

What Do We Know About Stray Voltage?

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Terms: The term stray voltage has been used for the past 40 years to describe a special case of voltage developed on the grounded neutral system of a farm. If this voltage reaches sufficient levels, animals coming into contact with grounded devices may receive a mild electrical shock that can cause a behavioral response. At voltage levels that are just perceptible to the animal, behaviors indicative of perception such as flinches may result with little change in normal routines. At higher levels avoidance behaviors may result.

The term stray voltage is often applied incorrectly to other electrical phenomena such as electric fields, magnetic fields and most recently electric current flowing in the earth. These phenomena are generally referred to as EMF or Electric and Magnetic Fields. The physiological interactions with these phenomena are different than the mild shock associated with stray voltage.

Sources: A diagram of a typical single-phase multi grounded Y rural distribution system is shown in Figure 1. Electric power is transmitted from a substation to the farm on the utility or 'primary' distribution system. Most rural distribution systems use a voltage of 7200 or 14,400 Volts between the primary neutral and primary phase wire. Electrical power is distributed as an alternating voltage and current with a frequency of 60 Hz (the voltage and current alternates from a positive value to a negative value 60 times per second). The 'flow' of electricity is actually back and forth in the wires, not a continuous stream as in a garden hose.

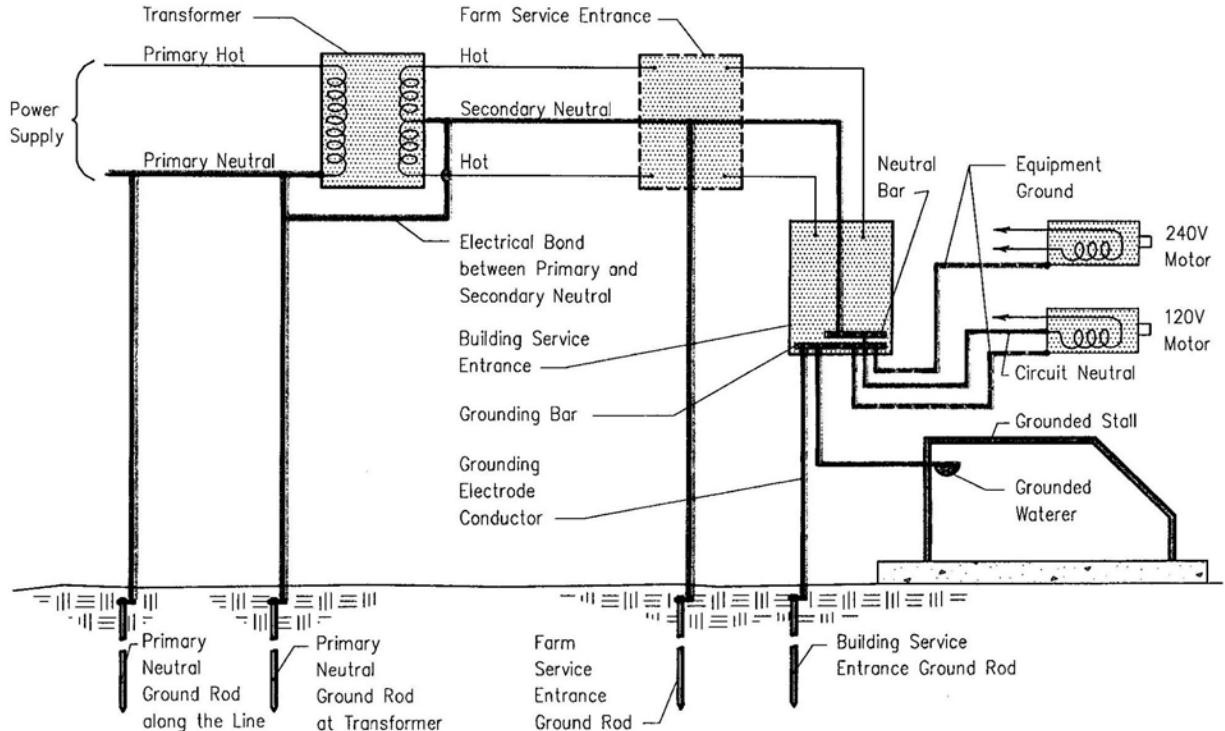


Figure 1. Grounded Neutral Single Phase System, some hot wires not shown for clarity (from Midwest Plan Service Handbook Number 28).

The neutral wire on the primary distribution system is grounded 6 times per mile or more. These grounds are provided, in part, to reduce damage caused by lightning striking the power lines. The high voltage and low current carried by distribution lines is converted to lower voltage and higher current at the farm transformer. The farm wiring system carries 240 Volt on 2 'hot' or phase wires and 120 Volts electrical power on one 'hot' or phase wire and one neutral wire. The neutral is also referred to as a grounded conductor (white colored insulation). The National Electric Code also requires the use of a grounding conductor (green colored insulation or bare copper) for safety reasons in agricultural buildings from the service entrance panel to the load for both 120 V and 240 V circuits.

Stray voltage is a voltage that develops on the grounded neutral system of either the farm wiring or utility distribution system. The voltage is a result of the current flow on the neutral wire and the resistance of the grounded neutral network. Stray voltage can be reduced by either reducing the resistance of the grounded neutral system or by reducing the current on the neutral wire. The most common cause of stray voltage is high resistance of the neutral wire caused by loose or corroded connections or undersized wires. Proper sizing, installation and maintenance of wiring systems is required to keep the resistance of the grounded neutral system low. Current flow on the neutral wire can be reduced by balancing 120 V loads between the phase wires, eliminating fault conditions, and using 240-volt equipment whenever possible.

Animal research: A great deal of research on the effects of stray voltage on farm animals has been conducted over the past 40 years. The first study of stray voltage on dairy farms was published in New Zealand in 1962. In this early study a series of experiments were carried out to establish the lowest level of contact voltage at which there was a response. It was concluded that 3 volts (rms) would be a likely minimum level for response.

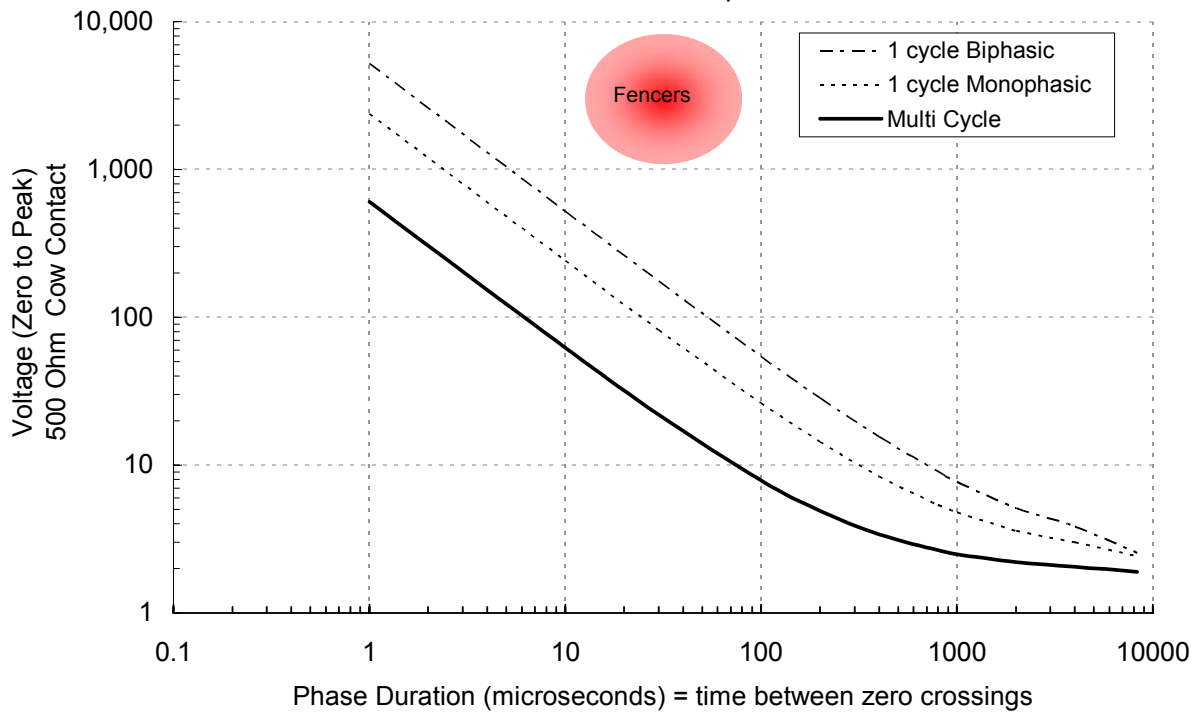
A summary of the effects of the most common form of stray voltage (steady 60 Hz contact voltage) on animals was published in 1991 by the USDA. The authors of this document reviewed the numerous studies of dairy cow reaction to voltage and current exposure and concluded that the most sensitive cows (less than 3 percent) begin to perceive contact voltage levels of about 1 volt causing 1 milliamp (measured as rms) of 60 Hz electrical current to flow through the cow. As the voltage and current is increased, a larger percentage of cows will perceive the current and behavioral responses will become more pronounced. Numerous studies have documented avoidance behaviors in the range of 3 to 6 milliamperes of current flowing through the cow. This response assumes that the cow comes into contact with objects that have different voltages and that this voltage causes sufficient current to flow through the cow. The authors recommended that cow contact voltage be kept below 2 - 4 volts (rms) to prevent adverse responses.

Transient Voltage: More recent research has investigated the effects of high frequency or short duration transient voltages on cows. The main sources of these transient voltages on a farm are improperly installed electric fences and switching of electrical devices on that farm. The very high frequency switching transient pulses decay very quickly and do not travel far from their source. Exceptions to this are electric fences, which produce a very powerful electric impulse designed to control animals. This type of pulse is designed to produce aversion but not cause harm to the animal. Improper installation of these devices can cause these pulses to appear in unintended areas on the farm.

More voltage and current is required to perceive an electrical pulse, as the duration of the pulse gets shorter. This has been well documented on humans for over 100 years. The same has been shown to apply to cows. This knowledge has been used in the design of numerous medical devices as well as electric fences. The average contact voltage required for 5% of cows to show a behavioral reaction to a short duration pulse is shown in Figure 2.

A 60 Hz pulse appears on the far right of this graph. Cows are less sensitive to a single pulse than to a continuous wave. The voltage required to elicit a behavioral reaction is more than 100 times higher for a 10 micro second pulse – typical of a fencer - than for an 8333-microsecond pulse (60 Hz).

Behavioral response for 5% most sensitive cows, sine waves
muzzle to hooves exposure



The phase duration referred to here is the time for the voltage and current to go from 0 to some peak positive value then back to zero. Examples of waveforms as they would appear on an oscilloscope screen are shown in Figure 3. The phase duration of wave A is 1.5 time units and the peak voltage is 1.5 Voltage units. The phase duration of wave B is 1.2 time units and the peak voltage is 1.8 Voltage units. The time and voltage scale settings of the oscilloscope when these recordings were made indicate the time represented by one time division and one voltage division. The phase duration and peak voltage must be measured accurately at an animal contact location in order to determine if animals could perceive these short duration electrical impulses.

The most common source of 60 Hz pulses (8333 microsecond phase duration) is starting of large electric motors. Electric fences typically produce pulses with phase duration of 10 to 100 microseconds. Switching of other electronic devices can produce pulses with phase duration of 1 to 10 microseconds or less.

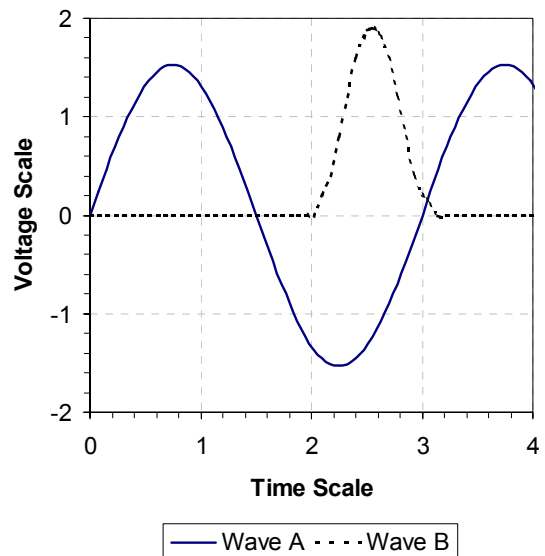


Figure 3. Example Waveforms.

Field Studies: Controlled research has indicated that stray voltage can be problematic if sufficient voltage levels are present and cows are forced to contact this voltage. The Public Service Commission of Wisconsin has identified 1 volt measured across a 500-ohm resistor as a level above which action should be taken. A recent report presented the results of a field study of more than 2900 stray voltage investigations performed by Wisconsin Utilities and the Public Service Commission of Wisconsin. More than 90 percent of farms tested were below this level at the time of their first stray voltage investigation. There was no meaningful correlation between primary neutral-to-earth voltage, secondary neutral-to-earth voltage, cow contact voltage, or ground rod current and either milk production or Somatic Cell count. This suggests that the standards in place in Wisconsin are effective in mitigating the adverse effects of voltage and current on dairy cows.

Ground Currents, Electric and Magnetic Fields: A recent concern has been the electric and magnetic fields caused by current flowing on the farm grounding system. Problems with utility and farm wiring can increase both the voltage on the neutral wire as well as the current flowing on the grounding system. The electric and magnetic fields produced by these currents are not perceptible to animals or humans and are much lower than normal household exposure. Electric and magnetic fields act on animals in a different way than the mild shock associated with stray voltage.

A team of experts was assembled by the State of Minnesota to review the evidence on the possible effects of currents flowing in the earth on the health and productivity of dairy cows. A survey of dairy producers conducted as part of the Science Advisors study revealed that the vast majority of dairy producers do not consider stray voltage or other forms of electrical exposure a problem on their farms. Several field studies have shown that the electric and magnetic field levels of found on dairy farms are well below those shown to produce biological effects. Although the science advisors found no evidence to suggest that earth currents or the EMF produced by them were harmful, one mechanism was postulated that could produce a biological effect; current flowing through a cow producing a small internal electric fields. Research conducted to examine this possibility showed no ill effect on cows exposed to these low level currents.

The Science Advisors gave three main findings in their report:

- *"We have not found credible scientific evidence to verify the specific claim that currents in the earth or associated electrical parameters such as voltages, magnetic fields and electric fields, are causes of poor health and milk production in dairy herds."*
- *"At the present time, there is no basis for altering the PUC-approved standards by which electric utilities distribute power onto or in the vicinity of individual dairy farms."*
- *"There are many well-documented non-electrical factors that are known and accepted by the scientific community, and by most farmers as well, to cause dairy cow health and production problems. Among the most noteworthy factors are poor nutrition, poor cow comfort and hygiene, and low or no use of vaccinations and related preventive veterinary practices. These factors should always be addressed by those who want to improve performance of dairy herds."*

More details on the studies and surveys as well as publications to help you measure voltages on your farm are available at the following web sites:

www.uwex.edu/uwmril

www.mrec.org