Effects of Electrical Voltage/Current on Farm Animals: How To Detect and Remedy Problems

1. Introduction

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Summary

While some knowledge of stray voltage has existed for many years, it was not until about 1982 that the national and worldwide nature of this phenomenon was recognized. Even when livestock problems were recognized, early solutions were not always fully effective and/or were not always satisfactory to both farmers and power suppliers. One of the challenges to solving stray voltage/current problems has been in persuading everyone involved to work as a team in diagnosing and solving the problems on the basis of a rational understanding of the factors involved.

Numerous research studies have quantified the physiological and behavioral responses of dairy cattle to electric currents. Cows were found to be more susceptible to stray voltages compared to humans due to cows' relatively lower body resistances. Animals respond to current and not directly to the voltage that produced the current. Ohm's law states that current equals voltage divided by resistance. Thus, for a given voltage, a lower body resistance will result in a higher current (and a greater effect). Even so, it is important to realize that the currents required for perception, behavioral change, or physiological effects to occur are widely variable. Furthermore, symptoms associated with stray voltage/current problems are not unique and many factors other than stray voltage/current can cause similar behavior, health, and/or production problems.

The sources of relatively small amounts of electrical currents passing through animals are often very difficult to locate. Stray voltages/currents may arise because of poor electrical connections, corrosion of switches, frayed insulation, faulty equipment, or heavily loaded power lines.

Solutions to stray voltage/current problems include voltage reduction, control of leakage voltage sources, gradient control by use of equipotential planes, and isolation.

While stray voltages/currents cannot be totally eliminated, they can be reduced.

History

Recognition

Anyone who has been involved in identifying, diagnosing, and correcting stray voltage/current problems in livestock facilities recognizes their complexity. These problems often cause frustration, since many, if not most, livestock farmers have little understanding of electrical distribution and farmstead wiring systems. At the same time, few electrical workers understand the behavioral and physiological responses of animals to small electrical currents. Furthermore, the importance of the farmers' reactions to these problems is not generally appreciated; i.e., their reaction to livestock behavioral changes associated with stray voltages/currents may create even more serious problems.

One of the challenges of solving stray voltage/current problems has been in persuading everyone involved to work as a team in diagnosing and solving the problems on the basis of a rational understanding of the factors involved. Successful solution of stray voltage/current problems usually involves many people, including the livestock (usually dairy) farmer, electrician, power supplier, milking equipment representative, veterinarian, milking company fieldman, nutrition consultant, and county Extension agent. It is very easy, particularly under the stress of serious economic losses, to try to shift the responsibility for the diagnosis and solution of a suspected problem to one person or organization. In most cases, teamwork by, rather than animosity among, the people involved is necessary to quickly diagnose and correct an existing problem.

It has been known for many years that problems associated with the management and milking of dairy cows may occur when relatively small electrical currents pass through cows' bodies. An Australian researcher (Churchwood 1948) implied that current resulting from electrical equipment in the milking area may have affected cows negatively. Similar statements were published some years later in New Zealand (Phillips 1962a and b). The first cases of stray voltage on the North American continent were reported in Washington State in 1969 (Craine et al. 1969a and 1970) and in Canada in 1975 (Feistman and White 1975). These cases were assumed to be unusual and to represent a primarily localized problem; thus, they received little attention and publicity in the popular press and trade journals.

Beginning in 1977, numerous farms with stray voltage/current problems were identified in the upper Midwest and east coast regions of the United States and Canada. Between 1978 and 1982, several comprehensive Extension Service bulletins relating to the identification and solution of stray voltage/current problems were prepared, the one by Cloud et al. (1980) being the most widely distributed throughout the United States.

By 1982, numerous articles and news releases concerning stray voltage were published. For example, Hoard's Dairyman — a popular magazine that most dairy farmers receive — published at least 12 articles, notes, or references related to the subject between 1980 and 1983. This period marked the beginning of national and worldwide recognition of stray voltage. The proceedings of a workshop on stray voltage in Minneapolis, Minnesota, were published in 1983 (National Rural Electric Cooperative Association 1983). In 1984, a national stray voltage symposium was held in Syracuse, New York; the proceedings of the symposium were published in 1985 by the American Society of Agricultural Engineers (Majerus et al. 1985). In the same year, a comprehensive review appeared in the Journal of Dairy Science (Appleman and Gustafson, 1985b).

Early Field Experiences

The first farms in which stray voltage/current problems were identified were suffering severe losses of milk production and income. The producers were generally aware they had problems and had spent considerable time and money attempting to improve their feeding program, the milking equipment, their milking procedures, and hygiene. But nothing seemed to help. Finally, when stray voltages/currents were measured and appropriate cor-

rective procedures were completed, favorable responses were often immediate and dramatic. Increases in daily milk production of 10 to 15 pounds per cow (20 to 30 percent) were commonplace. Improved cow temperament and a significant reduction in the time required to complete milking chores were often cited by farmers. Improved udder health, less mastitis, and improved milk quality were also frequently reported responses.

When these results were passed on to neighbors, and when reports began to appear in the popular press, other farmers suspected that they, too, might have similar problems and were quick to make demands of their electrical power suppliers, farm electricians, and milking equipment dealers. In general, these people had little knowledge of how and what levels of electrical current can effect animals, were unaware of methods for systematically identifying and mitigating stray voltage/current problems, and often reacted to the farmers with disdain and contempt. Sometimes, no real problem existed; other times, attempts were made to shift the responsibility of diagnosis and solution to other persons or organizations. When the latter occurred, farmers felt that no one cared, animosity between two or more individuals developed, and the teamwork required to solve the problem quickly dissolved.

In the 1980's, as a direct result of continuing research efforts, appropriate diagnostic and mitigation procedures were developed and adopted. Many dairy groups, including university Extension Services, conducted training sessions for persons with electrical expertise, held information sessions for producers and others providing support and assistance to dairy farmers, and established more uniform procedures for diagnosis and mitigation. It is hoped that the sense of teamwork needed for cooperation has been established.

Solutions

The causes of relatively small amounts of electrical current passing through cows are often very difficult to identify. Some factors that contribute to excessive voltages are poor connections, corrosion of switches, frayed insulation, faulty equipment, and heavily loaded power lines. Problems are frequently time dependent; e.g., problems during evening milkings are common. Someone who is familiar with electrical systems, wiring, and equipment and who is knowledgeable about stray voltage/current should be consulted and, if possible, be present when measurements are being made.

Solutions to the problem have included 1) voltage reduction by removal of bad neutral connections and faulty loads or by neutral current reduction by load balancing; 2) control of leakage voltage sources, i.e., removing or correcting wiring, grounding, and electrical loads; 3) gradient control by use of equipotential planes; and 4) isolation (See "Glossary" for definition of terms).

One significant problem was and continues to be that many farms are not wired and maintained in accordance with the National Electrical Code (the code which covers farm electrical wiring systems). Bringing farms to present code standards often, but not always, solves stray voltage/current problems. In the past, rewiring or improvement of electrical systems was one of the first solutions suggested to farmers. If rewiring failed to solve the problem, as it often did, farmers were then asked to install an equipotential plane in their milking area. Farmers were often reluctant to do so because of the difficulty and expense involved in replacing concrete already in place and perfectly usable. An alternative solution was isolation. If the problem source was primarily off-farm, and if tests showed that leaving the farm neutral disconnected from the primary neutral at the farm transformer eliminated the problem voltages, farmers wanted to operate in that manner. (This solution was sometimes termed "the disconnect.") Unfortunately, neutral disconnection is a cause of significant safety concern and is a violation of the National Electrical Safety Code (the code under which the power suppliers operate). Because of safety considerations, the primary and farm neutrals must remain connected under fault conditions and during lightning strikes. The problem was to allow the neutrals to be disconnected under normal operating conditions without affecting safety. The power supply industry turned to the installation of isolation transformers.

Installation of isolation transformers results in some system grounding being removed from the distribution system. Some electrical experts became apprehensive about this reduced grounding; and since isolation transformers are relatively expensive, some farmers resisted having to pay for them and, as required in some instances, also their installation costs. The farmers felt that the costs should not be their responsibility, because the transformers eliminated what the farmers perceived to be solely an off-farm problem. But most farmers made the purchase and, seeing favorable results, were simply happy to have the problem solved and appreciated the efforts of everyone involved in the diagnosis and mitigation process. Other devices to allow effective isolation while providing interconnections during faults have been developed. For example, devices to balance neutral-to-ground voltages at a point on the distribution system are available.

Where Do We Stand Now?

Today, stray voltage/current is a recognized phenomenon. The theoretical basis for stray voltage/current problems is understood, sources can be identified, and cost-effective solutions exist.

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The primary impact of stray voltages/currents on milk production involves changes in behavior. Because the effects of stray voltages/currents are primarily behavioral rather than physiological, good milk yield can probably be maintained despite the presence of moderate levels of stray voltage/current if the farming practice is good. One important conclusion concerning behavioral responses to electrical stimulation is that a farmer's reaction to animal behavioral changes can magnify existing management problems or even create new and more serious problems.

Detection of a stray voltage/current problem depends on the type of the problem, the knowledge of the investigator, and the use of standard electrical equipment for making measurements. It is important that the equipment and procedures used in the detection and measurement of stray voltage/current be matched to the desired function and to the electrical expertise of the investigator. While standard electrical instruments are adequate for most types of measurements required for stray voltage investigations, these measurements should be interpreted by professionals skilled in detecting the sources of stray voltage/current problems and making mitigation recommendations.

Approaches for controlling neutral-to-earth voltages fall into four categories: 1) voltage reduction, 2) active suppression, 3) gradient control, and 4) isolation. Most on-farm sources can be dealt with by improvement of wiring and elimination of faults (voltage reduction). The most common off-farm source is the inherent impedance of the grounded neutral system of the primary. All the approaches listed above are conceptually sound; all have their advantages and disadvantages. The most suitable approach in any given situation must be based on the available information and constraints of the situation.

Problems that may arise due to the use of electrical power on farms and the principles that apply to the mitigation of particular problems that may affect dairy cattle productivity and health are well understood. However, there is need for further research; and the types of research needed are identified and discussed in chapter 6.

While stray voltage cannot be totally eliminated, it can certainly be reduced to an acceptable level. The procedures and processes for reduction are discussed in the chapters that follow.