NEUTRAL-TO-GROUND VOLTAGE SHOCK INCIDENTS

SCOPE

This instruction defines policy and procedures to follow for neutral-to-ground voltage shock incidents.

POLICY

The Company has established a proactive neutral-to-ground farm program, where farms on the system will be isolated from the primary neutral. As part of this program (Operating Practice 331), the Company will place a low-voltage surge arrester between the primary neutral and the secondary/service neutral to assure that no normal primary neutral voltage can access the farm neutral system. In addition, the Company will review the customer's premises, with suggestions for remedial measures applicable to the customer's electrical system. The Company also inspects the Company's distribution facilities for potential problems. The scope of the remedial measures required to reduce/eliminate the problem determines the allocation of costs, but basically all changes on the farm are at the customer's cost and all line changes are at electric company cost.

PROCEDURE

The District Superintendent will prepare a list of all farms in that District and forward it to the Operations Engineer or Operations Technician for review and action for neutral isolation. The customer representative and/or farm representative should be made aware of the list <u>and</u> when each farm is scheduled for isolation. The results of the isolation and any on-farm problems noted should be forwarded to Marketing, to the attention of _____.

RESPONSIBLE ENGINEER OR TECHNICIAN

1. Determine nature and extent of the neutral-to-ground voltage.

2. Isolate the primary neutral from the secondary/service neutral.

3. Evaluate the preliminary test data. In addition to neutral isolation, the Company should initiate one or more of the steps listed below at the Company's expense:

   a. Install more ground rods, minimum 6 ft spacing, up to three each side of the service pole (deep grounds, in excess of 8 ft, may be required).

   b. Check neutral/ground connections at the transformer/service pole, and patrol the tap and eliminate any high resistance connections in the system neutral.

   c. Check possible leakage paths, such as the lightning arrester, fuse cutout, transformer, insulators, etc. at the transformer pole and along the distribution line. Leakage paths, contributing to excessive primary current, could also involve restricted faults on the secondary side of other transformers along the distribution line.

d. Check the load balance on the three-phase line serving the area. Balance loads more equally, if possible.

The device used for isolation may be one of the following:

1. A customer supplied saturable core reactor, to be installed on the pole by _____ Utility personnel. A proper release form <u>must</u> be signed for this installation. The installation of this type of device will be extremely rare. It is mentioned mainly for informational purposes only because such devices have been installed in the past.

2. A _____ Utility supplied and installed low-voltage surge arrester. No release form is required for this installation.

The separate, insulated pole ground and ground rod will be supplied and installed by _____ Utility, at no charge to the customer.

When a release is required, and after it has been signed, it should be so noted on the customer's account and anytime the name on that account is changed, it shall be brought to the attention of the District Manager, who will be responsible to get a new release signed. If a new release cannot be obtained, inform the Director of Distribution Engineering and notify the customer in writing that the neutrals are to be isolated with a low-voltage surge arrester.
When a release is not required, a record of the location of the isolated neutral must be kept on permanent file by the District.

4. For that portion of the neutral-to-ground potential originating on the customer's property, the customer shall be advised to initiate appropriate remedial measures as listed below. <u>At</u> customer's own expense, a licensed electrician should:

- Insure that bonding and grounding of the customer's electrical system meets the National Electrical Code.
- Check for insulation breakdown in the customer's equipment and wiring.
- Check the customer's neutral continuity and, if necessary, replace deteriorated neutral and ground connectors.
- Balance the customer's 120-volt loads in order to minimize service neutral currents.
- Insure that all possible motor loads are operated at 240 volt rather than 120 volt.
- If necessary, provide an equipotential grounding plane.
- Provide adequate power circuits.

GUIDELINES TO NEUTRAL-TO-GROUND VOLTAGE PROBLEMS

Some dairymen may be losing production due to low voltages existing on the grounded neutral of the electrical system. This condition has been called several names, including transient voltage, stray voltage, and neutral-to-ground voltage. We will call it “neutral-to-ground voltage” (N-G). Undoubtedly, this problem has existed to some degree for many years, but increased loads on rural distribution systems, higher producing dairy herds, and increased equipment requirements for modern dairy operations have amplified problems and concerns. Knowledge of its cause, symptoms, and means of minimizing its effects has increased but is still limited.

SYMPTOMS

Animal reactions will vary widely depending upon the severity of the problem. In many cases, the reactions may be mild and not easily observed. Some of the signs are: (a) cows are reluctant to enter the milking parlor or stall, (b) cows are extremely nervous while in the parlor, (c) uneven milk out, (d) longer milking times, (e) reduced feed intake, (f) reluctance to drink water, (g) increased mastitis, (h) high leukocyte counts, (i) lowered production. All cows will not be affected the same.

These symptoms are not exclusively caused by neutral-to-ground voltages or current. More usual causes of abnormal behavior should be investigated as well as searching for neutral-to-ground voltage problems.

SOURCES

The most correct terminology is neutral-to-ground (N-G) voltage. The problem is caused by the voltage required to move current through the grounded neutral system. This voltage exists on the grounded neutral conductors, which are electrically joined to everything that is grounded, such as feeders, waterer's, stanchions, stalls, bulk tank, water heater, and the barn fans.

The primary and secondary neutrals, together with the grounding system, make up a complex electrical circuit. Any electrical current in the grounded neutral system has an associated voltage dependent on the impedance of the system and the current it is carrying. This is probably best visualized as a voltage between the grounded neutral and a true or isolated ground. If the cow makes contact at two points with one at neutral voltage and the other near true ground (possibly the milking parlor floor), it can result in a flow of current through her body.

One point of contact is her feet on the concrete floor. Another point of contact is created when she touches the sides of the stall, eats grain from a metal feeder, or attempts to drink from a metallic water bowl. Some people tend to blame the milking equipment for this phenomenon. At first glance, this seems reasonable since so many symptoms are associated with the milking process. Unless there is an electrical fault (short), the milking equipment should not be the cause. However, even though the teat cups insulate the cow from the milker's, this insulation is broken when milk starts to flow.

The neutral-to-ground voltage depends on wire size and length, quality of connections, number of and resistance of ground rods and the current in the neutral. The variability in the many factors which affect the neutral-to-ground voltage partially explains the intermittent “here today, gone tomorrow” nature of the problem.

The causes of excessive neutral-to-ground voltages are often very difficult to locate. Some factors which will cause excessive voltages are heavily loaded power lines, with the problems frequently at its worst during the evening milking; poor connections, corrosion of switches, frayed insulation, faulty equipment, and excessive barn moisture. Its source may be on the farm, off the farm, or both. In addition, the problems can occur whenever the combination of neutral impedance and current creates a voltage large enough to cause a problem. This can be very frustrating since the condition can exist even with no electrical faults because it may be an <u>inherent characteristic of the electrical system.</u>

In attempting to correct the problem, one of the first things to do is to determine the major source of the voltage. A procedure for doing this is outlined later in the guideline.

<u>When can it be a problem?</u>

The adverse effect on dairy cattle is created by the neutral-to-ground voltage forcing a small current through their bodies. The current depends on the resistance of the cow’s body, her contact resistance with the concrete or stalls, and voltage. The milking machine operator will seldom feel these voltages because of the person’s relatively high body resistance and the insulating material of the operator’s boots. But the cows have four bare feet that may be on wet concrete and this, together with their low body resistance, will allow the neutral-to-ground voltage to force enough current through their bodies to create a problem. The question is: How much voltage is necessary to do this?

One volt may create an immediate response and is cause for concern in any dairy operation. Large voltages may cause increasingly severe problems. If the neutral-to-ground voltage is less than 0.5 volt, there probably is no serious cause for concern. If the voltage is in the range of 0.5 to 1.0 volts or higher, it should be monitored and some corrective measures may have to be taken.

<u>How to measure it?</u>

Someone familiar with electrical systems, wiring, and equipment should be consulted and, if possible, be there when measurements are being made.

Any AC voltmeter that has a scale of 0 to 2.5, 0 to 5, or 0 to 10 can be used for initial checks on neutral-to-ground voltages. However, most of the standard inexpensive volt-ohm-milliamp multimeters (VOM) will also detect DC voltages when they are on the AC scale. It is best to use a voltmeter that will read only AC voltages. Check this by measuring the DC voltage of a flashlight battery with the meter on the AC scale.

A multi-range battery operated AC/DC VOM multimeter should ideally have a full scale reading of one volt at 5,000 ohms or more per volt on AC. A handheld VOM of 2.5 volts full-scale sensitivity is often the best instrument available but is not fully reliable at the low end of the scale.

Digital read-out AC meters have proven to be very satisfactory for checking neutral-to-ground voltages. With these meters, the technician may be able to observe short period spike voltages that are considerably higher than the normal readings, especially when a motor or other electrical device is started or stopped. The spike voltage significance and effect on the cow has not yet been determined.

A particular concern to the dairy farmer is the voltage between any two points that the cow can simultaneously touch. These voltages can be checked by placing the leads of the voltmeter at the contact points. Good electrical contacts are necessary.

To provide a common reference and to standardize measurements, it is recommended to use a copper or copper-clad ground rod located about 50 feet from the barn and isolated from any other grounding component, such as metallic water piping. The ground rod should be at least four feet deep and in moist soil. Connect one insulated lead of the voltmeter to this isolated ground rod and the other insulated lead to the bare ground wire leading from the barn entrance box to the ground rod at the barn (service entrance grounding conductor). Extend the voltmeter leads using a 10 AWG insulated wire with good connections. In this position the voltmeter will read the voltage between the grounded neutral system and an isolated or true ground.

All of these readings must be documented and a simple diagram drawn showing the layout of the facilities being investigated.

Some questions may arise as to why this reference voltage is measured rather than voltages within the milking parlor itself. The reason is that this voltage is generally the maximum that would be expected between any two locations in the milking parlor, unless an electrical fault exists. If this voltage reaches a problem level, as discussed earlier, it is possible it exists in the milking parlor or barn. The local electrician and/or a representative of the power company could trace out the source of this problem. The electric company is not obligated to find barn-related stray voltage, but may make a practice of assisting to locate the problem.

<u>How to determine the source of the problem – (five-step procedure)</u>

1. Record the reading with the voltmeter connected between the isolated ground rod and the service entrance grounding conductor. Observe the magnitude of change when the main switches to the farm are turned off. A significant drop may indicate leakage current on the farm, or a primary neutral problem at the transformer, either of which should be corrected. No change indicates neutral voltage originating off-farm. In addition, it may be desirable to obtain readings between each of several possible cow contact points. Do this in mid-morning or mid-afternoon when the readings are expected to be at their lowest.

2. Turn on several 240-volt electrical devices and repeat the readings. Turn on the hot-water heater, vacuum pump, milk cooler, and any other 240-volt appliances, such as the house range. Have someone read the voltmeter as each piece of equipment is turned on, so that the voltage can be recorded both at the time of starting and after continued usage.

3. Repeat the procedure when electrical loads on the entire electrical system are expected to be high. The best time to do this is during the evening milking or about 6 p.m.

4. If no voltages over 0.5 volt are observed in steps 1, 2, and 3, repeat these steps with one lead of the voltmeter on the isolated ground rod and the other lead connected to various pieces of grounded equipment, such as motors, waterer's, tanks, feeders, or stanchions, in the milking parlor or barn. If significantly higher voltages are observed in these locations, it is probably caused by faulty equipment, faulty grounding, or faulty wiring within the milking parlor or barn.

5. Isolate the system neutral from the service neutral (test purposes only) and repeat the above four steps as required. After testing, reconnect the systems and service neutral.

To determine the source(s) of the problem, compare the recorded results. If the readings are lowered after the service neutral has been isolated, the voltage on the primary neutral was contributing to the problem. The neutral-to-ground potential contributed from the primary neutral may still be caused by a customer problem, although not the customer with the complaint. It is possible that another remote customer has a 240-volt appliance faulted, which in turn, is causing high neutral-to-ground potential on the primary neutral. Isolating transformers serving load to other customers in the area may help to locate this type of problem.

If the readings remain at the same level or are higher when the service neutral is isolated, the problem most likely originates on the farm. Be sure to study the results obtained at varying times of the day and with different local electrical loads. A marked increase in voltages observed may provide a lead to the source of the problem.

RELEASE

I, the undersigned, hereby request _____ Utility to isolate the _____ Utility primary neutral from the secondary neutral on the distribution transformer serving my premises and facilities located at _________________________________ so as to mitigate the "neutral-to-ground voltage" phenomenon that exists there.

The requested isolation will be made by the installation of a saturable core reactor, of suitable rating, furnished by the undersigned.

I acknowledge that this phenomenon is a naturally occurring event inherent in all electrical systems and in no way caused by the conduct or omissions of _____.

I further acknowledge that this phenomenon may be remedied and/or mitigated by any one of numerous methods and that _____ Utility has not in any manner or to any extent guaranteed the effectiveness of this particular remedy.

Moreover, I acknowledge that I voluntarily and with knowledge of all pertinent facts elected this method of alleviating the aforementioned phenomenon in lieu of other methods and to that extent assume any and all risks that this method may not be as effective as alternative methods or effective at all in alleviating the aforementioned phenomenon.

And in further consideration of the fact that _____ Utility is providing this service entirely as an accommodation to myself and free of charge, I hereby agree to indemnify and hold harmless _____, its employees and agents against any and all liabilities (including, but not limited to attorney's fees and other legal costs as well as payments made by _____ Utility under any Workmen's Compensation Plan) to myself, my successors, assigns, or other third persons resulting from or in any way associated with the isolation of _____ Utility's primary neutral from the secondary neutral of the transformer or the failure of said "isolation" to cure the neutral-to-ground voltage potential, whether or not said damages are caused in whole or part by the negligence of _____, its employees or agents.

I also understand and agree that this agreement shall be binding upon and inure to the respective successors, assigns, agents and heirs of the parties hereto and to that extent agree to inform such persons, or others who may be exposed to liability as a result of the aforementioned "isolation" of the "isolation," its purpose, and effects, as well as the risks associated with it.

Dated this _____day of ____________, _____

____

TRANSFORMER NEUTRAL ISOLATION

If the remedial steps do not satisfactorily mitigate the neutral-to-ground voltage and the customer requests the Company to isolate the primary neutral from the secondary neutral with the use of an approved protective device, the following procedure will be implemented.

1. **Customer supplied saturable core reactor.**

   The District Superintendent shall have the customer sign the proper release form prior to isolating the neutral, and the release shall be filed by location in a permanent file labeled “Transformer Neutral Isolation Releases.”

   The District Superintendent will notify the District Office Supervisor, who will enter through the terminal on the special instruction line, “Signed Isolation Release.”

   The District Office Supervisor will notify the District Superintendent if the account is to be transferred. The District Superintendent will be responsible for securing a new signed release. If the new customer is not receptive to the above, then the District Superintendent will have the isolation device removed and have the primary neutral and secondary neutrals reconnected.

2. **_____ Utility supplied low-voltage surge arrester.**

   No release form is required for this installation. The District Superintendent shall keep a record of all such installations.

In no case shall the primary neutral be separated from the secondary neutral other than for test purposes without the use of an approved isolation device

STRAY VOLTAGE PROACTIVE FARM PROGRAM

Although studies are inconclusive in determining the actual effects of stray earth to neutral voltage, the company has made the decision to undertake a proactive program to install isolators to separate the company and customer neutral systems at all operating farms, to measure and report to the customer any remaining stray voltage, and if any, to provide assistance in the form of detection and corrective expertise for those cases where levels may be a problem.

A form letter should be sent to each farm customer describing the stray voltage evaluation program. This letter should be sent by the District Superintendent. Caution should be used to schedule the mailings of these letters to allow the company representative to contact the customer within one week of receipt of the letter.

In addition to simply isolating each farm, we must also examine the supply system. Some farms may have transformers that are improperly sized for the load, undersized or exceptionally long services, or other related problems. These problems must be corrected as part of the isolation program. The transformer connection, both primary and neutral, must always be brought up to correct standards. The transformer should, if not already, be replaced with a non-PCB transformer.

The Operations Technician should be the primary contact individual following initial training to be provided by the Operations Engineer. The Operations Engineer or Senior Staff Distribution Engineer may be requested to provide assistance on more complex problems. The Operations Technician should coordinate any assistance through the District Superintendent to ensure adequate coordination to allow the district to maintain progress on all operational functions.

The Operations Technician should initially perform an overview of the farm supply system including customer load, transformer size, PCB content, service size, and length. Following this overview, an upgrade program, if required, should be determined for the farm supply and appropriate reconstruction completed. The non-PCB transformer should be isolated with the company approved low-voltage arrester. Earth-to-neutral voltage and other checks should be completed as detailed in the Stray Voltage Test Procedure.

A file folder should be maintained for each location where isolators are installed to separate the company and customer neutral systems. This file folder should contain the Stray Voltage File Information sheet, and information for file identified on the bottom on this sheet, including the Installed Material Checklist.