"A Stray Voltage Primer"
December 27, 2012
Al Haman, PE; CEO and Principal Engineer
STAR Energy Services LLC, Alexandria, Minnesota

Stray Voltage – a term selected by scientists and engineers, most likely as a passing thought, which was intended to allow a definition to be given to a particular electrical measurement they were investigating at the time. According to the United States Department of Agriculture, stray voltage is defined as "A difference in voltage measured between two surfaces that may be contacted simultaneously by an animal."[1] Unfortunately, the word "stray" in the English language is defined as "to wander" which tempts some to interpret stray voltage as something unusual, elusive in nature, and difficult to identify. In reality, stray voltage is present within all electrical networks and clearly understood. It is the stray voltage investigator's task to work in a team environment with farmers to determine if voltage levels are of interest and then find ways to mitigate. Everyone involved must participate to improve the electrical environment on the farm and within the barn.

Stray voltage has been studied in the United States and around the world. As I write this from Alexandria, Minnesota, in the heart of dairy country, we can have great pride that a significant portion of the leading research of stray voltage in dairy barns was conducted by the University of Minnesota, University of Wisconsin, and employees of the electric companies providing service to customers in these states. Their findings, dating back to the early 1980s, have been corroborated by additional research from around our nation and the world.

These leaders shared their findings with utility personnel who were conducting stray voltage measurements on farms and soon found that a close correlation existed between the research lab and farm environment. The researchers understood that a handbook was needed, which resulted in the USDA Agriculture Handbook Number 696, *Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems*. The handbook was published in 1991 by no less than 15 contributors, made up largely of university professors.

Stray voltage is a contact voltage between two points that an animal or human can touch simultaneously. If the level of voltage is high enough, some sort of sensation may be felt. When the sensation becomes unpleasant, animals will learn to limit exposure to those contact points or avoid those locations altogether. In the dairy farm setting, one of the most common contact points is between the water line and barn floor (see *Figure 1*). If the cow feels an unpleasant sensation each time it takes a drink, it may begin to alter behavior by limiting the number of times it makes contact with the water cup.

[1] United States Department of Agriculture, Agricultural Research Service, Agriculture Handbook Number 696, *Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems* (Washington, DC: U.S. Government Printing Office, 1991), 9-4

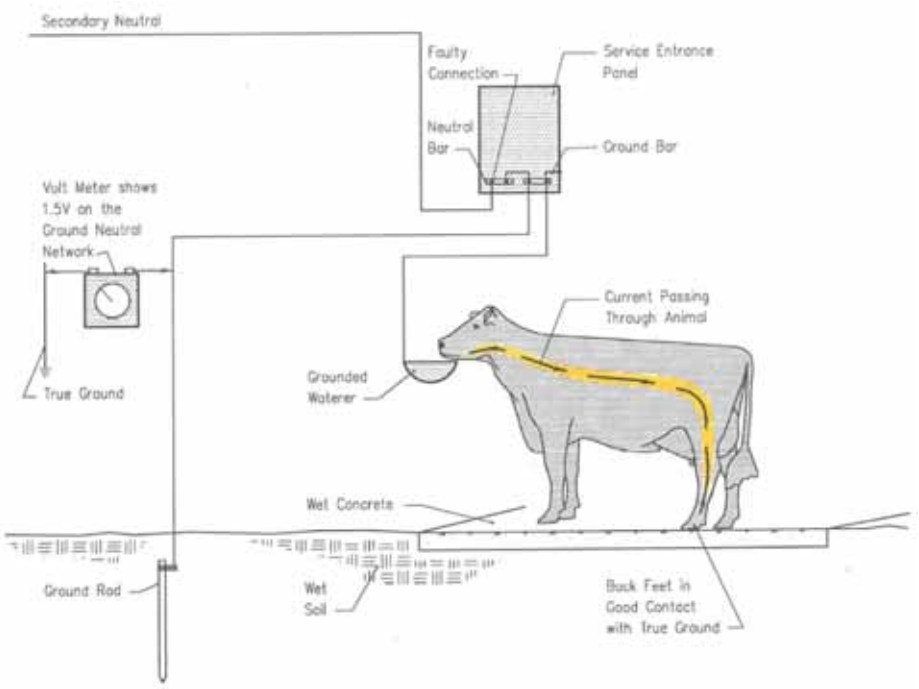

Figure 1 One Example of Stray Voltage[2]

So, what causes stray voltage? The delivery of electricity requires an outgoing path and a return path. Think of a "loop" or "circle" for electricity to make its way from the generator to the consumption point (e.g., a light bulb) and back to the generator. Unfortunately, conditions along the return path, commonly called the "neutral," can divert small amounts of electrical current onto grounded objects such as metalwork in a barn. If the diverted current is significant and occurs in contact areas that animals frequent, behavior changes may occur. In the case of dairy cows, avoidance may affect the farm's milk production.

Dairy cows respond to current being passed through the body. Many research studies have been conducted where electrodes were connected to a controlled barn environment and trained observers watched cow reaction to various levels of current which were artificially introduced with test equipment. Using Ohm's Law, which is the basis for understanding electricity, the researchers developed voltage levels of interest. Much like an individual person's sensitivity to hot or cold, individual dairy cows have varying levels of sensitivity to voltage in contact areas. Investigators measure voltage because it is difficult in a barn environment to measure current. Voltage is a point-to-point measurement, while current is a path measurement. It simply isn't practical to fasten test equipment around a cow, connect test leads, and expect it to act normal. Measuring voltage allows the investigator to discretely place test leads in a non-intrusive location which doesn't change cow behavior.

[2] MidWest Plan Service, Agricultural and Biosystems Engineering Department, *Farm Building Wiring Handbook*, 2nd Edition (Ames, IA: Iowa State University, 1992), 39

The National Electrical Safety Code® (NESC®) sets forth standards that require electrical distribution systems in the United States to use a multi-grounded neutral for the return path of the current. Multi-grounded means that the return path has several connections to earth—a minimum of four times per mile. This is needed for safety as it is important that the return current travel in both the neutral and earth to avoid an electrocution hazard.

The National Electrical Code® (NEC®) sets forth standards that electricians must follow as they perform installation and maintenance on the customer's side of the meter. This standard is revised every four years, but the customer's prior work is "grandfathered" and not required to be upgraded. A significant part of any stray voltage investigation is to evaluate how the customer's electrical work has integrated various revisions of the NEC. Often, the work may have occurred over decades, crossing multiple code revisions, multiple electricians, and improper installation may be adding to elevated stray voltage levels. The NEC also requires that all metalwork (e.g., electrical panels, water pipes, and equipment cases) be bonded together.

Since both the NESC and the NEC require that the electrical system neutral be bonded to earth through grounding electrodes or ground rods, and the utility neutral and the customer neutral be bonded together, deficiencies present on either the customer or utility side of the meter add to stray voltage levels. An investigation must examine whether voltage in cow contact areas exceeds published levels of interest and then determine the cause. The areas to investigate can be both on farm (customer equipment) and off farm (electric utility equipment.)

On-farm items include unbalanced load in electrical panels, corroded wiring, improper installation of electric fencers, loose panel connections, intermingling of various wiring codes, and lack of equipment bonding. All of these possible items can be diagnosed and corrected.

Off-farm items include corroded or loose connectors, broken pole grounds, damage to neutral conductors, and load levels on the utility system. Again, measurements can lead investigators to recommend action which can result in lower levels of stray voltage. The goal is to reduce the stray voltage levels in cow-contact areas to below what nearly all of the animals can sense.

At times, even after corrective action has been taken on and off the farm, stray voltage levels in cow-contact areas may remain higher than desirable. In those instances, the NESC allows electric utilities to install an isolation device between the utility's primary neutral and the secondary neutral of the farm. By removing all neutral voltage contribution from the utility side, the cow contact voltages due to on-farm grounding can generally be kept below the levels of concern. The isolation device will separate neutral-to-earth levels off the farm from the levels due to electric use 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 will return to the original state of separation.

Stray voltage investigators typically attend continuing education of various forms and participate in trade organizations which specifically focus on the topic. The Midwest Rural Energy Council (MREC) is a trade organization that has a website (mrec.org) considered to be a leading repository for all things related to stray voltage. The MREC also offers training for investigators, updates on new research, and hosts an annual conference specifically for those interested in stray voltage developments.

Stray voltage, by definition, is voltage that is present in animal contact areas, predictable, and can be measured. Its effect on dairy cows has been extensively researched over the last 30 years by numerous universities. Those findings provide investigators with guidance on methods of measurement, voltage levels of concern, and methods of mitigation. The United States Department of Agriculture has published a handbook which provides additional guidance. By building trust with farmers and working together as a team, electric utilities can help improve the electrical environment of the farm to the benefit of the dairy operation.