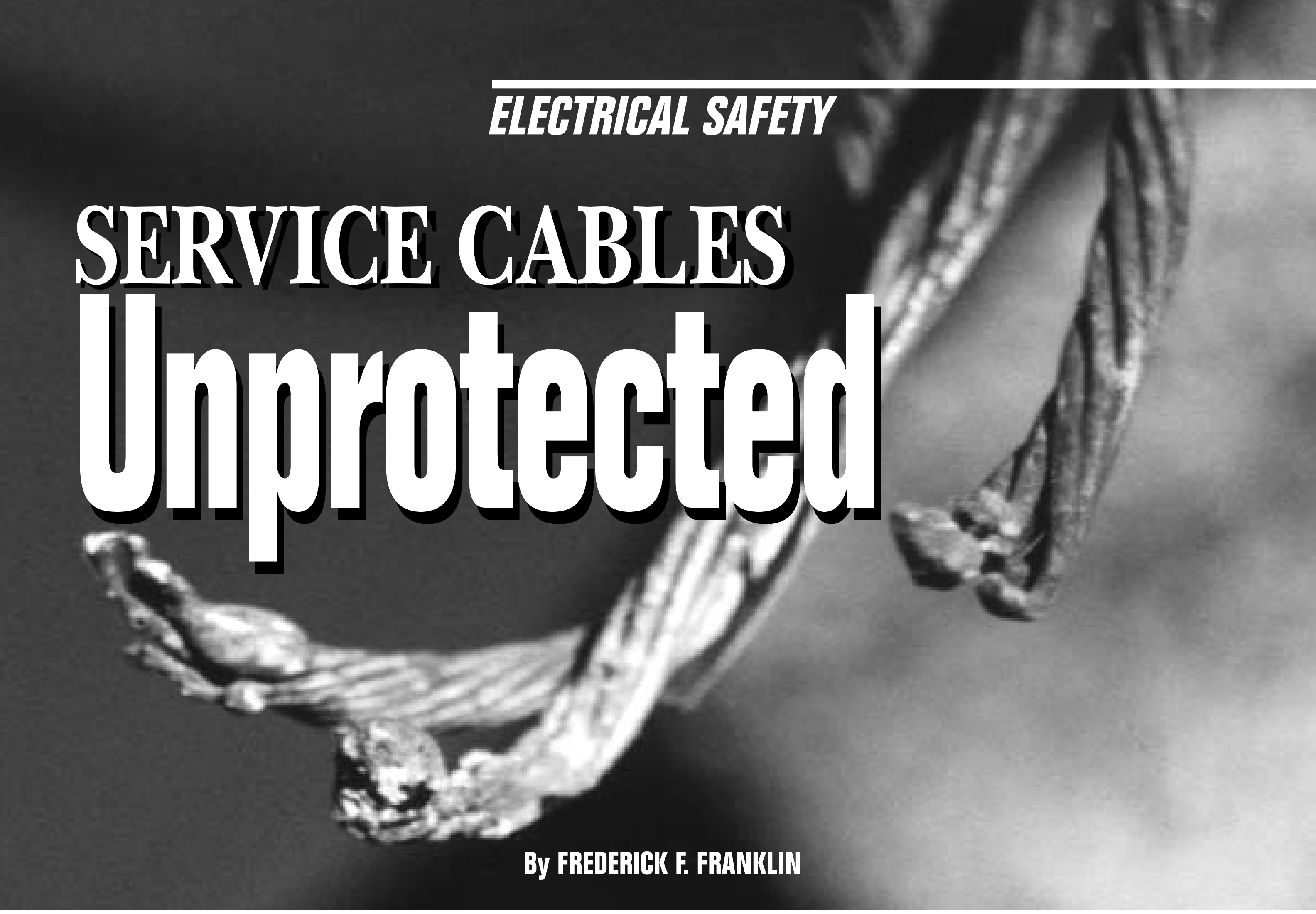

ELECTRICAL SAFETY

SERVICE CABLES Unprotected

By FREDERICK F. FRANKLIN

Electric utilities can prevent 5,500 fires each year by installing cable fuses in series with service cables connected to their transformers, the author says. Such installations would prevent 16 deaths, hundreds of injuries and $45 million in residential property loss each year.

According to National Fire Protection Assn. statistics, some 552,000 structure fires occurred in 1997 (Karter 76). In the author's opinion—and that of several other electrical experts polled—electrical arcing in service cables accounts for approximately one percent (or 5,500) of all building fires (Table 1). This arcing is similar to that seen in welding machines. When an arc occurs, its temperature surpasses 10,000°F, and the arc can spray out metallic globules onto nearby combustibles to cause fires.

Electric utilities can prevent 5,500 fires each year in the U.S. by installing readily available cable fuses in series with the service cables connected to their transformers. In the author's opinion, such installations would eventually prevent approximately 16 deaths, hundreds of injuries and $45 million in residential property loss each year. Industry can also benefit from the installation of cable fuses at transformers.

SERVICE CABLES & TRANSFORMERS

Service cables are the electrical conductors that bring power to houses from the utility transformers located on the street. According to the National Electrical Code, service cables consist of two elements: the service drop and service entrance conductors. The service drop is owned and installed by the utility company, while the service entrance conductor is owned and installed by the building owner.

Transformers reduce voltage provided by the electric utility from 7200 volts to 120/240 volts. (Power is delivered to transformers at 7200 volts because it is more economical and efficient.) Each transformer contains two electrical windings: 1) the 7200 volt input winding is the "primary" winding and 2) the 120/240 volt output winding is the "secondary" winding. Service cables are bolted to output terminals connected to the secondary winding.

Utilities provide a fuse for the primary winding, but none for the secondary winding. In the author's experience, this practice can lead to fires because it allows electrical short circuit arcing to occur in the service cables connected to the secondary winding. Fires can occur because service cables run alongside and/or through houses and other buildings; arcing can ignite nearby combustibles. Photo 1 depicts the roof of a house damaged by a service cable arc; the inset photo shows a closeup of service cable conductors melted apart by this arcing.

OPENING TIME COMPARISON

Fuses for secondary cables have been available for more than 30 years. Known as cable protectors or cable limiters, these

Opening the circuit quickly limits the arc's energy and, thus, greatly reduces the probability of a fire.

TABLE 1 Service Cable Arcing Fires
(Based on opinions of five forensic engineers)

	PERCENT OF ARCING FIRES	PERCENT OF ALL STRUCTURE FIRES
Author	5	1
Expert A	7.5	(1.5)*
Expert B	<5	<1
Expert C	1 to 2	(0.2-0.4)*
Expert D	<5	<1

*It is generally accepted that approximately 20 percent of all fires are due to arcing short circuits.

devices are useful because they open (pop) hundreds of times more quickly than a primary fuse does when a short circuit arc occurs in secondary cables. As soon as a fuse opens, the electrical circuit is disconnected and the arc is instantaneously extinguished. Opening the circuit quickly limits the arc's energy and, thus, greatly reduces the probability of a fire. The concept of opening an electrical circuit more quickly to prevent a fire when an arc occurs in the wiring was implemented in 1993 in circuit breakers for buildings and in vehicle fuses (Franklin 61; Franklin 63).

Tables 2 and 3 compare opening times in one brand of cable fuses for various lengths of service cable between transformer and arc. As Table 2 indicates, an arc between both hot conductors (phase to phase) in the 4/0 aluminum service cables for a 200 ampere residential service would take 30 seconds to open the primary fuse, if the arc occured in the service cables at a distance of 100 ft. from the utility transformer. As Table 3 indicates, a 200 ampere secondary cable fuse in the same situation would open in 0.025 seconds—which is more than 1,000 times faster.

If an arc occurs between a hot or phase conductor and the neutral or ground conductor at the same location, opening time is reduced from more than 1000 seconds to 0.09 seconds. Such arcs to ground often occur inside the circuit breaker panel between a hot conductor and the grounded metal case of the panel enclosure. The resulting arc can melt through the enclosure and spew melted steel onto nearby combustibles. Again, the main circuit breaker is *downstream* from the arc and cannot sense the arcing current in order to prevent a fire.

Primary fuses at the transformer are ineffective at preventing building fires because the internal impedances (resistances) of transformer windings and service cables reduce the current at the primary fuse to levels below that needed to open the fuse quickly. The same can be said for the impedance of the arc itself. However, secondary (service) cable fuses detect the arcing current directly and open so quickly that the arcing energy has no time to cause a fire. In addition, primary fuses must be sized at 250 percent of full-load primary current (amperes) so that nuisance outages do not occur. In contrast, cable fuses can be sized directly at secondary full load current.

Photo 1: The roof of a house damaged by a service cable arc. [Inset]: A closeup of service cable conductors melted apart by this arcing.

TABLE 2 Primary Fuse Opening Times in Seconds

Assume Arc Reduces Current 30%
Assume 2% Transformer Impedance

PRIMARY FUSE AMPS	XFMR KVA	SERVICE AMPS	CABLE SIZE	SECONDARY VOLTAGE	SERVICE CABLE LENGTH PHASE TO PHASE ARC 25'	50'	75'	100'	125'	150'	SERVICE CABLE LENGTH PHASE TO NEUTRAL ARC (OR GROUND) 25'	50'	75'	100'	125'	150'
20	50*	100	#2 Alum.	120/240	1	2	10	20	100	100+	100+ →					
20	50*	100	#1 Alum.	120/240	0.8	1.2	2	4	10	100	35	100+ →				
40	100*	200	#4/0 Alum.	120/240	4	6	15	30	60	80	400	1000+ →				
20	50*	200	250 MCM Alum.	120/240	0.3	0.8	1	1.3	1.7	2	6	20	100	100+ →		
40	100	400	500 MCM Copper	120/240	10	50	150	300	450	1000+	.6	.9	2	3	5	60
40	300	400	500 MCM Copper	277/480	0.5	.7	.9	1.0	1.4	1.7	.45	0.9	1.3	2	3	5
125	1000	1200	3 Each 500 MCM Copper Per Phase	277/480	1.5	4	9	35	100	1000+	200	350	500	1000+ →		

*Feeding multiple services.

TABLE 3 Cable Fuse Opening Times in Seconds

Assume Arc Reduces Current 30%
Assume 2% Transformer Impedance

XFMR KVA	SERVICE AMPS	CABLE SIZE	VOLTAGE	SERVICE CABLE LENGTH PHASE TO PHASE ARC 25'	50'	75'	100'	125'	150'	SERVICE CABLE LENGTH PHASE TO NEUTRAL ARC (OR GROUND) 25'	50'	75'	100'	125'	150'
50*	100	#2 Alum.	120/240	<.01	<.01	<.01	.013	0.2	0.3	<.01	.01	.04	0.2	0.4	0.9
50*	100	#1 Alum.	120/240	<.01	<.01	<.01	.01	.017	.025	<.01	.01	.035	.08	.22	0.6
100*	200	#4/0 Alum.	120/240	<.01	<.01	.014	.025	.05	.09	.01	.025	.09	0.2	0.6	1.2
50*	200	250 MCM Alum.	120/240	.04	.07	.11	.17	.25	0.4	.06	.15	0.4	0.8	1.8	3.5
100	400	500 MCM Copper	120/240	.03	.05	.09	.13	0.2	0.3	.045	.12	0.3	0.7	1.1	2.0
300	400	500 MCM Copper	277/480	.035	.04	.06	.07	.09	.12	.04	.07	0.1	.17	0.3	.35
1000	1200	3 Each 500 MCM Copper Per Phase	277/480	<.01	<.01	<.01	<.01	.01	.15	.035	.07	0.1	.17	.20	0.4

*Feeding multiple services.

COST VS. BENEFIT

The cost of the installation must be compared to potential benefits. When purchased in great quantity, the cost of fuses for the two hot conductors that carry 120/240 volts to each residence is $50 to $60. These fuses have a long life; once installed, they will last at least 100 years (Neeser). Spread over that timeframe, for two fuses, this equals $0.50 per year, per residence.

As noted, some 5,500 of all building fires each year (one percent of the total) are caused by service cable arcing (Table 1). According to NFPA, fires in residences account for $4.585 billion in property damage (Karter 79). In 1997, the U.S. Dept. of Commerce reported that there were 110 million residences throughout the U.S. This averages to $41.70 fire damage per residence each year for all types of fire damage. One percent of this total (attributed to service cable arcing) is $0.42 per year—compared to the $0.50 cost per residence per year to install cable fuses. One other note: Arcing is not just a problem in old wiring; new wiring can also arc if it has been damaged during installation (Franklin 26).

Industry requires more and larger cable fuses for its service cables—therefore, the cost is correspondingly higher. However, industry has a larger financial stake than just its buildings (which are usually more expensive than houses). Other concerns include business interruption costs, employee hardship and customer dissatisfaction. Table 4 offers comparative costs for industry. Each facility should calculate the risk and benefit of cable fuses for each electrical service. An electrical supply company can estimate the cost of cable fuses (one fuse is required for each hot conductor).

Human costs—in terms of injuries and fatalities—must also be considered. Consumer Product Safety Commission estimates that 320 deaths occur each year due to electrical fires in the U.S. (CPSC 1). Electrical arcing fires account for approximately 20 percent of all fires, with one percent per year—and 16 deaths—due to service cable arcing.

For each fatality, at least six fire-related injuries occur (Karter 76). If one postulates that a large corporation should be willing to pay $2.5 million for each life saved, and $100,000 for each burn injury prevented—costs typical in litigation today—this equals about $50 million each year or $0.45 per residence per year—close to the $0.50 cost per year of installing cable fuses at every residence.

TABLE 4 Comparative Costs for Industry

	NUMBER OF ESTABLISHMENTS*	1997 FIRE LOSS**	YEARLY LOSS PER ESTABLISHMENT	1 PERCENT OF YEARLY LOSS
Residences	109,457,000 (1995)	$4,585,000,000	$41.88	$0.42
Office Buildings	4,579,000 (1995)	$1,779,000,000	$388.51	$3.89
Manufacturing	382,000 (1992)	$723,000	$189.27	$1.89

*Statistical Abstract of the U.S. Washington, DC: U.S. Dept. of Commerce, 1997. **NFPA Journal, Sept./Oct. 1998.

INSTALLATION

Fuse installation is not difficult. One end is crimped onto the end of a service cable; the other end is bolted onto the secondary terminal of the utility transformer by utility installers. This puts the fuse in "series" with the service cable so that all electrical currents running through the cable are sensed by the fuse—including any arcing current that might occur.

UTILITY RESPONSE

To determine why electric utilities do not use cable fuses in the secondary circuits of transformers, the author spoke to the representative of one utility that uses cable fuses in a special situation—many parallel feeds located within a one-square-mile section at the center of a large city. The most important information gleaned from this discussion was the fact that cable fuses do not produce nuisance outages. This is key; if a fuse is too sensitive, it may open when it is not supposed to (e.g., during power surges, motor start-up currents), resulting in a nuisance service call to replace the fuse.

When asked why fuse use is not universal, the spokesperson cited cost. As mentioned, a utility owns only the portion of service cable up to the power meter, not beyond; therefore, the utility assumes no responsibility for a fire that originates in service cables beyond the power meter.

Although concerned homeowners could install cable fuses themselves at the power meter, such an installation would not protect those portions of service cables upstream—between the power meter and transformer. Service cables often attach at the roof of a house, then run down the side of the house to the power meter. If arcing should occur in this service drop, any cable fuses at the power meter would be downstream from the arc. Arcing currents would not circulate through these fuses and, consequently, would provide no protection.

In a publication reprinted by Seattle's Dept. of Lighting, one of its senior engineers states that utilities provided no protection in early distribution service because they expected that the arc would physically move the service cable conductors far enough apart to extinguish the arc (Anderson). This is termed "burn-off"; however, in the experience of forensic engineers, it does not prevent a fire in practice. This same engineer also notes that residences might benefit from "cable limiters" (Anderson).

CONCLUSION

Based on the information presented, electric utilities should be encouraged to install cable fuses in series with service cables at their transformers. Such a change is cost-effective and would prevent approximately 16 deaths, hundreds of injuries and $45 million in residential property loss each year. The savings to industry would also be significant. ■

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