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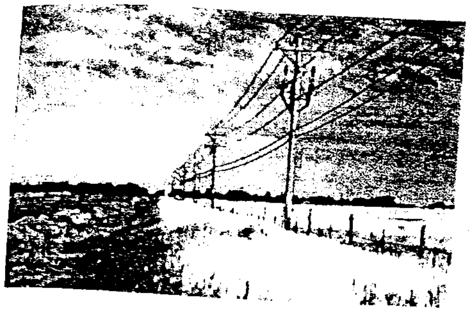

Allen Clapp's

DANESC Update™

Development and Application of the National Electrical Safety Code and related standards

Volume 10 Number 2

Newsletter for power, CATV, telephone and railroad utilities

In This Issue

There Is No Safeguard For A Wandering Mind:

PLAN YOUR WORK
and
WORK YOUR PLAN!

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From the Editor

The appropriate extent of pruning, frequency of pruning, and cost of vegetation management programs for overhead utility lines are all frequent sources of confusion and consternation for regulators and utilities alike. In addition, these matters are sometimes involved in civil or regulatory litigation. This issue starts our discussions of the real world of vegetation management around overhead lines. With reasonable care and planning, utility lines and trees can coexist and allow safe, reliable utility service at a reasonable cost.

Summer often brings with it unexplained outages. Many of these can be traced to a combination of local birds and wire spacing. In this issue, we show how even small birds can congregate on a utility wire and cause service interruptions—sometimes even causing extensive damage to wires over time. Span length and wire spacings are keys to having a reliable system.

Allen Clapp

Bulletin Board

Arc Flash energy calculations and selection of Cclothing systems to protect electric power and communication utility workers

The 2007 Edition of National Electrical Safety Code Rule 410A3 has given electric power and communication utilities until January 1, 2009 to evaluate the expected exposure to energy from electric arcs that might be expected should an arc occur during the various types of work required to be performed by utility workers. Among the considerations are the time required for system protective devices to operate, available fault currents, working distance from the arc, and clothing or clothing systems appropriate for each type of work.

Allen Clapp and John Dagenhart of Clapp Research Associates, P.C., (www.clappresearch.com) have joined with Hugh Hoagland and Don Bauman of E-Hazard (www.e-hazard.com) to produce a hands-on workshop to discuss the issues involved, explore the available software programs for arc energy calculations, show how boundary studies can be used to determine available energy at different work sites, and show how to select appropriate clothing systems for different exposures. The first public seminar presented by the Power & Communication Utility Training Center will be in Myrtle Beach, SC on October 22-25, 2007. In-house versions of this seminar are also available.

Practical design of grounding and bonding systems to meet NESC and system performance requirements

Recent problems and alleged problems with grounding telephone, CATV, and electric power system components and with bonding between these systems have indicated that some personnel are operating with the assumptions that some myths are, in fact, true. The result has been equipment and installation damage that could easily have been prevented by proper grounding and bonding.

John Dagenhart of Clapp Research Associates, P.C., (www.clappresearch.com) has joined with Jim Burke of Infrasource, Inc. (www.infrasourceinc.com) to produce a seminar to discuss NESC grounding and bonding requirements, characteristics of

(Continued on page 6)

Vegetation Management for Overhead Utility Lines: Part I – NESC Requirements and Practical Considerations

Part 1 reviews the history and intent of the National Electrical Safety Code (NESC) ANSI C2 requirements that apply to vegetation management around overhead utility lines and discusses practical considerations applicable to the design and implementation of an effective vegetation management program for overhead lines.

Part 2 (in the next issue) will discuss codes and standards applicable to work methods employed for managing vegetation around overhead utility lines.

Review of NESC Requirements

The NESC is the American National Standard for safe design, construction, operation and maintenance of electric supply and communication lines and equipment. It applies to both public and private power, telephone, CATV, railroad power and railroad signal utility systems.

The NESC rules pertaining to vegetation management around overhead lines are contained in Rule 218 (formerly Rule 281 in the 1987 and earlier editions). With the exception of the relatively recent changes that (a) added crossing requirements and (b) limited the application of the rule to ungrounded (i.e., energized) conductors, the rule remained relatively the same for almost 80 years through 2002, as shown below.

218. Tree Trimming (2002)

A. General

1. Trees that may interfere with ungrounded supply conductors should be trimmed or removed.

   NOTE: Normal tree growth, the combined movement of trees and conductors under adverse weather conditions, voltage, and sagging of conductors at elevated temperatures are among the factors to be considered in determining the extent of trimming required.

2. Where trimming or removal is not practical, the conductor should be separated from the tree with suitable materials or devices to avoid conductor damage by abrasion and grounding of the circuit through the tree.

B. At Line Crossings, Railroad Crossings, and Limited-Access Highway Crossings.

The crossing span and the adjoining span on each side of the crossing should be kept free from overhanging or decayed trees or limbs that otherwise might fall into the line.

As a result of recent questions, the title and language of Rule 218 were changed in 2007 to better reflect the long-time intentions of the rule. The 2007 changes are emphasized with red letters.

218. Vegetation Management (2007)

A. General

1. Vegetation that may damage ungrounded supply conductors should be pruned or removed. Vegetation management should be performed as experience has shown to be necessary.

   NOTE: Factors to consider in determining the extent of vegetation management required include, but are not limited to: line voltage class, species' growth rates and failure characteristics, right-of-way limitations, the vegetation's location in relation to the conductors, the potential combined movement of vegetation and conductors during routine winds, and sagging of conductors due to elevated temperatures or icing.

2. Where pruning or removal is not practical, the conductor should be separated from the tree with suitable materials or devices to avoid conductor damage by abrasion and grounding of the circuit through the tree.

B. At Line Crossings, Railroad Crossings and Limited-Access Highway Crossings.

The crossing span and the adjoining span on each side of the crossing should be kept free from over-hanging or decayed trees or limbs that otherwise might fall into the line.

There are three safety concerns and one additional reliability concern related to proximity of trees to overhead power line conductors: (a) damage to the conductor from arcing against a tree limb, (b) forest fires and grass fires, (c) injury to people climbing trees, and (d) outages caused by high-current contacts between conductors and trees.

Although the NESC rule was initially intended to primarily address (a) and (b), the resulting rule also promotes avoiding (c) and (d).

Rule 218 has been carefully crafted to reflect the practicalities that may affect vegetation management programs. Rules 218A1, 218A2, and 218B are *should* rules, not *shall* rules. With respect to the differences between *should* rules and *shall* rules, Rule 215 contains the following language.

015. Intent (emphasis added)

A. The word "shall" indicates provisions that are mandatory.

B. The word "should" indicates provisions that are normally and generally practical for the specified conditions. However, where the word "should" is used, it is recognized that, in certain instances, additional local conditions not specified herein may make these provisions impractical. When this occurs, the difference in conditions shall be appropriately recognized and Rule 012 shall be met.

The portion of Rule 012 that applies is Rule 012C, as follows.

012. General Rules

C. For all particulars not specified in these rules, construction and maintenance should be done in accordance with accepted good practice for the given local conditions known at the time by those responsible for the construction or maintenance of the communication or supply lines and equipment.

Discussion

There are a variety of reasons why it may not be practical to prune or remove all branches that may contact a power line. One major one is rights-of-way pruning limits of governmental authorities, such as city, county, or state departments of transportation. Another is that, once trimmed, the sucker growth on some tree species is much more unpredictable than for others. I.e., while most new sucker growth limbs will not grow beyond the trimming limits before the next trimming cycle, a few may do so.

Further, even though the natural pruning method is used to help direct future limb growth away from power lines, it does not always work or may take several cycles to produce the full redirection. In the meantime, an occasional fast-growing sucker may try to re-establish the original limb. See Figure 1-1.

Figure 1-1. Natural pruning method directs growth away from overhead lines

The only sure method of keeping limbs out of power lines is to cut the trees to the ground, but that method is not acceptable to society for wholesale application to all locations.

Probability of service interruption or fire due to tree contact

It is well known that many tree contacts with overhead power line conductors will not cause an outage, because of self-limitations on the amount of current that can flow through limbs. A study titled "Species-Specific Variation in Impedance as Related to Electrical Fault Potential" (by Environmental Consultants, Inc. of Stoughton, WI; dated 25 June 2004), hereafter referred to as the ECI study, clearly indicates the probability of an outage, or lack thereof, that would be expected to occur from tree limbs of various sizes and species bridging across two energized phase conductors or across a phase conductor and a neutral conductor. The study shows that the probability of an outage increases with the voltage across the tree and the size of the limb but decreases with the distance across which the voltage drop occurs.

The ECI study shows that, as the distance between the conductors contacted increases, the voltage gradient in kV/ft decreases and reduces the current flowing through the limb. Thus, as a practical matter, the ECI study overstates the expectations of outages due to tree contacts, since it is rare that a limb will bridge across two phases or a phase and a neutral—unless the tree itself has fallen into the line.

Where the issue is a tree growing into a line before the next trimming cycle, the typical path is only between one conductor at limb level and the ground at the base of the tree, a distance of four or more times those used in the ECI study. As a result of the longer distance and static voltage across the distance, the voltage drop per foot of tree length between the contact point and ground is usually too low to cause enough current to flow through the tree to trigger the operation of protective devices.

Further, most line contacts by tree growing into a line conductor will neither damage a conductor nor cause a fire. For example, when the top of a tree or sucker growth initially contacts an energized power line conductor with a leaf, the leaves on the end of the stem will generally wilt back without causing major arcing, damage to the conductor, or an interruption in service.

Although subsequent contact with the dried leaves may start a fire in a tree like that in Figure 1-2 if the leaves are dry, it is rare for such contact to cause a service interruption. Further, in the higher moisture areas of the United States, such as much of the Midwest through to the Atlantic Ocean and the coastal areas of Oregon and Washington, it is rare for a small treetop fire to result in a forest fire; such fires usually only occur in the more arid climates.

A lack of a significant local history of forest fires caused by trees contacting power lines is a good indicator that the trimming program in effect in the area has been effective from the fire standpoint.

Potential for injury to climbers in trees

While the upper limbs of the tree in Figure 1-2 are obviously not capable of supporting a climber, other trees are certainly strong enough to do so. A relatively few incidents have occurred where a person climbed a tree and contacted a power line close to the trunk of the tree. However, contact by the person in the tree is not required to produce significant injury.

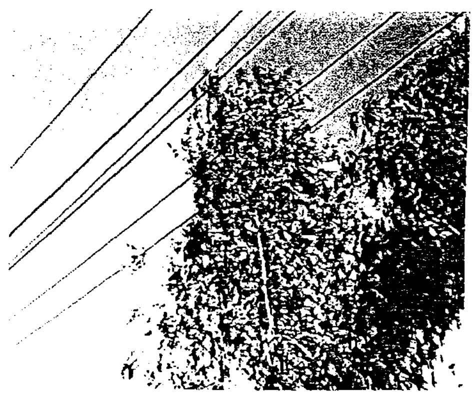

Figure 1-2 Tree ignited by power line contact

Although very rare, a few accidents have occurred with trees where the off-center weight of a person climbing at a lower level was enough to pull the tree over into the line; the subsequent current through the tree being shared by the parallel path of the person at the lower level was great enough through the person to produce permanent injury or death. Usually, the small diameter of the contacting limb has such a higher impedance (resistance) than the lower portion of the tree that most of the voltage drop occurs above the level of a climber in such a circumstance, and the climber is not injured.

If the only contact between the tree and the line is casual contact by leaves, there will not be enough current going down the tree to cause electrical injury. The leaf and supporting stem have too much impedance to allow enough current to flow down the tree to a climber location to cause injury. However, as the size of the contact limb goes up and the distance between the contact and the climber goes down, the voltage drop and current though the tree at the climber location will increase. As a result, with small limb contact, enough current may flow to produce a startle reaction that may cause the climber to lose balance and fall; at greater current levels, electrical injury or death can occur.

One of the reasons that such incidents are very rare is that the normal trimming programs of electric utilities keep the major limbs far enough away from the line conductors to limit the opportunity for such contact. In addition, many tree species are not easily climbable and do not present a significant climbing concern for vegetation management programs. Further, many species that can be climbed are located in an area where climbing is unlikely. As a result, while the climbing issue is of general concern, it rarely affects tree trimming requirements, particularly where the program recognizes such concerns in its trimming distances or cycle times.

A lack of a significant history of contact with power lines by persons climbing trees is a good indicator that the trimming program in effect has been effective from the climbing standpoint. Most instances of electrical injury to tree climbers results from adults using aluminum pool skimmer poles or similar extended reach devices to harvest nuts or cones without watching where they were waving the device and are not related to any lack of appropriate trimming of the tree around the line conductors.

Potential for conductor damage from tree contact

The current that flows through a tree limb contact is a function of the resistance of the limb and tree. This varies with tree species and with time of year. Generally, not enough current can flow through a small limb to cause either an outage or significant conductor damage. However, with repeated contact with major tree limbs, conductors can be damaged enough to be severed, either at the time of the contact or later under the increased tension that results from colder temperatures or ice loading. This is why NESC Rule 218A2 requires the use of an insulating tree guard over the conductor in cases where the tree cannot be pruned (such as in a historic district where pruning is limited by ordinance).

Such guards are rarely needed, because normal tree pruning distances and cycle times limit the likelihood and size of any growth that could be large enough to contact a conductor between trimmings. As a result, conductor damage is not typically expected from contact by new-growth leaves or even small limbs that grow or blow into casual contact with an energized power line phase conductor.

As a practical matter, since new leaves will be wilted back as they near an energized conductor, limbs cannot grow out or up into a line conductor, but limbs can grow beside the conductor and contact the line later during storms or ice loading. In addition, if there are significant changes in sag during the year, leaves that grow into a conductor and are wilted back early in the growth season may be contacted on later, warmer days when conductor temperatures increase the sag in the conductor.

Reliability and safety issues

Contact by leaves or small limbs is rarely a reliability issue, as evidenced by the ECI study and for the reasons discussed above. So long as such contact does not cause a fire in dry leaves and either (a) the tree is not one expected to have a climber in it or (b) if the contact would only be during storm winds, when climbers are not expected, such contact by leaves or small limbs are not expected to present a hazard to either the public or the structural integrity of the conductors.

The climate at the site and the species of trees will affect both the expected growth rate of the trees and the likelihood that a contact will cause an outage or fire.

Spacer cable and tree wire

It is sometimes argued that the use of so-called covered conductor (see NESC Rule 230D), particularly heavy-walled tree wire or spacer cable, will solve all tree-related problems. While such conductor or cable may be useful under certain limited circumstances, history shows that it cannot be depended upon for personal safety. Even if the covering is tested at the factory and found to be continuous, the covering may exhibit pinholes or broken slits after installation, due to handling and tension. Even if the covering initially remains complete, it deteriorates over time and will eventually decrease its effectiveness.

Heavy-walled tree wire has appropriate mechanical strength to resist abrasion due to tree contact, unlike weatherproof wire that has a thinner covering used only to limit damage from exposure to atmospheric contaminants. Spacer cable is essentially heavy-wall tree wire with spacers to limit the opportunity for the conductors to contact each other and to allow lesser clearances between the wires than would be appropriate for tree wire.

Thus tree wire or spacer cable is sometimes used to limit damage to conductors that are expected to have tree contact (such as in historical areas where pruning is prohibited or limited). Tree wire, weatherproof wire, and spacer cable all have bare conductor at connections and their coverings all deteriorate over time.

Neither tree wire, weatherproof wire, nor spacer cable can be expected to prevent injury to personnel who come in contact with it. As a result, it is not appropriate for use in or very near to trees that are expected to be climbed.

Spacer cable is sometimes used in areas with high frequencies of ice loading that cause trees to bring down power lines. A plus for reliability is that the cables will often remain energized even when on the ground, thus continuing services to homes to run heaters, furnace fans, lights, etc., during the aftermath of an ice storm.

However, the very thing that increases reliability after an ice storm decreases potential safety, since the areas of exposed conductor at contact points may be exposed to homeowners and other personnel cleaning up debris after the storm. Deaths have occurred due to contact with exposed conductors at connection points or areas in midspan where the covering was damaged when the line came down.

Statutory requirements

Most states have statutes that require utilities to promote adequate, reliable and economical utility service to all of the citizens and residents of the State and to provide just and reasonable rates and charges for public utility services without unjust discrimination, undue preferences or advantages. To that end, utilities adopt standardized construction and maintenance systems applicable to particular conditions and select the appropriate construction and maintenance based upon the given local conditions.

Successful vegetation management

A well-designed and well-administered vegetation management program will evaluate the expected growth rates of the species of trees normally encountered in an area of interest, including consideration of the climate or microclimate, and establish trimming distances and cycle schedules that limit the opportunity for tree contact with lines before the next trimming cycle. For example, both the species and the environmental effects of temperature and moisture will differ between a mountain service district and a coastal service district for the same utility and will, therefore, affect the trimming distance, cycle time, or both. Such a program will limit the likelihood of such species causing a reliability or safety problem, and will do so in an economical manner. Typically a consistent cycle that is funded consistently and includes appropriate hazard assessment will produce the most appropriate results from the standpoint of safety, reliabililty and economy.

Although NESC Rule 218A1 was revised in the 1984 Edition by inserting the word *ungrounded* before *conductors* to recognize that fire damage and conductor damage do not occur from tree contact with a neutral, structural damage and reduced clearances can occur if ice or snow loading on tree limbs growing through cables or above the neutral force the supported facilities down and the increased tension on structures damages the attachments or makes the structures lean. As a result, in some areas, good practice (see Rule 012C) requires consideration of the effect of such loading and will increase pruning to the lower levels. However, minor contact by small limbs that grow into or above a neutral or cable between pruning cycles will not have the strength or size to exert significant pressure on such facilities under ice loading and would, thus, not interfere with them.

Typical vegetation management programs around distribution lines will limit overhanging limbs and cut side limbs and limbs below the line conductors to such distances that the only contact expected between trees and power lines is if (a) a tree comes down across the line in a storm or (b) abnormal new growth reaches up or out to the line before the next trimming cycle. The first is rarely preventable by the utility. As discussed above, the second is (a) rarely either a reliability or a safety problem and (b) often so unpredictable as to be impractical to catch before before contact occurs.

It should be recognized by all personnel concerned with vegetation management that there is no sure, 100% reliable method of vegetation management that will prevent all contacts by trees with overhead power lines short of (a) cutting trees to the ground and (b) clearing to the side a distance equal to the height of the adjacent trees. This is not acceptable to the public from an aesthetic standpoint and is not acceptable to ratepayers from a cost standpoint. In order to appropriately address the requirements of the public for safe, reliable, and economical utility service, as well as the aesthetic considerations, all of these interests must be balanced.

Conclusions

1. It is not practical to prevent all contacts between trees and overhead power line conductors. This fact is intentionally recognized by the National Electrical Safety Code in Rule 218.
2. Contact by leaves or small limbs with energized overhead power line conductors does not produce enough conductor heating to significantly damage the strength of the conductors.
3. Contact by leaves or small limbs with energized overhead power line conductors does not produce enough current to operate line protection devices and interrupt the reliability of the line.
4. Contact by green leaves or small limbs with energized overhead power line conductors would not be expected to ignite a fire in the tree. However, if the leaves are dry, such as with subsequent contacts or during the fall of the year, a fire can result from such contact. Contacts by leaves or small limbs during rain storms are not expected to produce a fire.
5. Contact by leaves or twigs with energized overhead power line conductors would not be expected to produce enough current through the tree to electrically injure a tree climber.

6. Contact by small tree limbs with energized overhead power line conductors may produce enough current through the tree to cause a startle reaction in a tree climber and cause the climber to fall. As the size of the tree limb involved in the contact increases, so does the current through the tree and through the parallel path of the climber, thus increasing the possibility of electrical injury to the climber.

7. Not all species of trees are easily climbable and many locations have little expectation of climbing. Further, most vegetation management program specifications of trimming distances and cycle periods are sufficient to limit the likelihood of injury of a climber.

8. It is not possible, much less practical, to prevent all contacts between trees and overhead power line conductors. However, it is practical to recognize growth habits of the local vegetation species and climates and to design and implement an effective vegetation management program that will limit the likelihood of vegetation contact to a level that (a) presents little effect on system reliability or conductor strength and (b) does not present a significant fire or personal safety hazard.

9. The requirements for a utility to provide safe, reliable and economical utility service require consideration of all of the competing interests, including the willingness of the public to accept the extreme measures necessary to completely achieve any of these interests. Thus, it is not practical to maximize all of these interests.

10. When history indicates that (a) the level of outages due to tree contacts with power lines related to growth of trees between cutting cycles is low, (b) no significant history of forest fires caused by tree contacts with power lines exists, and (c) no significant history of tree climbers personally contacting energized line conductors without the use of reach-extending devices exists, it can be reasonably assumed that the vegetation management program of the utility involved is working appropriately.

Additional Information

The following documents assist in understanding the safety considerations and practical aspects of requirements of the National Electrical Safety Code and other standards and governmental requirements related to vegetation management around overhead utility lines.

A. "Safety Considerations of Aerial Systems Using Insulated and Covered Wire and Cable" presented at the IEEE T&D Expo, Los Angeles, September 1996

B. Chapter 11 (same title as Reference 1 and based on that paper) in Practical Utility Safety (available from www.utilitybookstore.com)

C. "Design and Application of Aerial Systems Using Insulated and Covered Wire and Cable" delivered at the same IEEE T&D Expo as Reference 1

D. Chapter 10 of Practical Utility Safety with the same title as Reference 3 and based upon that paper

E. Chapter 25 of Practical Utility Safety: titled "Balancing Tree Trimming Requirements vs. Municipal Tree Removal Standards"

F. "The Safety Effects of Municipal Line Clearance and Tree Removal Standards" DANESC UPDATE Vol 4 No 4

G. "NESC Rule 218 on Tree Trimming" DANESC UPDATE Vol 5 No 2

H. Chapter 23 of Practical Utility Safety titled "Calculating Widths of Rights-of-Way"

Bulletin Board cont.

(continued from page 1)

requirements, characteristics of different kinds of distribution systems, characteristics of ground faults, the fallacy of the 40-ohm number often used in fault current studies, stray voltage problems, overvoltage issues, and more. The first public seminar presented by the Power & Communication Utility Training Center will be in Myrtle Beach, SC on December 4-6, 2007. In-house versions of this seminar are also available.

Advanced seminar on utility contact accidents

The existing seminar *Utility Contact Accidents I: Investigating & Litigating Public & Worker Accidents* has been renamed and revised. It will continue to be offered in May and September in Myrtle Beach, SC. That seminar focuses on investigating utility contact accidents and presenting technical information to a jury.

A new, advanced seminar *Utility Contact Accidents II: Advanced Topics—Analyzing and Litigating OSHA Citations & Civil Actions* has been added to the mix and will be presented by the Power & Communication Utility Training Center on July 15-17, 2008 in Myrtle Beach, SC. The new UCA II seminar uses case studies to emphasize the use of OSHA's "Employee Misconduct" defense criteria and "multiemployer work site citation policy" to determine responsibility for any worker-related accident. The intent is to help investigators and litigators understand how to better analyze an accident to determine the responsibilities of various parties and how to present that information effectively. These discussions and tactics are useful regardless of whether the incident involves only your worker(s) and OSHA or it involves employees of other parties.

Nuisance Trips From Birds on Wires

In recent years, the number of unexplained outages and momentary interruptions has increased in both rural and urban settings, particularly on longer spans of smaller conductors.

In many cases, the cause has eventually been traced to the weight and dynamic loading of birds that congregate on overhead power lines during certain parts of the year.

Congregations of birds on wires

It is quite usual for certain species of birds to congregate on overhead lines during seasons—and especially in the hours of late afternoon and early evening before roosting for the night. Typically, most of the birds will congregate on one wire—usually whichever was highest before the birds weighed it down. See Figure 2-1.

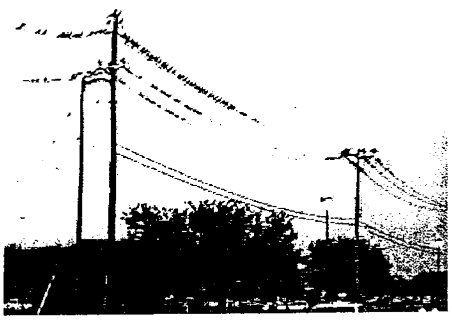

Figure 2-1. Birds on Lines

Because flesh will begin to cook above 130° F, birds rarely congregate on conductors with high electrical loads in the summer. However, in cooler seasons, birds sometimes welcome the extra heat from conductors with high line losses.

Mechanism of contact

Most of the birds tend to face into the afternoon breeze. Sometimes a few birds will face the other way acting as sentinels. Note that all of the birds in Figure 2-2 face the sunset.

Generally when birds start to fly, they attempt to leap up into the air far enough to beat their wings without hitting the ground. When birds on a line are startled, they all attempt to fly off the line at the same time, generally pushing the conductor down and to the rear of the majority of birds (much like skiers pushing off the hill with ski poles).

If (a) enough birds are on the center wire to sag it down between the crossarm phases, (b) the wire is small enough, and (c) the span is long enough, the forces from birds leaping off the wire can cause the center wire to be displaced down and laterally into a crossarm phase before it retracts to its unloaded condition, thus causing an arc.

In some cases, the bird-weight problem is severe enough that faults on vertical construction have occurred due to the weight of birds on an upper conductor sagging the wire down into a lower conductor.

The result is usually only a momentary blink the first time it occurs. However, as the conductor gets chewed up over time, the likelihood of the two conductors snagging long enough to cause an outage increases, as does the likelihood of eventually damaging the conductor enough for it to part and fall—either at the time of last contact or under ice loading.

Bird weight, length and wingspan

Table 2-1 shows the length, wingspan and weight for six varieties of birds known to congregate on overhead lines during some portion of the year. The size ranges from the relatively light Field Sparrow through the middle range of the Redwing Blackbird, European Starling, and Mourning Dove to the larger American Crow and Common Raven.

In addition, Table 2-1 shows the pounds per lineal foot of conductor that would be added by each bird if the birds spaced themselves by a distance of (a) their own length or (b) their own wingspan. This data was used to produce Tables 2-2 and 2-3.

Increased span loading due to birds

The total loading on a span of conductor depends upon both the spacing of the birds and the length of the conductor covered by the birds.

During certain times of the day and year, birds are quite social. It is typical for congregating birds to space themselves very close together on an overhead conductor—often at a spacing equal to their foot-to-head length, which is shorter than their total length—even if there is room on the conductor to spread out. See Figure 2-2.

In some cases, birds will congregate only near the structures, as in Figure 2-1. If so, the rigid spacing

Table 2-1. Weights of Common Birds that Congregate on Wires

Bird Name	Length Range (in)	Length Average (in)	Wingspan Range (in)	Wingspan Average (in)	Weight per bird Range ounces	Weight per bird Range pounds	Pounds per foot Average (lb)	Pounds per foot at Length Spacing	Pounds per foot at Wingspan Spacing
Field Sparrow	5 - 6	5.5	8 - 8.5	8.25	0.39 - 0.53	0.024 - 0.033	0.029	0.063	0.042
Redwing Blackbird	7 - 9	8.0	12 - 16	14	1.13 - 2.72	0.071 - 0.170	0.121	0.182	0.104
European Starling	8 - 9	8.5 i	12 - 16	14	2.12 - 3.39	0.133 - 0.212	0.173	0.244	0.148
Mourning Dove	9 - 13	11	15 - 18	16.5	3.04 - 6.00	0.190 - 0.375	0.283	0.309	0.206
American Crow	16 - 21	18.5	33 - 39	36	11.15 - 21.89	0.697 - 1.368	1.033	0.670	0.344
Common Raven	22 - 27	24.5	44 - 56	50	24.32 - 57.36	1.520 - 3.585	2.553	1.250	0.613