MINNESOTA STRAY VOLTAGE GUIDE

A Guide Addressing Stray Voltage Concerns

SEPTEMBER 2015

This document supplements the United States Department of Agriculture Handbook 696 titled *"Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems"* December 1991, commonly referred to as the Red Book.

The following organizations developed this guide.

MREA

minnesota power
AN ALLETE COMPANY

Minnesota Farmers Union

OTTER TAIL POWER COMPANY

MINNESOTA DEPARTMENT OF AGRICULTURE

Cooperative Network

Minnesota Farm Bureau
Farmers • Families • Food

MMUA
Minnesota Municipal Utilities Association

Xcel Energy
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MINNESOTA DEPARTMENT OF LABOR & INDUSTRY

PREFACE

Sponsoring Organizations :

The following sponsoring organizations were involved with the development of this guide:

Minnesota Rural Electric Association

Minnesota Power

Xcel Energy

Otter Tail Power Company

Minnesota Farm Bureau

Minnesota Farmers Union

Cooperative Network

Minnesota Municipal Utilities Association

The Minnesota Department of Labor and Industry and the Minnesota Department of Agriculture also participated in the development of this Guide.

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Disclaimer

The information in this Guide is intended for use as educational material to assist utility representatives, farmers, licensed electrical contractors and their advisors to understand processes and procedures that can be used to resolve stray voltage concerns. Identification and diagnosis of stray voltage problems can sometimes be difficult and requires electrical expertise. Working with electrical systems can be dangerous. Stray voltage problems are normally at low levels and are difficult to detect without special instruments. A possible hazard to life exists if an electrical shock can actually be felt or if animals are knocked down. The device or electric circuit responsible for the shock should be disconnected by unplugging the device or de-energizing the circuit at the electrical panel. The situation should be examined by a licensed electrical contractor as soon as possible.

This document is not meant to provide legal advice or establish an attorney-client relationship. Consult your legal representative and the responsible state or federal agencies regarding your specific situation before utilizing these materials in a legal proceeding. Reasonable efforts have been made to ensure the accuracy of the information contained in this guide; however, the nature and content of the guide are subject to changes in the law and in scientific advancement. The effect of future regulatory and judicial developments may alter the interpretation and effect of the recommended processes and procedures discussed in this handbook. The utilization of these materials by any person represents an agreement to hold harmless the authors, and the sponsoring organizations for any liability, claims, damages, or expenses that may be incurred by any person as a result of reference or reliance on the information contained in this Guide.

TABLE OF CONTENTS

INTRODUCTION

The Minnesota Stray Voltage Guide outlines the steps farmers, licensed electrical contractors, utilities and their advisors can take to discover and resolve stray voltage concerns on livestock farms. When farmers and utility companies work together, stray voltage concerns are more likely to be satisfactorily resolved. This compilation of information was a collaborative effort of Minnesota Rural Electric Association, Minnesota Department of Labor and Industry, Minnesota Power, Xcel Energy, Otter Tail Power, Minnesota Farm Bureau, Minnesota Farmers Union, Minnesota Milk Producers Association, Minnesota Department of Agriculture, Cooperative Network and Minnesota Municipal Utilities Association.

The contact information for each utility is included for easy reference. Farmers and utilities may also include their advisors, such as veterinarians or licensed electrical contractors, in this process to put additional knowledge and experience to bear on resolving the issues.

The information included in this Guide is intended to provide a base level of knowledge for those who are concerned about whether the animals on a livestock farm are experiencing a level of stray voltage which may be impacting animal behavior or milk production. The processes outlined in this guide provide a systematic method for determining whether stray voltage might be causing a problem and how to best address the problem. While stray voltage may never be completely eliminated, steps can be taken to reduce stray voltage to acceptable levels.

The Guide includes a list of common causes and a farm wiring checklist to address possible causes and ways to avoid on-farm stray voltage. It also goes through what the farmer and utility should expect when conducting a stray voltage investigation, including the proper testing procedures for stray voltage. Although this Guide is focused on cattle and dairy farms, the processes and procedures are relevant to all types of livestock and livestock housing facilities.

The primary source document and model format for this Guide was the Iowa Stray Voltage Guide published July, 2014. The developers of the Iowa Guide used several sources of information as the technical basis for their Guide. The principal foundation for the processes and procedures of the Iowa Guide was the U.S. Department of Agriculture Handbook, "Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems", as well as material sourced from the Wisconsin Public Service Commission and the Midwest Rural Energy Council. Although the Iowa Stray Voltage Guide was used as a primary source document for the Minnesota Stray Voltage Guide with permission from the authors of the Iowa Guide, said authors have not actively participated in the development of this Minnesota Guide and they disclaim any liability or responsibility for the content hereof.

The USDA Handbook examines:

1. The history of stray voltage/current problems on farms
2. The physical and electrical sources of stray voltage/current phenomena
3. The physiological and behavioral basis for losses in milk production
4. Methods for identifying and detecting stray voltage/current problems
5. Methods for mitigating such problems; and
6. Areas where further research may be warranted

A full list of resources and reference material can be found at the end of this Guide.

Commitment to Research:

The Minnesota Stray Voltage Guide relies upon published and peer reviewed research available as of its publication in the summer of 2015, and uses the currently recognized "level of perception" for cows. New research may produce findings that alter our understanding and our practices in a number of fields of study. While the threshold voltages referenced and relied upon in this Guide are widely recognized, the participants in the Working Group acknowledge that future research or on-farm data collection, analyzed and published in peer reviewed technical journals may lead us to different conclusions and different practices which would necessitate amending the Guide.

FARMER HAS CONCERNS WITH STRAY VOLTAGE

Call Electric Utility?

- **No**[1]
  - Utility unaware of farmer's stray voltage concerns
- **Yes**
  - Utility explains stray voltage investigation protocols and policies
  - Farmer explains any investigation work done or completed by others

Is an investigation necessary?

- **No**
  - Utility performs no on-farm stray voltage testing
- **Yes**
  - Farmer explains biosecurity protocols and policies
  - Date & time set for utility site visit for stray voltage investigation[2]
  - Utility visits farm to begin Phase I testing *(See page 24 of this guide)*
  - Utility returns to farm to retrieve equipment and data from Phase I testing

Is stray voltage level above 0.5 volt at the animal contact point?

- **No**
  - Utility and farmer review report and discuss options of reducing on-farm contribution
  - Utility testing complete
  - Utility and farmer discuss options for future monitoring or other actions
- **Yes**
  - Utility and farmer review results from Phase I testing
  - Phase II testing begins *(See page 24 of this guide)*
  - Utility returns to farm to retrieve equipment and data from Phase II testing

Is utility contributing 0.5 or more volt at the animal contact point?

- **No**
- **Yes**
  - Utility takes action to reduce its contribution to below 0.5 volt at the animal contact point

[1] This is not a recommended path under the *Minnesota Stray Voltage Guide.*
[2] The utility or the farmer may use experts as necessary during the process.

COMMON CAUSES OF STRAY VOLTAGE

The following are examples of some common causes of stray voltage. These lists are not intended to be all inclusive but rather a list of common causes.

Common Causes of Stray Voltage

On-Farm

- Poor neutral conductor terminations and connections
- Damaged neutral conductors or conductor insulation
- Improper grounding and bonding of electrical systems and equipment
- Imbalance of 120 volt loads resulting in higher levels of neutral current
- Undersized neutral conductors for the neutral current load
- Improper separation of equipment grounding and neutral conductors in buildings
- Equipment problems
- Unintentional ground fault connections on conductors and equipment
- Electric fences, crowd gates or trainers

Off-Farm

- Loose neutral conductor connections
- Damaged neutral conductors or conductor insulation
- Improper grounding and bonding of electrical systems and equipment
- Undersized neutral conductors for the existing load
- System load imbalance on three-phase distribution lines
- Improperly functioning utility equipment
- Unintentional ground fault connections at neighboring properties

For more details on the above see chapter 6 of the "Wiring Handbook for Rural Facilities" a publication of MidWest Plan Service. A copy can be purchased at the following website: https://www-mwps.sws.iastate.edu/catalog/construction/wiring-handbook-rural-facilities

FARM WIRING CHECKLIST

This checklist will assist farmers and electrical contractors in visually inspecting farm electrical systems and noting potential stray voltage sources. A check mark placed in the "Yes" column indicates a potential problem. A licensed electrical contractor should be contacted if any electrical equipment or wiring needs to be repaired or replaced.

	Yes	No
Main farm service or distribution point		
Connections to grounding electrodes – loose or corroded	____	____
Grounding electrode(s) missing at the building or structure disconnecting means	____	____
Building or structure disconnecting means		
Grounding electrode(s) missing at the building or structure disconnecting means	____	____
Connections to grounding electrodes – loose or corroded	____	____
Accumulation of dust, debris, corrosion, etc.	____	____
Corroded or loose neutral connections	____	____
Panel covers removed or missing	____	____
Unused openings in equipment enclosures that are not properly sealed	____	____
Milkhouse		
Cords and cables sitting in water	____	____
Portable electric heaters on bulk tank	____	____
Broken or missing bonding strap for milk line	____	____
Damaged or missing covers for light fixtures, switches, receptacle outlets and other controls	____	____
Damaged, corroded or inoperable lighting fixtures	____	____
In the parlor or around the barn		
Pulsator wiring		
– Pinched wires	____	____
– Loose, hanging wires, stripped screws, etc.	____	____
– Scrapes, breaks or cracks in insulation with exposed conductors	____	____
– Broken stall cocks	____	____
Loose, hanging cables	____	____
Energized open conductors (not enclosed in conduit or electrical boxes)	____	____
120-volt equipment or appliances with attachment plugs that are not polarized or have no grounding prong	____	____
Cow trainer insulators broken, missing, dirty or covered with paint	____	____
Light fixtures alternately brightening or dimming when motors start	____	____
Light fixtures appear to be brighter than normal	____	____
Electrical shocks, tingles or perceptions from equipment or metallic objects	____	____
Cords, cables, electrical equipment or motors in damp or wet locations	____	____
Frequent tripping of overcurrent devices (fuses or circuit breakers)	____	____
Electric fence or cow trainer ground conductor connected to building AC electrical system	____	____
Electric fence or cow trainer ground conductor connected to water or milk lines or stanchions	____	____
Damaged electrical conduit	____	____
Damaged cable or wire insulation with exposed conductors	____	____
Cords and cables wrapped around metal piping or other metal systems	____	____
Damaged portable extension cords, connectors and plugs	____	____
Motors, operating irregularly under load, arcing, overheating, etc.	____	____
Receptacle outlets are not properly grounded or will not accept 3-prong attachment plugs	____	____
Broken, damaged or missing equipment grounding pins on cord attachment plugs or connectors	____	____

The following "Farm Wiring Checklist" and "Farm Wiring Summary Based on the National Electrical Code® (NEC®)" will assist farmers and licensed electrical contractors with an evaluation of the farm electrical system and to plan wiring improvements. Using these lists to identify potential problem areas and to implement on-farm wiring improvements can help reduce stray voltage levels and prevent unacceptable levels in the future.

PROPER FARM WIRING SUMMARY

Farm Wiring Summary Based on the National Electrical Code® (NEC®)

Customer Name	Representative, Inspector or Advisor Name		Date
Farm Address	City or Township	County	Zip Code

Note: A comprehensive electrical inspection is not normally performed as part of the utility stray voltage investigation. An existing premises electrical safety and electrical system inspection should be performed by a licensed electrical contractor. All electrical installations are required by law to comply with the National Electrical Code® (NEC®). The licensed electrical contractor is encouraged to consult with the state or municipal electrical inspector to discuss or clarify required code provisions. The electrical contractor will also arrange for any required electrical inspections with the state or municipal inspector for any new construction, remodeling, replacement or repair.

The following is a general list of farm wiring requirements based on the National Electrical Code® and other resources.

The National Electrical Code® contains the minimum installation rules and provisions that are considered necessary for electrical safety. With proper maintenance, the electrical installation should be essentially free from safety hazards. However, an electrical installation that only meets the minimum safety standard may not necessarily be efficient, convenient or adequate for good service and it may not have the capacity to allow for future expansion.

For the purpose of this document the term “listed” means electrical equipment and materials that have been evaluated and tested by an OSHA accredited Nationally Recognized Testing Laboratory (NRTL) and that meet appropriate standards and have been found to be suitable for a specific purpose.

Grounding and Bonding

- Alternating-current (ac) premises systems must be properly grounded.
- The premises central distribution point and each building supplied with electricity must be properly grounded to one or more grounding electrodes in accordance with the NEC®.
- The type and quantity of available grounding electrodes may vary at each location.
- Typical grounding electrodes include metal underground water piping, metal frames of buildings or structures, concrete-encased electrodes (footings and foundations), ground rings and ground rods.
- In general, grounding electrode conductors must be installed continuous without a splice or joint and be secured and protected from physical damage. Grounding electrode conductor terminations must be made with listed lugs, connectors, clamps or other listed and approved means.
- Raceways, enclosures and equipment at a central distribution point or at buildings must be properly grounded and bonded.
- At buildings served with an electrical supply, metal water piping systems, other metal piping systems and structural metal must be bonded to the building’s electrical system.
- All electrical equipment must be connected to an equipment grounding conductor of the correct type and size. Equipment grounding conductor continuity must be assured and connections must be made with listed devices that are suitable for the application and location.

Neutral Conductor (Grounded Conductor)

- The neutral (grounded) conductor must be bonded to the equipment grounding conductors at the premises service equipment, and only at this location. Unless otherwise permitted by the NEC®, the neutral (grounded) conductor shall NOT be used for grounding electrical equipment on the load side of the service disconnecting means. If the neutral (grounded) conductor is re-grounded downstream from the service disconnecting means, neutral current will flow back to the service equipment via the equipment grounding conductors, all intervening metallic raceways, metallic enclosures, other metallic systems and possibly the earth itself, which could significantly contribute to stray voltage problems.

Environmental Considerations

- Agricultural facilities are susceptible to the accumulation of excessive dust, dust with water, litter dust, feed dust, feed particles, fertilizers and other contaminates that can damage electrical equipment.
- Agricultural facilities may also have corrosive atmospheres, vapors and particles that can damage electrical equipment.
- Electrical equipment and devices at agricultural facilities, especially motors, must be installed in a manner that will allow the equipment to function at its full rating without developing surface temperatures in excess of the normal safe operating temperature for the equipment.
- Agricultural facilities are often damp or wet locations due to periodic cleaning and sanitizing or through the normal use associated with livestock confinement.
- Adverse environmental conditions in agricultural buildings can have a significant deteriorating impact on all electrical systems and equipment.

Wiring Methods

The NEC® permits the following wiring methods to be installed in agricultural buildings;

- Type UF cable (underground feeder and branch-circuit cable)
- Type SE cable (nonmetallic-sheathed service entrance cable with copper conductors, not aluminum)
- Type MC nonmetallic-jacketed cable (metal clad cable)
- Type PVC (rigid nonmetallic conduit) (See Note #4 below)
- Type LFNC (liquidtight flexible nonmetallic conduit)
- Type EMT (electrical metallic tubing) (where permitted by the following chart)
- Other cables and raceways that are suitable and approved for the application and location

The following chart is intended to outline the common types of farm buildings or portions thereof, and the required or permitted wiring methods, light fixtures, boxes, motors, panelboards and equipotential plane

Building or area	**Wiring Method**	**Light Fixtures**	**Boxes, Fittings, Controls**	**Motors**	**Panelboards**	**Equipotential Plane** See Note #1
Livestock confinement	Types SE, UF or PVC	Enclosed and listed for wet locations. Dusttight, watertight and corrosion resistant	Dusttight, watertight and corrosion resistant	Totally enclosed fan cooled (TEFC)	Not permitted	Required

PROPER FARM WIRING SUMMARY

Building or area	Wiring Method	Light Fixtures	Boxes, Fittings, Controls	Motors	Panelboards	Equipotential Plane See Note #1
Open-sided building or structure (no gates or doors to confine livestock)	Types SE, UF or PVC	General use	General use	TEFC	Not permitted	Required
Horse barn or stable	Types SE, UF or PVC	Enclosed over stalls, hay or bedding areas. General use elsewhere. See Note #2	In bedding areas, switches and receptacle outlets and controls must be in dusttight enclosures with weatherproof covers	TEFC	General use	Required
Milking parlor	Types SE, UF or PVC	Listed for wet locations	Watertight and corrosion resistant	TEFC	Not permitted	Required
Dairy barn	Types SE, UF or PVC	Enclosed, listed for wet locations and corrosion resistant	Dusttight, watertight and corrosion resistant	TEFC	Not permitted	Required
Milk room	Types SE, UF or PVC ,or EMT with watertight fittings	Listed for wet locations	Watertight	TEFC	Raintight	Not required
Equipment room, office, lunch room or other ancillary areas	General use. See Note #3	General use	General use	General use	General use	Not required
Poultry confinement	Types SE, UF or PVC	Dusttight, watertight and corrosion resistant	Dusttight, watertight and corrosion resistant	TEFC	Not permitted	Not required, but permitted
Silo and feed rooms and similar areas	Types SE, UF or PVC	Listed for damp locations, corrosion resistant and dusttight	Moisture and corrosion resistant and dusttight	TEFC	Raintight	Not Required
Hay or bulk feed storage or similar areas	Types SE, UF, PVC or EMT	Enclosed and dusttight	Dusttight	TEFC	Not permitted	Not required

Note #1:

Indoors:

An equipotential plane is required to be installed indoors in livestock confinement areas with concrete floors where metallic equipment is located and which may become energized and is accessible to livestock. Precast slatted floors that are supported by structures that are part of an equipotential plane are not required to be individually bonded.

Outdoors:

An equipotential plane is required to be installed outdoors in concrete slabs where metallic equipment is located and which may become energized and is accessible to livestock. The outdoor equipotential plane must encompass the area where livestock stand while accessing metallic equipment that may become energized.

Note #2: Light fixtures over stalls must have substantial guards where the fixture mounting location does not prevent contact by horses. Horses have a reputation for damaging electrical equipment that is within reach.

Note #3: Only wiring methods approved for the location shall be installed in concealed walls and ceilings of buildings, or portions thereof, which are contiguous with or adjoin livestock confinement areas (e.g. offices, lunch rooms, ancillary areas, etc.). Metallic-sheathed cables, metallic raceways or nonmetallic raceways are permitted. Nonmetallic-sheathed cables are NOT permitted to be installed concealed in walls and ceilings. Rodents and other pests will damage nonmetallic-sheathed cable-type concealed wiring. This type of damage has resulted in catastrophic fires and loss of buildings, animals and property.

Note #4: Expansion fittings for Type PVC raceways must be installed when required by the NEC®

General Information:

- Motors must be installed so that dust and debris build-up will not create motor surface temperatures in excess of normal operating temperatures.
- Line-voltage thermostats are considered motor controllers and must be provided with a disconnecting means in accordance with the NEC®.
- All electrical equipment must be readily accessible and capable of being reached quickly for operation, renewal or inspection without personnel having to remove obstacles or resort to portable ladders, etc.
- To ensure safety for personnel, minimum working clearances must be provided where required by code.
- It is advisable to consult with the appropriate insurance company before proceeding with any electrical installation. Insurance companies may have additional prescriptive electrical requirements.

Equipment enclosures, boxes, conduit bodies and fittings

- Equipment enclosures, boxes, conduit bodies and fittings installed in areas with excessive dust must be designed and approved to minimize the entrance of dust.
- Equipment enclosures, boxes, conduit bodies and fittings installed in damp or wet locations must be approved and shall prevent moisture from entering or accumulating within the enclosure, box, conduit, etc. In wet locations or normally dry or damp locations that are subject to periodic washing, boxes, conduit bodies and fittings must be listed for wet locations and equipment enclosures must be weatherproof, rainproof or raintight as applicable.

PROPER FARM WIRING SUMMARY

• Where wet dust, excessive moisture, corrosive gases and vapors or other corrosive conditions may be present, electrical equipment must be corrosive resistant and suitable for the conditions.
Flexible Connections • Where flexible connections are necessary, dusttight flexible connectors, liquidtight flexible metal conduit, liquidtight flexible nonmetallic conduit or hard usage flexible cord is permitted to be used.
Physical Protection • All electrical equipment, wiring and light fixtures, etc. must be protected from physical damage.
Equipment Grounding Conductors • Underground equipment grounding conductors must be insulated or covered.

Receptacles (GFCI Protection)
 	
Ground-fault circuit-interrupters (GFCI) are designed to protect people from severe or fatal electrical shocks
 	
• All 125-volt, single-phase, 15- and 20-ampere general purpose receptacles installed in the following locations must have ground-fault circuit-interrupter protection (GFCI):
  ○ All areas having an equipotential plane
  ○ Outdoors
  ○ Damp and wet locations
  ○ Dirt confinement areas for livestock

Switches, Receptacles, Circuit Breakers, Fuses, Controllers, Etc. • All switches, pushbuttons, relays, receptacles, circuit breakers, fuses, controllers and similar apparatus must be installed in approved enclosures that are suitable for the location.
Motors • Motors and other rotating machinery must be totally enclosed or designed to minimize the entrance of dust, moisture or corrosive particles.
Lighting Fixtures • Lighting fixtures must be designed and installed to minimize the entrance of dust, foreign matter, moisture and corrosive material. • Lighting fixtures exposed to physical damage must be protected by location or suitable guards. • Lighting fixtures exposed to water from condensation, cleansing water, power washing, etc. must be listed as suitable for use in wet locations.
Electrical Supply to Buildings or Structures from a Distribution Point Note: The various prescriptive requirements in the NEC® for configuring the electrical supply to buildings or structures for a premises are beyond the scope and purpose of this document. See the NEC® for detailed installation requirements. Following is a brief overview of the prescriptive requirements in the NEC®.

- A Distribution Point is defined as an electrical supply point from which service drops, service conductors, feeders or branch circuits are supplied to buildings or structures under single management on the premises (The distribution point is often referred to as the center yard pole, meter pole or common distribution point).
- Overhead Supply: A premises with overhead electrical supply must have a site-isolating device installed if two or more buildings or structures are supplied from the distribution point.
- Overhead Supply: For a premises with overhead electrical supply and a site-isolating device, the service disconnecting means and overcurrent protection may be located at the buildings or structures served.
- Overhead Supply: Alternatively, for a premises with overhead electrical supply, the service disconnecting means and overcurrent protection may be located at the distribution point.
- Underground Supply: For a premises with underground electrical supply to the buildings or structures served, the service disconnecting means and overcurrent protection must be located at the distribution point.

Equipotential Planes

- An equipotential plane is required to be installed indoors in livestock confinement areas with concrete floors where metallic equipment is located that may become energized and is accessible to livestock.
- Precast concrete slatted floors that are supported by structures that are part of an equipotential plane are not required to be individually bonded.
- An equipotential plane is required to be installed outdoors in concrete slabs where metallic equipment is located that may become energized and is accessible to livestock.
- The outdoor equipotential plane shall encompass the area where livestock stand while accessing metallic equipment that may become energized.
- Note: Methods for establishing equipotential planes are published by the American Society of Agricultural and Biological Engineers (ASABE) http://www.asabe.org/

Other Stray Voltage Reduction Strategies

- Balancing 120-volt loads: Within any given panelboard, balance the circuitry and loads to ensure that an approximate equal amount of load is being supplied by each hot (ungrounded) busbar. Balancing the electrical loads will minimize the amount of current flowing in the neutral conductor. Unbalanced excessive neutral current can contribute to stray voltage issues.
- Whenever possible, use 240-volt equipment instead of 120-volt equipment. Equipment operating at straight 240-volts does not need a neutral conductor and it reduces the potential for stray voltage.
- For single-phase installations, install a four-wire distribution system throughout the entire premises (two ungrounded (hot) conductors, a neutral conductor and a separate equipment grounding conductor).
- For three-phase installations, install a five-wire distribution system throughout the entire premises (three ungrounded (hot) conductors, a neutral conductor and a separate equipment grounding conductor).
- Install 240-volt livestock waterers and equipotential planes at each waterer to reduce stray voltage.
- For new buildings or structures or additions or alterations to existing buildings or structures, install equipotential planes as required by the NEC® and as prescribed by the American Society of Agricultural and Biological Engineers.
- If the existing electrical load or proposed new additional load will exceed the capacity of the premises electrical system, consider upgrading to three-phase service to the premises. In addition to increasing the capacity to the entire premises, three-phase electrical supply may help to reduce stray voltage.
- Ensure that all electrical equipment is listed and labeled by a Nationally Recognized Testing Laboratory (NRTL) such as Underwriters Laboratory® (UL®) or another OSHA-accredited testing laboratory.
- Ensure that all electrical equipment is installed in accordance with the manufacturer's installation instructions. The manufacturer's installation instructions are part of the listing and approval the manufacturer obtains from the NRTL. Full compliance with the NEC® is not achieved unless the equipment has also been installed in full compliance with the manufacturer's installation instructions.

FREQUENTLY ASKED QUESTIONS

Stray voltage investigations

1. **When a farmer calls about stray voltage, what happens?**

   The utility will listen to what type of concerns you have, what you want to happen and determine what the utility can do for you. If you are interested, the utility will make an appointment for the beginning of an actual stray voltage investigation.

2. **What does an initial stray voltage investigation include?**

   - Spot voltage checks are done at a representative number of animal contact locations to identify where animals may be exposed to voltage. Spot checks also identify the areas with higher voltage readings and where extended time animal contact voltage recording should be done. Voltage measurements are monitored with a recording voltage meter for a minimum of at least two milkings or approximately 24 hours. A nominal 500-Ohm resistor is used for extended animal contact monitoring in order to accurately measure the voltage livestock may feel. The recorder is also monitoring voltage levels on the utility electrical system at the transformer and the farm electrical system at a livestock building on the farm.
   - Detailed reports, data and explanations.
   - Providing a copy of *Farm Wiring Summary Based on the National Electrical Code® (NEC®).*

3. **How long does the utility test during an investigation?**

   The recording voltage meter is installed for two milkings or approximately 24 hours. Monitoring usually continues until it is determined that the entire electrical system has been evaluated and the concerns of the farmer are addressed.

4. **Does the testing include the utility system or just the farm wiring?**

   The utility will evaluate both the on-farm and off-farm electrical systems. The utility can show the measurements from both systems to you.

5. **Does the farmer get a copy of the testing results?**

   Yes, you will receive a summary letter, copies of the recorded data as graphs, and an explanation of all the data collected.

6. **Is there a cost to the farmer for an investigation?**

   The initial stray voltage investigation is usually provided by the electric utility to livestock farmers at no charge. Check with your electric utility for its specific practice or policy.

7. **Can the utility install a neutral isolator on my farm?**

   - Yes, the utility can install an isolator.
   - Isolation at the transformer can only be completed by the utility. A neutral isolator is a safety reconnect device. It is installed between the utility's primary neutral and the secondary neutral for the farm and disconnects the direct bonding connection between the utility and farm neutral conductors (isolation). Under normal operation this reduces stray voltage on the farm. However, under abnormal conditions (e.g., short circuits or lightning strikes) the isolator automatically reconnects the primary neutral and the secondary neutral for safety. After the event has passed, the isolator returns to the original state of isolation.

- Contact your utility representative to obtain any applicable forms and obtain information about the process and costs for installing an isolating device. If an isolation device is installed, you will need to discuss maintenance and inspection obligations with your electric utility.

8. What happens after initial testing?

- After testing is completed, the measured animal contact voltages are reviewed to determine further actions. While stray voltage can never be completely eliminated, steps can be taken to reduce the levels.
- Stray voltage can come from on-farm or off-farm sources. If a voltage difference of 1.0 volt AC or more exists between animal contact points (measured with a nominal 500-Ohm resistor in the circuit) it is recommended that action be taken to reduce this voltage. The utility will take action if 0.5 volt or greater is coming from off-farm sources and the farmer is encouraged to take action if the on-farm contribution is 0.5 volt or greater. If the utility distribution system contributes 0.5 volt or more to the animal contact voltage as determined by a load test of 20 kW (approximately 27 hp) of 240 volt load, the utility will take steps to address the issue until the utility's contribution to animal contact voltages are less than 0.5 volt. This level is used so proactive measures can be taken to prevent animal avoidance behavior and animal production losses.
- If animal contact voltages are due to the wiring on your farm, consult with your licensed electrical contractor and utility representative to resolve problems or improve the farm wiring system.

9. Is there any follow-up testing?

Your utility representative can also perform follow-up testing to determine the effectiveness of any modifications. Consult with your utility representative and licensed electrical contractor on new construction projects for the installation of equipotential planes.

10. Can farmers perform their own stray voltage testing?

There are certain tests of the utility electric system that can only be completed by the electric utility. The Midwest Rural Energy Council is a good source of information related to stray voltage. They have published a document titled "Stray Voltage Detection: A Self-Help Guide". This publication is intended to give you a basic understanding of stray voltage, some of its common sources, how to determine if harmful levels exist on your farm and when and how to call for assistance to help reduce stray voltage levels. This document is not intended to make you a stray voltage expert, but should provide you with the information necessary to safely determine if a problematic level of stray voltage is present on your farm at locations that are accessible to your livestock. This publication is specifically oriented toward the dairy farmer; however, most of the information provided is applicable to all livestock operations. A copy of this publication can be found on the web at: http://fyi.uwex.edu/mrec/files/2011/02/svd1.pdf

FREQUENTLY ASKED QUESTIONS

11. Can a stray voltage meter be installed for regular monitoring?

- An in-expensive and effective way to monitor the level of stray voltage in a cow contact area is for the livestock farmer to install a stray voltage meter. There are several brands of meters on the market that are currently being used to monitor stray voltage. All are effective, if they are installed and maintained properly.
- Even a good meter is not useful if it is not checked and maintained. All meter connections must be clean and tight to ensure accurate voltage readings. Routine checking of the voltage terminals, line clamps and wires is essential. Breaks in the wire, corrosion and excessive dirt build-up will severely impact voltage readings. You may want to keep a log of voltage readings from your meter for future reference. Follow your meter manual for instructions for proper operation and maintenance.
- For advice regarding installation of a stray voltage meter, please consult with your utility and an electrical contractor.

12. How might the Minnesota Public Utilities Commission be involved in a stray voltage investigation?

The Minnesota Public Utilities Commission regulates Minnesota's utility companies. This regulatory authority encompasses certain power quality issues, such as stray voltage. If you have an issue that cannot be resolved by the parties, you may file a complaint with the Commission. The following link on the Commission's website will give you more information about filing with the Commission: http://mn.gov/puc/electricity/for-consumers/index.html

13. What should I consider when selecting a stray voltage investigator?

- Your electric utility offers stray voltage information and some testing at no charge. Please contact your utility for more information about its specific policy and procedures for testing. A list of electric utility contacts is on page 23. When selecting a stray voltage investigator, care should be taken to ensure the investigator has the training and expertise necessary to help you identify the cause of the stray voltage problem. You may want to ask where they received their training and get referrals from other farmers. One such training program is through the University of Wisconsin Extension Service (See: http://fyi.uwex.edu/mrec/whats-new-calendar-of-events-2/). For best results in solving the problem, you should ask the investigator to follow the procedures and protocols outlined in this guide.
- There are also well recognized training and certification programs offered in Wisconsin and Michigan. More information can be found at the Wisconsin Department of Agriculture, Trade and Consumer Protection (See: http://datcp.wi.gov/Farms/Wisconsin_Farm_Center/Farm_Rewiring/Stray_Voltage/index.aspx), or the Michigan Agricultural Energy Council (See: http://maec.msu.edu/training.htm).
- For additional information, you may want to review the Iowa State University Extension publication entitled "Considerations when hiring a consultant", available at: https://www.extension.iastate.edu/agdm/wholefarm/pdf/c5-60.pdf

Steps for reducing stray voltage

14. What changes can be made on the farm to reduce stray voltage levels?

- Common practices used to reduce stray voltage levels on the farm include increasing the size of neutral conductors, improving neutral, grounding and bonding connections, and adding additional grounding electrodes.
- Levels can also be reduced by balancing 120 volt loads and replacing 120-volt equipment with 240-volt equipment.
- Equipotential planes that electrically bond together all accessible metallic structures and equipment, indoor concrete floors and outdoor concrete slabs in the animal confinement areas also effectively reduce stray voltage levels and help to prevent electric shocks during fault conditions.
- Converting a three-wire, single-phase premises distribution system to a four-wire, single-phase distribution system (with a separate equipment grounding conductor) may have a significant impact on reducing the possibility of stray voltage.
- Upgrading old incandescent and fluorescent lighting with new LED lighting fixtures or lamps reduces power consumption, cost and excess heat, and may help to reduce stray voltage.
- Periodic inspection and cleaning of electrical equipment, panelboards, enclosures, connections, etc., similar to what is done in every industrial establishment, not only ensures a safe and reliable electrical system, but it will also help to minimize outages, overheating, fires and other problems.
- Experienced stray voltage investigators can utilize the results of the Phase I and/or Phase II test results to prioritize and identify the most effective mitigation options for the farm.
- To reduce the influence of the neutral voltage, add an equipment grounding conductor along with the neutral and hot (ungrounded) conductors to animal confinement facilities in accordance with National Electrical Code®.

15. What changes can be done to the utility system to reduce stray voltage levels?

- Similar to mitigation options with the farm system, stray voltage levels can often be reduced by increasing the size of the utility neutral and improving connections and grounding.
- Balancing loads can be effective where multiple phases are available.
- Another option is to increase the primary system voltage to reduce the return current on the utility neutral for a given load and effectively reduce stray voltage levels.
- Separating the farm neutral and grounding system from the utility neutral and grounding systems by installing a neutral isolation device on the transformer may also reduce stray voltage levels but care must be taken to ensure both systems are adequately grounded and that the increase in neutral voltages on the utility system does not negatively impact neighboring farms.

FREQUENTLY ASKED QUESTIONS

Planning for the future

16. I am considering expanding my livestock operations. Are there any resources to help me plan for this?

- Your licensed electrical contractor and utility representative are important resources to involve early in the planning process.
- A significant amount of Minnesota's farms are served by single-phase distribution lines. Additions of motorized equipment or farm expansions may add to the electrical capacity requirements of the farm. The utility service should be evaluated to determine the impact of this new electrical load on stray voltage levels. Using recommended farm wiring practices that reduce stray voltage is important. The utility must also plan for increased loads on their system to prevent stray voltage from becoming a problem. This may include additional cost for upgrading the utility system neutral or extending three-phase distribution lines.
- Additionally, the Midwest Rural Energy Council has a good publication titled "Planning Electrical Systems for Dairy Expansions". A copy of this publication can be found on the web at: http://fyi.uwex.edu/mrec/files/2011/02/pes2.pdf. Another resource is the Coalition to Support Iowa's Farmers, call: 1-800-932-2436 or see: http://www.supportfarmers.com/

17. Are there any resources to help me plan for the installation or operation of cow trainers, crowd gates and electric fences?

Yes, the Midwest Rural Energy Council has a publication titled "Installation and Operation of Electric Fences, Cow Trainers and Crowd Gates". This publication can be found on the web at: http://fyi.uwex.edu/mrec/files/2011/02/ElectricFencers_MREC_051.pdf

18. I am considering the installation of wind energy on my farm. Are there any considerations related to stray voltage for adding wind energy to my farm?

- The Midwest Rural Energy Council has a publication titled "Wind Turbines and Farm Stray Voltage". A copy of this publication can be found on the web at: http://fyi.uwex.edu/mrec/files/2014/03/WindTurbinesStrayVoltage-pages.pdf
- While the above information applies to wind energy, it would likely also apply to solar photovoltaic (PV), methane digesters or other on-farm generation sources.

19. If I am considering the installation of a generation resource, do I need to contact my electric utility (e.g., wind, solar photovoltaic, methane digester, etc.) ?

Yes, it is essential and very important that you contact your electric utility when considering the purchase of any stand-alone or utility-interactive generation for your farm. Your electric utility is a valuable source of information related to your decision so contact them when considering investing in any generation resource.

Electrical licensing, permits, inspections and codes

20. Is the performance of electrical work a regulated activity in Minnesota?

Yes. Occupational and business licensure related to electrical work was established by the legislature in 1899 due to the expanding use of electricity and the hazards associated with its use. Currently, there are several classes of business (contractor) licenses and numerous classes of occupational (personal) licenses. Contractor and personal licenses have distinctly different purposes; an entity with only a contractor license cannot perform electrical work without also holding a personal license. An entity with only a personal license cannot perform or offer to perform electrical work as an electrical contractor without also holding a contractor's license.

21. How is electrical work defined?

"Electrical work" is defined in law as the installing, altering, repairing, planning or laying out of electrical wiring, apparatus or equipment for electrical light, heat, power, technology circuits or systems or other purposes and includes, but is not limited to, the performance of any work regulated by the National Electrical Safety Code® (NESC®) and the National Electrical Code® (NEC®).

22. What are the mandatory electrical safety standards that are applicable in Minnesota?

- The National Electrical Safety Code® (NESC®) and the National Electrical Code® (NEC®) are the two electrical safety standards that are adopted by law in Minnesota.
- The NESC® (published by IEEE) is the electrical safety code that is applicable to the electrical systems and equipment under the control of electric utilities.
- The NEC® (published by NFPA) is the electrical code that is applicable to the premises electrical system under the control of the property owner.

23. Where is the demarcation between the electric utility system and the premises electrical system?

The NESC® and the NEC® share a common definition for "service point", which is defined as the point of connection between the facilities of the serving utility and the premises wiring. The location of the service point is typically determined by the electric utility. The service point location can vary greatly depending on several different configurations and characteristics of the electrical installation.

24. Who is allowed or required to perform electrical work in Minnesota?

- **Electric Utility System**
  There is an exemption from electrical licensing and inspection for employees of electric utilities when they are performing electrical work related to generation, transformation, transmission and distribution on the utility side of the service point.
- **Premises Electrical System**
  Virtually all electrical work on the premises side of the service point is required to be performed by licensed electrical contractors and their licensed or registered employees.

FREQUENTLY ASKED QUESTIONS

25. Are inspections required for electrical work?

Virtually all electrical work that is installed on the premises side of the service point is required to be inspected. There is an exemption from inspection for minor repair work, which is defined in law as the adjustment, repair or replacement of worn or defective parts of electrical equipment and the replacement of defective receptacle outlets and light switches.

26. How much does an electrical inspection cost; how much are the inspection fees?

Electrical inspection fees are very reasonable and nominal due to the large volume of electrical permits issued in the state (well in excess of 100,000 electrical permits on an annual basis). In state inspection areas the minimum inspection fee for one electrical inspection is only $35. Electrical inspection fees for a project are calculated based on the service, feeders, branch circuits, transformers, etc.

27. Who is responsible for filing the Request for Electrical Inspection (permit)?

Each entity that performs electrical work on a given project is required by law to file the electrical permit under their own contractor or personal name. If a licensed electrical contractor performs the electrical work, they are responsible for filing the permit. If the farmer (owner) performs their own electrical work as noted below, they are responsible for filing the permit.

28. Who performs the electrical inspections?

The state of Minnesota utilizes contract electrical inspectors to provide electrical inspection service across the entire state. There are also several municipalities that provide their own electrical inspections using contracted or employed electrical inspectors. All electrical inspectors in Minnesota are required to hold either a journeyman or master electrician license. Most electrical inspectors have 20 or more years of electrical industry experience. All electrical inspectors are bonded and insured and belong to the International Association of Electrical Inspectors (IAEI) which is dedicated to electrical inspector education and training.

29. Who oversees the electrical licensing and inspection programs?

In municipal jurisdictions, electrical inspections are supervised by the municipality. In state jurisdictions, contract electrical inspectors are monitored by the state's electrical area representatives, who report to the Chief Electrical Inspector, who reports to the managers and directors in the Construction Codes and Licensing Division (CCLD), who ultimately report to the commissioner of the Department of Labor & Industry (DLI).

30. Is a farmer permitted to perform their own electrical work on their own premises?

Yes. If a farmer meets the definition of "owner" as defined in law the farmer is exempt from having to possess an electrical license. An owner (i.e. homeowner) is defined as an individual who physically performs electrical work on the premises the individual owns and actually occupies as a residence or owns and will occupy as a residence upon completion of its construction. In addition to the premises residential dwelling, the exemption from licensing is also applicable to garages and accessory buildings (including farm buildings and structures) that can only be used by the owner. An owner is required by law to obtain an electrical permit and have all of their electrical work inspected, the same as it is required for an electrical contractor.

31. Is there more electrical information available online?

Following are some links to the Department of Labor & Industry's website:

- **Construction Codes and Licensing Division Home Page (CCLD)**

  Information about the State Building Code and all of its various components

  – http://www.dli.mn.gov/Ccld.asp

- **Hiring a Contractor**

  Tips for hiring contractors

  – http://www.dli.mn.gov/CCLD/RBCConsumer.asp

- **CCLD Contact Directory**

  Online lookup directory of all CCLD staff

  – http://www.dli.mn.gov/CCLD/CCLDContactUs.asp

- **Verify Contractor and Personal Licenses**

  Online lookup tool for checking contractor or personal licenses

  – https://secure.doli.state.mn.us/lookup/licensing.aspx

- **Jurisdiction Directory**

  Online lookup tool for codes and inspections by city, township or county

  – http://workplace.doli.state.mn.us/jurisdiction/

- **Electrical Licensing and Inspection Home Page**

  Online portal to electrical licensing and inspection information

  – http://www.dli.mn.gov/CCLD/Electrical.asp

- **Electrical Permits for Contractors and Homeowners**

  Information about filing electrical permits online or via paper forms

  – http://www.dli.mn.gov/CCLD/etrakit_electrical.asp

- **Directories for Electrical Inspectors and Electrical Area Representatives**

  Online lookup directory for state and municipal electrical inspectors

  – http://www.dli.mn.gov/CCLD/ElectricalInspect.asp

- **Approval of Electrical Equipment**

  Information about Minnesota's requirements for electrical equipment

  – http://www.dli.mn.gov/CCLD/ElectricalEquipment.asp

HIRING A LICENSED ELECTRICAL CONTRACTOR

For on-farm wiring

Finding the right licensed electrical contractor to do work on your farm is important. Not just to make sure you get your money's worth, but to make sure the work is done right and safe, in compliance with all applicable codes, and in a way that can help reduce stray voltage concerns rather than compound them. There should be more to the analysis than just how much the job might cost. In order to assist individuals in selecting a licensed electrical contractor, the following questions should be asked:

- Are you licensed in Minnesota as an electrical contractor?
- Do you have any experience with farm wiring?
- If yes, how long have you been doing this work?
- What special training or experience do you have with farm wiring?
- Do you have any training in the areas of stray voltage and power quality issues?
- What assurances can you provide that all wiring will be performed in accordance with the National Electrical Code®?
- What assurances can you provide that all equipment and materials will be approved for the farm environment (i.e., weatherproof, raintight, dusttight, UL listed, etc.)?
- Will you provide references for past work similar to what is proposed?
- Will you provide a written estimate and what the estimate includes?
- What assurances can you provide that you will obtain the required electrical permits and arrange for the required electrical inspections?
- Are services available after-hours and in case of emergencies?
- Are services available to evaluate and troubleshoot existing electrical systems?
- Will an itemized statement be provided?
- Do you have a good working relationship with the local electric utility and the local electrical inspector?
- Will you guarantee or provide a warranty for your work?

In addition, although not specific to licensed electrical contractors or contractors for farms, the following links provide some relevant tips on how to hire contractors, consultants, builders or other service providers:

- **Federal Trade Commission – Hiring a contractor**
  - http://www.consumer.ftc.gov/articles/0242-hiring-contractor
- **Department of Labor & Industry Consumer Information – How to hire a contractor**
  - http://www.dli.mn.gov/CCLD/RBCConsumer.asp
- **Consumer publications from the Office of the Minnesota Attorney General**
  - https://www.ag.state.mn.us/Office/Publications.asp
  - https://www.ag.state.mn.us/Brochures/pubHomeBuilding.pdf

UTILITY CONTACT INFORMATION

The following is current contact information for electric utilities in Minnesota regarding stray voltage.

Distribution Cooperative

Agralite Electric Co-op	320-843-4150
Arrowhead Cooperative	218-663-7239
Beltrami Electric Co-op, Inc.	218-444-2540
BENCO Electric	507-387-7963
Brown County Rural Electrical Association	507-794-3331
Clearwater-Polk Elec Co-op, Inc.	218-694-6241
Connexus Energy	763-323-2600
Cooperative Light & Power	218-834-2226
Crow Wing Power	218-829-2827
Dakota Electric Association	651-463-6212
East Central Energy	800-254-7944
Federated Rural Electric Assn	507-847-3520
Freeborn-Mower Co-op Services	507-373-6421
Goodhue County Co-op Elec Assn	507-732-5117
Itasca-Mantrap Co-op Electrical Association	218-732-3377
Kandiyohi Power Cooperative	320-796-1161
Lake Country Power	800-421-9959
Lake Region Electric Cooperative	800-552-7658
Lyon-Lincoln Elec Co-op, Inc.	507-247-5505
McLeod Cooperative Power Association	320-864-3148
Meeker Cooperative Light & Power Assn	320-693-3231
Mille Lacs Energy Cooperative	218-927-2191
Minnesota Rural Electric Association	763-424-7233
Minnesota Valley Co-op Light & Power Association	320-269-2163
Minnesota Valley Electric Co-op	952-492-2313
Nobles Cooperative Electric	507-372-7331
North Itasca Elec Co-op, Inc.	218-743-3131
North Star Electric Co-op	218-634-2202
People's Energy Cooperative	507-367-7000
PKM Electric Cooperative, Inc.	218-745-4711
Red Lake Elec Co-op, Inc.	218-253-2168
Red River Valley Co-op Power Assn	218-456-2139
Redwood Electric Co-op	507-692-2214
Renville-Sibley Co-op Power Assn	320-826-2593
Roseau Electric Co-op, Inc.	218-463-1543
Runestone Electric Assn	320-762-1121
Sioux Valley Energy	605-534-3535
South Central Elec Assn	507-375-3164
Stearns Electric Assn	320-256-4241
Steele-Waseca Cooperative Electric	507-451-7340
Todd-Wadena Electric Co-op	218-631-3120
Traverse Electric Co-op, Inc.	320-563-8616
Tri-County Electric Co-op	507-864-7783
Wild Rice Elec Co-op, Inc.	218-935-2517
Wright-Hennepin Cooperative Electric Association	763-477-3000

Investor Owned Utilities

Minnesota Power	800-228-4966
Otter Tail Power	800-257-4044
Xcel Energy	651-779-3131

Municipal Utilities

Minnesota Municipal Utilities Association	800-422-0119

TESTING PROCEDURES

Description of Phase I and Phase II Testing Procedures

Information about Biosecurity Protocols

It is always important when scheduling the initial appointment to ask the farm owner or manager what biosecurity guidelines you must follow.

Phase I Protocol

This is an initial screening for stray voltage at a farm done by conducting a 24-hour test. It is used to determine stray voltage levels at animal contact locations. It is also used to assess the basic characteristics of the farm's electrical system and the utility distribution system in the vicinity of the farm. A Phase I investigation would include the following:

- Spot voltage checks are done at a representative number of animal contact locations to identify where animals may be exposed to voltage. Spot checks also identify the areas with higher voltage readings and where extended time animal contact voltage recording should be done. Voltage measurements are monitored with a recording voltage meter for a minimum of at least two milkings or approximately 24 hours. A nominal 500-Ohm resistor is used for extended animal contact monitoring in order to accurately measure the voltage livestock may feel. The recorder is also monitoring voltage levels on the utility electrical system at the transformer and the farm electrical system at a livestock building on the farm.
- Care must be taken to document the circuit being measured to avoid needless disagreement about the voltages found. Also, calculating the Source Resistance and using it to ensure an accurate voltage has been established is advised. See Definition of Source Resistance in the Glossary for explanation and description of how to perform the test.
- Detailed reports, data and explanations.
- Providing a copy of *Farm Wiring Summary Based on the National Electrical Code® (NEC®).*

(See page 8)

Phase II Protocol

A comprehensive test strategy designed by the Wisconsin PSC and used to determine all sources of animal contact voltage both from on-farm and off-farm sources. There are five specific tests: (1) the load box test, (2) the secondary neutral voltage drop test, (3) the signature test, (4) the primary profile test, and (5) the 24-hour test. Other tests may be performed as necessary to give a complete account of the electrical activity on the farm.

Load Box Test (LB test)

Purpose: This test is used to determine the extent to which the primary system contributes to stray current or voltage at animal contact points.

Description: This test is used to help determine the amount of utility contribution to any animal contact voltage/current exclusive of any contribution from on-farm sources. In this test, all farm loads are disconnected from the electrical system. The primary transformer has a 240-Volt resistive load box of 18 to 25 kW size connected to it. Various currents and voltages are measured to determine if the utility system has the ability to contribute 1 milliAmp of current or more to the animal contact area under that maximum proxy load of 18 to 25 kW.

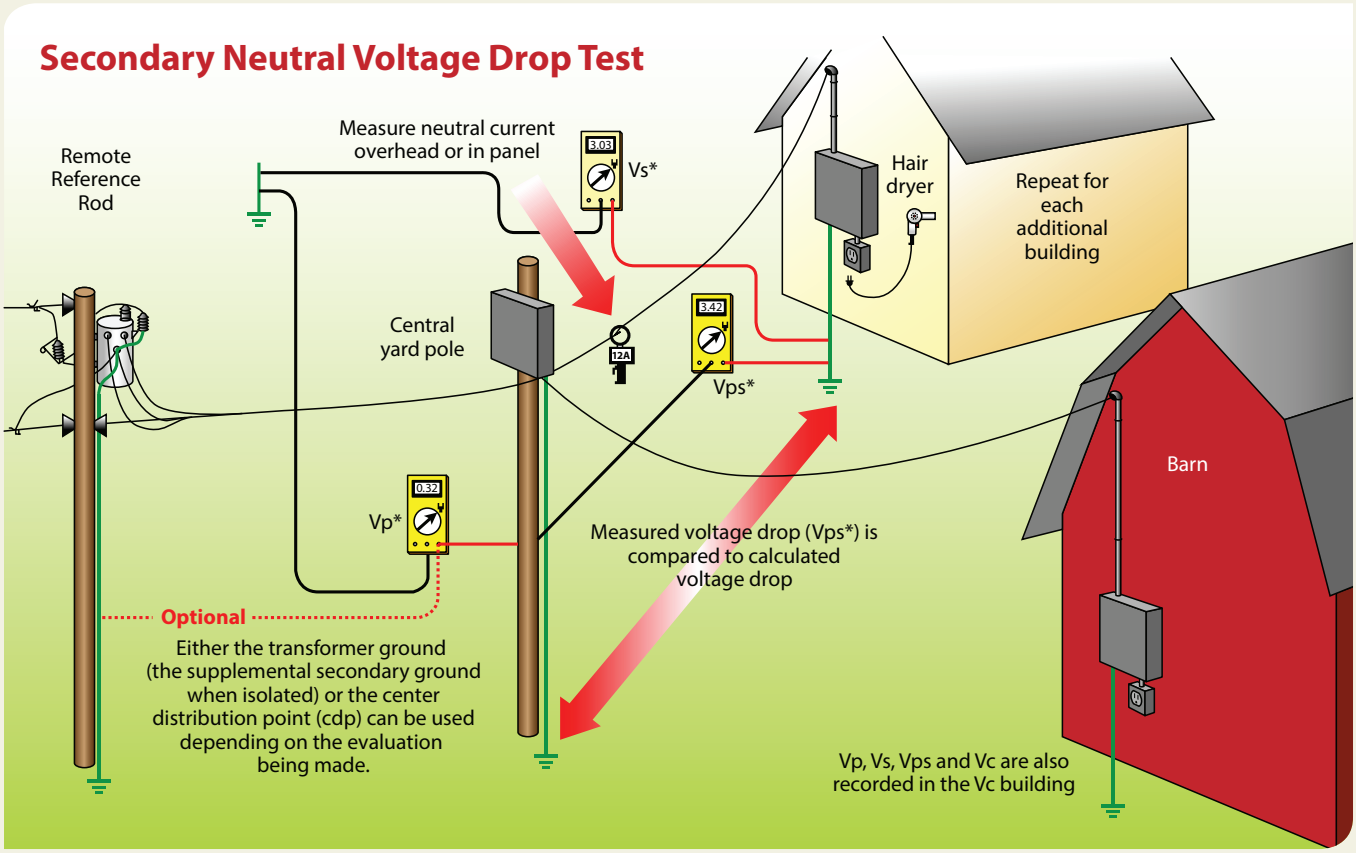
Sample Form See Appendix A.

Secondary Neutral Voltage Drop Test (SNVD test)

Purpose: This test is used to determine the impact of each secondary service on the neutral-to-earth (NEV) and animal contact voltages on the dairy under controlled conditions.

Description: A test that looks at each farm electrical service to determine its possible contribution to animal contact voltage. For this test, one service at a time is energized and only one proxy load is powered. This load is usually a hair dryer or paint peeler having a uniform current draw at 120 V rms AC in excess of 10 Amps. Measurements are made of the physical length of the neutral from the main distribution panel to the sub-panel or load point being tested. The exact type of conductor used for that neutral is noted so that its resistance per 100 feet can be ascertained. A calculation is made of the product of the distance of the neutral (in hundreds of feet) and the resistance per 100 feet resulting in the total resistance of the neutral conductor. A measurement is made of the proxy load current and, using Ohm's Law, a calculation is made of the expected voltage drop on the neutral conductor at full load. The voltage drop from the source point to the load point is then measured and compared to the calculated value. If they differ significantly, this may indicate some unexpected resistance in the neutral circuit. The contribution to the animal contact voltage of this source is also measured and if it is significant, the condition is noted for possible mitigation.

Sample Form See Appendix A.



The above is a sample illustration of this test.

TESTING PROCEDURES

Description of Phase I and Phase II Testing Procedures

Signature Test

Purpose: This test is used to determine the contribution to stray current or voltage of individual pieces of equipment operating on the farm. The test is best performed when there is minimal farm electrical activity.

Description: During this test, individual pieces of major current drawing equipment are started and stopped. The effects of starting, operating and stopping of equipment will be measured and recorded for a period of operation of at least fifteen (15) seconds. The person conducting the test will identity and record the equipment being tested and record the specific times that the equipment was started and stopped. A digitizing data recorder is usually used to measure and record the required electrical data. These measurements are usually taken at the same locations at the dairy where measurements were taken for the purpose of the load box test and twenty-four (24) hour test.

Sample Form See Appendix A.

Primary Profile Test

Purpose: The purpose of this test is to measure or calculate neutral-to-earth voltage (NEV) for a multi-grounded distribution system.

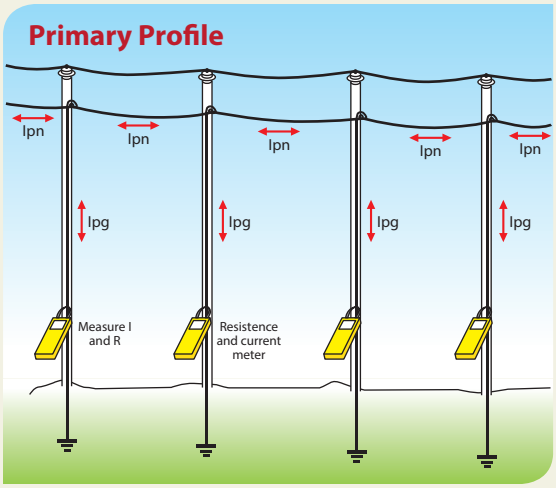
Description: A test where nearly simultaneous readings of primary system grounding current and ground rod resistance are made. These readings are taken for all grounded primary distribution poles for three quarters of a mile from the farm's transformer pole. From this data and using Ohm's Law, a primary neutral to earth voltage can be calculated for each pole. This data is useful in analyzing the character and capabilities of the distribution neutral/ground system in the vicinity of the farm.

Sample Form See Appendix A.

"24-Hour" Test

Purpose and Description: The primary purpose of the "24-hour" (at least two milkings) test is to monitor animal contact voltage levels over approximately a 24 hour period during normal farm operations. Testing should be scheduled during a time that reflects the operating conditions when impact of stray voltage is suspected. For example, seasonal variations in electrical load (on-farm or off-farm) or changes in ground resistance due to soil moisture can impact measureable levels of stray voltage. This test is typically done by installing a recording voltmeter which will continuously record voltage levels for the duration of the test. This test is useful in monitoring changes in voltage as farm load fluctuates during the test period. It will also help to determine if additional testing is necessary. Instantaneous spot checks are initially performed around the farmstead at animal contact points such as stalls and waterers in order to identify the areas with the most significant animal contact voltage exposure. The recording voltmeter is then installed for about 24 hours.

Care must be taken to document the circuit being measured to avoid needless disagreement about the voltages found. Calculating the Source Resistance and using it to ensure an accurate voltage has been established is advised. See Definition of Source Resistance in the Glossary for explanation and description of how to perform the test.



APPENDIX A

The following are sample forms for performing the various tests for stray voltage. These forms were developed from materials from the Wisconsin Public Service Commission. For details on completing the forms visit the following website:

http://psc.wi.gov/utilityinfo/electric/strayvoltage.htm

PRIMARY NEUTRAL VOLTAGE DROP-LOAD BOX

Date	Customer Name	Customer Premise No.

NEUTRAL ISOLATOR INSTALLED: ❒ Yes ❒ No

	FARM OFF			FARM ON	
	NO LOAD	1/2 LOAD *(Low)*	FULL LOAD *(hi)*	FULL LOAD	LOAD BOX OFF
TIME					
Ip ❒ Meas ❒ Calc					
Ipn					
Isn					
Isn net	XXXXXXX	XXXXXXXX	XXXXXXX		
Vp					
Vs					
Vps					
Vc					

Notes:

CALCULATIONS *(Farm Off)*	SUMMARY
Rt = Vp hi - Vp Low / Ip hi - Ip Low = _____ = _____ ohms	
Rp = Vp hi - Vp Low / Ipn hi - Ipn Low = _____ = _____ ohms	
Rf = Vs hi - Vs Low / Isn hi - Isn Low = _____ = _____ ohms	
K = Vc hi / Vs hi = _____ = _____ %	
CR = Ipn hi - Ipn Low / Ip hi - Ip Low = _____ = _____ %	

Primary Phase Current may be calculated using the measured secondary current of the load box and the known transformer ratio (ex. for a 240 volt secondary load box you measure 100 amps, with a 30:1 transformer ratio, the phase current at 7,200 volts would be 100 amps / 30 = 3.3 amps)

APPENDIX A

Continued

DEFINITIONS

Ip = Primary Phase Current

Ipn = Primary Neutral Current

Isn = Secondary Neutral Current

Isn net = Net current when simultaneously clamping the two secondary phase and the neutral conductors

Vp = Primary voltage taken with handheld or recording voltmeter

Vs = Secondary voltage taken with handheld or recording voltmeter

Vps = Voltage between primary and secondary neutrals taken with handheld or recording voltmeter

Vc = Animal contact voltage taken with a handheld or recording voltmeter

Rt = Combined resistance of farm and utility system

Rp = Resistance of primary system

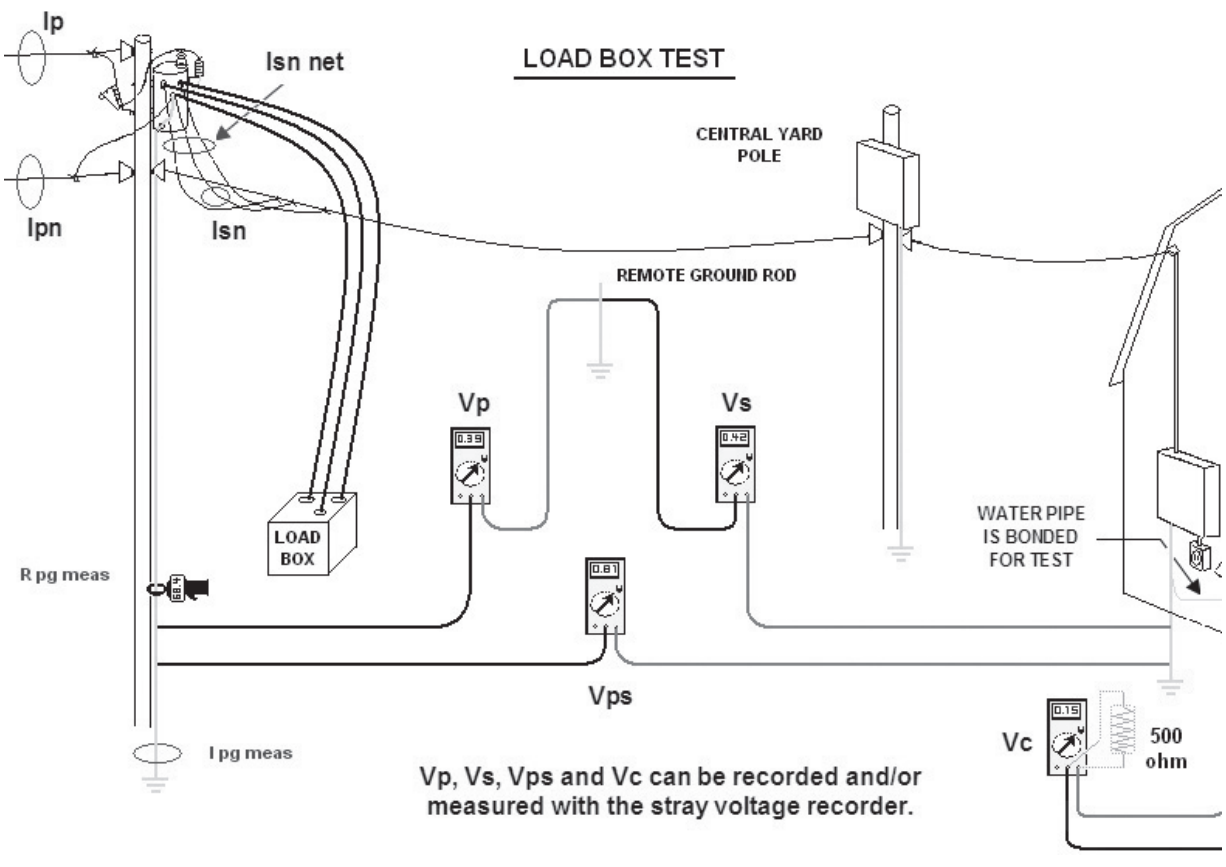
Rf = Resistance of farm

K = K-factor, ratio of Vc to Vs, % of secondary voltage at animal contact

CR = Current ratio, % of primary current returning on utility neutral

Voltage Ratio (VR) test – If the K factor exceeds 50%, the VR test can be used to see if the reference rod is under the influence of the farm/primary electrical system. Measure the farm primary pole ground resistance (Rpg meas) and current (Ipg meas). If the main disconnect is within 30 feet of this ground rod, use the next existing rod back toward the substation. Calculate primary neutral voltage (i.e. Vp calc=Ipg x Rpg) and compare to value measured by load box test with load box off, farm on (Vp). If the two values are within 20% (high or low), reference rod is in the correct location.

LOAD BOX TEST DIAGRAM



SECONDARY NEUTRAL VOLTAGE DROP TEST

PHASE II - SECONDARY NEUTRAL VOLTAGE DROP TEST

	Customer Name:				Isolated? **Y N**		
	Date:	Utility Rep:					
(All other farm loads off, and use only one load per site. Notes and exceptions recorded at bottom)							
Location							
A.Wire size							AWG
B.Wire Length/100							Ft
C.Ohms/100ft							
D.Total Ohms (BxC)							
Hairdryer (120V load) time	OFF	ON	OFF	ON	OFF	ON	
E.Measured neutral current							A
F.Calculated Voltage Drop (DxE)							V
Vps* -measured VD (Equipment ground to cdp / xfmr / ssg **)							V
Vs* (Equipment ground to ref rod)							V
Vp* ref. rod to NOTE - **circle one** cdp / xmfr / ssg **							V
Recorder in building with Vc **Vp**							V
Vs							V
Vps							V
Vc							V

Comments:

* Indicates a building other than the Vc building.
** Center Distribution Point Ground (cdp)
Supplementary Secondary Ground (ssg)
Transformer Ground (xfmr)
Either the transformer ground (ssg when isolated) or the center distribution point (cdp) can be used depending on the evaluation being made. If using tranformer ground, Vp=Vp* when not isolated.

Resistance Chart (Ohms per 100 feet)

Size	Al:	Cu:	Size	Al:	Cu:
14	0.420	0.260	3	0.034	0.020
12	0.260	0.160	2	0.027	0.016
10	0.170	0.100	1	0.021	0.013
8	0.110	0.064	1/0	0.017	0.010
6	0.067	0.041	2/0	0.013	0.008
4	0.042	0.026	3/0	0.011	0.006
			4/0	0.008	0.005

SIGNATURE TEST

PHASE II SIGNATURE TEST

INSTRUCTIONS:

1. Note type and voltage of load. For 120 volts, use enough load to generate 10 amperes of load current.
2. For existing farm loads, note the type of load and voltage (ex. Barn Cleaner, 240 volts, Barn Lighting, 120 volts).
3. Note the location of load (ex. Barn, Shed, NW corner of Feed Bunk, etc.).
4. Note times for turn-on and turn-off. Equipment should be turned on for the signature for a period of not less than 10 seconds.
   Put an asterisk in the last column if you found the equipment already on and you turned it off, so that the times shown in reverse order make sense.

Customer Name				Date		
Utility Representative Name				Utility Isolated ☐ Yes ☐ No		
TEST NO.	LOAD TYPE AND VOLTS	LOCATION OF LOAD	TIME ON	TIME OFF	(*)	MISCELLANEOUS NOTES
Utility Representative Signature				Date		

PRIMARY PROFILE TEST

PRIMARY PROFILE DATA FORM

Customer name: _____ Date: _____

Test performed by: _____

Record the current (Ipg) and the resistance (Rpg) of each ground rod in a linear pattern ¾ ths of a mile on each side of the farm's tap/transformer pole. Calculate, using Ohm's Law, the primary neutral to earth voltage (Vpne) for each pole. Use the notes section to annotate the condition of each pole and if the pole has a transformer, capacitor bank, recloser, arrestor, telephone pedestal or CATV device, etc. attached.

POLE #	POLE ID #	Ipg (mA)	Rpg (Ω)	Calc. Vpne (V)	Notes
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					

APPENDIX B

Model Report for Utilities to Use with Farmers

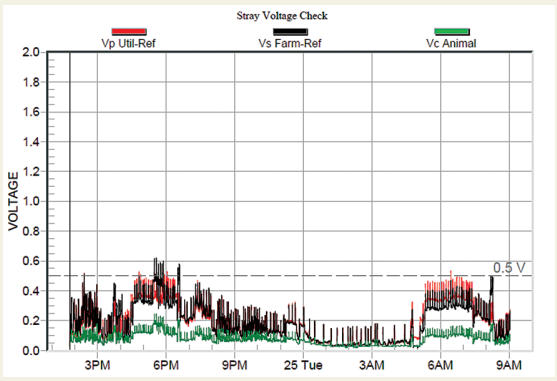
Examples of items to include:

1. Graph of voltages recorded during the monitoring period.
2. Highest animal contact steady-state voltage measured during testing and the location of that measurement.
3. Reference to the standard used by the utility for decision making regarding more testing to determine voltage sources.
4. If necessary, a description of any utility changes that were made during testing or will be made after testing.
5. Provide farm wiring recommendations or reference a farm wiring guide or checklist.

Sample Letter for Utilities Report to Farmers:

Dear {Insert farmer name},

This report summarizes the stray voltage analysis that your utility conducted on your farm (INSERT DATE). Thanks for your cooperation during this time.



Following is a graph from the stray voltage recorder showing voltage levels measured. The green line shows animal contact (stall to floor at the north parlor entry door) voltage. The red line shows primary neutral at the transformer to remote ground rod levels and the black line shows the parlor and milk house service panel grounding bar (secondary neutral) to a remote ground rod.

The highest cow contact steady state voltage level measured in the parlor was 0.25 volt. Cow contact measurements were taken with a nominal 500-Ohm resistor.

Stray voltage can come from on-farm or off-farm sources. The utility uses a conservative, preventative action level of 1.0 volt steady state voltage for animal contact areas to prevent cow avoidance behavior. The levels of steady state voltage measured on your farm do not exceed this level. The utility will take action if 0.5 volt or greater is coming from off-farm sources and the farmer is encouraged to take action if the on-farm contribution is 0.5 volt or greater. For your farm, the off-farm contribution was measured at 0.25 volt, which is under the 0.5 volt level where your utility will take action to reduce its contribution to animal contact areas based on a 20 kW load test. In order to keep stray voltage levels low, refer to the enclosed farm wiring checklist. Electrical construction, remodeling, replacement and repairs are required to be made in accordance with the National Electrical Code®.

If you have any questions on this report, call me at xxx-xxx-xxxx.

Sincerely,

APPENDIX C

List of Reference Materials for Utilities, Farmers and Electrical Contractors

The following is not intended to be an all-inclusive list of resources but at least a beginning point.

United States Department of Agriculture Handbook

(USDA Handbook) titled "Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems" issued December 1991 *naldc.nal.usda.gov/download/CAT92970513/PDF*

Public Service Commission of Wisconsin

psc.wi.gov/utilityinfo/electric/strayvoltage.htm

Midwest Rural Energy Council (MREC)

The Midwest Rural Energy Council (MREC) (*http://www.mrec.org/)* has developed a number of publications on rural energy issues. The following brochures are from 8 to 20 pages long and provide detailed coverage of the subject matter. For orders of 500 or more copies of one brochure, the brochures may be special printed with your logo attached. If you would like a single copy or would like to review these MREC publications, they are available for download by clicking the following links.

- **Wiring Handbook for Rural Facilities**
  https://www-mwps.sws.iastate.edu/catalog/construction/wiring-handbook-rural-facilities
- **Equipotential Planes for Stray Voltage Reduction: Installation Guidelines**
  http://fyi.uwex.edu/mrec/files/2011/02/2006-MREC-Equipotential-Planes.pdf
- **Planning Electrical Systems for Dairy Expansions**
  http://fyi.uwex.edu/mrec/files/2011/02/pes2.pdf
- **Farming Safely and Efficiently with Electricity**
  http://fyi.uwex.edu/mrec/files/2011/02/farmsafe.pdf
- **Stray Voltage Detection: A Self-Help Guide**
  http://fyi.uwex.edu/mrec/files/2011/02/svd.pdf
- **Power Quality and Computers on the Farm**
  http://fyi.uwex.edu/mrec/files/2011/02/pq.pdf
- **Installation and Operation of Fencers, Cow Trainers and Crowd Gates**
  http://fyi.uwex.edu/mrec/files/2011/02/ElectricFencers_MREC_05.pdf
- **Wind Turbines and Farm Stray Voltage**
  http://fyi.uwex.edu/mrec/files/2014/03/WindTurbinesStrayVoltage-pages.pdf

MREC Informational Sheets

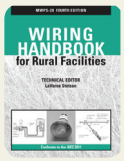
These short, one page informational sheets give a brief overview of a specific subject. These informational sheets can be downloaded for you to get up to speed quickly on some frequently asked questions. The MREC encourages you to distribute these documents in electronic or printed format to anyone with a question.

- **Installation and Maintenance of Cow Trainers** (landscape – duplex or print double sided in order to view this publication correctly)
  http://fyi.uwex.edu/mrec/files/2011/04/Trainer-TriFold-16july05.pdf
- **Installation and Maintenance of Cow Trainers** (portrait – follow regular printing instructions)
  http://fyi.uwex.edu/mrec/files/2011/04/trainer-portrait-16july05.pdf
- **Installing Electrified Crowd Gates** (landscape – duplex or print double sided in order to view this publication correctly)
  http://fyi.uwex.edu/mrec/files/2011/04/crowd-gate-TriFold-16july05.pdf

APPENDIX C

Continued

- **Installing Electrified Crowd Gates** (portrait – follow regular printing instructions)
  http://fyi.uwex.edu/mrec/files/2011/04/crowd-gate-portrait-16july05.pdf
- **Stray Voltage**
  http://fyi.uwex.edu/mrec/files/2011/04/StrayVoltage_InformationalPage_05.pdf
- **High Frequency Noise**
  http://fyi.uwex.edu/mrec/files/2011/04/HighFrequencyNoise_InformationalPage_05.pdf
- **Earth Currents**
  http://fyi.uwex.edu/mrec/files/2011/04/EarthCurrents_InformationalPage_05.pdf
- **Electrical Pollution**
  http://fyi.uwex.edu/mrec/files/2011/04/ElectricalPollution_InformationalPage_05.pdf
- **Electric and Magnetic Fields (EMF)**
  http://fyi.uwex.edu/mrec/files/2011/04/Emf_2008.pdf



Wiring Handbook for Rural Facilities

https://www-mwps.sws.iastate.edu/catalog/construction/wiring-handbook-rural-facilities
Note: The above handbook can be purchased for a nominal fee from the above website.

National Electrical Safety Code® (NESC®)

http://standards.ieee.org/findstds/standard/C2-2012.html
This is the electrical safety code that applies on the utility side of the service point. The above website has the applicable code book available for purchase.

National Electrical Code® (NEC®)

http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70&DocNum=70
This is the electrical safety code that applies on the premises (customer) side of the service point. The above website has the applicable code book available for purchase.

In addition, the NEC® is also available for free, in read-only format, as follows:
http://www.nfpa.org/freeaccess

Rural Electricity Resource Council Home Page

http://www.rerc.org/index.shtml

Catalog of Publications
http://www.rerc.org/documents/catalog2009web_version.pdf

GLOSSARY OF TERMS

Earth Current: Once electrical current leaves the structure of a grounded object or made electrode to flow within the three dimensional soil structure of the earth itself, it becomes an earth current. (See also Ground Current, Return Current and Neutral Current.)

Equipotential Plane: A grid, sheet, mass or masses of conducting material that when bonded together, offer a negligible impedance to current flow and significantly reduce step and touch potentials within the plane.

Fault: A partial or total local failure in the insulation or continuity of a conductor.

Ground Current: Electrical system current that is on a grounding conductor, a grounding electrode, or some other conductive path way between the neutral (grounded) conductor and the earth. (See also Earth Current Neutral Current and Return Current.)

Neutral Current: Electrical system current that flows in the neutral conductor. (See also Return Current, Earth Current, and Ground Current).

Neutral to Earth Voltage (NEV): A voltage measured between the neutral conductor or an extension of the neutral conductor (e.g. primary or secondary grounding conductor, bonded metallic water pipe) and a location at a remote ground rod driven into the earth's surface approximately 25' from any buried conductive material (remote earth). These measurements are used by the investigator to determine the stray voltage sources.

Qualified Reference: A measurement reference point that has been verified to be at zero potential relative to remote earth and have a low impedance path way to the earth.

Primary System: A term that describes the high voltage utility electrical system including the generation, transmission and distribution systems. It also refers to the high voltage side of a distribution transformer.

Reference Rod: A metal rod driven into the earth at a remote earth location that is verified to be a low impedance connection to the earth. The reference rod can be used as a common reference point for the measurement of voltages (e.g. neutral to earth voltage) on earth-referenced electrical systems.

Remote Earth: The distant point on the earth's surface where an increase in the distance from a ground electrode will not measurably increase the impedance between that ground electrode and the new distant point.

Return Current: Electrical system current that returns to its source by way of grounded and grounding conductors, the earth, and any other parallel conductive pathway (e.g. cable messenger) between the location of the load or fault and the current source. (See also Neutral Current, Earth Current and Ground Current.)

Service Point: The point of connection between the facilities of the serving utility and the premises wiring.

Source Resistance: A term used to refer to all the various physical resistances that exist between a source voltage and an animal contact area. It cannot be measured directly by an Ohmmeter, but can be easily calculated after measuring the voltage at an animal contact area both with and without a shunt resistor in place across the voltage meter leads. The formula used is as follows: subtract the voltage measured with an animal contact shunt resistor ($V_{w\ shunt}$) from the voltage measured without the shunt resistor ($V_{w/o\ shunt}$). Divide that difference by the voltage measured with the shunt resistor. Multiply that result by the value of the shunt resistor and the answer is the value of the source resistance in Ohms.

$$R_{source} = ((V_{w/o\ shunt} - V_{w\ shunt})/ V_{w\ shunt}) * R_{shunt.}$$

Stray Voltage: Any steady-state, 60 Hz (including harmonics thereof), rms, AC voltage of less than 10 volts, across (in parallel with) a 500 Ohm resistor connected between cow contact points, as measured with a true rms meter. Stray current or voltage is a normal, inherent and unavoidable result of electricity traveling through grounded utility's distribution system, which systems are required by the National Electrical Code® and the National Electrical Safety Code® to be grounded to earth to ensure continuous safety and reliability.

SEPTEMBER 2015

For questions about stray voltage contact your electric utility. **See page 23 for a list of utility contacts.**

The following organizations developed this guide.

MREA

minnesota power
AN ALLETE COMPANY

Minnesota Farmers Union

OTTER TAIL POWER COMPANY

MINNESOTA DEPARTMENT OF AGRICULTURE

Cooperative Network

Minnesota Farm Bureau
farmers • families • food

MMUA
Minnesota Municipal Utilities Association

Xcel Energy
RESPONSIBLE BY NATURE

MINNESOTA DEPARTMENT OF LABOR & INDUSTRY