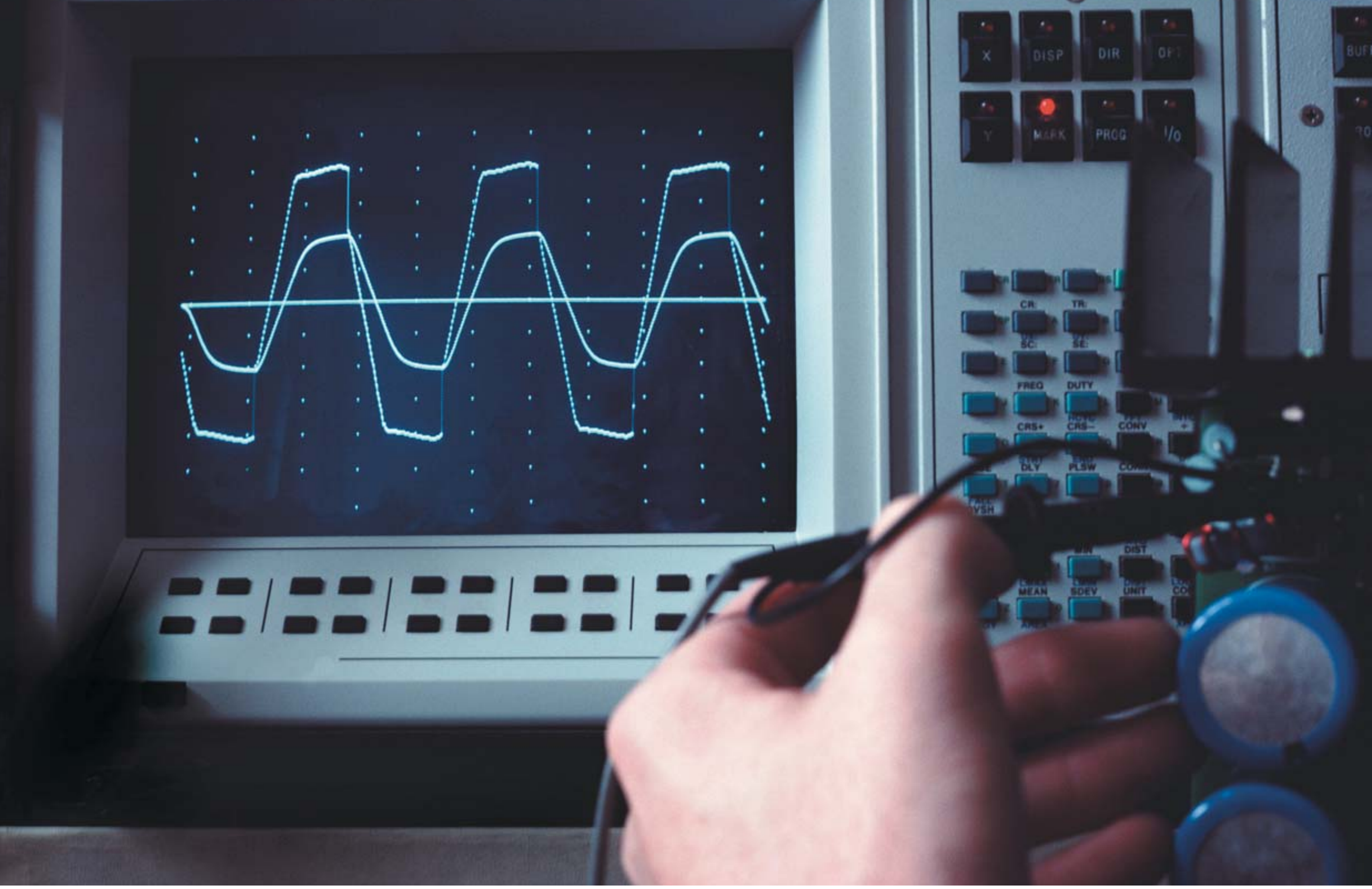


Grounding & Surge Suppression As Seen By A PQ Troubleshooter

By J.L. Miller, P.Eng

A few years ago, I was commissioned to evaluate the electrical systems at several medium sized (10-300 kWh per month) industrial locations. Most of the sites had at least one qualified electrician on staff, but two hadn't seen a qualified electrician for years. In all, some 15 sites were thoroughly evaluated. Commercial and residential locations were surveyed only if they were experiencing some sort of grief related to their electrical system. Five different utility companies, one of which was in the U.S., serviced these sites.

At the outset, I asked about any problems that they might have experienced relative to grounding or surge damage. All were unaware of any but, as it turned out, only two of them were correct in the assessment of their own systems. In fact, the annual cost of damage that could be related to grounding and voltage surges was in the area of 50 to 100% of their monthly utility bill. This cost estimate was for the cost of equipment damage only and did not include loss of production or cost of labour to replace the damaged components. The damage and/or premature failure of components were directly related to substandard grounding and the lack of surge protection.

Typically, supervisory personnel were aware of only lightning damage when they saw parts of components reduced to charcoal. Corrective action had been limited to replacing damaged equipment and possibly complaining to their utility. Premature failure of components that had sustained frequent or even infrequent voltage surges slightly below their individual damage thresholds were not recognized as being from surge damage. (Light bulbs that continually burn out are a good example of this little known phenomenon.)

Where accessible, grounding was evaluated with a clamp-on ground meter. All sites were monitored for at least a week with an energy logger to record volts to ground on each phase, and the current in the ground line, if possible. Several visits were made to each of the sites and it became increasingly interesting as to why some of the sites were suffering extensive damage yet two of them weren't.

Blown-Out Motors Produced Mushroom Cloud

Of the sites that had a WYE connection on the secondary side to the supply transformers, four chose to leave the WYE point ungrounded. The electrical code allows the choice of either leaving the WYE point ungrounded or being required to supervise the ground current tripping the main when it reaches a certain level. Personnel at these sites rationalized that it was easier to live with ground faults than to have the entire plant go off line at irregular intervals. These plants tended to employ more electricians than other sites and they were kept legitimately busy replacing and recalibrating sensitive equipment.

The same scenario applied to sites with delta secondary systems not having artificial neutrals installed. One location had artificial neutrals installed but the units had not been connected.

The sites with solidly grounded systems generally had fewer problems, but the state of the ground systems at all sites was a problem more often than not.

Some case histories are interesting and will help explain the state of systems in the field. One of the plants with an ungrounded WYE point had its systems subjected to short durations of severe harmonic disturbances several times a week for a two-month period. During these incidents, among other damage, they lost about a dozen small horsepower motors. When these motors blew, a dense cloud of smoke about half a metre in diameter would rise 2 metres above the motor and then billow out into a mushroom cloud. I never quite believed what I just described until I actually witnessed one of the motors blow. With the WYE point grounded, and a number of ground faults sourced and eliminated, the problems were, for the short term, reduced.

$30,000 In Damages From Frequent Lightning Strikes

The energy logger can be a great tool to help source ground faults that go undetected in plants. Usually ground faults aren't sourced until production is threatened, and then interest ceases once the first fault has been located.

Grounding problems fit into two categories: ground connections that are either corroded or physically damaged, thus preventing an effective ground, or those that are the result of an ineffective ground location. Typically, grounds installed in back-filled sites do not provide effective grounding.

One particular complex I evaluated was suffering extensive surge damage ($30,000 / year) from frequent lightning strikes. A survey of their system revealed that the service panels were all grounded to the hard copper water lines within the complex. Unfortunately, water was supplied to the complex through a cast iron supply line but it switched to hard copper once inside the building. The problem was solved with adequate grounding, upgrading the lightning protection, and introducing surge suppression techniques. For the purposes of this article, lightning protection is defined as the removal of voltage surges from the primary side of distribution transformers, whereas surge suppression is defined as the removal of surges from the secondary side.

Two sites surveyed having no evidence of surge damage were solidly grounded and had large capacitor banks installed adjacent to main distribution panels.

Power Poles Grounded In Back Filled Earth

Utility customers fed from distribution lines that are suspended over a river, lake or valley, tend to sustain heavier surge damage than locations remote from such elevated lines. The elevated lines do an excellent job of absorbing surges from lightning activity, which stresses and deteriorates the connected lightning protection equipment. When this happens in a residential area there is a halo of damage that radiates out from the distribution point. Similarly, when plants are subjected to a steady diet of voltage surges, damage radiates out from their primary distribution point.

One commercial establishment located on the fringe of one these areas had over 100 fluorescent light fixtures. Among other issues, it was losing two or three ballasts a month. Minor servicing to the ground, and the installation of a panel mounted surge protector solved the problem. There have been no significant losses in the last two years compared to the more than $1000 damage suffered during the twelve months prior to the survey.

Two kilometres away, another commercial establishment with sophisticated electronic equipment suffered over $10,000 in losses during its first six months of operation, not including product losses. Fortunately for the company, the manufacturer's warranty covered the majority of the equipment damage.

At one river crossing feeding an isolated residential development of about forty homes, twelve of the homes were having significant problems amounting to several hundred dollars annually. The twelve homes were suffering damage even though they all had excellent grounds. In this case, the pole grounds on both sides of the river were ineffective as they had been installed in back filled earth. I am not aware of any further problems occurring after the utility grounds had been upgraded.

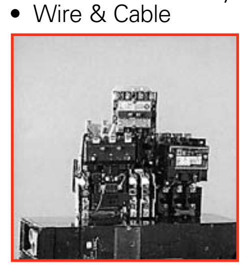
Lightning protection at 7 of the sites surveyed required upgrading. Of the 48 lightning arrestors replaced, 24 had failed and 9 were initially sized incorrectly. The initial objective was to replace the dated silicon carbide lightning arrestors with current generation MOV arrestors, and upgrade the wiring standards to meet the manufacturer's recommendations of connecting the arrestor ahead of the equipment to be protected. Incredibly, it is not uncommon to see arrestors connected downstream of the equipment they are intended to protect, or with lead lengths so long that they don't have a chance to clamp a surge. In other words, the arrestors are being connected for esthetic value only! I have never noted a problem from the transmission side of the utilities. Their substations are engineered and constructed from blueprints.

Ground Side Of Arrestor Responsible For Many Problems

The criteria used for the rewiring of lightning arrestors are:

- Lightning arrestors should be attached at least 2 metres ahead of the service to be protected and, when necessary, the line coiled to provide this length and to increase inductance.
- The use of a lead line to connect the arrestors should be discouraged. For every 20 cm of lead length, the arrestors' effectiveness is reduced by 40 %.
- Connections to ground lines should be as short and straight as possible.

The ground side of the arrestor is often responsible for many problems. Benjamin Franklin was the first to recommend that ground lines should be as short and straight as possible. It appears his recommendations have been lost in the translation. It is not uncommon to see ground lines coming from arrestors installed with several unnecessary 90° bends and the odd 180° turn. The grounds for pole-mounted transformers installed at the sides of roads or parking



lots that had been back filled were in the 'esthetic value only' category. Where this occurred alongside a river or lake, a copper line extended into the water provided an excellent ground at nominal cost. With a clamp-on ground meter, the effectiveness of the earth used for ground can be easily evaluated.

At one of the smaller sites, it could be seen that two of the three arrestors were damaged. Two kilometres down the road at the substation feeding the site, the damage to 7 out of 9 arrestors was also apparent to the eye. Other substations of this particular system weren't as bad but had suffered the same neglect as far as lightning protection was concerned.

The electrical components in our homes and in industry are far smaller and faster in operation than they were ten years ago. They are also thousands of times more susceptible to voltage surges because they are designed to be left on line 24/7.

As far as utilities are concerned, the arrestors are only installed to protect individual transformers and related utility equipment, not to provide any softening of voltage surges to their customers. Utilities don't feel they have any obligation to protect a customer's service from surge damage.

As mentioned earlier, maintenance personnel weren't aware of the amount of damage they were sustaining. Once their systems were properly upgraded, there was a dramatic decline in damage sustained over a one to two year period. Again the operators were unaware of their progress until the situation was reviewed.

The obvious signs that a system has grounding and/or surge problems are:

- There are burned out lights throughout the system.
- There are continuous problems with PLC's and the other expensive, vulnerable equipment.
- Equipment has to be continually recalibrated.
- Failed capacitors and capacitors that are only pulling a percentage of their rated kvars.
- Burned out ground fault lights, modules, and photo cells.
- More problems located closer to power distribution points.

When I first got serious about the problems in my own home, I started at the grounding connection. It always did look okay but was improved with some emery paper and antioxidant. When I installed a surge protector in the panel, the number of burnt out light bulbs was reduced from two or three a month to one or two a year. Similarly, I was no longer getting annual repair bills of $200 and $300 to repair TV's, VCR's, microwaves, etc. Again, the panel mounted surge protector must be installed in such a manner as to clamp an incoming surge before it gets into the house circuits, not after. These units can be installed to be operated efficiently, be completely useless, or actually increase the damage.

The technology exists! Maintenance and education are far behind and it is costing consumers and industry dearly. Ω

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