Stray Voltage Troublshooting Tips for Electric Utility

An orderly and systematic approach to Stray Voltage (SV) and Neutral to Earth (NEV) investigations ensures appropripate handling of customer inquiries. The timely investigation of requests and the documentation of the results will result in maintaining customer satisfaction.

Introduction

A key element to any stray voltage situation is attention to and focus on customer relations. An orderly approach to NEV investigations is needed because the source of the voltage is often difficult to find. There could be more than one source including the customer, a nearby customer or the utility system. Frequently, a significant amount of time is required at the site using visual inspections and electrical measurements to determine the problem and implement a solution.

This policy describes procedures that can be followed by the region engineer (reliability engineer) for customer contact, record keeping, measurements and determining solutions. For more difficult cases the Distribution Department NEV/SV experts will assist the region engineer.

Definition

Stray voltage (SV) is a special case of neutral to earth voltage (NEV) which is the voltage measured between the electrical system neutral conductor and anything connected to the earth. NEV exists on all grounded electrical systems and is the result of neutral return current flowing in the earth. Theoretically, approximately 1/3 of the return current in a multi-grounded wye connected system returns to the source through the earth "ground" path. Thus, stray voltage, in reality, is caused by stray current. When this stray current creates a voltage between two points that can be contacted by a human or animal, and is above the threshold of perceptibility, it is referred to as "stray" voltage. Thus, not all NEV is stray voltage.

Due to the common grounding of the Utility System and the Customer electrical system any NEV on the utility system will be transferred to any grounded objects in a building including metal water pipes. If this NEV/SV exceeds "Levels of Concern" it generally occurs when there is something that needs to be corrected either on the utility system or the customer wiring system. Stray voltage is not EMF, ground current, or fault current.

NEV/SV Investigation (See Appendix B Flowchart):

Initial Customer Contact:

All Stray Voltage related customer calls and complaints are to be forwarded to the region reliability engineer in the local region operating headquarters. The engineer will contact the customer within two working days to schedule an appointment. A Stray Voltage Data Sheet (Appendix C) should be started at this time.

At the initial meeting with the customer, the region engineer will provide the customer a copy of the Utility Power Stray Voltage Brochure. The region operating engineer should ask the questions listed on the Stray Voltage Data Sheet and document the answers. These can be used to help determine the source of the problem.

Initial Investigation:

After filling out the question section of the SVDS the local engineer/representative will conduct an initial investigation to determine if there is a NEV level that exceeds the recommended limit. Measurements should be performed when the electrical load on the feeder and the customer load is high. Experience has confirmed that measurements made early in the day or after rainy weather will be significantly lower than in the afternoon during very dry weather. Generally, point to point type measurements are made (between two contact points that can be simultaneously contacted by a person or animal). However, in more difficult cases measurements from a contact point to a reference ground can be made for repeatable results over a period of time (these type voltage readings will usually be higher than the point to point readings).

It is recommended that actions should be taken to reduce NEV when the neutral to earth voltage at the service entrance or between contact points is in the range of 2 to 4 volts or higher. (Special circumstances are listed in Appendix A1.) With a true RMS voltmeter (set on the 10 volt scale if it is an analog meter) measure the voltage between contact points as described by the customer. (Due to possible problems with some high input impedance digital voltmeters, measurements might need to be repeated using a 1 k ohm to 10 k ohm resistor shunted across the voltmeter leads.)

If NEV measurements indicate voltage readings below the level of concern (i.e. no problem exists), then complete the SVDS and send a follow-up letter to the customer. However, if the NEV voltage limit is exceeded:

- (a) Ask the customer to open the main and re-measure the voltage. If the voltage is diminished, the source is likely from the customer.
- (b) If the voltage remains above the limit, contact a troubleman or crew to open the service transformer and measure again.
- (c) If the voltage remains, with the service de-energized, open all connection paths between the customer secondary and the primary system neutral. This would include the CATV and telephone if appropriate. (Note: Always exercise extreme caution when opening neutrals or grounding paths. Avoid series contact with an open neutral or neutral to ground electrode.) If the voltage is reduced or disappears, the source is most likely the utility system or a possible fault or problem from a neighboring customer. If the voltage does not essentially go away, contact the General Office NEV/SV expert.
- (d) If the NEV is affected by separating the primary and secondary neutrals, and it is not practical to find the problem in a timely manner, a neutral isolator (blocker) may be installed on a temporary basis. Every effort should be made to determine if the NEV is due to problems in neighboring customer electrical systems or from the Utility distribution system (could involve the GO NEV/SV expert as indicated below).
- (e) After permanent corrections are made, measurements will have to be made again. The blocker should be left in place if the NEV is not reduced to acceptable levels. The blocker should be removed if the levels are below the level of concern.

If the voltage is determined to originate from the customer, the region reliability engineer should explain the investigation to the customer. Depending on the situation, the region engineer and/or the GO NEV/SV expert might be able to have the customer turn off individual loads or look for damaged wiring, improper grounding etc. to try to isolate his problem. In most cases the customer will need the assistance of a licensed electrician. See Appendix A for helpful information for the region engineer. The engineer should send the appropriate form letter (Appendix D). A follow-up with the customer should be done within two weeks to see if the problem has been corrected. If the customer and/or the electrician has taken corrective measures that have not resolved the problem, the engineer will need to reinvestigate verifying that there is still a customer problem and not a utility NEV contribution.

If the voltage does originate from the utility as NEV, but is at or below the normal threshold level, it still may be a concern for swimming pools. Swimming pools should be checked for compliance with the NEC. In particular, bonding of all metal parts including ladders, concrete rebar, any underwater lighting, pool pumps etc. This creates an equipotential plane between the water in the pool and the surrounding contact areas.

Documentation of all actions should be kept on the SVDS form. All actions taken should be communicated to the customer using the appropriate form letter in Appendix D.

Expert Investigation:

If an "expert" investigation is required, the Expert will perform any tests that he deems necessary. In cases where the problems can be traced to the primary system, he may need the assistance of local line and engineering personnel for disconnecting neutrals at the transformer, checking neutral connections, measuring primary current etc. Typical corrective actions that may need to be implemented by local operating crews include: repairing neutral connections, replacing the neutral, or verifying and regrounding as necessary. If a blocker had previously been installed, measurements will need to be made after the corrective action (with the blocker disconnected) to determine if the blocker can be removed or must remain. (A special tag has been printed to attach to all transformers that have been modified to accommodate a blocker installation). The most common applications requiring a blocker are agricultural with some residential (water faucets etc.) Swimming pools should have an equipotential plane as described above. (See Appendix E. for detailed installation instruction for overhead and underground installations.) The "expert" will complete the documentation, with all actions taken including dates, and return a copy to the local representative at the completion of his investigation. In all cases, the customer must be notified of the actions taken.

Summary:

Communication with the customer is required during all phases of the investigation to keep him informed as to the actions being taken and results of those actions. (Form letters are provided in Appendix D.) Final documentation of all actions and customer contacts, from the initial to the final is required, and should be kept on file at the local level and by the NEV/SV expert in the General Office.

Appendix A

General Information and Common Solutions

<u>Sources</u>

Stray voltage (currents) can come from the utility distribution system, a customer's wiring system, a neighboring customer's wiring system, another utility (phone, cable TV, pipeline, EMC), or combinations. If the customer is in the poultry, dairy, or other farm business, the following publications can be a valuable source of information for the reliability engineer: **"Understanding Neutral-to-Earth and Stray Voltage"** by Consumers Energy and **"Effects of Electrical Voltage/Current on Farm Animals-How to Detect and Remedy Problems"** by USDA.

Both the utility electrical grounding system and the customer electrical grounding system are inherently tied together at the same potential. Since 1961 the NESC has required the primary and secondary neutrals at the utility transformer to be connected. Additionally, since 1978 the NEC has required the neutral conductor to be bonded to all non-current carrying metallic parts in a premise. Thus any voltage on the utility system neutral will be transferred to the customer neutral and any grounded objects in a building including any metal water pipes.

Typical NEV sources from the utility distribution system include: system imbalance on a three phase system, long (especially heavily loaded) single phase lines, poor neutral connections, small neutral conductor, lack of or poor grounding on a multi-grounded system, leaky insulators, or faulty equipment such as capacitors or arresters.

On customer systems, poor or faulty ground or neutral connections, improper wiring, or faulty equipment are typical sources. This is true of neighboring customers also. It is very important in agricultural situations and for swimming pools that an equipotential plane be established in accordance with the National Electrical Code (NEC) since NEV levels lower than normal in other cases could exceed the levels of concern in these particular situations.

In general, for any single phase or multi-phase grounded system, ground return current, or neutral current will obey Kirchoff's laws and return through all parallel paths in proportion to the impedance of each path. On a multi-grounded system, this will include all grounding electrodes (ground rods), the system neutral, customer grounds, cable and phone shields, metallic water lines, and other metallic objects connected in series or parallel to the system neutral as well as earth return paths. "High" impedance in any of the preferred paths will force more current to flow in the other parallel paths.

Common Solutions

In accordance with ohms law, either/or both the current and the impedance must be reduced in order to reduce the NEV. There are four common solutions for reducing NEV problems. They are:

- (1) gradient control
- (2) NEV reduction
- (3) isolation and
- (4) active voltage suppression.

The same principles applied in obtaining solutions can be used in design as well to prevent or minimize NEV. Some of these would include utilization of equipotential planes, balancing three phase system loading to minimize neutral current flow, installation of same size neutral conductor on single phase systems, and properly installed and maintained grounding systems.

Appendix A

General Information and Common Solutions (page 2)

- A. Gradient control is employed through the use of an equipotential plane. This involves bonding all metal items that can be contacted simultaneously and results in the elimination of any potential difference between contact points. See Article 547 of the National Electrical Code (NEC) for agricultural applications (chicken farms are a special). See Article 680 of the NEC for Swimming Pools
- **B. NEV reduction** is accomplished by removing situations or conditions which cause or intensify the problem. Examples applying to both the utility and customer systems include: repairing or replacing neutral connections, balancing loads, improving or correcting wiring and grounding, and removing any faulty equipment or loads etc.
- **C. Isolation** is the separation of the utility system neutral (primary side) from the customer (secondary side) neutral. Either a neutral isolator (blocker) or an isolation transformer can be installed. In the case of a blocker electrical separation does not occur unless telephone and CATV are also separated. Note that the telephone grounding MUST be separated on the primary side of the Utility transformer rather than the secondary side in order to comply with the NEC and to retain the best protection from lightning. The customer's neutral system may also require separation of sensitive animal areas from the rest of the system neutral (limited special case allowed by exception no. 2 of Section 547-8e. of the NEC.)
- **D.** Active voltage suppression measures voltage to reference ground and applies a current in the opposite direction to cancel the problem. This is not recommended due to the high initial cost, cost and time involved in maintenance, and the masking of wiring problems which should be corrected. This solution is not approved for the utility system nor recommended for customer systems.

Common Techniques

- A. Review existing records including the maintenance and inspection data that might exist on the feeder. In addition, look for missing or damaged ground wires, check grounding resistance and improve if necessary, check for loose or damaged neutral connections, neutral size and length, loading conditions, etc.
- **B.** A feeder patrol to look for faulty equipment should be performed with emphasis on blown capacitor fuses in three phase banks, faulty arresters, broken insulators, etc.
- **C.** If this is a three phase system, load balancing should be done.
- **D.** If it is determined in the investigation that the source is from a neighboring customer, that customer should be contacted and the source located.

Appendix A

General Information and Common Solutions (page 3)

Recommended Levels

Based on experts, mostly university researchers, the following levels of NEV/SV are significant in determining the levels of concern and whether or not corrective actions need to be taken.

1 Volt or less Reducing the NEV at the service entrance to less than one volt is unwarranted. Similarly, it is unnecessary to reduce cow contact voltages below the range of 0.5 to 1 volt. 1 to 2 Volts NEV of 1 to 2 volts at the service entrance to buildings with dairy cows, swine or chickens may warrant further investigation. It is recommended that actions should be taken when NEV/SV at the service entrance 2 Volts or more (of an agricultural facility) or in the animal contact area exceeds two volts. 4 Volts or more There is no effect on milk production or animal health until contact voltages exceed four volts. The same level of concern applies to swine parlors. Until further research is completed, it is not known what the level of concern is for breeder hens. Research is ongoing at this time. Generally, experts agree that the level of concern for NEV/SV in swimming pools and on faucets either inside or outside is about 4 volts.

Appendix B



Power Compay NEV/Stray Voltage Investigation Flowchart

Appendix C

Stray Voltage Data Sheet (SVDS)

INITIAL CUSTOMER DATA:

Customer	
Address	

Please Check Type of Inquiry			
Residence:	Pool	ð	
	Other	ÿ	
Farm:	Dairy	ÿ	
	Chicken	ÿ	
	Swine	ÿ	
Other than a	above:	ÿ	

Customer was called on (date): ______ Appointment was scheduled for :______ Date of first visit to customer: ______ Description of problem:

When was problem first Noticed?

When is the problem most noticeable? Morning \ddot{y} Evening \ddot{y} All the time \ddot{y} Is the problem affected by weather? More noticeable when dry \ddot{y} or when wet \ddot{y} If animals are involved - do all animals react? Yes \ddot{y} No \ddot{y} Are electric fences installed? Yes \ddot{y} No \ddot{y}

DIAGNOSTIC MEASUREMENTS:_____

Date and time:_____

Secondary Service size, length, description _____

Initial NEV measurements:	After Isolation:Secondary	Primary
<u>"Main" turned On</u>		
Transformer Sec. to earth	VV	V
Main Grounding ElectrodeV		
Contact Point #1	V V	V
Contact Point #2	VV	V
Contact Point #3	VV	V
V	V	V
"Main" turned Off		
Transf. Sec.to earth	V V	V
Main Grounding Electrode V		
Contact Point #1	V V	V
Contact Point #2	VV	V
Contact Point #3	V V	V
	VV	V
Transformer Fuse Pulled		
Transf. Sec to earth	V V	V
Main Grounding Electrode V	··	v
Contact Point #1	V V	V
Contact Point #1	VV	V
Contact Point #2	VV	V
	VV	V
Primary and Secondary Neutrals Separated		
Transf Sec to earth	V V	V
Main Grounding Electrode V	••	·
Contact Point #1	V V	V
Contact Point #2	VV	V
Contact Point #2	VV	V
	VV	V
Neutral Isolator (Blocker Installed		
Transf. Sec.to earth	V V	V
Main Grounding Electrode V		
Contact Point #1	V V	V
Contact Point #2	VV	V
Contact Point #3	VV	 V
	VV	V

Assistance provided and/or any recommendations made

RECOMMENDED FOLLOWUP

1.

- 2.
- 3.

Stray Voltage Form Letters (Examples)

The following examples serve as a guide only. Each letter will have to be modified to fit your particular situation, ie. is the concern dealing with people affected by a swimming pool, faucet either inside or outside etc. or does it concern animals such as dairy cattle, swine, or chickens. Other local conditions will affect the content of the letters as well. Again the goal is too maintain good communication with the customer, keep records of actions taken, and to solve the problem in an efficient, safe and timely manner.

A. NO NEV PROBLEM (After investigation by local region engineer or NEV/SV expert)

(Date)

_____; ______;

This letter is a follow-up to the voltage measurements I performed with your assistance at your property on

As you may recall, I mentioned during my visit that certain conditions or factors must exist for a Neutral to Earth Voltage (NEV) problem to exist. First, of course, the person or animal has to come into contact with the voltage. Then, the path from the source of the voltage to the person or animal being affected must allow the voltage to be felt. However, the measurements that you and I made showed that there were only _____ volts at the measurement position where the voltage reading was greatest. This indicates that you do not need to take action now to reduce the NEV level.

Please be aware, however, these measurements do not guarantee that you will never have NEV problems. Therefore, please feel free to call me in the future if you think you or your livestock are experiencing problems due to NEV.

If you have any questions about my interpretation of the voltages we measured, or any other NEV issues, please call. My direct line is ______. If I'm not in, I will return your call as soon as I can.

Sincerely,

Stray Voltage Form Letters (Examples)

B. Problem exists at residence/ farm (customer premise) due to his/their electrical system (Note: This letter might be sent by the region engineer or in some cases the stray voltage expert might followup with the customer)

(Date)

This letter is a follow-up to the Neutral to Earth Voltage (NEV) measurements I performed with your assistance at your property on ______. As you recall, I left a recording voltmeter in place to measure the NEV level between ______and _____. The recording meter was in place for hours.

The resulting NEV levels indicated that we should investigate further. With your "main" turned off, measurements showed that the NEV level had dropped to approximately _____ volts. This indicated that there is an electrical problem at your ______. After turning the "main" on, you and I tried to find the problem with your wiring and/or equipment. Together we found ______. Due to these findings, I recommend that you call in a licensed electrician to help you resolve the electrical problem.

After your electrician has finished the work to reduce NEV to an acceptable level, there can be no guarantee that the NEV will remain at a low level. Any of the electrical systems (ours, yours, or your neighbor's) may have a future problem that will affect your electrical system and cause a higher NEV level. Should a problem arise again, feel free to call me.

I hope to follow up with you in a few months to confirm that your NEV problem has been solved and that it has not returned. In the meantime, if you have any questions about my interpretation of the voltages we measured or any other NEV issues, please call. My direct line is ______. If I'm not in, I'll return your call as soon as I can.

Sincerely,

Stray Voltage Form Letters (Examples)

C. Problem exists at residence/ farm (customer premise) due to utility electrical system contribution (could be some contribution from neighboring customer).
(Note: This letter might be sent by the region engineer or in some cases the stray voltage expert might followup with the customer). Neutral Isolator Installed

(Date)

This letter is a follow-up to the Neutral to Earth Voltage (NEV) measurements I performed with your assistance at your property on ______. As you may recall, I left a recording voltmeter in place to measure the NEV level between ______and _____. The recording meter was in place for ______hours.

The NEV levels that we measured indicated that we should investigate further. With your "main" turned off, measurements showed that the NEV level did not drop significantly nor did it significantly drop when the transformer fuse was pulled. This indicates that your electrical system is, in all probability, not the source of the NEV. As a further part of our investigation, a Utilitycrew disconnected some of the wires at the transformer serving your property. The measurements we took then showed a very significant drop in the NEV, indicating either a problem with a nearby customer's electrical system or with a component of _____'s distribution system.

As an interim solution, we have installed a neutral isolating device (blocker) which safely separates your farm from the NEV on the Utility distribution system. After the isolator was installed, the total NEV at your property fell to a level which should not cause any problems.

We will continue to check with other nearby customers and check our distribution system in order to determine if the NEV levels can be reduced to a level that will allow the blocker to be removed. If the levels can not be reduced to an acceptable level, then the blocker will need to remain connected. Even with the blocker, however, there is no guarantee that the NEV will remain at a low level. Any of the electrical systems (ours, yours, or your neighbor's) may have a future problem that will cause a higher NEV level.

I hope to follow up with you in a few months to confirm that your NEV problem has been solved, and that it has not returned. In the meantime, if you have any questions about my interpretation of the voltages that we measured or any other NEV issues, please call. My direct line is ______. If I'm not in, I will return your call as soon as I can.

Sincerely,

Stray Voltage Form Letters (Examples)

D. Neutral Isolator Removed

(Date)

This letter is a follow-up to my _____, 19___ letter regarding the Neutral to Earth voltage (NEV) problems that you had been experiencing. In that letter, I told you that Utility had installed a neutral isolation device (blocker) device to give you immediate relief from the problem.

Since then, we have performed work on our electrical lines so that the NEV produced by the Utility system has been minimized. On _____, 19___, a Utility crew removed the neutral isolation device and I repeated the NEV measurements at your property. The NEV measurements are now at an acceptable level.

There can be no guarantee that the NEV will remain at a low level. Any of the electrical systems (ours, yours, or your neighbor's) may have a future problem that will cause a higher NEV level. Should you experience a problem, feel free to call me.

I hope to follow up with you in a few months to confirm that your NEV problem has been solved, and that it has not returned. In the meantime if you have any questions about my interpretation of the voltages that we measured or any other NEV issues, please call. My direct line is ______. If I'm not in, I will return your call as soon as I can.

Sincerely,

Appendix E Overhead & Underground Blocker Installation Diagrams

Two manufacturers of neutral isolators or blockers are listed below. General information is provided in A. and B. below. For further details see NESC Rule 97 D.2 (1997 edition) and the literature from the respective company.

- 1. Ronk Electrical Industries Stray Voltage Isolator Blocker
 - P.O. Box 160 Nokomis, IL 62075-0160 Tel: 217.563.8333 Fax: 217.563.8336
- DEI (Dairyland Electrical Industries) Variable Threshold Neutral Isolator (VT/NI) P.O. Box 187 Stoughton, Wisconsin 53589 Tel: 608.877.9900 Fax: 608.877.9920
- A. Overhead Transformer Installation Diagram



B. Underground Transformer Installation Diagram (The blocker can be installed either in the transformer cabinet or in a special pedestal/cabinet near the transformer. The exact location of the blocker will have to be determined in the field at the time of installation.)



Note: A sign shall be placed at each blocker location to indicate that the primary and secondary wiring to the transformer has been modified (on the pole near the blocker for overhead installations and inside the door at a practical location for padmount transformers). Typical Sign (provided by Corporate Distribution Department):

CAUTION

TRANSFORMER HAS BEEN MODIFIED FOR INSTALLATION OF A NEUTRAL ISOLATOR (BLOCKER) WHEN REPLACING THIS TRANSFORMER: REMOVE ALL CONNECTIONS BETWEEN THE PRIMARY AND SECONDARY NEUTRALS INCLUDING THE TANK STRAP ON THE SECONDARY BEFORE REINSTALLING THE NEUTRAL ISOLATOR CONTACT CORP. DISTRIBUTION DEPT.