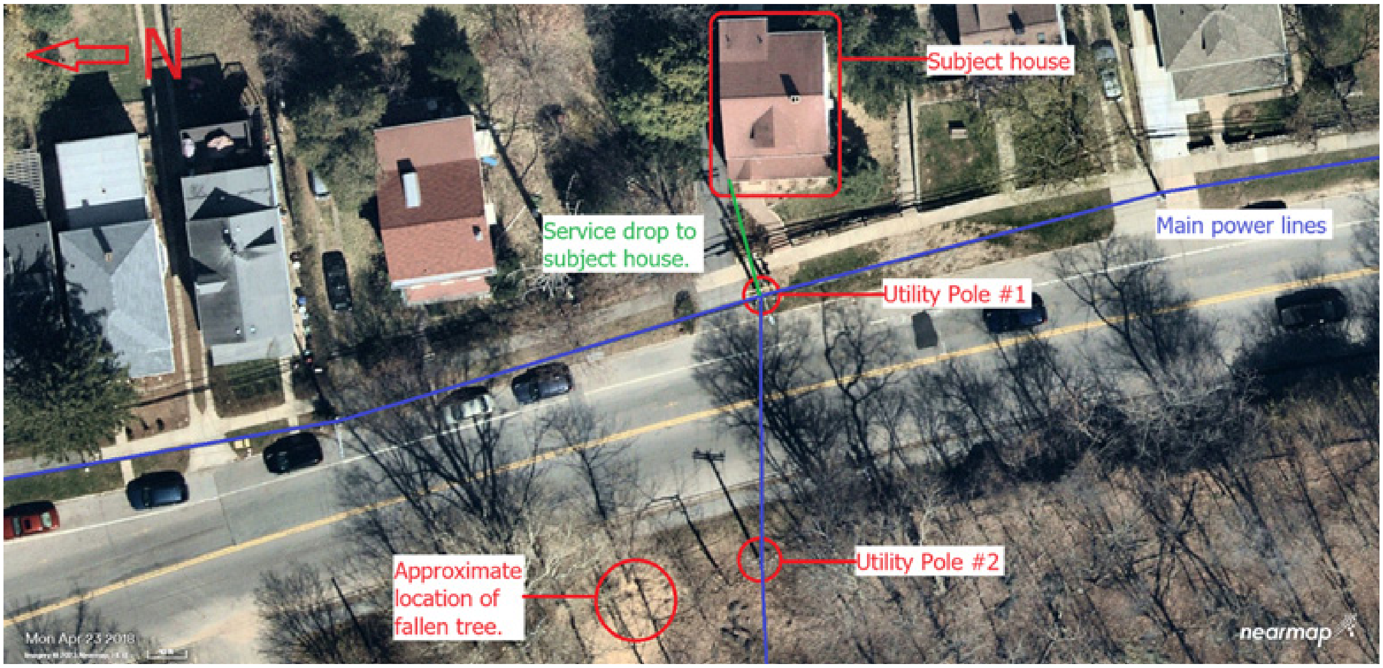


Figure 2
Aerial view of the subject property and surrounding area obtained from Nearmap.com (dated April 23, 2018).

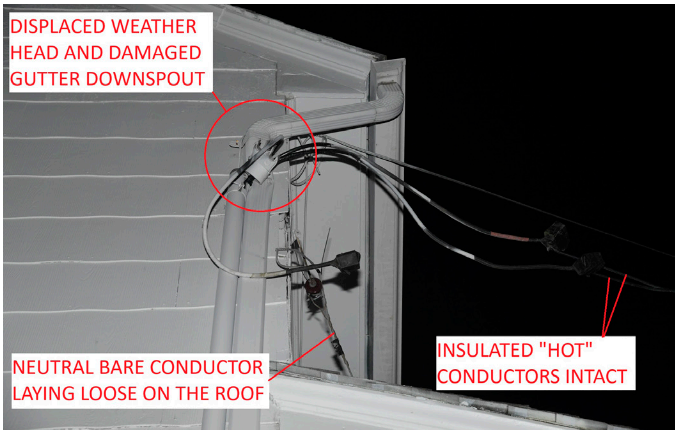


Figure 3
View of the service drop connection at the service entrance to the house — night of the fire (looking south).

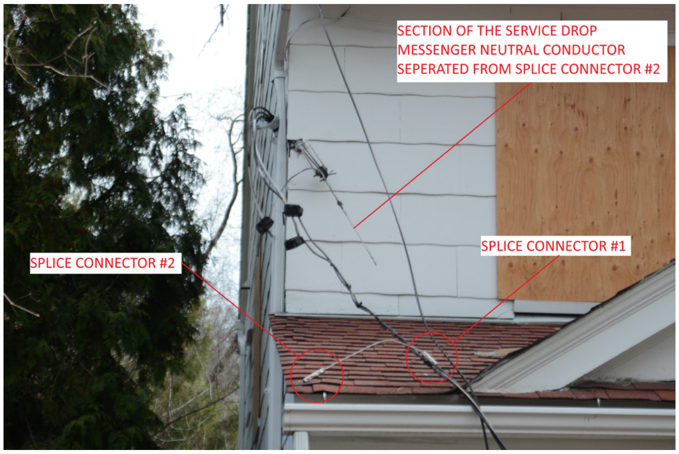


Figure 4
View of the service drop connection at the service entrance to the house (looking east).

neutral conductor had separated from the splice connector closest to the weather head. A service insulator bail was attached to an eyelet that was firmly attached to the building structure. Note: A service insulator bail is a component used in electrical service installations to hold and support the overhead service drop. The insulator bail provides a non-conductive support for the power lines and ensures the proper distance between the electrical conductors and other parts of the structure.

A section of the messenger neutral conductor wire was still connected to the insulator bail, as shown in **Figure 5**. Displacement of the weather head mast was visible as evidenced by the recent crushed gutter downspout near the subject vertical service entrance mast. There was no evidence of any lightning strike (e.g., scorch marks on the exterior).

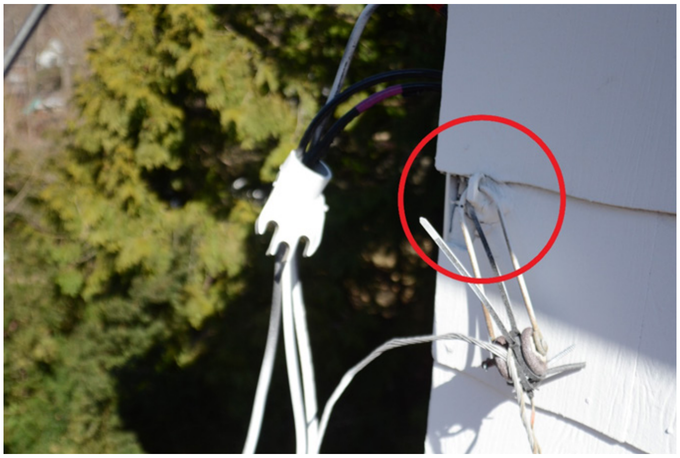


Figure 5
View of the insulator bail firmly attached to the building structure.

Figure 6
View of the utility pole #1 leaning away from the house.

Utility pole #1 (located directly in front of the house on the east side of the street) had fractured at the base and was leaning toward the street (**Figures 6** and **7**). The utility pole was found leaning on the main power lines running in the north-south direction along the street. No guyed wires were found attached to utility pole #1. Directly across the street (on the west side of the street) was another utility pole (utility pole #2). Power lines crossed the subject street from utility pole #1 to utility pole #2 to feed a nearby school.

The subject tree that fell was located approximately 30 feet north of utility pole #2. The tree fell onto the primary feeder lines, crossing between utility pole #1 and utility pole #2. Utility pole #1 was pulled in a southwest direction and fractured the utility pole at the base.

Figure 7
Utility pole #1 fractured at the base (night of the fire).

The house was serviced by a 200A service. A service panel was in the basement and contained 38 breakers. A 20A breaker servicing the living room of the subject house was found in the "tripped" position.

The triplex service drop conductors and connectors were disconnected from the service entrance and taken as evidence. Additionally, the subject tripped breaker and various wiring and electrical appliances from within the subject house were removed and taken as evidence for further examination.

Fire Origin

The local fire department determined that the fire originated in the living room near the TV entertainment center. The cause of the fire was determined to be accidental and electrical in nature. The author further evaluated the fire scene using the scientific method as detailed in the 2017 edition of the National Fire Protection Association *Guide for Fire and Explosion Investigations* (NFPA 921-2024)[1]. Note: NFPA 921-2017 was the version of the guide in place at time of the site visit. Combining witness statements, physical evidence (i.e., degree of damage, fire patterns, fire dynamics), and conducting an arc survey (mapping) of the area of origin, the source of the fire was confirmed to have originated in the living room in the vicinity of the entertainment equipment. Further analysis determined that the cause of the fire was due to a failure of a relocatable power tap (RPT) — a.k.a., a power strip — located in the living room.

Laboratory Examination of Evidence

The following items, amongst other components, were present in the area of fire origin: Soundbar, phone charger, Bluray DVD player, Sony charging station, Play Station (PS4), Nintendo Switch, Roku, Verizon Modem and Wi-Fi router, LG television, and two unknown RPT devices. One of the RPT devices was significantly more damaged than the other. All of the electronic devices were plugged into the various RPT devices, which were plugged into a duplex receptacle (outlet) located on the living room wall to the right of the entertainment center. A 20A Murray model circuit breaker was protecting the living room circuit. That circuit breaker was found to be in the "tripped" position after the fire. The circuit breaker was tested in the laboratory and found to be functional. None of the devices (except for the lesser-damaged RPT) was found to exhibit signs of electrical activity or failure. Once the 20A circuit breaker tripped, the entire entertainment area was not energized. Therefore, these devices would not have caused the fire.

Failure Mode of Power Strips

RPTs are equipped with voltage suppression devices called metal-oxide-varistors (MOVs) that "clamp" or restrict transient (or voltage) fluctuations in an electrical circuit. These devices can fail catastrophically if exposed to higher-than-normal voltage. The authors have personally performed laboratory testing in the past on MOV devices subjected to higher voltages (up to 220V), proving these effects. Based on previous testing performed along with historical research, MOVs can overheat and cause fires[2].

Standard for Safety Surge Protective Devices (UL 1449) sets requirements for surge protective devices (SPDs), also known as surge protectors or surge suppressors[3]. The standard specifies these devices' testing and performance criteria to ensure they effectively protect against transient voltage surges and spikes. The standard covers various aspects, such as surge current ratings, response times, endurance, and safety considerations, to ensure the reliability and effectiveness of surge protection devices. For end products to comply with the UL 1449 standard, some level of protection must be afforded to the MOV to prevent failure from an abnormal over-voltage/limited current condition. Traditionally, various methods for thermally protecting MOVs have been provided to meet the requirements of UL 1449[4].

X-rays performed on the lesser-damaged RPT confirmed the failure of at least one MOV device due to overvoltage. The more-damaged RPT was destroyed, with only the metal electrical busses remaining or recovered during the fire scene overhaul and evidence collection. The fact that this RPT was more severely damaged is evidence that it was exposed to fire effects for a longer period of time.

All experts involved in the forensic investigation agreed that the fire was caused by an MOV failure within the damaged RPT device. The more-damaged subject RPT was never excavated from the solidified debris and never evaluated to determine if the MOVs within the device were thermally protected to meet the requirements of the UL1449 standard.

Open or Floating Neutral

Per Section 9.5.2 of NFPA 921-2017, "[a]n electrical installation with an open neutral conductor will not have a fixed 120V between each hot leg and the neutral. There will still be 240V between the two legs, but instead of the voltages of the two legs being fixed at 120V to neutral each, they may vary to some other values that add up to 240V (**Figure 8**). All 120V circuits connected to the open neutral conductor will be affected. The actual voltages in the legs will depend on the loads on the two legs at any particular time. For example, the voltages might be 60 and 180 as in Figure 9.5.2. The higher voltage can overheat or burn out some equipment, and the lower voltage can damage some electronic equipment. Occupants may have seen incandescent lights that were too bright or too dim or appliances that overheated or malfunctioned in some way. A floating neutral condition is not dependent on proper grounding of the service. Removing the grounding electrode connection does not cause an open neutral[1]".

In a multiwire circuit, such as the case at this property, the neutral conductor carries the load imbalance. **Figure 9**, showing a three-wire circuit, has been supplied to assist in the explanation of an open neutral. As shown in Figure 1 of **Figure 9**, the neutral conductor is designed to carry the imbalance of the two loads. In this example, there is one load requiring 0.5A on one phase, while the load on the second phase is drawing 2.5A. The difference of the two currents, 2A, will flow back to the transformer and into the service supply. When the loads are balanced (a very unusual condition), the current on the neutral is 0A. When the neutral conductor is "open," the voltage becomes unstable, and no current flows through the "open" messenger neutral conductor. Note: An "open" neutral condition refers to an interruption in its continuity (i.e., broken, disconnected).

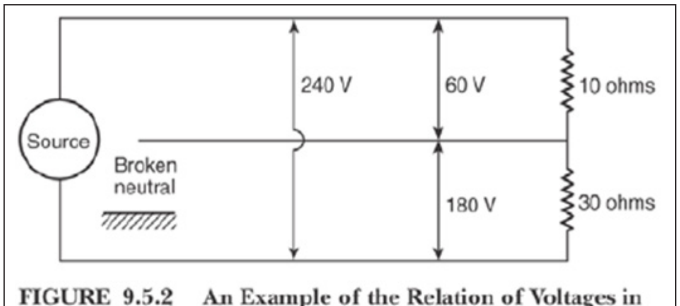


FIGURE 9.5.2 An Example of the Relation of Voltages in 120/240 V with an Open Neutral.

Figure 8
Figure 9.5.2 from NFPA 921-2017.

The flow of current is the same for both loads, only flows on the live conductors, and the neutral returns no unbalanced load to the service. When this occurs, the voltage drop across a load can be calculated using equation 1 (Ohm's Law) — where I is the electrical current (which is the same in an open neutral condition), and R is the resistance of the loads[5].

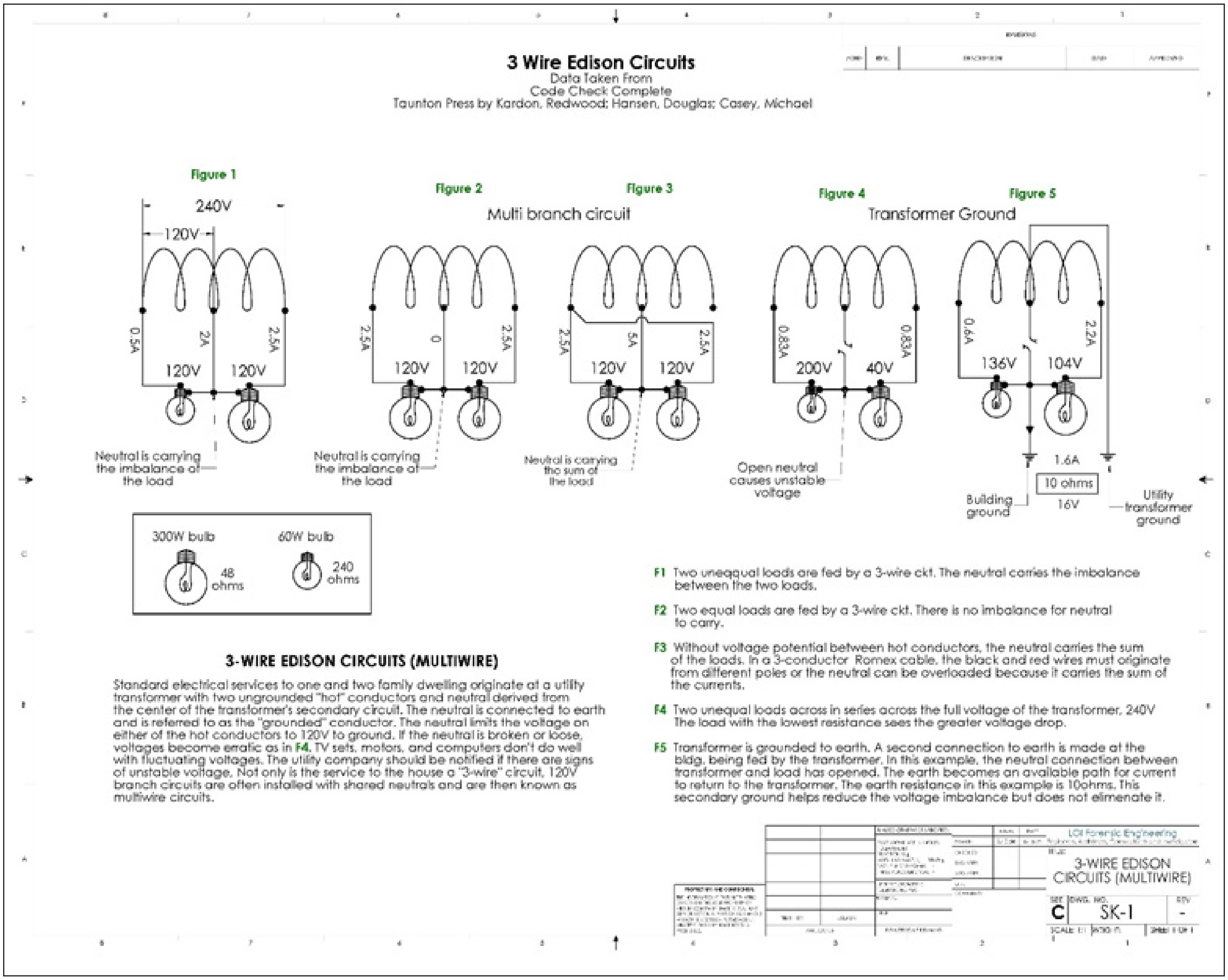
(Eq. 1) $V = I \times R$

A higher-wattage device will have a lower resistance than a lower-wattage device. In an open neutral condition, the smaller wattage device will see the larger voltage drop. In Figure 4 of **Figure 9**, the 60W bulb will be very bright because its voltage drop is five times greater than the voltage drop across the 300W bulb.

A neutral conductor provides a return path for electric current to the utility company's electrical system[5]. When the messenger neutral conductor wire became separated — and because the loads in the home were not balanced — it caused an imbalance in the electrical voltage to the RPT and the various components connected thereto.

"An open or floating neutral poses a significant risk to electrical equipment and can result in equipment failure or fire[6]." Typically, the failure mode of the MOV devices occurs when they are exposed to overvoltage (greater than 120V). This overvoltage can cause excessive heat and failure of an MOV device, causing a fire before an overcurrent protection device, like the circuit breaker, trips or opens, as was confirmed at this location based on the evidence.

Note that when a power strip fails, the heating effects and the resulting fire exposure to the first fuels can occur immediately thereafter, followed by ignition to the secondary and tertiary fuel loads. "First fuels" refer to the materials that initially catch fire and begin the burning process (e.g., paper products, cooking oils, clothing, wood, etc.). "Secondary fuels" refer to materials that catch fire after the "first fuels" have ignited and help spread the fire (e.g., furniture, drywall and plaster, insulation materials, appliances, etc.). "Tertiary fuels" refers to materials that ignite after the fire has grown and spread (e.g., wooden beams



3-WIRE EDISON CIRCUITS (MULTIWIRE)

Standard electrical services to one and two family dwelling originate at a utility transformer with two ungrounded "hot" conductors and neutral derived from the center of the transformer's secondary circuit. The neutral is connected to earth and is referred to as the "grounded" conductor. The neutral limits the voltage on either of the hot conductors to 120V to ground. If the neutral is broken or loose, voltages become erratic as in **F4**. TV sets, motors, and computers don't do well with fluctuating voltages. The utility company should be notified if there are signs of unstable voltage. Not only is the service to the house a "3-wire" circuit, 120V branch circuits are often installed with shared neutrals and are then known as multiwire circuits.

F1 Two uneqqual loads are fed by a 3-wire ckt. The neutral carries the imbalance between the two loads.

F2 Two equal loads are fed by a 3-wire ckt. There is no imbalance for neutral to carry.

F3 Without voltage potential between hot conductors, the neutral carries the sum of the loads. In a 3-conductor Romex cable, the black and red wires must originate from different poles or the neutral can be overloaded because it carries the sum of the currents.

F4 Two unequal loads across in series across the full voltage of the transformer, 240V The load with the lowest resistance sees the greater voltage drop.

F5 Transformer is grounded to earth. A second connection to earth is made at the bldg. being fed by the transformer. In this example, the neutral connection between transformer and load has opened. The earth becomes an available path for current to return to the transformer. The earth resistance in this example is 10ohms. This secondary ground helps reduce the voltage imbalance but does not elimenate it.

Figure 9
A sketch showing a three-wire Edison circuit (multiwire).

and framing, roof materials, flooring, etc.). There was no one at home when the fire started.

Subject Neutral Service Splice

The messenger neutral conductor was examined at the scene and in the lab. The bare conductor contained two compression-type splices approximately 2 feet from each other (**Figure 10**)[7]. A compression splice is designed to connect two ends of a conductor.

A destructive examination of both the intact and separated splices was performed during a lab examination. Splice connector #1 was intact, and both conductors were still attached. Before destructive examination, the section of the messenger neutral conductor with the purple taped end extended toward utility pole #1. The section of the messenger neutral conductor between splice connectors

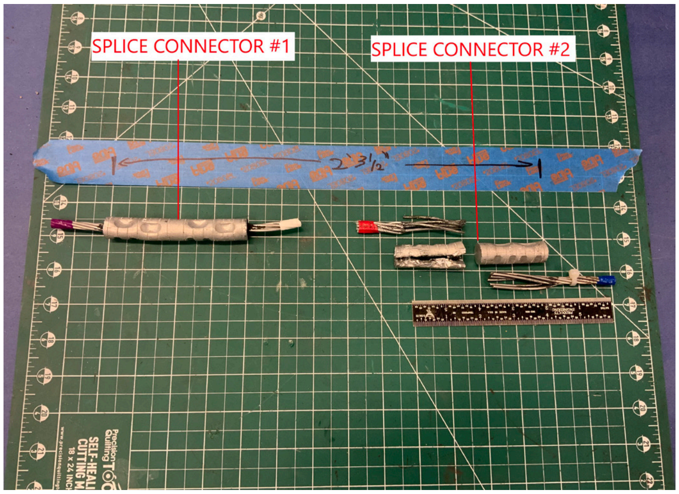


Figure 10
Splice connector #1 and #2 examined during a destructive lab examination.

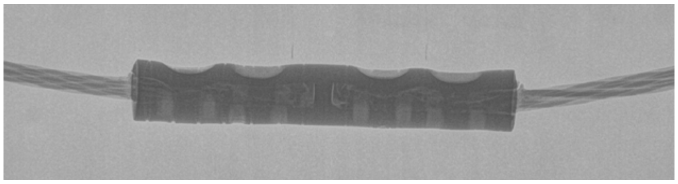


Figure 11
X-ray of splice connector #1 showing proper embedment of the conductors.

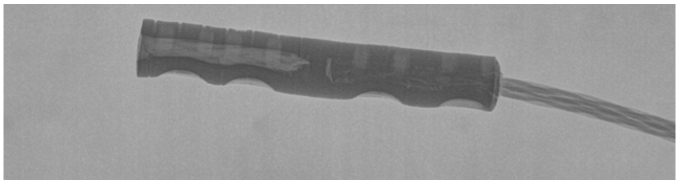


Figure 12
X-ray of splice connector #2 showing proper adequate embedment of "house"-side conductor.

#1 and #2 are identified by the white and red taped ends. The red taped end of the messenger neutral conductor was intentionally pulled from splice connector #2 during the examination. The conductor connected to the "house" side of splice connector #2 (shown taped in blue) had separated because of the tree fall, resulting in the "open" neutral condition. X-ray examination showed that the crimp was within manufacturer guidelines/specifications (**Figures 11** and **12**).

Crimp splices are used to connect two ends of a conductor. The compression sleeve/splice is designed to service drop or short-span overhead distribution lines. These splices are designed for a holding strength of 700 pounds.

The plaintiff's initial theory put liability on the utility company for not properly de-energizing the service to the home and properly pulling the meter after the tree fell. Through the course of the investigation, the plaintiff's theory shifted to a "defective" splice with no analysis or testing to support their theory. The authors had planned on further testing of the compression splice; however, the case settled — and no further testing was performed.

Utility Pole #1

Utility pole #1 was installed sometime in 2001. At the time of installation, the utility pole was approximately 45 feet long and buried approximately 8 feet in the ground. This placed the top of the pole at approximately 37 feet above the ground. The primary power lines were located approximately 35 feet above the ground, and the service drop to the subject house was located approximately 25 feet above the ground.

The utility company classified utility pole #1 as a "class 1" pole with a specified wood species of Southern pine. The subject utility pole was last inspected and treated in 2013 by the utility, and no issues were noted at the time. During the scene examination, no wood rot or insect damage around the base of the utility pole was discovered.

The strength of a utility pole is determined by the fiber strength of the wood species from which the pole is produced. The *National Electrical Safety Code* (NESC-1997) references ANSI O5.1-1992 for determining the permitted stress level of natural wood poles based on fiber strength[8,9]. Note: Although NESC-1997 is not the current version, it was in place at time of the utility pole installation.

The fiber strength provided by ANSI O5.1-1992 represents the Modulus of Rupture (MOR) for that wood species. The MOR represents the maximum load-carrying capacity of a member in bending, and it is an accepted criterion of strength[10]. For Southern pine and Douglas fir wood poles, the fiber strength is given as 8,000 psi. A similar value for the fiber strength of Southern pine is also referenced by the North American Wood Pole Council[11].

It is worth noting that the *National Design Specification Supplement for Wood Construction* (NDS) also provides tabulated design reference values for use in the design of wood structures. However, the values provided in the NDS have been developed using American Society for Testing and Materials (ASTM) standard D2555, *Standard Practice for Establishing Clear Wood Strength Values*, and Standard D245, *Standard Practice for Establishing Structural Grades and Allowable Properties for Visually Graded Lumber*. When comparing average strength values (i.e., MOR values) of a specific wood species to the design reference values given by the NDS, the design reference values often have a built-in safety factor for material strength, thus the discrepancy in strength values. Nevertheless, when designing utility poles, the material's properties should be obtained from ANSI O5.1 as required by the NESC-1997.

Based on the length and class type of the pole, ANSI O5.1-1992 also provides the minimum required circumference at 6 feet from the butt and the minimum circumference at the top of the pole. For a Southern pine pole approximately 45 feet in length, the minimum circumference at 6 feet from the butt is equal to 43 inches, and the minimum circumference at the top of the pole is 27 inches.

Force Exerted on the Neutral Service Splice

The subject tree near utility pole #2 fell toward the south and onto the power lines going east-west between utility pole #1 and utility pole #2. The force of the tree caused utility pole #1 to fracture and be pulled toward the west. As a consequence, the service drop conductors between the subject house and utility pole #1 were placed under tension.

Figure 13 is a free-body diagram of utility pole #1 showing the various forces acting on the utility pole following the tree fall and immediately after the utility pole fractured. The utility pole represents a cantilevered beam with a circular cross-section. At the top of the member, the forces acting on the pole are represented by F_p, the force exerted by the primary power lines crossing the street between utility pole #1 and pole #2, and by F_s, the force resisted by the service drop conductors extending toward the subject house. The distance from the ground to the primary power lines is represented by d_p, and the distance from the ground to the service drop is represented by d_s.

Before the failure of the pole, the utility pole was in a state of static equilibrium with no net forces acting on the utility pole. During a state of static equilibrium, the sum of moments about any point on the pole would be equal to zero. Following the failure of the utility pole, in order to maintain static equilibrium, the sum of moments acting on the pole would have to be maintained at zero. Taking the sum of moments about point A, equation 2 is derived.

$$\text{(Eq. 2)}\ \sum M_A = (F_p \times d_p) - (F_s \times d_s) = 0$$

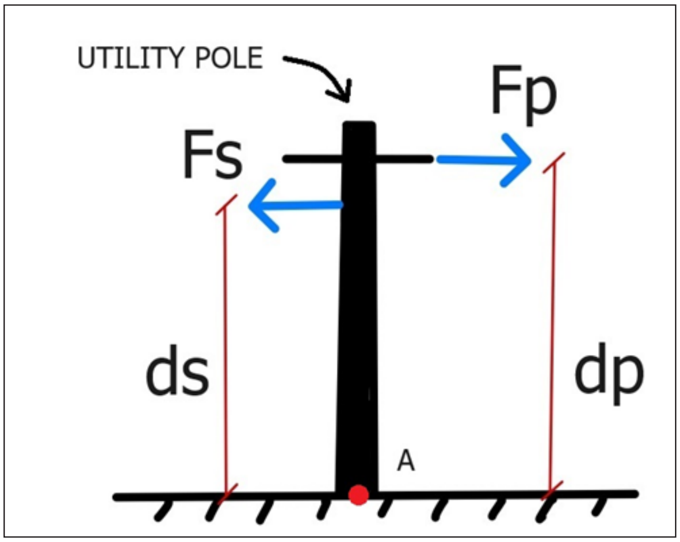


Figure 13
Free-body diagram showing the forces acting on utility pole #1 at the time of the tree fall.

Following the tree fall, the subject pole fractured at the base because of a net bending moment imposed on the subject pole greater than the resisting moment of the subject utility pole. The resisting moment is the amount of force a pole can withstand at the point of maximum stress before it breaks[10].

The resisting moment for the subject utility pole can be obtained by solving for M_{max} in equation 3, where σ represents the fiber strength of the wood species, and S is the section modulus of the cross section of the subject member. The section modulus of the cross section can be calculated by using equation 4 and 5, where d represents the diameter of the circular cross section and C, represents the circumference of the pole at ground-line.

$$\text{(Eq. 3)}\ \sigma = \frac{M_{max}}{S}$$

$$\text{(Eq. 4)}\ S = \frac{\pi * d^3}{32}$$

$$\text{(Eq. 5)}\ d = \frac{C}{\pi}$$

The minimum circumference provided by ANSI O5.1-1992 for a wood pole is based on a classification point located 6 feet from the butt. The setting depth of utility pole #1 provided by the utility company was approximately 8 feet. A pole is a tapered cylinder; therefore, the circumference of the utility pole at the ground line, C, was derived from equation 6 to account for the additional two feet of depth. C_b is the pole circumference at 6 feet from the butt, C_t is the circumference of the pole at the top, D_p is the distance from butt of pole to top of pole, D_g is the distance from the pole butt to the ground-line, and D_b is the distance from pole butt to classification point given by ANSI O5.1-1992.

$$\text{(Eq. 6)}\ C = \frac{(D_p - D_g)*(C_b - C_t)}{(D_p - D_b)} + C_t$$

$C = 42.1''$

$C_b = 43''$

$C_t = 27''$

$D_p = 45'$

$D_g = 8'$

$D_b = 6'$

Using equation 3 and solving for M_{max}, we can derive at equation 7:

$$\text{(Eq. 7) } M_{max} = \frac{\sigma * \pi}{32} * \left(\frac{C}{\pi}\right)^3$$

$$M_{max} = \frac{8000psi * \pi}{32} * \left(\frac{42.1''}{\pi}\right)^3$$

$$= 1{,}890{,}107 \; lb\text{ - }in$$

$$= 157{,}508 \; lb\text{ - }ft$$

The calculated maximum allowable bending moment of utility pole #1 represents the maximum bending moment that can be resisted by the pole before catastrophic failure. The subject force exerted by the falling tree on the primary lines between utility pole #1 and pole #2 created a net bending moment on the subject utility pole that equaled or exceeded the resisting moment of the pole. The net bending moment exerted at the base of the cantilever utility pole can be calculated using equation 8.

$$\text{(Eq. 8) } M = M_{max} = (F_p * d_p)$$

As a result of the failure of the utility pole (i.e., $M \geq M_{max}$), the service drop conductors were placed in tension in an attempt for the system to maintain static equilibrium. We can derive equation 9 from equations 2 and 8 using this relationship.

$$\text{(Eq. 9) } M_{max} = (F_p * d_p) = (F_s * d_s)$$

Solving for F_s, we can derive at equation 10.

$$\text{(Eq. 10) } F_s = {M_{max}}/{d_s}$$

$$= {157{,}508 \; lb - ft}/{25 \; ft}$$

$$= 6{,}300 \; lb$$

Based on the above calculations, a force of approximately 6,300 pounds was exerted on the service drop conductors as it resisted the net bending moment exerted on utility pole #1 by the fallen tree.

Based on the manufacturer's information for the subject splice on the neutral wire closest to the house, the subject splice had a holding strength of approximately 700 pounds. Under the force of the fallen tree, the subject splice was subjected to a force much greater than 700 pounds and thus resulted in the failure of the neutral splice connector closest to the house.

The eyelet and insulator bail at the point of attachment were discovered to be undamaged following the tree fall. Additionally, no portion of the bare neutral conductor between the point of attachment and utility pole #1 was discovered to have failed. It is the authors' opinion that, based on the inherit sag in the service drop conductors as well as the relatively low holding strength of the splice connector, the force exerted on the service drop was immediately relieved by the failure of the splice connector.

Based on the location of utility pole #1, the pole was a dead-end pole for the power lines extending toward the west. Rule 264 of NESC-1997 provides that the use of "guys, braces, or other suitable construction" shall be provided to provide additional strength when the loads on the structure are greater than can be supported by the structure alone[8]. NESC-1997 further provides that "such measures shall also be used where necessary to limit the increase of sags and provide sufficient strength for those supports on which the loads are sufficiently unbalanced, for example, at corners, angles, dead-ends, large differences in span lengths"[8]. However, at the time of the joint-scene examination, utility pole #1 did not contain any guyed wires or braces. The use of guyed wires at this location would have been expected to have provided additional lateral support to utility pole #1 and significantly decreased the forces exerted on the service drop conductors.

Conclusion

The authors concluded that the fire was caused by an open neutral event that caused the failure of RPT devices, resulting in overheating. The open neutral event was created because a large tree caused catastrophic damage to a utility pole, exposing the home's service line neutral to excessively large forces. These excessively large forces acted upon a properly installed splice on the neutral, causing it to separate. The utility service provider properly spliced the service neutral in accordance with the manufacturer's specifications and industry standards. The utility pole was not installed with guy wires at the time of the tree fall. Guy wires would have reduced the forces exerted on the compression splices as a result of the tree fall.

Acknowledgements

Special thanks to the laboratory staff at LGI Forensic Engineering, P.C.

References

1. National Fire Protection Association, 921 Guide for Fire and Explosion Investigations, NFPA, Quincy, MA, USA, 2024.

2. M.F. Stringfellow, "Fire Hazard of Surge Suppressors," in Power Quality Conference Proceedings, September 1992, pp. 153-159.

3. Standard for Safety - Surge Protective Devices, UL 1449, Underwriters Laboratories, Inc., January 8, 2021.

4. Paul Traynham and Pat Bellew, "Using Thermally Protected MOVs in TVSS or Power Supply Applications," in Power Systems World, Intertec Exhibition Proceedings, September 2001.

5. C. Novak and B. Fukuda, "Open Neutrals-The Point of "No Return," Fire and Arson Investigator, vol. 64, no. 2, pp. 16-19, October, 2013.

6. S. Hamilton, PE, CFEI, "Is That Neutral Floating?" in International Symposium on Fire Investigation Science and Technology, 2016, pp. 69-78.

7. Burndy. "YSS4R, Single Aluminum Sleeve." Hubbell.com. https://www.hubbell.com/burndy/en/Products/Power-Utilities/Connectors/Splices/Compression/Aluminum/YSS4R-Single-Aluminum-Sleeve/p/1711273#prod-resources-section (accessed November 1, 2023).

8. National Electrical Safety Code, C2-1997, Institute of Electrical and Electronics Engineers, Inc., 1997.

9. Wood Poles: Specifications and Dimensions, ANSI O5.1-1992, American National Standard for Wood Utility Products, American Wood Protection Association, PO Box 36174, Birmingham, AL 35236.

10. Wood Handbook-Wood as an Engineering Material. General Technical Report FPL-GTR-282., U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, 2021, pp. 117-129.

11. W. Richard Lovelace, "Wood Pole Design Considerations," North American Wood Pole Council, No. 17-D-202, July 2019.

12. National Design Specifications Supplement: Design Values for Wood Construction, American Wood Council, Leesburg, VA, 2018.