PRIORITY TRIMMING TO IMPROVE RELIABILITY

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Abstract

At BGE, changes in vegetation management practices were required to improve upon system reliability. Due to resource limitations, a systematic approach to vegetation management was implemented. Vegetation management activities were prioritized by voltage class and construction type. Concurrent with this process, actual impacts to service reliability from tree/wire contacts were investigated through controlled testing. With some modification, the testing validated the systematic management approach. As a result, a foundation has been formed for a flexible vegetation management program that factors in tree health, customer concerns and tree/outage relationships in its implementation.

Background

The Baltimore Gas and Electric Company (BGE) is an investor owned utility that serves over 1.1 million customers in the largely metropolitan Central Maryland Region. Over 9,000 miles of distribution lines are situated in a region where elevations range from sea level in the Atlantic Coastal Plain to almost 800 feet in the gently rolling hills of the Piedmont Plateau. The forest cover type is diverse, with many fast-growing species that, when combined with an average rainfall of 43 inches per year and up to 232 growing days , create challenging conditions for a vegetation manager.

At BGE, considerable amounts of operation and maintenance dollars are spent each year in managing vegetation as part of the process to provide reliable electric service to our customers. In the United States alone, almost 2 billion dollars are consumed each year by utilities on vegetation management activities. With this back-drop, there is one striking fact that is entirely incredible. Since the time that trees and wires have conflicted, no one to our knowledge has performed any significant research on the effects of trees on service reliability, or simply put--how trees cause outages.

In the early 1980's, we at BGE began to realize that many of the electric service interruptions attributed to trees were inconsistent with follow-up observations of the actual incidents. In many instances it did not appear that trees were responsible for outages attributed to them, or they were responsible in different ways than reported by field personnel. As a result of these observations, a seven year field study was conducted in one of our operating districts that investigated over 3,000 outages associated with trees.

During the course of this investigation, budgeting constraints required formulation of a different approach to our business. Rather than trying to trim the entire distribution system somewhat unsuccessfully, we decided to direct our limited resources where they could provide the greatest benefit to the greatest number of customers. This is not a new concept. Previously, we did not have a systematic vegetation management approach to the subtransmission system, and in the distribution program, single phase lines that only served a few customers were given equal priority to 3-phase mains that served as arteries to the feeder system.

A prioritization scheme was devised. First, a plan was developed to gain control of the 34.5 kV subtransmission system through a biannual inspection program. The purpose of this effort was to achieve reliability approaching that of our transmission system--0 outages due to trees. In conjunction with the subtransmission plan, a 3-phase-only plan was incorporated for the distribution system. The goal was to have all of the 3-phase system on a three year cycle within a 3 year period. The one and 2-phase systems were delegated to a "trim only as necessary" status. In theory, the improved condition of the subtransmission and 3-phase distribution systems would allow for more rapid maintainance in subsequent cycles. As a result, more time could eventually be devoted to the one and 2-phase systems.

Investigation

In the meantime, the on-going field investigations revealed some interesting observations that when analyzed, indicated that the prioritization plan was a good approach. A key concept was identified in the process that was consistent among the 3,000 tree-related outages. Formation of a carbon path in or on the wood seemed to be required before the wood could carry fault current. Other valuable information was compiled. Of all sustained outages attributed to trees, which comprise about 20% of our system outages, 75% were caused by dead shorts--where a good path to ground or a second phase, across a limited distance, existed over a sustained period of time. A limb across two or more conductors would be a good example. Further, 23% of the outages were caused by mechanical damage where actual physical damage was the cause, and 2% were labeled as incidental contact--a non-verifiable catch all category that assumed a problem such as temporary contacts by burning branch tips. Temporarily ignoring the 1 and 2-phase systems seemed to be a least-risk approach since natural growth beneath the lines did not appear to be a significant contributor to outages, especially where cross-arm construction was not a factor.

Based on these observations, and with apologies to Isaac Newton, we developed Birx's Law of Gravity. "What grows up must come down". In essence, 98% of sustained system tree outages appeared to be the result of trees or tree parts falling or leaning onto lines. These contacts could be quick and destructive, or they could be the result of more sublime associations such as a branch laying across multiple phases or a sapling leaning against a phase and neutral wire. Less than 2% of the outages may be attributed to natural growth or burning branch tips beneath the lines, vectors that have historically and conventionally been associated with a significant contribution to both sustained and momentary service interruptions

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Testing

The results were intriguing although somewhat controversial. Naturally, we wanted to determine if the field observations would stand-up to testing under controlled conditions. This measure necessitated involvement of engineering personnel with technical capabilities associated with electric system operation. So a partnership with two engineering supervisors and their respective organizations was developed. An abandoned 13.2 kV distribution tap that was seven pole spans long was selected for the test. The vegetation had grown up through and around the three conductors along the entire length. The growth was so profuse that the conductors were actually pushed out of normal alignment--something that would not typically occur if the lines were energized and the branches were burnt clear. The ultimate goal of this test was to try to develop some correlation between the amount of tree contact and current and voltage readings. Meters were installed on the lines for this purpose. When the lines were energized, not only did the fuses not operate, but the instruments did not record any measurable variation in the voltage or current.

In the absence of metered data, it was decided to attach a rope to a tree and pull it into contact with a phase and neutral wire. Within minutes, burning started to occur at the two contact points. After a period of about 14 minutes a carbon path had developed along 75% of the length of the tree between the two points. No outage occurred and more importantly, again no significant readings were obtained from the instruments.

Finally, a piece of freshly cut aspen was placed across two phases. Within one minute and twenty seconds, a carbon path had developed almost the entire length of the limb and fault current was generated, operating the in-line fuse. Just prior to fault current, readings of up to 4 amps were recorded.

The most important information gained in this test validating the field observations, was that a carbon path did indeed need to be present in order for a tree or tree part to conduct fault current. The requirements are simple. A small amount of current passes through moisture in the wood. In the process, the moisture heats-up and is driven from the wood, usually in streams of water and as steam. As the moisture disappears, the wood begins to carbonize. As the carbon path develops to a point of near completion, along a limb for instance, an avenue for the fault current to travel is provided. We call this the “carbon path theory”. This phenomena has not been observed for distances greater than 10 to 15 feet in our distribution testing or in the field. Trees appear to have too much inherent resistance to conduct electricity over distances that would be typical of phase to soil contacts.

The question that remained unanswered was how much current would a typical tree conduct. If this information could be obtained, perhaps the data could be extrapolated to determine the cumulative impacts from trees on system reliability for either sustained or momentary interruptions.

A second test was constructed on another abandoned distribution tap. In this instance, the line was cleared so that no trees or branches were in contact with the phase or neutral wires. The design called for a sequence of test iterations with test equipment that was significantly more sensitive than in the first series of tests. Each iteration was designed to measure or calculate the amount of current experienced at ground level for one tree under constant, tensioned contact with the 7.6 kV line. A variety of species were used over the seven iterations. Two of the iterations were performed under a constant spray of water that thoroughly saturated the trees and overhead facilities. As in the first set of tests, the time of year was mid-spring.

While it was difficult to obtain consistent and reliable measured ampere readings from the trees, calculated results were obtained by two different methods. The first was through measured touch potential and tree resistance readings. The second utilized measured line and transformer excitation currents. The calculated amperages ranged from .006 to .041 amps. Although no significant difference was detected between the same species when tested with and without the spray stream, current readings for wet or wetted wood trended lower than the dry control specimens, and seemed to favor conditions that would delay the onset of carbon path development.

This second series of tests seemed to validate what appeared obvious from the first test experience. It would probably require hundreds, perhaps even thousands of trees that are in the ground and in constant contact with the overhead wires to potentially cause sustained or momentary service interruptions. Due to branch tip burning, it is highly unlikely that this type of constant contact could occur. The carbon path theory seemed to hold-up as well. It is important to note that these tests were performed within proximity of substations and reclosers with high potential fault currents, and that no momentary outages were recorded at those locations. It should be further noted that the overhead aluminum wires used in these tests were not damaged by the tree contacts.

A third and final test was conducted in a controlled test facility. Phase to phase contacts were tested with different limb diameters, and with a variety of tree species, utilizing both live and dead specimens. Distances between phases were varied during the test process. The test iterations were performed one branch at a time utilizing highly sensitive equipment.

Results

The results supported the conclusions derived from the earlier testing. Additional conclusions were drawn as well. Tree species with higher moisture contents seemed to require a longer period of time before carbon path creation. And, distance between phases and not the branch diameter seemed to affect the carbon formation.

The summation of all the testing has indicated that a carbon path must form before fault current can be conducted. And, moisture must be present initially in the carbon path development process, but must be eliminated before carbon formation can occur. Testing has also indicated that the distances typical of incidental branch or tree phase-to-soil contacts contain too much inherent resistance to allow carbon path formation. From this information and from field experience, the likelihood of carbon path formation decreases substantially as distance increases. This rate of decrease seems to increase rapidly beyond the 8 to 10 feet normally associated with phase to neutral separation. We can further surmise that outages due to trees are more likely to occur where multiple lines exist--most notably with cross-arm or armless constructed facilities. Pole-top-pin lines create significantly fewer opportunities for tree-related problems. It should be noted in the midst of these observations, that conclusions from our testing are only valid for lines that carry 13.2 kV or lower.

Discussion

A note on trees and momentary faults. This is more of an hypothesis based upon all of the data and not from direct observation. As mentioned previously, hundreds or even thousands of trees in the ground touching an energized wire do not appear to be associated with momentary faults. There are two likely causes where trees are concerned. The first, is from branches above multiple phases that when wet, lie across the phases and eventually form a carbon path that conducts fault current. The intense heat from the fault current will dry the branch or branches causing them to lift above the lines. If a recloser or station breaker is on-line, the fault should clear and become transient. As the branches get wet once again during the same storm or in subsequent storms, they will drop back down onto the wires with the previously formed carbon path and cause additional momentary faults. The second connection to a momentary fault is much simpler. Trees adjacent to multiple phases that knock the phases together during periods of high wind.

The significance of this information has impacted BGE in a number of ways. The test data have been utilized to tailor a program that is somewhat unique, and I might add, in a state of continual transition by design. Since the field observations and test results indicated that the single phase system is generally less vulnerable than the rest of the system, we elected to continue a form of the 3 phase versus 1 and two phase program. The new, modified version creates a dichotomy between cross-arm or armless construction and pole-top-pin constructed facilities. The change is not substantial. Now, all 2-phase lines and single phase lines with a neutral on a crossarm are given the same priority status as 3-phase lines.

As I mentioned earlier, BGE is largely a metropolitan utility. We do not typically have “right-of-way” on our distribution system to perform corridor clearing. Instead, we obtain the maximum clearances possible consistent with the intent to maximize service reliability, and balanced by adherence to regulatory requirements and the desire to enhance customer satisfaction.

We know that multiple phase lines and equipment are more prone to outages since they act as collectors of debris from above and have relatively short paths to ground, or close phase-to-phase associations. Wherever possible, we strive to remove as many overhangs above equipment and crossarm or armless constructed facilities. In most cases, this approach is species dependent and is phased-in over a number of trimming cycles to minimize adverse health effects to the trees. For pole-top-pin facilities, overhangs are targeted only where imminent hazards exist.

Hazard or danger trees adjacent to the facilities are candidates for removal if a risk to the facilities is presumed. This approach applies to all types of primary voltage construction. Trees in this category can be severely destructive to our facilities, are costly, and usually result in longer outages for our customers.

Natural growth beneath the lines is trimmed routinely for crossarm or armless facilities. If left untended, natural growth can escape through the phases, branch-out, and form potential cross-phase hazards. For pole-top-pin construction, the focus is on utilizing the tree's natural growth form to train the limbs past the wires. The ultimate goal is to form canopies over the facilities. This approach will eventually suppress sprout growth within the tree's interior, or inhibit regeneration from the forest floor. The interlocking canopy will also help protect the lines from catastrophic ice or wind storm damage.

Where off-cycle or hot spot trimming work is concerned, we focus on looking specifically for the tree or trees that may be causing service interruptions instead of trimming an entire tap. A car analogy is appropriate. If an engine is not working, why replace the entire engine when replacing the distributor cap will suffice. This approach is most appropriate when faced with limited budgets. With tight budget parameters, efficient, incisive trimming techniques will minimize valuable time away from routine maintenance trimming. It is important to note that we are not advocating that trees or branches should remain in constant contact with the overhead wires. That is not our intent. Sufficient clearances are helpful to buffer tree conditions that could become critical. A sapling leaning against phase and neutral wires is a good example. We also want to provide adequate clearances to minimize the likelihood of incidental contact by the public.

An important component of our vegetation management program is a thorough understanding of how trees cause outages and the utilization of this information through continual inspection of the overhead facilities. Not only do we prioritize the work based upon the tree conditions associated with various construction types and voltages, but we also look for other contributory causes to service interruptions. Faulty lightning arrestors, cracked insulators and deficient wildlife protection on equipment are but a few. Most importantly, we try to factor our customer's concerns into the program. We are improving in this area, but need to go further. We can never lose sight of why trees are trimmed--to maintain or improve upon service reliability. Although we are vegetation managers at one level, ultimately, we prefer to consider ourselves as outage reducers. The task is enormous, but the entire outage reduction equation is best solved by a partnership between forestry, system operation, construction and design personnel

Conclusion

At BGE we had a problem that needed to be solved. A vegetation management program that did not provide a consistent contribution toward service reliability. We needed to prioritize the work to obtain maximum value from our efforts. Concurrently, we noticed from field observations that trees did not appear to cause outages as traditionally perceived. Subsequent controlled electrical testing supported the field observations that trees do cause outages, but under very specific circumstances. Accordingly, we have utilized the test results to temper our prioritization approach to trimming which has created a technique-intensive, flexible vegetation management program. Our program is not fully implemented throughout the service territory at this time. We still need to make substantial inroads into the single phase system. Nonetheless, we are optimistic and even excited about the prospects.

What does all of this mean to other utility vegetation managers? Not much to some. Perhaps portions of our program may have relevance to other utilities with similar circumstances. In any event, and at the very least, I believe that further testing of how trees cause outages is in order. Is what we have found at BGE valid? Can even more useful information be found? I believe the industry would benefit from a collaborative effort to fund an expanded, more thorough analysis of the interaction between trees and wires.

In the customer and environmentally sensitive business in which we operate, knowing how trees cause outages is a very valuable asset, even beyond the practical field applications. Many times, we in the industry are seen as adversaries by our customers with disconnected interests. We are viewed as the people who want to clear as much as possible for as long as possible. This shouldn't be so. When we propose to a customer or regulator that we need to minimize the trimming around single phase facilities and tell them why, they may begin to realize that there is some rhyme to our reason. The program is not a one-size-fits-all solution. We stand to gain a measure of credibility as a result. If you can educate your customers proactively, not only about how you plan to manage the vegetation, but why you need to do so, you can allow them to intelligently participate in the management process. We will all win as a result.

Can what we learned at BGE benefit your company--you decide.

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