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Twenty Things to Remember About Distribution Reliability

Almost 10 years ago, I put together a list called Ten Things to Know about Reliability and presented it at an EEI customer operations executive workshop. Many of those same insights are still valid, such as my old push to protect the backbone. Here is an expanded list that reflects what is still true and what else we have learned since then:

1. An underground secondary network is the most reliable form of distribution with a low frequency of interruption (but it has the capability of cascading into a complete network shutdown once every 10 years or so if the network is run at close to capacity).
2. The second most reliable distribution architecture is a well-sectionalized set of feeders, with backfeed from multiple sources with the capacity to do so. This is a key feature of the distribution automation aspect of smart grid, often referred to as self-healing networks.
3. The reason these architectures work so well is because generally, it is more effective to mitigate outages than to prevent them. If you don't do some prevention, there will be so many failures that mitigation won't work, but generally we do enough prevention (almost by default) that mitigation is effective.
4. On radial distribution, an effective strategy is to protect the backbone, the unfused three-phase part of the line, including reclosers, especially (when there are no good ties for backfeed) the upstream part of the backbone (the breaker zone). Otherwise, about half of customer interruptions will occur from backbone faults.
5. Underground cable is generally more reliable than overhead line but much more expensive to build. It is mandated in many states for new developments, but often they are still fed from one or more risers coming off of overhead line.
6. Many, if not most, overhead distribution faults can be cleared by the operation of a relay-activated device's opening and reclosing—perhaps more than once, but rarely more than three times.
7. In the old days, most companies followed the philosophy of letting the feeder breakers do the bulk of system protection. Then it became obvious that it was best to rely heavily on fusing (and

sectionalizing switches or reclosers) to limit the number of customers interrupted by a fault. Still, in storms, it means a lot of fuses blow. Hence the strategy of adaptive relaying. (For circuits that normally have the instantaneous trip off to avoid nuisance momentaries, they are turned on as a storm approaches.) Better still is to understand the particular nature of your distribution faults and what clears them.

8. Most distribution feeders have considerable excess capacity most of the year, and many have it even at peak. At least some of that excess capacity is essential to be able to sectionalize and backfeed from multiple sources if you have to restore all or a large part of a circuit from the alternate direction, such as when there is a long-duration fault on the top end or a loss of supply because of substation or transmission failures.
9. Many faults involve only one phase. In areas where there are not any three-phase customers (or where they can tolerate losing a phase), it helps to have devices that can isolate one phase.
10. An outage cause that is growing at only 5 percent per year will double the number of such outages in about 14 years (based on the mathematical rule of 70).
11. Most distribution equipment failure rates are low: about one-half to 2 percent per year. Equipment that fails at high rates—more than 10 percent per year—tend to get replaced with better equipment once the problem is recognized and then are practically gone in 10 years.
12. Equipment failure tends to increase with exposure to hazardous conditions. Equipment failure increases with age, but usually an age-based replacement strategy is not optimal because we have better indicators of failure than age. (For example, we don't replace poles based on their install date; we use a cheap inspection test to see if they are rotten or damaged.) Longer circuits see more outages because they have more exposure to what can cause failure.
13. The Arrhenius equation relates that most chemical reactions are exponentially sped by heat. A piece of paper left in the sun will get brittle after many years—or it will get brittle in a few hours if left in a hot oven. Much insulation reacts similarly. Being an exponential relation means that heat does not cause much of a problem at low levels. Also, some forms of plastic react to ultraviolet light like paper reacts to heat: creating broken tie-ons and other issues.
14. Trees are dumb. Animals are a little smarter. Electrons are

very smart. That is why tree trimming is generally very effective, animal guarding is pretty effective and lightning mitigation (and in a sense, even insulation) can be ineffective if it leaves an easy path to ground anywhere the electrons can find it.

15. Predicting failure just before it happens is the Holy Grail of reliability, the ideal that is so often sought yet is virtually impossible to achieve. Even if an inexpensive, nondestructive failure test could be found, it would have to predict a fairly high rate of failure to be useful. Even if 10 percent of the tested devices were shown to fail soon, you would have to replace or renew 10 of them to avoid one failure. If the consequences of failure were not that high, you would just as soon run them to failure and replace only one at a time (unless, like some distribution line transformers in a heat wave, they all fail about the same time and cause extended restorations).

16. Overly sensitive tests can be counterproductive if they cause premature replacement or renewal. The joke about partial discharge in the early days is that it predicted 10 of the last two failures.

17. The Pareto rule (the 80/20 rule) is alive in distribution failures. A large percentage of the outages come from a small percentage of the circuits, and similar statements can be made about other distributions of failures. A large percentage of the failures come from the same zones or taps until you get down to particular pieces of equipment. Similarly, a large percentage of outages come from a small percentage of the days of the year, and so forth. This leads to strategies that go after the worst first.

18. Reliability strategy should generally take the consequences of failure into account in prioritizing which strategies to employ most. This is another form of going after the worst first. It is also why protecting the backbone makes such good sense.

19. A key aspect of any targeted reliability strategy is a property that might be called persistence of failure. The idea of preventing failure assumes that you can predict it, but if failure is random (like the way many electronic components fail according to a memory-less exponential distribution so that their age is really irrelevant), then preventive replacement or pre-treatment will be of no use or costly because you have to do it to the whole population. Programs that target the worst circuits or devices should realize that there might be a tendency of regression to the mean. The worst circuit last year might not be that bad this year if the cause was just a random fluke, like it got hit by a tornado or microburst. Likewise, circuits that got lucky and had no outages last year might regress toward the mean and have a few this year.

20. Customer attitudes about outages are important. Customers have their own sense of what should be reasonable, which is why blue-sky outages seem to provoke more ire than storm-caused outages. Many companies and their regulators use system averages like SAIDI, SAIFI and CAIDI to measure their performances on reliability. This is reasonable but incomplete. It is also important to measure, plan for and respond to outages of excessive frequency or duration for individual customers or pockets of customers (using, for example, CEMI, CELID and customer complaints about reliability). It is not enough to look solely at the means of the distributions of outage measures; it is important to manage the upper tail of the distribution, as well.

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