Ontario Energy Board

EB-2007-0709

Staff Discussion Paper

Farm Stray Voltage: Issues and Regulatory Options

May 2008

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Abbreviations

ACC	Animal Contact Current
ACV	Animal Contact Voltage
DPUC	Connecticut Department of Public Utility Control
DSC	Distribution System Code
EDA	Electricity Distributors Association
ESA	Electrical Safety Authority
Hydro One	Hydro One Networks Inc.
IPUC	Idaho Public Utilities Commission
mA	MilliAmpere - 1/1000th of an ampere
MAPAQ	Le ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MPSC	Michigan Public Service Commission
NEV	Neutral to earth voltage
OFA	Ontario Federation of Agriculture
OMAFRA	Ontario Ministry of Food, Agriculture and Rural Affairs
PSCW	Public Service Commission of Wisconsin
UPA	L'Union des producteurs agricoles
V	Volt

Executive Summary

This staff Discussion Paper has been prepared as part of a consultation process initiated to assist the Ontario Energy Board in identifying measures that could be implemented by it to ensure that electricity service to farm customers, in relation to “tingle” or “stray” voltage, is of a quality that does not unduly impact the operation of the farm. The consultation process was initiated in response to a Directive dated June 22, 2007 issued to the Board by the Minister of Energy. The purpose of this staff Discussion Paper is to elicit written comments from stakeholders, which will serve as an input to further staff’s work in formulating policy proposals for Board members to consider.

Information used in the preparation of this Discussion Paper was collected through a number of activities, including monthly meetings of a Farm Stray Voltage Consultative Group; reports prepared by three consultants to provide information on specific aspects of the issue; six meetings with farmers and other members of the agricultural community; and a stakeholder consultation conference to present and receive feedback from participants on the consultants’ preliminary findings and direction of the overall consultation process.

The term ‘stray voltage’ refers to the difference in voltage potential (generally agreed to be 10 volts or less) between two points that a farm animal could make contact with at the same time. It can originate from a number of sources both on and off the farm. The electricity distribution system is the primary off-farm source, but frequently, voltage potentials at a given animal contact location are the combined result of two or more contributing factors. A solution to a given case where stray voltage is affecting farm operations may therefore involve both the distribution utility and the farmer, working with an electrical contractor or other qualified service provider.

The main cause of contributions to stray voltage on farms is elevated current on the distribution neutral conductor, which is connected to the earth by groundings and to the farm customer’s wiring system via a code-required bonding between the primary neutral ground and the secondary neutral on the transformer at the farm customer’s service entrance(s). Current from the distribution system can therefore be transmitted to animal contact locations both through the earth and by way of the farm wiring system.

There are some 28,000 livestock farms in Ontario, of which nearly 5,000 are dairy farms. Dairy farms are the most affected by stray voltage due to the sensitivity of large animals to current exposure, the opportunities for animal contact exposure in buildings where electricity is used, and the typically wet conditions in confinement areas which facilitates exposure and enhances conductivity. Most of the public meeting participants who shared their experiences were dairy farmers. Some reported significant difficulty diagnosing and remedying stray voltage that was adversely affecting their farm operations. Of these, the majority expressed some level of dissatisfaction with the way Ontario distributors handle farm customers' requests for assistance with suspected stray voltage situations and/or with the outcome of the distributors' efforts to mitigate the problem.

According to the scientific literature on the subject, the impact of stray voltage on farm operations is through animal responses to being exposed to electric current.[1] Farmers have observed, and studies have confirmed, that some animals will avoid or minimize the amount of time they spend drinking or feeding if they experience stray voltage when performing these essential functions. The most sensitive dairy cows may experience mild behavioural modifications at current exposures exceeding 2 mA (60 Hz AC rms) of cow contact exposure in farm exposure situations.[2] These behavioural effects can result in lower farm output; higher labour costs associated with animal handling; and increased expenditures related to maintaining animal health and wellbeing.

Distribution utilities can reduce their contributions to farm stray voltage by lowering the amount of electric current flowing onto the farm either through the earth or by way of the primary/secondary neutral connection point(s).[3] The choice of remediation method can depend on the characteristics of the situation and amount

[1] Please see the literature review accompanying this Discussion Paper by Dr. D.J. Reinemann, Professor of Biological Systems Engineering at the University of Wisconsin (Madison) entitled *Literature Review and Synthesis of Research Findings on the Impact of Stray Voltage on Farm Operations* (Reinemann 2008). The report is posted on the Board's Farm Stray Voltage web page.
[2] Equivalent to 1 Volt (60 Hz AC rms) if cow + contact resistance is assumed to be 500 Ohms.
[3] Please see the report accompanying this Discussion Paper by Kinectrics Inc. entitled *Stray Voltage Mitigation* (Kinectrics 2008). The report is posted on the Board's Farm Stray Voltage web page.

of reduction required. Some methods, such as increasing the number of groundings or balancing the loads on three phase lines, involve modifications to the distributor's system at and/or near the farm. These are relatively low cost measures. If remediation involves modifications to the entire circuit, such as increasing the distribution voltage, costs can be significant depending on the length of the circuit and/or the number of customers connected to it. The most cost-effective solution can vary from one case to another and no solution is without drawbacks.

At present, Canadian distributors are not subject to regulation with regard to farm stray voltage.[4] Rather, distributors operate according to standards and procedures developed internally. In the U.S., a number of regulatory bodies have taken steps to direct distributor actions when responding to farm customer requests for assistance with stray voltage situations. Regulators in Wisconsin, as well as Idaho and more recently Michigan determined that if the voltage measured between animal contact points exceeds 2 mA, distributors must take steps to ensure their system contributes no more than 1 mA. Other regulators have chosen different measures, and not all jurisdictions have adopted a compulsory approach.

Based on consultations to date and the input of Board staff's consultants, Board staff's initial view is that distributors should be required to take action where a threshold level of farm stray voltage is exceeded. Furthermore, for the purposes of discussion, two alternative indicators are suggested whereby distributors could gauge whether remedial action on their part is required: one based on primary neutral to earth voltage; the other based on contributions to animal contact voltage from sources within the control of the distributor.

Written comments are invited on these suggested alternative approaches, related implementation issues, and the need for and forms of supporting regulatory elements. These elements are: investigation procedures; investigator training; customer response procedures; distributor record-keeping and reporting; distributor remediation options and the provision of farm stray voltage-related information to farmers.

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[4] For a survey of selected Canadian and U.S. jurisdictions, please see the report accompanying this Discussion Paper by BDR NorthAmerica Inc. entitled *Regulatory Approaches to Addressing the Impact of Stray Voltage on Farm Operations* (BDR 2008). The report is posted on the Board's Farm Stray Voltage web page.

1 Introduction

1.1 What is Farm Stray Voltage?

Stray voltage refers to the difference in voltage potential between two objects that if contacted by an animal at the same time will result in a small electric current flow through the animal

The term ‘farm **stray voltage**’ refers to the difference in voltage *potential* (generally agreed to be 10 volts or less[5]) between two points that a farm animal could make contact with at the same time. The word ‘potential’ is used here because it is only when an animal touches two objects, each with a *different* voltage potential, that an animal’s body completes an electrical circuit allowing current to flow between the two objects.

The electric current that passes through the animal has been referred to as ‘**stray current**’.[6] If the difference in voltage between the two contact points[7] is high enough, the animal may feel a tingling sensation (hence the term ‘**tingle voltage**’). In fact, the animal is feeling the *current* in the circuit, not the voltage on the points of contact *per se*.

Voltage potentials can originate from a number of sources both on and off the farm. The electricity distribution system is the primary off-farm source, the main cause of which is elevated current on the distribution neutral conductor. This wire is connected to the earth by groundings and to the farm customer’s wiring system via a connection (or “bonding”) between the primary neutral ground and the secondary neutral on the transformer at the farm customer’s service entrance(s). This bonding is required under the Ontario Electrical Safety Code. Current from the distribution neutral can therefore be transmitted to grounded metal stabling, watering devices, feeders, milk pipelines, wet concrete floors, etc. both through the earth and by way of the farm wiring system.

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[5] All voltage or current measures refer to alternating current. Currents originating in electrical faults, disturbances etc. high enough to cause catastrophic effects (burns, injury, or mortality) are not considered stray voltage as defined here and are therefore beyond the scope of this discussion.
[6] Lefcourt, A.M. (ed); *Effects of Electrical Voltage/Current on Farm Animals*; U.S. Dept. of Agriculture, Agricultural Research Service, Agriculture Handbook Number 696 (USDA 1991); p. 9-4 defines stray current and stray voltage.
[7] Current will not flow between two contact points (e.g. on a barn floor) with the same voltage potential.

When livestock make contact with stray voltage and the resulting current is sufficiently high, they may begin to avoid or spend less time in drinking, feeding or milking areas. Production losses and higher operating costs can result. Ontario farmers have been dealing with farm stray voltage situations since the late 1970s. While many cases have been dealt with successfully, some have proven more difficult to resolve.

1.2 The Minister's Farm Stray Voltage Directive

On June 22, 2007 the Ontario Energy Board (the "Board") received a Directive (the "Directive") from the Minister of Energy of Ontario. The Directive states the following:

The Minister's Directive

> *The Board shall implement such measures which, in its own discretion, having regard to the objective related to quality of electricity service provided for under paragraph 1(1) of the Act, are necessary to ensure electricity service to farm customers, in relation to "tingle" or "stray" voltage, is of a quality that does not unduly impact the operation of the farm.*[8]

The reference to "the Act" in the Directive is to the *Ontario Energy Board Act, 1998* (also referred to in this Discussion Paper as the "Act"). Paragraph 1(1) of the Act, also referred to in the Directive, contains one of the objectives that guide the Board in the performance of all of its responsibilities, including its regulation of electricity distributors. Specifically, the objective refers to protecting the interests of consumers with respect to prices and the adequacy, reliability and quality of electricity service.

1.3 Purpose and Outline of this Discussion Paper

The purpose of this staff Discussion Paper is to elicit written stakeholder comment on measures that could be implemented by the

[8] The Minister's Directive and the Order-in-Council accompanying it are attached as Appendix A.

The purpose of this staff Discussion Paper

Board in response to the Directive. Stakeholder comments received on this Discussion Paper will serve as an input to further the work of Board staff in formulating policy proposals for Board members to consider.

The staff Discussion Paper consists of nine sections, the first of which is this introduction. The remaining eight sections deal with the following:

- Section 2 describes the consultation activities undertaken to date;
- Section 3 describes the mandate of the Board in relation to the Minister's Directive;
- Section 4 provides a brief explanation of how and why farm stray voltage occurs;
- Section 5 gives an overview of the livestock farming industry in Ontario, a brief recounting of Ontario's past experience with farm stray voltage and a summary of the perspective of Ontario farmers on farm stray voltage;
- Section 6 describes and explains the potential impact of stray voltage on farm operations through its effect on farm animals;
- Section 7 lists the various ways distributors can reduce stray voltage levels caused by the operation of their distribution facilities and the costs and relative effectiveness of each;
- Section 8 looks at how farm stray voltage is managed in other jurisdictions, including several U.S. states that have adopted regulatory measures to address the issue; and
- Section 9 identifies measures that Board staff suggest could be implemented in response to the Directive.

2 The Farm Stray Voltage Consultation

Board staff has prepared this Discussion Paper as a further step in a consultation process initiated by the Board in response to the Directive. To date, the consultation process has involved the formation of a Farm Stray Voltage Consultative Group (the 'Consultative Group'), meetings with farmers and other interested parties to discuss the farm stray voltage issue in Ontario, the commissioning of consulting studies to address specific farm stray voltage issues and a meeting of all interested parties.

2.1 Farm Stray Voltage Consultative Group

The first step in the consultation process was to form a Farm Stray Voltage Consultative Group

The Consultative Group was formed to facilitate the consultation. The group consisted of representatives of farm customers, electricity distributors, and representatives of other stakeholders with experience in various aspects of stray voltage and its effects on farm operations. The members of the Consultative Group were:

- Hydro One Networks Inc. (Hydro One)
- Ontario Ministry of Agriculture & Rural Affairs (OMAFRA)
- Electrical Safety Authority (ESA)
- Electricity Distributors Association (EDA)
- Ontario Federation of Agriculture (OFA)
- Ontario Ministry of Energy
- Waterloo North Hydro

The role of the Consultative Group was twofold: to provide Board staff with information and insight based on experience with farm stray voltage; and to ensure stakeholder constituencies were kept informed as to the progress of the consultation. The Consultative Group met monthly between August 2007 and January 2008.

2.2 Consulting Studies

In addition to the Consultative Group, expert assistance was sought to augment information otherwise available in three subject areas:

a) The body of literature concerning the impact of farm stray voltage on animals and farm operations has grown considerably over the years. A review of this literature was carried out by Dr. D.J. Reinemann, Professor of Biological Systems Engineering at the University of Wisconsin – Madison, to provide a synopsis of the evolving consensus view on key issues, as well as an indication of the direction of future research.

Three consultants were engaged to provide insights based on reviews of literature, experience elsewhere, and technical expertise

b) A survey of regulatory approaches in other jurisdictions was carried out by BDR NorthAmerica (a management consulting company) to provide insights about the various options for addressing the issue that might be applicable to the Ontario context. The farm stray voltage problem is not new. Farmers and their electricity service providers have been dealing with the issue for many years, and in some jurisdictions, distribution utility regulators or other public bodies have intervened to clarify the responsibilities of various parties.

c) A review of both sources and mitigation methods related to neutral current and farm stray voltage was carried out by Kinectrics Inc. (an electrical engineering research consulting company). Choosing measures to address the impact of farm stray voltage must be based on an understanding of both the potential sources of farm stray voltage, especially those involving electricity distribution systems, and the measures available for mitigation or correction.

Copies of the consultants' reports are available on the Board's Farm Stray Voltage web page.[9]

2.3 Meetings with Farmers across Ontario

Province-wide meetings with farmers were held

At the first meeting of the Consultative Group on August 17, 2007, the Ontario Federation of Agriculture (OFA) suggested that Board staff meet with farmers across Ontario to hear directly from farmers about

[9] The web page can be accessed from the OEB web site (oeb.gov.on.ca) or by clicking here.

their experiences dealing with farm stray voltage situations affecting their farm businesses.

Accordingly, a total of six meetings with farmers were planned for the late October to early November period as shown in Figure 2-1. Arrangements for the meetings were made by OFA Member Service Representatives in each region, who also ensured OFA members in nearby communities were notified as to the particulars of the meeting in their community.

Figure 2-1: Farmer Consultation Meeting Locations

The meetings were attended by a variety of interested participants, including farmers, farm equipment and service suppliers, representatives of farmer organizations and current and former distribution utility personnel. Attendance varied with the size of the farming community in the area surrounding the meeting venue, ranging from about 12 in Verner to over 50 in Woodstock. Comments and other input received at these meetings provided both useful information as to the history and current state of Ontario farmer experience with stray voltage, and guidance to Board staff as to the key issues pertaining to farm stray voltage.

2.4 Stakeholder Consultation Conference

A Stakeholder Consultation Conference was held to present and receive feedback on information collected

In addition to the six meetings described above, a Stakeholder Consultation Conference was held in Toronto on December 5, 2007 to report on the progress to that date and provide farmers and other interested parties with a summary of the information collected through the consultation process. In addition, Board staff's consultants presented preliminary findings concerning the literature review as to the impact of stray voltage on farm operations and concerning the survey of the approaches other jurisdictions have taken in addressing farm stray voltage.

About 50 people participated in the conference, including farmers and farm service providers, distributor personnel and representatives of other stakeholder groups, and a number of other interested parties, some from outside Ontario.[10]

[10] A list of conference attendees is available on the Board's Farm Stray Voltage web page.

3 The Board's Role

3.1 Mandate under the Directive

Stray voltage is part and parcel of the "quality of electricity service" distributors provide to farm customers

The Directive calls upon the Board to implement such measures as the Board considers necessary to ensure that farm stray voltage does not unduly impact the operation of the farm. The Directive makes it clear that farm stray voltage is an issue of electricity service quality.

As with all of its other responsibilities, in responding to the Directive the Board is to be guided by the two objectives that are set out in section 1 of the Act. One of the objectives refers to the protection of the interests of consumers,[11] and the other refers to promoting economic efficiency and cost effectiveness in the distribution of electricity and to facilitating financial viability in the electricity sector.[12] The Board is often called upon to determine the appropriate balance between these two objectives, weighing the benefits to consumers of the actions or activities of distributors against the costs to ratepayers flowing from those actions or activities. Board staff anticipates that the Board will want to be satisfied that measures to be taken by distributors in order to maintain or improve the quality of electricity service as it pertains to farm stray voltage are both warranted and cost effective.

3.2 The Regulation of Electricity Distributors

One of the key responsibilities of the Board is to regulate the rates charged by, and the conduct and business practices of, electricity distributors. To that end, the Board has at its disposal a number of regulatory instruments or tools, as well as enforcement powers necessary to ensure that distributors comply with applicable legal and regulatory requirements.

[11] More specifically, paragraph (1) of section 1 of the Act refers to protecting the interests of consumers "with respect to prices and the adequacy, reliability and quality of electricity service".
[12] More specifically, paragraph (2) of section 1 of the Act refers to promoting "economic efficiency and cost effectiveness in the generation, transmission, distribution, sale and demand management of electricity" and to facilitating "the maintenance of a financially viable electricity industry".

An exhaustive or comprehensive description of the Board's powers and instruments in relation to electricity distributors is outside the scope of this Discussion Paper. It is sufficient, for present purposes, to note the following:

- Unless exempt by regulation, anyone that owns or operates a distribution system must be licensed by the Board.[13] The Board regulates the conduct of distributors through binding obligations (licence conditions) set out in these licences, as well as through codes[14] and standards, targets or criteria for evaluating distributor performance.[15]

- The Board's approach to any given issue can and does vary as appropriate to the circumstances. In some cases, the Board has taken a "minimalist" approach, allowing each distributor the flexibility to develop its own practices or policies to address an issue. In others, the Board has taken a "prescriptive" approach, specifying in detail exactly how a given matter is to be addressed by all distributors. And in yet others, the Board has taken a hybrid approach, specifying certain key rules or objectives and allowing each distributor to develop its own practices or policies to fill in the necessary implementation detail.

The Board's Distribution System Code ("DSC") contains the majority of the rules that relate to the operation of distribution systems and the provision of electricity service to customers. The DSC currently requires each distributor to establish Conditions of Service which set out the terms and conditions according to which the distributor will provide electricity service to its customers, and to include in its

[13] Act, section 57. The Board's power to establish licence conditions is set out in section 70 of the Act.
[14] Under section 70.1 of the Act, the Board may issue codes that are incorporated by reference as conditions of a distributor's licence. Among other things, a code may incorporate by reference, in whole or in part, any standard, procedure or guideline.
[15] Under section 83 of the Act, the Board may establish standards, targets and criteria for evaluation of performance of distributors.

Conditions of Service the quality of service standards to which its distribution system is designed and operated.[16]

While the Board has broad powers to establish requirements for electricity distributors, the Board does not directly regulate most customers. However, the Board's regulatory instruments can, and do, condition the conduct of distributors based on customer actions or circumstances. For example, while a distributor is required to maintain a certain voltage variance standard, the DSC makes it clear that the distributor is not responsible for variations in voltage from external forces, such as exceptionally high loads.[17] Similarly, a distributor can disconnect a customer where the customer fails to take corrective action as directed by the distributor in circumstances where the customer is causing adverse effects to the reliability of the distribution system.[18]

[16] DSC, sections 2.4.6 and 4.1.1. Conditions of Service must be filed with, but are not approved by, the Board. Other standards mentioned in the DSC relate to power quality management; control of voltage levels and harmonic distortions; investigating power quality complaints; and the distributor's authority over customer use of power supplied.

[17] DSC, section 4.1.2.

[18] DSC, section 4.1.8.

4 Electricity Distribution & Farm Stray Voltage

4.1 Potential Sources of Farm Stray Voltage

Stray voltage can originate from a number of sources both on and off the farm. Frequently, voltage potentials at a given animal contact location may be the combined result of two or more contributing factors. However, electricity distribution systems are cited most frequently as the primary source. How this can happen is explained in section 4.2 below.

Regarding the farmer's own assets, or those of a neighbouring farmer, the main source of stray voltage is voltage potential rise on the farm electricity distribution neutral conductor(s) and grounding system. This can be the result of a variety of causes, including:

- Unbalanced 120 V electrical loads;
- Improperly grounded farm equipment (e.g. water or manure pumps);
- Improperly installed electric fences, cow trainers and electrical panels; and
- Electrical equipment faults.[19]

In addition, assets owned by third parties – telephone lines; cable TV lines; and metal pipelines - on or near the farm can be sources contributing to stray voltage appearing on a farm. Telephone and cable TV lines, like the primary neutral conductor, are bonded to the farm's secondary neutral and grounding system. Normally they are not active contributors to farm stray voltage. Steel gas pipelines, which carry a low voltage (DC) current on them to inhibit rust, can make a small contribution to farm stray voltage under certain conditions.

However, metal pipelines and telephone and cable lines in contact with the earth near a farm can contribute passively to farm stray voltage. For example, if a buried metal pipeline runs parallel and very close to a

[19] The various on-farm sources of stray voltage are described in detail in USDA 1991, Chapter 2.

high voltage transmission line, current can appear on the pipeline. If the pipeline route passes close to where livestock are kept, current on the pipeline can flow through the earth and potentially contribute to farm stray voltage at that location.

It follows that farm stray voltage investigations must be designed to not only identify each source but also measure the contribution from each source to the overall farm stray voltage measured. As the focus of this discussion is the electricity service provided by distributors, the balance of this section examines how electricity distribution systems can contribute to stray voltage situations on farms.

4.2 Neutral to Earth Voltage

As shown on Figure 4-1, electricity distribution lines carry electric current ('1' in Figure 4-1) out to customers on power wires, called 'phase conductors' ('A'). A 'three phase line' is one that uses three phase conductors together; a 'single phase' line uses only one. A 'neutral conductor' ('B') completes the circuit by providing one pathway for unbalanced[20] or **neutral current** ('2') to flow back to the distribution substation that it came from.

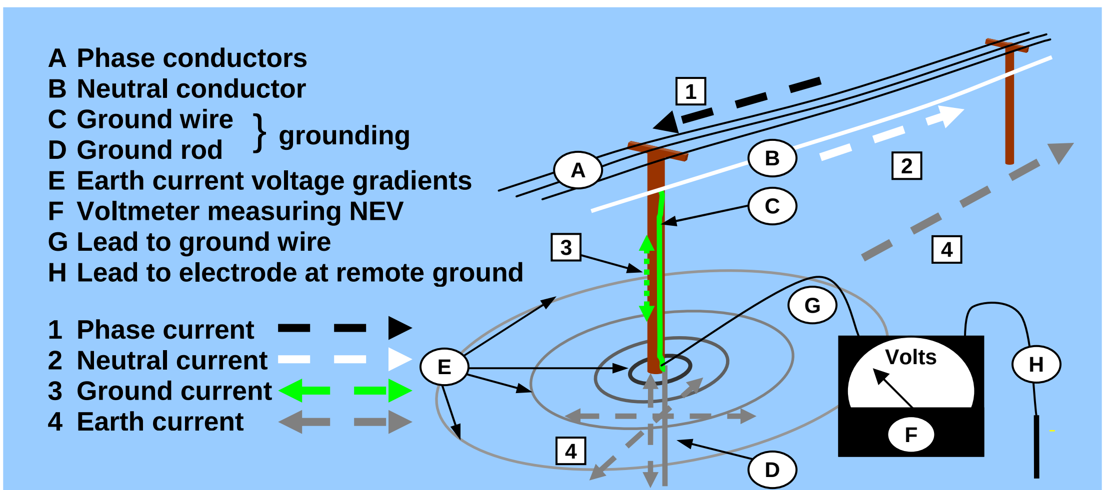

Figure 4-1: Electricity Distribution System Current Flows
Source: OEB

[20] For an explanation of unbalanced current and how to minimize it, see section 7.1.

Electricity safety regulations and safety codes for Ontario utilities and property owners respectively, require that neutral conductors and many types of electrical equipment and devices be grounded to the earth.[21] Neutral conductor groundings typically consist of a ground wire ('C') and ground rod ('D').

Electrical systems and equipment are grounded to the earth for safety

Groundings protect against electric shock and fire hazards that may result from faulty electrical equipment or a lightning strike. They do this by bonding the neutral to the ground through a ground rod in order to minimize the potential difference between the neutral conductor and the earth. Current flows on groundings are called **ground current** ('3'). Groundings are connected directly to the neutral wire, so a small amount of ground current flows to (or from) the earth at all times.

Once in contact with the earth, electric current travels in all available directions. Generally, the higher the moisture content and less rocky the soil, the more easily current is able to flow through the earth. Current can spread widely through the earth and tends to flow deeper in the earth, so that very little current usually exists at the surface.[22] Eventually, however, all **earth current** ('4') returns to the distribution substation. Both the neutral conductor and the earth provide return paths to the substation for neutral current.

Earth current flows in all directions, setting up voltage gradients that weaken with distance from the source

Due to the physical properties of the earth itself and of the earth current flowing through the earth, voltage zones - known as 'gradients' ('E') - are formed around each current source (in this case, ground rods). Each gradient has a different voltage potential. Generally, the voltage potential of an earth current gradient will vary with the voltage of the ground current, the resistance of the soil and distance from the ground current source.

[21] Approved designs, materials and equipment must be used. Distributors are regulated under Ontario Regulation 22/04; unlicensed utilities and electrical installations on private property must comply with the provisions of the Ontario Electrical Safety Code (ESC). Both O.Reg. 22/04 and the ESC are administered by the Electrical Safety Authority.
[22] Public Service Commission of Wisconsin; *Electricity 101 as it Applies to Stray Voltage*; by R.S. Reines and M.A. Cook; PSCW White Paper Series; January 2003 (PSCW 2003); p. 23-24.

Since the neutral conductor is physically connected to the earth (by way of the grounding wire and rod), both provide a return path for current on electricity distribution lines. Normally, the neutral conductor will be the main path for current because compared to the earth, current can move through the neutral conductor much more easily.[23] However, at any given point the primary neutral's share of total current returning to the substation compared to that flowing in the earth will depend on the relative resistances of the parallel return current paths at that point.[24]

The relationship in terms of voltage among neutral, ground, and earth current is measured using a voltmeter ('F') connected to a specified neutral conductor grounding point ('G') and an electrode driven into the earth ('H').[25] The voltage measurement is known as primary '**neutral to earth voltage**' (primary NEV).

In general, primary NEV will rise and fall depending on how the distribution system is being used at any given time. Primary NEV will also vary with changes in the amount of moisture in and therefore conductivity of the soil.[26]

4.3 Farm Stray Voltage

The term 'stray voltage' refers to the difference in voltage *potential* (generally agreed to be 10 volts or less) between two points that a farm animal could make contact with at the same time. Stray voltage is often referred to more specifically as '**animal contact voltage**' (ACV)

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[23] The neutral conductor, now made of aluminum, copper or copper alloy, is described as has having a lower impedance (or lower resistance) than the earth.
[24] To illustrate, data from measurements taken on farms in Wisconsin show about 74% of the phase current returns through the neutral conductor, while 26% returns through another path, including the earth. Public Service Commission of Wisconsin; *Stray Voltage Phase I and Phase II Combined Database Summary*; January 26, 2006 (PSCW 2006); p. 27. This ratio may be different for Ontario farms.
[25] In practice, NEV is measured between the neutral conductor grounding point and a 'reference' or 'remote' grounding electrode driven into the earth far enough away from the neutral grounding point being tested that it is unaffected by the current introduced at that grounding point.
[26] Section 7 reviews causes of elevated primary NEV and related mitigation methods.

when measured in volts or '**animal contact current**' (ACC) when measured in milliamperes.

On the farm, neutral conductors, equipment groundings and metal objects are all connected together for safety reasons

The electricity distribution system, specifically current on the distribution neutral conductor that results in elevated primary NEV, is the primary potential off-farm source of stray voltage.[27] Figure 4-2 illustrates how this comes about. For safety reasons, the distributor's ('primary') neutral conductor ('A') must share a grounding ('B') with the farm's ('secondary') neutral wire ('C') at the farm service transformer ('D'). In addition, the ESC requires that all electrical equipment and metal objects in the barn (such as the metal water bowl 'E') are connected (bonded) to the barn service entrance grounding ('F'), as is the farm's neutral wire.

Neutral, ground, and earth currents are elements in an inter-related electrical system

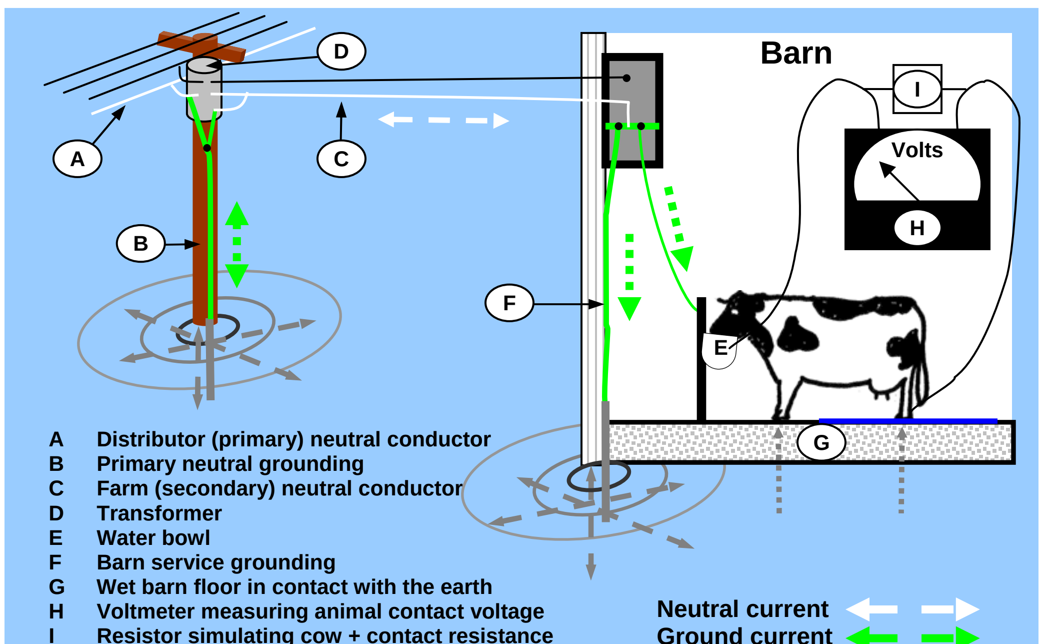

Figure 4-2: Farm Stray Voltage
Source: OEB

This network of groundings should not normally cause problems at animal contact locations. However, the interconnection of the primary and secondary neutrals at the farm service entrance grounding allows current on the primary neutral to flow onto the farm's secondary neutral

[27] The PSCW notes that average primary NEV measured at the farm and average animal contact current are significantly correlated. The other major contributors are secondary NEV and other farm service voltage drops. See PSCW 2006; pp. 11 – 12.

(and vice versa). Since the secondary neutral is bonded to the farm's grounding system, current from the primary neutral can flow throughout the secondary neutral and grounding system. If the primary NEV becomes too high, voltage potentials that can cause stray voltage may appear on objects in animal contact areas such as the wet concrete floor ('G') and water bowl shown in Figure 4-2.

It is important to distinguish between the voltage an animal may be exposed to and the level of current the animal feels. The voltmeter in Figure 4-2 ('H') is designed to measure the voltage between the two animal contact points. Note that the two leads are in good contact with the floor and the water bowl, and the device itself is calibrated to correct for any effect its own physical characteristics might have on the voltage reading.

Animals feel less voltage than registers on a voltmeter – important to remember when relevant voltage levels are so low

However, the hooves and muzzle of the animal in Figure 4-2 may not be making as good a contact with the floor and water bowl respectively as the voltmeter leads do. Also, the animal's body tissues - through which the current must pass - are less than perfect electrical conductors. In general, the current felt by the animal will not be as high as predicted by a simple voltmeter reading.

As discussed in section 6 below, the combined resistance of the voltage source, contact points and animal body tissues must be accounted for in order to provide an accurate indication of what an animal feels. The method used to correct for these factors involves attaching a device (known as a 'resistor') between the voltmeter leads ('I' on Figure 4-2) to ensure the measured current appropriately simulates what an animal is likely to feel.

The relationship between distributor NEV and animal contact voltage is not consistent

A second clarification is that while primary NEV can contribute to stray voltage situations, the system of relationships illustrated in Figure 4-2 varies in its particulars from one farm to the next and among different distribution system characteristics and configurations.[28] For example, on-farm sources can add to or cancel out distributor contributions to animal contact voltage.[29] Consequently, a given level of primary NEV measured at the farm may not contribute the same amount to animal contact potentials at every farm.

[28] Stray voltage is typically 40% to 60% of primary NEV according to Hydro One Networks Inc.; *Distribution System Stray Voltage Mitigation – Distribution Standard*; June 26, 2007 (Hydro One 2007b); p. 5.

[29] It is therefore important to identify properly the respective sources and interactions when determining appropriate mitigation measures. *PSC Staff Report: Wisconsin's Stray Voltage Experience – An Update* (R. Reines, M. Cook and D. Dasho); Public Service Commission of Wisconsin; April 1998 (PSCW 1998); p. 4.

5 Livestock Farms & Farm Stray Voltage in Ontario

5.1 Ontario's Livestock Farming Sector

Ontario has a total of 21,276 livestock farms, of which 4,937 are dairy farms. Figure 5-1 shows the number of livestock and dairy farms in each Ontario region. In each box on the diagram, dairy farms are included in the total livestock farm numbers, and are also shown separately.

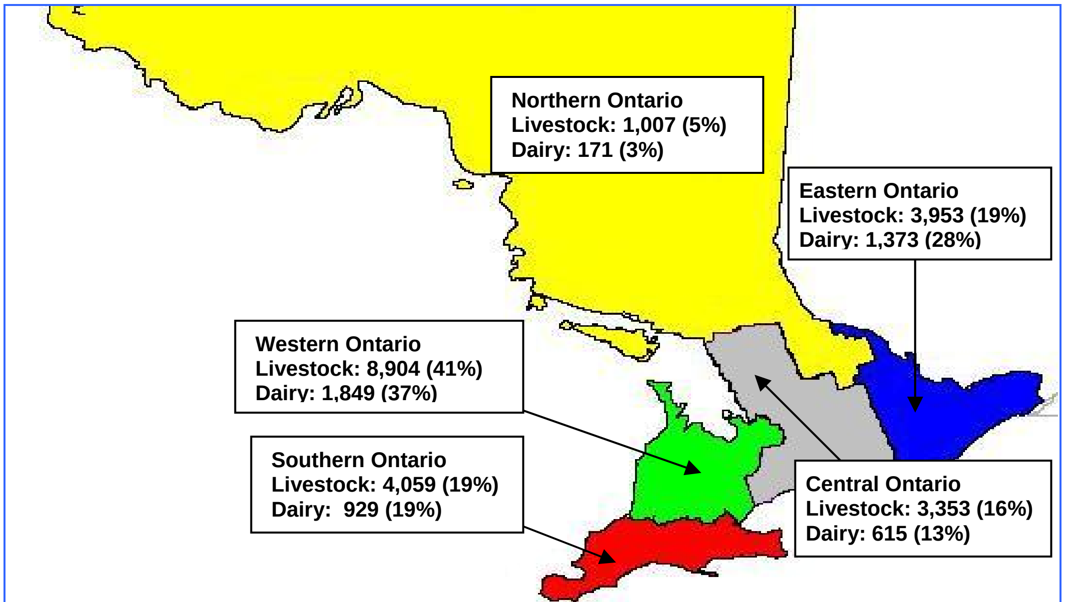

Figure 5-1: All Livestock & Dairy Farms by Region – Number and Share of Total
Source: Statistics Canada, Census of Agriculture 2006
Note: Figures for total livestock farms include beef, dairy, hog/pig, poultry & sheep/goat operations only; horse and 'other' farms are excluded

The Western region, with 8,904 livestock farms - of which 1,849 are dairy farms - has the highest number and largest provincial share of both. Within that region, the counties where the greatest numbers of dairy farms are found are Perth (431), Wellington (373) and Waterloo (263) counties. Eastern and Southern Ontario account for about 4,000 (19%) of Ontario's livestock farms each, and 1,373 (28%) and 929 (19%) of the province's dairy farms, respectively. The county with the largest number of dairy farms in Eastern Ontario is Stormont, Dundas & Glengarry, with 448 farms. Oxford County, with 363 farms, has the largest number of dairy farms in the Southern Ontario region. Northern Ontario has the smallest number of both total livestock and dairy farms; most of the region's dairy farms are found in the counties of Timiskaming and Thunder Bay, with 62 and 32 farms, respectively.

About 43,000 farmers operate some 28,000 livestock farm businesses in Ontario

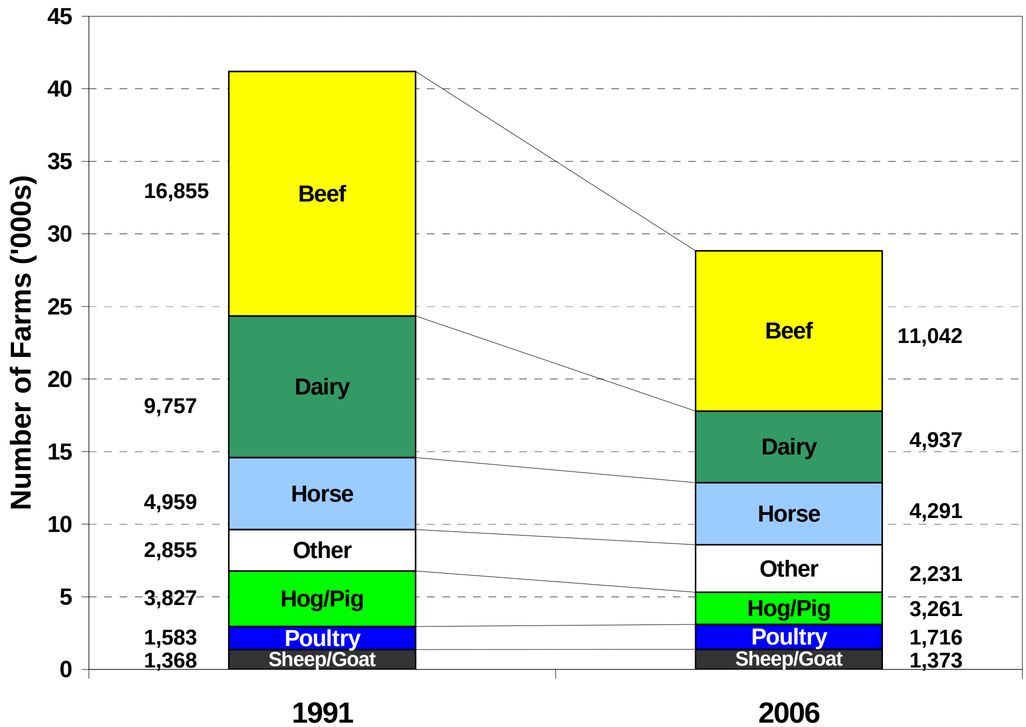

Figure 5-2: Number of Livestock Farms by Industry (1991-2006)
Source: Statistics Canada, Census of Agriculture 1991; 2006

Figure 5-2 illustrates the trend in numbers of livestock farms by type over the 17 year period from 1991 to 2006.[30] The numbers of beef cattle and dairy farms have declined by 34% and 50% respectively over the period, with horse and hog/pig farms showing smaller decreases. The numbers of other farms have remained fairly constant over the period.

There appears to be a long term trend whereby especially beef cattle and dairy farms are being amalgamated into increasingly large operations in terms of both land area and the number of animals per farm. This trend, combined with advances in the level of automation on farms, may have affected individual farm electricity demand and consumption over the years.

[30] Statistics Canada began to classify farms by Standard Industrial Classification code in 2001. Although the methods of classification are different for the years shown, the overall trends shown can be considered indicative.

5.2 Distributors Serving Livestock Farm Customers

Distributor service areas are shown in Figure 5-3. Hydro One, with both the largest overall service territory and largest share of the total rural area of Ontario, serves about 100,000 farm customers of all types, and about 4,500, or 90% of the 4,927 dairy farm customers in the province. The balance of Ontario's farm customers are served by a number of distributors, including:[31]

Chatham-Kent Hydro	Southern Ontario Region
Festival Hydro	Western Ontario Region
Kitchener-Wilmot Hydro	Western Ontario Region
Milton Hydro Distribution	Western Ontario Region
Norfolk Power	Southern Ontario Region
Ottawa Hydro	Eastern Ontario Region
Peninsula West Utilities	Southern Ontario Region
PowerStream	Central Ontario Region
Waterloo North Hydro	Western Ontario Region
Woodstock Hydro Services	Southern Ontario Region

5.3 Farm Stray Voltage in Ontario

Ontario farmers and the utilities serving them were dealing with stray voltage situations well before the first cases were reported in the agricultural literature.[32] The first Canadian case was documented in 1975.[33]

[31] Information provided by members of the Consultative Group.
[32] Comments made by attendees at the Farmer Consultation Meetings mentioned in section 2.2.3.
[33] The agricultural literature on farm stray voltage dates to at least the 1960s. See Gustafson, R.J. Ph.D.; 'Stray Voltage Overview'; *Proceedings from Stray Voltage and Dairy Farms* (Camp Hill PA, April 9-11, 2003); Natural Resource, Agriculture, and Engineering Service, NRAES-149 (NRAES 2003a); p. 3.

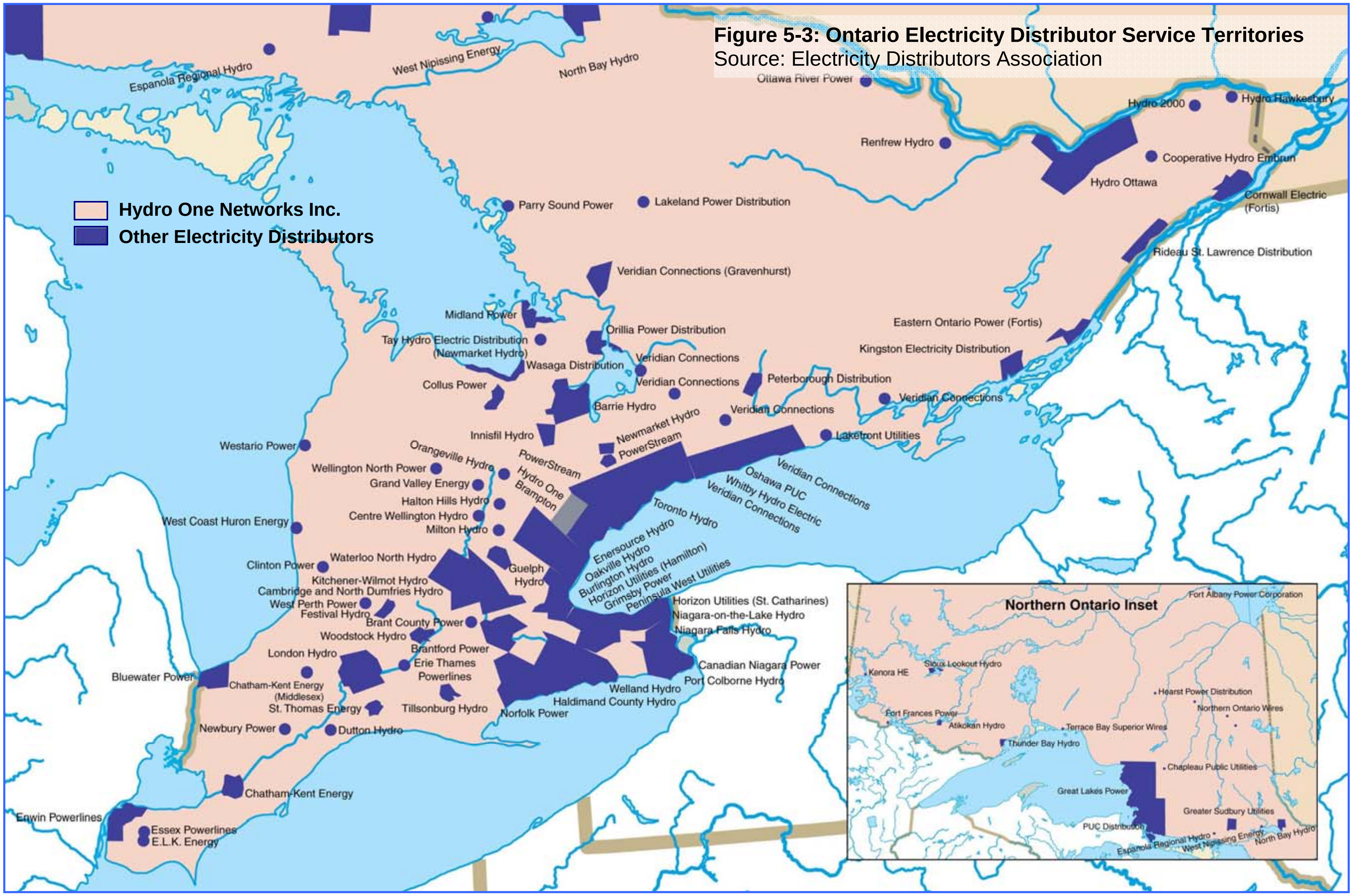

Figure 5-3: Ontario Electricity Distributor Service Territories
Source: Electricity Distributors Association

Ontario farmers have been dealing with stray voltage for many years

In the late 1970s and early 1980s, a combination of factors led to a marked increase in reports of farm stray voltage, including:[34]

- New safety-related standards for electrical wiring that resulted in the introduction of neutral to earth voltage onto farms;
- Growth in the use of electric power on individual farms due to technological change, increased mechanization and the consolidation of farm businesses into increasingly larger operations; and
- Increased economic sensitivity of dairy farmers to even small changes in the production levels of individual animals.

Farmer SV complaints grew through the late 1970s and early 1980s

The phenomenon became more widely known during the late 1970s during which time complaints from farmers about stray voltage grew in number. Ontario Hydro had an estimated 700 such complaints in 1981 alone.[35]

Initially, the problem was not well understood; distributor investigators tended to believe that any electrical problems on the farm were likely due to poor wiring and that animals were not susceptible to low voltages.[36] However, investigations by Ontario Hydro staff showed that in many cases the distribution system neutral conductor was the stray voltage source.[37] To address the problem on a temporary basis, Ontario Hydro began to disconnect the grounding bond between the distributor's primary and farm's secondary neutral conductors at the farm service transformer.[38]

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[34] NRAES 2003a; p. 4.
[35] Hydro One 2007a; p. 1.
[36] Hydro One 2007a; p. 1. This may have been generally true of North American utility and farm related professionals (NRAES 2003a; p. 4).
[37] Hydro One 2007a; p. 1.
[38] Ontario Ministry of Agriculture, Food and Rural Affairs; 'Stray Voltage Problems in Livestock Production'; by J. Rodenburg; 1998 (OMAFRA 1998); p. 8 - 9. For details on neutral separation devices see Section 7.

Information concerning how to identify and rectify farm stray voltage improved and spread

In the meantime, research began to shed some light on the impact of stray voltage on animal behaviour and hence, farm operations.[39] In 1982, the Ontario Ministry of Agriculture and Food (now OMAFRA) issued a pamphlet entitled *Stray Voltage Problems with Dairy Cows* (OMAFRA 1982), which explained the problem; described how to identify sources of stray voltage; and provided a guide to mitigation measures.

The Hammond Filter proved to be a practical and effective method of preventing or mitigating stray voltage problems

During this period, engineers at Ontario Hydro were developing a device capable of isolating the grounding systems in individual barns and buildings from neutral current on distributor systems.[40] Made in Guelph Ontario by the Hammond Manufacturing company, about 3,000 'Tingle Voltage Filters' (commonly known as the 'Hammond Filter') were sold in Ontario in subsequent years.[41] The device, which absorbed current that would otherwise pass from the secondary neutral to the building grounding system, was found to reduce stray voltage levels by between 77% and nearly 100%.[42] Farms where the primary and farm neutrals had been disconnected at the transformer were subsequently reconnected following the installation of the filters.

In 1984, OMAFRA surveyed 140 Ontario dairy farms selected at random, recording data on neutral to earth voltage and "cow contact voltage".[43] Table 5-1 summarizes the results of the study.[44] Generally, NEV was relatively low, with levels of 3 volts or less recorded on 72% of farms.

"Cow contact voltage" also appears to have been low, with 79% of farms measured at 1 **volt** or less. However, the barn stabling on 40% of the farms tested was not bonded as required by the Ontario

[39] For example, a paper entitled '*Stray Voltage on the Dairy Farm*' was presented at an IEEE Conference in 1980. See Seeling, Richard S.; *Stray Voltage on the Dairy Farm*, Conference Paper No. 80CH1532-1-IA-C3, Institute of Electrical and Electronics Engineers, 1980.
[40] OMAFRA 1998; p. 9.
[41] The Hammond 'tingle voltage filter' is no longer manufactured according to OMAFRA 1998; p. 9.
[42] For a diagram and explanation as to how this device works, see section 7.6.
[43] NEV measurements were taken between the service entrance neutral and remote earth.
[44] It is Board staff's understanding that the methods OMAFRA used to take these measurements may differ from those currently in use where farm stray voltage regulations are in place.

Electrical Safety Code. Accordingly, the influence of any voltage on the distribution system neutral would not be apparent in the readings for these farms. Nonetheless, OMAFRA investigators were of the view that "nearly all of the voltage found could be attributed to primary neutral resistance in the distribution system".[45]

Table 5-1: 1984 Ontario Dairy Farm Survey Results

***Measurement I* Category**	**# of Farms[1]**	**% of Farms[2]**
Neutral to Earth Voltage		
1 volt or less	28	20%
2 volts or less	63	45%
3 volts or less	101	72%
More than 3 volts	39	28%
Cow Contact Voltage		
0.5 volts or less	70	50%
1 volt or less	111	79%
2 volts or less	125	89%
More than 2 volts	15	11%

Source: OMAFRA 1998

Note: 1. Farm numbers calculated from the percentages shown.
2. OMAFRA 1998 expresses the results of the survey in terms of the percentages of farms where voltage levels were in excess of the NEV or cow contact thresholds indicated.

The number of farmers contacting their utility with stray voltage concerns is smaller now than circa 1980

As knowledge about stray voltage and its various remedies became more widespread, the incidence of farmer complaints began to decline. Six of 33 Ontario utilities that responded to an EDA survey reported having received farm stray voltage inquiries over the years. Many distributors reported a noticeable decline in the annual number of complaints in recent years. By 2000, it appears that farm stray voltage complaints were a fraction of the number experienced in the 1980s and 1990s.[46]

[45] OMAFRA 1998. In a few cases on-farm electrical faults or wiring problems were the main source, and where on-farm sources were identified, animal contact voltage readings were usually higher than those taken on farms where faults were not present.

[46] Electricity Distributors Association; *EDA Survey Regarding Farm Stray Voltage*; August 21, 2007 (EDA 2007).

At present, available information suggests that each year an estimated 15 to 20 Ontario farmers may report a suspected stray voltage situation to their distributor. However, since distributors do not make special tabulations of data on farm stray voltage complaints, this figure must be viewed with caution. Also, not all farmers with a possible farm stray voltage problem will report their concern to their distributor. Rather, they may contact the ESA, OFA, OMAFRA or another party for assistance.

Ontario distributors design their own approaches to addressing farm customer stray voltage concerns

Distributor procedures and practices regarding responses to stray voltage concerns are determined by the individual distributor. For example, according to an internal procedures manual, Hydro One responds to farm customer stray voltage complaints by measuring primary NEV, stray voltage and a number of other relevant parameters.[47] If stray voltage measurements exceed the "acceptable limit" (the document mentions that OMAFRA recommends 1 volt as a "safe exposure limit"), further tests are conducted to determine whether and to what extent the distribution system is responsible. If primary NEV is found to be above Hydro One's internal 10 V standard, remediation on the distribution system is required. If not, the customer may choose to have a mitigation device installed.[48]

Hydro One has developed and posted on its website a *Stray Voltage Solutions Guide for Electrical Contractors* and a *Stray Voltage Test Procedure for Electrical Contractors*.[49] The ESA is also in the process of reviewing and updating procedures manuals for investigators working on stray voltage related to both farm wiring and equipment and distribution systems.

[47] According to the manual, on most lines the primary NEV peaks at less than 5 V. If actual primary NEV exceeds this level, timely investigation is needed so that "necessary improvements can be made before the 10 volt limit is exceeded". See Hydro One Networks Inc.; *Distribution System Stray Voltage Mitigation – Distribution Standard*; June 26, 2007 (Hydro One 2007b); p. 7.
[48] Hydro One 2007b; p. 15.
[49] For more information see: **hydroonenetworks.com/en/customers/farm/strayvoltage**

5.4 The Ontario Farmers' Experience

While the number of farms affected may be fewer now than was the case in the late 1970s and early 1980s, stray voltage remains a problem that can have a significant impact on farm operations. This was made apparent to Board staff in comments received from farmers and other stakeholders living across the province who attended the series of six Board-sponsored meetings held between October 29 and November 9, 2007.

As noted above (see section 2.3), the purpose of these meetings was twofold: to provide information to farmers about the purpose of the Farm Stray Voltage consultation and the various activities involved; and to provide farmers with an opportunity to share with Board staff the benefit of their experience dealing with stray voltage situations. The subsections that follow reflect Board staff's view of the participants' comments, perspectives and issues arising from the meetings.

5.4.1 Impact on Farm Operations - Past & Present

The impact of stray voltage on farm operations ranges from mild and temporary to severe and persistent

Farmers reported a wide range of impacts of stray voltage on their farm operations, from behavioural impacts to lower productivity and in some cases illness and even death among their animals.[50] Some of the symptoms observed and ascribed to stray voltage were:

- Refusal to enter stabling or milking parlours, or to go near metal fences or stalls;
- Altered drinking and resting habits;
- Refusal of newborn calves to suckle;
- Production loss, including reduced milk production from individual cows or overall herds and weight loss by individual animals; and
- Livestock illnesses such as mastitis, anaemia, hide dryness, and calving difficulty.

[50] Farmers with active farm stray voltage concerns were invited by the Hydro One representatives at the meetings to provide their contact information for the purpose of follow up by Hydro One staff.

Farmers attributed these symptoms to a variety of potential stray voltage sources. Most often, distribution lines or substations were suspected. However, some farmers indicated that neighbouring industrial facilities or nearby wind generation turbines might be the ultimate source of stray voltage on their farms. These conclusions were often based on farmer observations as to the timing of stray voltage type conditions coinciding with the hours of operation of these neighbouring facilities.

Distribution lines and substations are identified most often as the source of stray voltage, but some farmers also point to other off-farm sources and on-farm electrical faults

A number of attendees indicated that on-farm sources were either responsible for or contributed to their problem, including electrical faults related to machinery, well casings, sentinel lights, etc. Some reported that symptoms began only after a new barn or barn extension had been built, new machinery installed, or old wiring replaced with new (safety inspected) facilities.

Farmers described the impact of stray voltage on farm operations in terms of one or more of the following:

Increased operating costs and lower farm production combine to reduce net income for farmers affected by stray voltage

- Increased costs related to higher livestock turnover rates due to premature culling of ill or unproductive animals
- Increased costs associated with veterinary services and medications
- Increased costs related to stray voltage mitigation
- Reduced income due to lower production volume

5.4.2 Views on Technical & Safety Code Issues

Generally, farmers in attendance were very well informed on many of the technical aspects of farm wiring, including various ESC requirements for new buildings and equipment installations. Concern was raised as to the relationship between NEV on the distribution system and stray voltage measured on water cups, stalls, etc. In this regard some farmers, who had been informed that the safety standard for NEV in Ontario is 10 volts, expressed the view that this level was unacceptably high. As well, farmers referred to regulatory standards and approaches in other jurisdictions and expressed the view that

The maximum level of distributor NEV is a concern, as is the potential effect on animals of contact voltages below 1 volt negative effects on animals can occur even at stray voltage levels of less than 1 volt.

Farmers have questions about grounding options under the ESC

Issues regarding aspects of the ESC were also raised. For example, farmers questioned whether some alternative grounding techniques (e.g. plates vs. rods) allowed under the ESC might be better at reducing the potential for stray voltage than others. In this regard, it was mentioned that electrical contractors and distributors may choose grounding options based on installation cost alone, without due consideration of the potential stray voltage implications.

5.4.3 Distributor Responses to Farmer Complaints

Distributor responses to farmer stray voltage concerns are not consistent

Most farmers had reported their stray voltage concern to their distributor (usually Hydro One) at some point in the process of trying to identify the cause of the symptoms they were noticing on their farm. Although some farmers reported they had developed a productive relationship with their distributor and had resolved the stray voltage problem together, farmers variously observed that distributor investigators:

- Seemed unfamiliar with stray voltage and how to investigate it;
- Failed to behave in a way that would indicate the farmer's concerns were being taken seriously;
- Did not report the results of the investigation to them;
- Reported that the tests had shown stray voltage to be present, but that because the distributor's NEV test showed the safety standard was met, no action on the part of the distributor was required;
- Could not or did not provide any information on how to deal with the situation in the event that the distributor was not responsible; or
- Distributor testing, once interrupted, was not always completed.

5.4.4 Experience with Mitigation Measures

A number of farmers at each meeting responded in the affirmative when asked whether they had Hammond 'tingle voltage filters' installed in their buildings. Some indicated that the devices were installed many years previous, while others said that the filters had been installed by a previous owner of the property. A few 'tingle voltage filter' owners stated that the devices either no longer worked, or were not adequate to deal with their stray voltage problem. It was further observed that even if filters and isolators are effective at reducing distributor contributions to stray voltage, they do not address on-farm sources.

While some performed well, experience showed that no single mitigation method can resolve all stray voltage situations

A variety of other devices similar to the 'tingle voltage filter' were mentioned, including the Dairyland Filter, the Ronk Blocker, and the Agri-Volt System. Farmers commented that the installed cost of any of these devices could be substantial and that the performance was not always as expected.

Some farmers commented on the differences they observed between one rural distribution feeder line and another, including the age and number of groundings per kilometre. The suggestion was made that farms served by lines that had been upgraded in the recent past seemed to have fewer problems with stray voltage. It was also mentioned that increasing the number of ground rods does not always provide an effective solution.

Not all mitigation methods produced satisfactory results

The effectiveness of equipotential planes – which are now required under the ESC – was questioned. It was observed that this mitigation technique, which involves installing a grounded wire grid into the concrete floor of a building where animals are present, is expensive to retrofit into existing floors. Again, the general feeling expressed was that equipotential planes are not sufficiently effective.

5.4.5 Roles of Government Agencies and Utilities

Farmers remarked on the changes in the institutional structure of the electricity sector in Ontario, which have resulted in Ontario Hydro being replaced by a number of government and other bodies. While each has a role to play, this role is not always clear. Questions were raised as to the respective roles and authority of the Board, ESA and Hydro

The respective roles of the various agencies potentially involved in resolving a stray voltage situation are unclear to many people

One and other distributors with regard to resolving stray voltage complaints. The questions included matters concerning the training of stray voltage investigators, setting investigation procedures, conducting investigations, implementing remediation solutions, ensuring compliance and providing a mechanism for dispute resolution where outcomes are unsatisfactory to farmers. The results of a survey of approaches to these issues used in other jurisdictions are provided in section 8.

5.4.6 Compensation for Losses

Farmers expressed the desire to be compensated for financial losses related to stray voltage.

5.4.7 Participants' Suggestions

In the course of the discussions, a number of suggestions were made by participants to address aspects of the farm stray voltage issue.

Meeting participants made a number of suggestions addressing various aspects of the farm stray voltage issue

- Information on the following subjects should be available to farmers:
  - How to recognize stray voltage;
  - The proper procedure for determining whether stray voltage is present and whether it is responsible for observed symptoms; and
  - How to obtain compensation for losses due to stray voltage.
- Distributors should have a standard complaint response procedure implemented by staff knowledgeable about the issue.
- Stray voltage investigations should
  - Follow a standard procedure;
  - Include recording weather, soil and moisture conditions;
  - Include a report to farm customers; and
  - Be carried out only by suitably trained investigators.
- Rural electricity distribution systems should be upgraded or replaced.

- Experts in on-farm aspects of farm stray voltage should be available to respond to farmers' concerns.
- A stray voltage ombudsman's office (or equivalent means of appeal) should be available to farmers unsatisfied with a distributor's response to their stray voltage complaint.

6 Potential Impact of Stray Voltage on Farm Operations

Stray voltage affects farm businesses through its impact on livestock

The nature of farm stray voltage is such that the contributing sources, resulting voltage potentials and severity of effects can vary from farm to farm and at different locations on the farm. This is reflected in the experience of Ontario farmers as related in the previous section. The purpose of this section is to explain the range of impacts stray voltage – whatever its origins - can have on farm operations through the effect stray voltage has on farm animals.

Much of the information provided here is from a report prepared for Board staff by Dr. D.J. Reinemann, Professor of Biological Systems Engineering at the University of Wisconsin (Madison) entitled '*Literature Review and Synthesis of Research Findings on the Impact of Stray Voltage on Farm Operations*'.[51] The main purpose of this report was to summarize the findings of field studies and experimental research undertaken over the years that examined the impact of exposing livestock to different levels of stray voltage. In the context of examining the effects of stray voltage on farm operations, the consensus view on stray voltage exposure levels above which farm operations can be affected was of particular interest.

6.1 Effects on Farm Operations

The main impact of stray voltage on farm operations is through the consequences of animal reactions to contact at feeding, watering or milking devices.

The main impact of stray voltage on farm operations is through animal responses to electric current exposure.[52] Farmers have observed, and studies have confirmed, that some animals will tend to avoid or minimize the amount of time they spend in locations where they have experienced stray voltage. When animals avoid drinking or feeding, farm output (e.g. dairy cow milk production or swine weight gain) can be affected adversely.[53] Labour costs can rise because it takes more

[51] This Discussion Paper section has been prepared by Board staff and is for general information only. This section is NOT intended to replace the report prepared by Dr. Reinemann. Dr. Reinemann's report should be relied upon in the event of any perceived discrepancy between the information provided in this section and Dr. Reinemann's report. Dr. Reinemann's full report (with an Executive Summary in French) is available on the Board's Farm Stray Voltage web page.
[52] Reinemann 2008; p. 2.
[53] Reinemann 2008; p. 42.

time to move and manage animals that are adverse to stray voltage contact points; and costs related to maintaining animal health can rise if animals are not obtaining appropriate amounts of feed and water.[54]

6.2 Animal + Contact Resistance[55]

An animal will respond to electric current flowing through its body if the level of current is high enough. The difference in voltage between the objects the animal is in contact with is one factor that determines the level of current.

The level of current flowing through an animal depends on which body parts are contacting the voltage sources…

There are two other factors: one relates to how well electricity is conducted through the animal; the other relates to how well electricity is conducted from the voltage source to the animal contact points. The combination of these two resistance values determines the level of electric current that flows through the animal as a result of exposure to a given level of voltage at the animal contact location.

The resistance values associated with typical current pathways through an animal (e.g. muzzle and all four hooves) have been studied for some time. Resistance was found to vary widely from one pathway to another. For example, the resistance of the front to rear hooves pathway for cows is about double the resistance for the mouth to all hooves pathway.[56]

…and on how readily the contact points conduct electricity

The muzzle to all hooves pathway is associated with two essential daily livestock activities: drinking and eating. Water intake is essential for animal productivity and health.[57] Accordingly, farm animal contact with watering devices has been the single most widely studied area of stray voltage exposure.[58]

[54] USDA 1991; p. 3-1 - 3-2.
[55] See Reinemann 2008; section 2 for a more detailed explanation.
[56] USDA 1991; p. 3-6.
[57] Reinemann 2008; p. 44. A Holstein cow producing 60 lbs. (27 kg) of milk per day will consume from 17 to 30 gallons (64 to 113 L) of water per day depending on the ambient temperature. See USDA 1991; p. 3-7.
[58] Metallic water pipes are required by electrical codes to be bonded, or electrically connected, to the grounded neutral system of a farm. This connection provides a safe path for fault current to flow into

Animals may avoid drinking or modify their drinking habits in response to a range of factors, such as group dominance challenges, or confinement-related issues.[59] However, studies have shown that the most reliable symptoms of stray voltage at watering devices are changes in drinking behaviours. This can involve reductions in the number of drinks per day, longer intervals between drinks and at extreme exposure levels, avoidance resulting in lower daily water intake and in some cases refusal to drink for extended periods.

There are two contact pathways that determine the level of animal contact current experienced by an animal at a watering device for a given level of stray voltage exposure.[60] This is a result of the resistance of the contact pathways combined with the resistance of the pathway through the animal.

Different devices will conduct electricity more or less readily, so some are more likely to be sources of problem levels of stray voltage than others

One contact pathway is between the animal's muzzle and the watering device. The resistance of watering devices (bowl, trough, etc.) varies by type. For example, metallic water bowls, typical in tie-stall or stanchion barn applications, have a relatively low contact resistance. Typical designs require a large area of an animal's muzzle to make firm contact with a large metallic paddle in order to start the flow of water into the bowl. Concrete water tanks, on the other hand, allow animals to drink without actually touching the concrete sides of the tank. The contact resistance is therefore quite high given that the water in the tank is a relatively poor conductor.

The most common second contact point related to watering devices is the floor. The contact resistance of this surface will be influenced by the type of flooring (usually concrete), the amount and type of debris that may be present on the floor and the wetness of the floor.

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the earth in the event that a 'live' wire comes into contact with the pipes. However, this same connection also provides a conduit for voltage on the grounded neutral system to access watering devices. Reinemann 2008; p. 44.

[59] Reinemann 2008; p. 45.

[60] Reinemann 2008; p. 44.

Barn conditions, especially the amount of moisture on the floor in confinement areas, has an impact on the potential current flow

Experiments using typical concrete floors indicate that the contact resistance for animal containment flooring can range widely - between several hundred and several thousand Ohms.[61] Generally, the more liquid (water, urine) standing on the floor surface the lower the resistance and therefore higher potential current flow for a given voltage potential.[62]

Research has shown that 500 – 1,000 Ohms are typical values representing animal + contact resistance for cows

Studies of dairy cows have shown that cow + contact resistance values vary by location and the body parts making contact. Typical combined resistance values range from 500 to about 1,000 Ohms.[63]

6.3 Evolution of Farm Stray Voltage Research

Research interest in farm stray voltage grew in the early to mid-1980s.

While observations of animal responses to voltage on the farm were documented much earlier[64], studies of animal responses to voltage exposure were first carried out in the early 1960s in New Zealand.[65] The first North American controlled exposure study was published in 1975, but both field (on-farm) and laboratory studies began to appear with increasing frequency in the Canadian, U.S. and European literature through the early to mid-1980s. This resulted in increasing awareness and interest in the issue among government agencies and the agriculture-related academic community.

Since the mid-1980s researchers have published widely on the subject, examining different aspects of the issue, including: the behavioural and physiological effects on animals exposed to various levels of stray voltage measured in milliamperes (mA) or volts (V); differences in impacts resulting from exposure through different

[61] Reinemann 2008; p. 44.
[62] Reinemann 2008; p. 30.
[63] Reinemann 2008; p. 42. An assumption as to cow + contact resistance value allows field tests of stray voltage measured in Volts to be converted to the equivalent in milliamps. For example, using 500 Ohms, stray voltage measurements of 1 and 2.5 Volts would be the equivalent of 2 and 5 mA; using 1,000 Ohms would yield 1 and 2.5 mA. See Reinemann 2008; p. 19 (referencing USDA 1991) and p. 33.
[64] NRAES 2003a; p. 3.
[65] Reinemann 2008; p. 10.

'pathways' (points of body contact and locations); and differences in impact due to the duration or characteristics of exposure.[66]

Many of the symptoms attributed to stray voltage can have a number of other causes

Based on the information provided regarding field (on-farm) and experimental (controlled conditions) studies undertaken over many years, it is evident that exposure to stray voltage can have negative impacts on farm operations; and that generally, the higher the level of exposure, the more serious the potential implications if not addressed in a timely manner. It is also noted that many factors other than stray voltage can be responsible for the types of production and animal health symptoms commonly attributed to stray voltage.[67]

6.4 Effects of Stray Voltage on Farm Animals

6.4.1 Behavioural Responses of Dairy Cows to Stray Voltage

Exposure to electrical current flows through its body has direct behavioural effects

Controlled experiments have shown that exposing an animal to electrical voltage so that current flows through its body has direct behavioural effects that can be observed.[68] These effects range from mild to severe, depending on the level of current experienced by the animal, the current pathway to and through the animal's body, the level and frequency of current flow and the sensitivity of the individual animal to the sensation of current flow. Generally, behavioural responses that can be observed when an animal senses a level of current or voltage can be divided into three categories:[69]

- *Mild Behavioural Response (MBR)* – Mild physical reactions indicating that the animal's nerves are being stimulated sufficiently that the animal feels sensation (e.g. tingling). Such mild behavioural responses may be exhibited by only a few animals in a herd and may be indistinguishable from reactions caused by some

[66] Studies conducted in the 1980s focussed primarily on steady state 60 Hz voltages and currents. In the 1990s the focus shifted to the effects of 'transient' 60 Hz voltage and current and high frequency stimuli. See Reinemann 2008; p. 20.
[67] "…factors such as mistreatment of cows, milking machine problems, disease, poor sanitation, and nutritional disorders can cause cows to exhibit all the symptoms that have been reported to occur on farms reporting stray voltage." USDA 1991; p. 3-2.
[68] Reinemann 2008; p. 2.
[69] See Reinemann pp. 32 – 34.

other sources of stress. Pain is unlikely at this level, so behaviours that can impact farm operations such as avoiding water or feed locations are minimal.

- *Discomfort Behavioural Response (DBR)* – More pronounced and/or repeated actions, both voluntary (adaptive movements) and involuntary (i.e. muscle contractions such as twitching) due to current exposures sufficient to produce aversion. The resulting effects on farm operations depend upon specific exposure locations and the time history of exposures. For example, cows will delay drinking where their only source of water is associated with stray voltage exposure at this level.
- *Aversive Behavioural Response (ABR)* – This involves distinct physical responses including aversive actions indicative of pain, including avoidance behaviour. Where alternative sources of sustenance are not available, farm operations may be affected by reduced daily water and feed intake.

Figure 6-1 summarizes the results of a number of experiments that have been divided into three groups. In each group, cows were subjected to a range of stray voltage exposures in order to identify for each cow the exposure level at which an MBR, DBR or ABR is first observed. As shown in the graph, a total of 355 cows were involved in studies designed to identify their individual MBR thresholds; 125 cows were studied for their DBR thresholds; and ABR thresholds were assessed for 36 cows.[70]

[70] Reinemann 2008; pp. 36 – 37. While all of these studies looked at contact current - measured in milliamps (mA) - different animal contact situations were used. Also, the indicators of behavioural response used by the various investigators were not the same in every study. Accordingly, the information provided in Figure 6-1 should be considered indicative only of the range of animal responses to various levels of exposure to contact current.

Animals respond differently to the same level of current exposure

The respective current levels at which an animal initially detects, then becomes irritated and finally experiences pain vary from one animal to another.[71] As illustrated in Figure 6-1, 50 percent of the cows in the MBR, DBR and ABR groups exhibited response thresholds at about 5, 6.5 and 8.2 mA respectively.

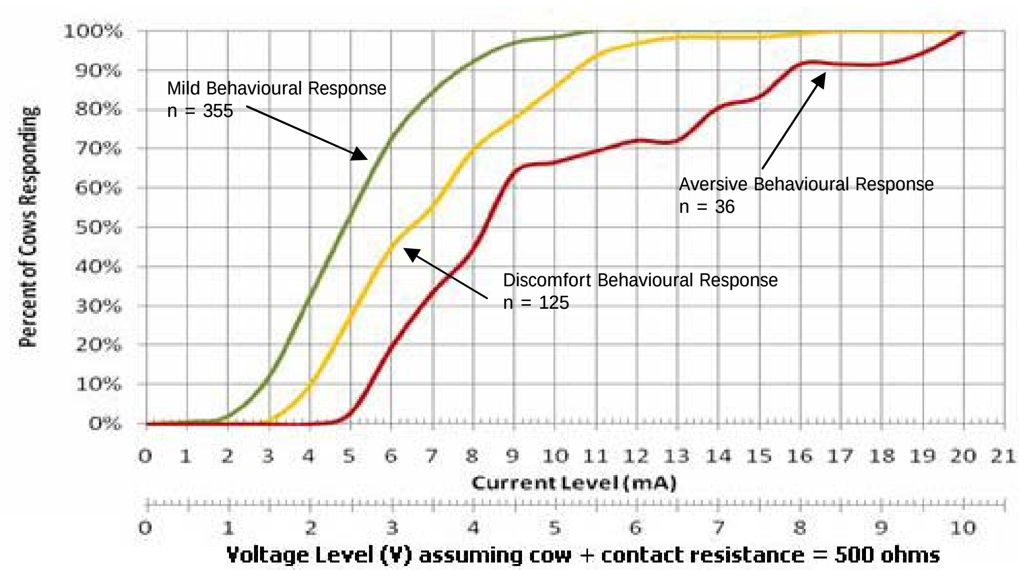

Figure 6-1: Cow Behavioural Response Thresholds
Source: Reinemann 2008

The graph also shows that based on the overall results documented in the literature, *the most sensitive cows* would exhibit mild behavioural responses at current levels of about 2 mA (or 1 V assuming cow + contact resistance is 500 Ohms), whereas aversive behaviours would be expected to occur at levels of about 5 mA (or 2.5 V equivalent). These experimental results are consistent with the findings of a recent detailed analysis of data from over 8,000 dairy farm investigations in the State of Wisconsin.[72]

[71] This variation may be due, at least in part, to the animal's prior experience with exposure, the implication being that prior experience will tend to push up the level at which one of the response types will be observed. USDA 1991; p. 3-3

[72] See Reinemann 2008; p. 28.

6.4.2 Behavioural Responses of Other Animal Species to Stray Voltage

Sensitivity to current varies with body mass: the higher the body mass, the more sensitive an animal is likely to be

While most of the laboratory and field research on stray voltage has focussed on dairy cows, the basic principles and animal exposure relationships identified for dairy cows and cattle apply to all types of livestock and their associated housing facilities.[73] The sensitivity of animals to electric current varies directly with body mass. Hence, beef cattle should exhibit about the same current sensitivity levels as dairy cows, but sheep - which have a lower body mass - will be less sensitive than cows or cattle because their lower body mass increases their body resistance.[74]

Accordingly, studies show that voltage exposure sensitivity thresholds for sheep are about twice those for dairy cows. Aversive behaviour responses, for example, are observed at exposure levels of about 5 to 5.5 V compared to the most sensitive cows at about 2.5 V.[75]

Swine have exhibited drinking behaviour changes at levels of 3.0 mA (3 V assuming 1000 Ohm resistance value[76]), short term reductions in water intake at 4.0 mA (4 V), and avoidance behaviour at exposures of 8 V. Research also suggests that swine adapt to voltage exposure in ways similar to those of dairy cows.[77]

6.4.3 Physiological Effects of Stray Voltage on Farm Animals

The effect of current exposure on immune system function has been studied extensively

When dairy cows are under stress for any reason, their milk production can decline. Cortisol is a hormone known to be released when cows are under stress. Accordingly, some researchers studied the effect of stray voltage on the concentration of cortisol in cow's blood. It was found that cortisol levels rise when dairy cows are exposed to stray voltage, but relatively high exposure levels are required to elicit this

[73] U.S. Dept. of Agriculture, Rural Utilities Service; 'Revisiting Stray Voltage'; *Summary of Items of Engineering Interest* (August 2000) (USDA 2000); p. 2.
[74] Reinemann 2008; p. 46.
[75] Reinemann 2008; p. 46 and Figure 6-1.
[76] A conservative value for the body + contact resistance for swine appears to be about 1000 Ohms, or at the high end of the range found for dairy cows. Reinemann 2008; p. 46.
[77] Reinemann 2008; p. 46.

physiological response, that is, levels that would typically cause most cows to avoid the source of exposure due to discomfort or pain.[78] In addition, several experimental and field studies failed to demonstrate that exposure to current at levels that elicit behavioural changes has a detrimental effect on the incidence of mastitis (an infection of the mammary gland) and immune function response.[79]

[78] Reinemann 2008; p. 3.
[79] Reinemann 2008; p. 3.

7 Managing Distributor Contributions to Farm Stray Voltage

Section 4 explained how farm stray voltage can result from elevated neutral to earth voltage on the distribution system, and from contributing factors on the farm itself. The purpose of this section is to describe briefly the nature, effectiveness and relative costs of various measures distributors can take to reduce NEV on their system, both in general and at specific locations in an effort to reduce contributions from the distribution system to stray voltage levels on a farm.

Much of the information provided here is from a report prepared for Board staff by Kinectrics Inc., entitled '*Stray Voltage Mitigation*' (Kinectrics 2008).[80] The central purpose of this report was to evaluate the main methods distributors can use to ensure stray voltage has no undue impact on farm operations. Included in Kinectrics' evaluation are cost vs. effectiveness assessments for a range of techniques, including modifications to the distribution system and the installation of devices at the distributor's transformer or on the farm itself.[81]

Reducing distributor contributions to stray voltage can involve one or more measures depending on the conditions and characteristics of each farm situation and the cost and effectiveness of measures available. Measures discussed in this section are:[82]

Depending on the situation at hand, distributors can use one or a combination of techniques to mitigate their contributions to FSV

1. Balancing loads on multi-phase distribution lines
2. Converting from single phase to three phase lines
3. Improving neutral grounding on poles or at substations
4. Replacing lower voltage lines with higher voltage lines
5. Replacing the neutral conductor with a larger diameter conductor
6. Adding a second 'dedicated' neutral conductor ("5 wire" system)

[80] This Discussion Paper section has been prepared by Board staff and is for general information only. This section is NOT intended to replace the report prepared by Kinectrics. Kinectrics' report should be relied upon in the event of any perceived discrepancy between the information provided in this section and Kinectrics' report. The full report (with an Executive Summary in French) is available on the Board's Farm Stray Voltage web page.

[81] All dollar figures appearing here are estimates based on 2007 data. Actual prices and costs may vary.

[82] This list is not intended to be exhaustive.

7. Isolating the primary and secondary neutral conductors at the transformer
8. Adjusting conductor & line configurations

All of the measures listed above are designed to either manage or limit NEV on the distributor's distribution circuit, or limit current flows between the distribution neutral and the farm neutral/grounding system. Some measures are targeted at specific causes but all approaches can reduce primary NEV to some degree. However, costs and potential implications for the distributor's system, the farm customer and other customers must be considered as well.

7.1 Load Balancing

Distribution lines serving farm customers are typically either single phase (one phase conductor plus a neutral conductor) or three phase (three phase conductors plus a neutral) lines. Two phase lines are also used, but much less frequently. Often a three phase line extending from the distribution substation will have a number of single phase 'lateral' lines connected to it. In that case, farm customers can be connected to either one of the lateral lines, or to the three phase 'backbone' line.

Balancing loads along 3-phase distribution lines is a relatively low cost and effective means of managing NEV

Where three phase lines are used, it is important for distributors to ensure that farm and other customers are connected to the individual phase conductors so that customer loads are evenly distributed among all three phases. This is called 'balancing'. Balancing the amount of current on all three phases minimizes the amount of total return current, and therefore minimizes NEV on the distribution system.

In practice, customers use power in different amounts at different times. Accordingly, there is always some amount of NEV due to load 'unbalance' among the three phases. Distributors typically have target levels of 'unbalance' they try to maintain, and make adjustments from time to time as needed, usually as part and parcel of overall distribution system management programs. Ideally these adjustments are made along the length of the line, because changes at one location can create unbalance conditions elsewhere on the line.

The adjustment process consists of physically disconnecting customers from one phase conductor and reconnecting them to a different phase conductor based on measurements of loads on each of the three phases.[83] Typically, the process does not take very long for each customer to be disconnected and reconnected and is one of the more effective methods of reducing NEV on the distribution system. The cost of balancing an entire rural circuit will likely be less than $10,000, but will vary depending on the length of the circuit and number of customer connections.[84]

7.2 Converting Lines from Single Phase to Three Phase

As noted in the previous section, three phase lines extending from the distribution substation typically have a number of single phase 'lateral' lines connected to them. Single phase lateral lines with relatively heavy customer loads can produce significant NEV along the line.[85] Whereas loads can be balanced among the phase conductors on three phase lines, thereby reducing NEV as explained above, balancing is not possible for single phase lines. Converting single phase lines to three phase lines allows distributors to reduce NEV by balancing the loads along the line.

Adding phase conductors to a single phase distribution line allows loads on the line to be balanced, lowering NEV at all points on the line

The cost of converting a line from single to three phases depends on whether the existing line needs to be rebuilt. For a 5 km line, the estimated cost of conversion would range from $65,000 if only two new phase conductors need to be added; to $160,000 if the line has to be rebuilt.

[83] Single phase lines cannot be balanced in this way because there is no alternative phase conductor.
[84] See Kinectrics 2008; p. 10. A table comparing remediation costs is provided in section 7.9.
[85] Kinectrics 2008; p. 11.

7.3 Improved Grounding

As explained in section 4, the distribution system neutral wires are grounded at the distribution substation, at certain intervals along the line, at the transformers where farm customers are connected to the system, and at the service panels of buildings on the customer's farm. Improving the quality as well as the number of groundings can reduce NEV on the distributor's system and consequently, the potential for stray voltage.[86]

Adding groundings either at the substation or along the distribution line can lower the NEV at all points on the line

Soil conditions affect the quality of groundings - rocky soils present the greatest difficultly. Where elevated NEV is due to distribution facilities having to be built over a rocky area, it may be necessary to install a grounding 'grid' nearby where soil conditions are more suitable, or bury a 'counterpoise' grounding wire along the line.

Including the cost of installation, adding a single grounding (ground rod, ground wire and connectors) to a distribution line would cost about $210.[87] Therefore, adding four ground rods per km to, for example, 40 km of distribution line would cost about $33,600.

7.4 Increasing Circuit Voltage

Doubling the distribution voltage on the line can reduce NEV by half

For a given level of load, the higher the voltage of the distribution line, the lower the NEV at all points on the line. If for example the voltage of an 8.32 kV distribution line is increased by 50% to 12.5 kV, NEV (assuming the load is unchanged) will decline by about 34%.[88] Combining a distribution voltage increase with another measure, say increasing the number of groundings along the length of the line would lower primary NEV even further compared to the original levels.

Voltage upgrades are relatively costly

The cost of increasing the distribution line voltage depends on the amount of voltage increase and whether the existing poles can be used. Generally, higher voltages require taller poles to provide more

[86] Kinectrics 2008; p. 12.
[87] Kinectrics 2008; p. 13.
[88] Kinectrics 2008; p. 14.

ground clearance and more spacing between the phase and neutral wires. Where a distributor plans to upgrade the voltage of a feeder in the future, poles are installed that will accommodate higher voltages, so pole replacement can be avoided when the upgrade takes place. There can also be cost savings, especially for single phase lines, if existing poles can be extended rather than replaced.

The cost of increasing the voltage on a circuit can be estimated from typical replacement costs for poles, insulators, distribution transformers and substation transformers.[89] Assuming the circuit consists of 17 km of 3 phase main line and 25 km of single phase line, the cost of upgrading the voltage would be about $800,000 to $2 million, depending on whether the poles need to be replaced. Actual costs can vary ±25% depending on the voltages being used and characteristics of the circuit.[90]

7.5 Increasing Neutral Wire Size

Generally, the larger the diameter of a neutral conductor, the lower its resistance will be. Therefore, increasing the size of the neutral conductor on a rural distribution line will increase the share of total return current carried by the neutral compared to that transmitted through the earth.

Replacing the existing primary neutral with a larger diameter conductor will lower NEV, but not by a significant amount

Compared to increasing the number of ground rods along the line or balancing loads along a line, increasing the size of the neutral on a distribution line is less effective at lowering primary NEV. Consequently, increasing the size of the neutral by, for example, 60% will reduce distribution system NEV by about 12%.[91]

The cost of upgrading the neutral wire depends on the length of the distribution line and the size of the replacement conductor. However, in order to mitigate a stray voltage situation on a given farm, it may not

[89] Unit costs are provided by Kinectrics 2008; Table 4.3; p. 15.
[90] Kinectrics 2008; p. 14.
[91] The larger the wire, the lower its resistance, but its reactance is relatively unchanged. See Kinectrics 2008; p. 15.

be necessary to replace the entire length of neutral conductor on the line. For example, the cost of retrofitting 10 km of distribution line with neutral conductor costing $2,000 per km would be about $55,000 including labour.[92]

7.6 "5-Wire" (Dedicated Neutral) System

Distribution systems can be designed to eliminate the connection between the distributor (primary) and farm (secondary) neutral conductors. One such design – not used in existing distribution systems - includes two neutral conductors instead of the conventional single neutral.[93]

With a '5-wire' design, the primary and secondary neutral are not connected at the farm so neutral current cannot flow from the distributor's system to the farm system

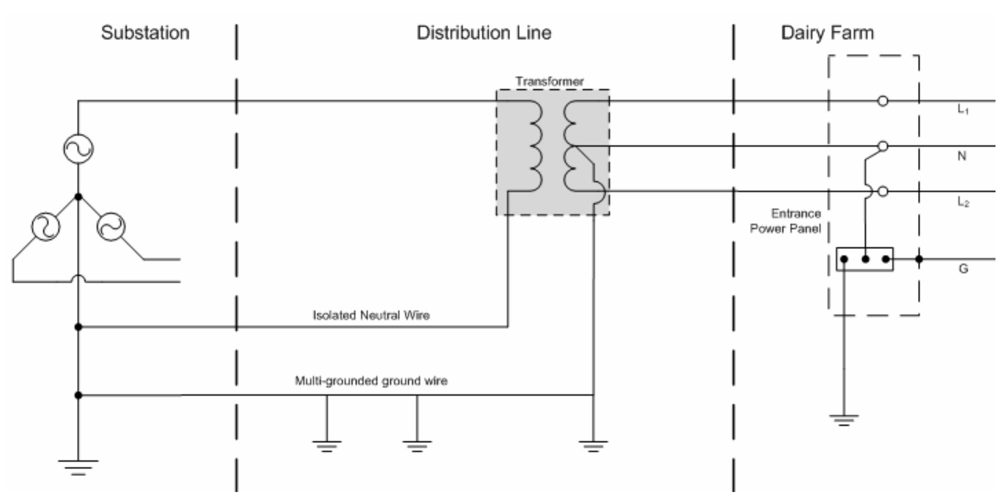

Figure 7-1: '5-Wire' Distribution System Design
Source: Kinectrics 2008

As shown in Figure 7-1, one neutral wire is dedicated to returning current on the circuit to the distributor's substation and is grounded only at the substation transformer. The other neutral is grounded at intervals along the line in the same way as neutral conductors on existing 3 phase systems and at the transformer located close to the farm. The farm (secondary) neutral is connected to this multi-grounded neutral wire but not to the neutral conductor that is dedicated to returning current to the substation.

[92] Kinectrics 2008; p. 16.
[93] See Kinectrics 2008; p. 19.

Since the primary and secondary neutrals are not connected at the farm, neutral current from the distributor's system does not flow to the customer's farm. The cost of retrofitting a distribution circuit to accommodate this system design is similar to the cost of upgrading the voltage of an entire line.

7.7 Isolation Devices

7.7.1 Variable Threshold Neutral Isolators

VTNI devices connect the primary and secondary neutral conductors only when significant faults occur

Variable threshold neutral isolators (VTNI) devices are installed at the pole transformer on the distributor's side of the demarcation point, as illustrated in Figure 7-2. They consist of a voltage limiting device that separates the primary from the secondary neutral wires under normal operating conditions, but joins them together when voltage transients ("spikes") occur due to a lightning strike, ground fault or other unusual condition. Making this connection under fault conditions allows the farm system access to the overcurrent protection on the distribution system. VTNI devices cost $900 to 1,700 excluding installation.[94]

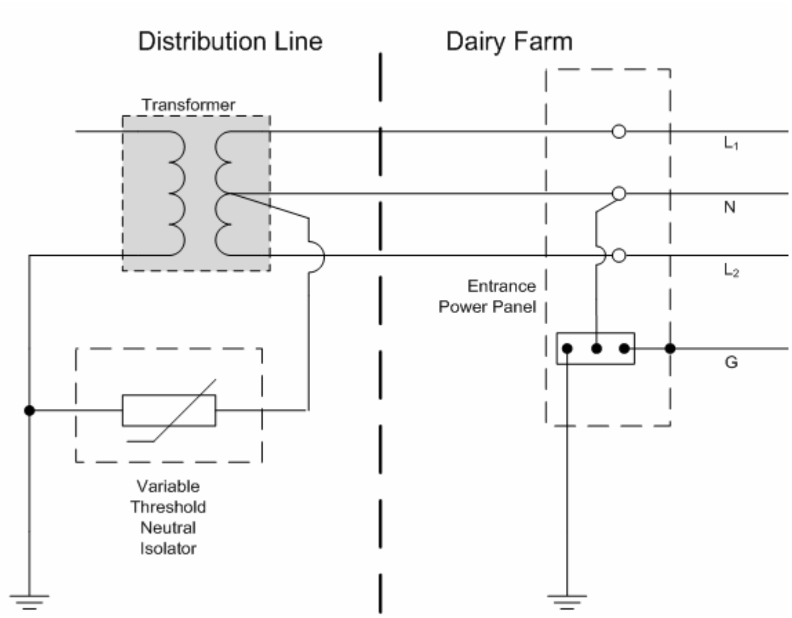

Figure 7-2: Variable Threshold Neutral Isolator
Source: Kinectrics 2008

[94] Kinectrics 2008; p. 20. Installation adds an estimated $2,000 to the total cost (BDR 2008; p. 27).

Although effective at limiting distributor contributions to stray voltage through the connection between the primary and secondary neutral wires, VTNI have potential drawbacks. First, if a severe fault occurs, some devices 'burn open', effectively isolating the primary and secondary systems and compromising protection against short circuits on the farm. Moreover, some devices are not equipped with visible indicators of failure, so farmers may not know when a device has failed.

Secondly, installing this type of device on one farm may have the unintended consequence of raising the local NEV on the distribution line, potentially contributing to the creation of a stray voltage problem further down the line.

7.7.2 Saturable Reactor Filters

Saturable reactor voltage 'filters', like the Hammond 'tingle voltage filter' installed on many Ontario dairy farms, operate in a different way but serve essentially the same purpose as VTNIs. Unlike VTNI devices, these devices are installed on the farm electrical distribution system, specifically between the farm (secondary) neutral and the ground connection in the power panel in the barn or building where animal contact can occur. The filters cost about $500, excluding installation.[95]

7.7.3 Isolation Transformers

Isolation transformers are effective but expensive.

Disconnecting the bond between the primary and farm neutrals is the basic concept behind this type of device, which is installed between the distributor's transformer and the farm's electrical panel. While they permanently eliminate the distributor contribution to farm stray voltage, isolation transformers are expensive relative to similar, more flexible devices (see above). In addition, an undetected on-farm fault (lightning strike, system fault, or wiring error) could produce a potential

[95] See Kinectrics 2008; p. 21. The 'Hammond' filter is no longer manufactured (OMAFRA 1998; p. 9); the price given refers to refurbished units.

shock hazard. For these two reasons, isolation transformers are not generally considered a practical solution to stray voltage situations.[96]

7.8 Adjusting Conductor & Line Configurations

Current flow on the distribution neutral and therefore NEV can result from a type of interaction between phase and distribution neutral conductors called ‘induction’ or ‘inductive coupling’. Induction can occur where: the spacing is unequal between the three phase conductors and the neutral conductor on a three phase distribution line[97]; medium voltage lines are located on the same poles as a distribution line[98]; and where the spacing is unequal between the phase conductors of a high voltage transmission line and the neutral conductor of a distribution line located close to and parallel with the high voltage line.[99]

Primary NEV caused by induction can be mitigated using any of the methods and devices mentioned in the preceding sections. In addition, physical adjustments made to the conductors on the lines or to the lines themselves can mitigate the impact of induction. For example, reconfiguring the phase and neutral conductors from a vertical arrangement to an armless triangle or horizontal crossarm configuration will mitigate primary NEV caused by induction due to unequal spacing between the phase and neutral conductors on distribution lines. The cost of this kind of reconfiguration depends on the length of line and the number of circuits sharing the poles. Assuming a single circuit line is reconfigured as described the cost would be about $4,000 per km of distribution line.[100] If elevated primary NEV is due to induction related to multiple circuits sharing poles with a rural distribution line, the approach to rearranging the circuits on the poles would be similar but the costs would be higher

[96] Kinectrics 2008; p. 20.
[97] Kinectrics 2008; pp. 17 – 19.
[98] An illustration of this situation, involving collection lines from a larger scale distributed generation facility sharing poles with a rural distribution line, is found in the Kinectrics report; pp. 23 - 25.
[99] Kinectrics 2008: p. 25.
[100] Kinectrics 2008; p. 19.

given that multiple crossarms would be needed. Relocating the distribution circuits on separate poles (e.g. across the road) would also reduce the effect of induction.[101]

7.9 Comparison of Remediation Measures

Comparisons among the various measures mentioned above are difficult given the differences in scope of application, effectiveness and cost. Some measures address potential stray voltage situations for all customers on the feeder circuit, while others would affect a portion of the circuit, a single farm, or specific farm building.

The remediation measure that best suits a given situation is a function of its efficacy, cost and consequences for the customer and other customers on the same line

Table 7.1 – Comparison of Remediation Measures

Technique/Device	Effectiveness	Cost ('000)
Distribution Load Balancing[1]	30% - 80%	< $10
Converting to three phase lines[2]	30% - 80%	< 160
Increasing number of ground rods[3]	30% - 80%	< $200
Increasing distribution voltage[4]	30% - 80%	$500+
Increasing neutral wire size[5]	< 30%	$50+
Changing pole configuration[6]	< 30%	$50+
'5-wire' distribution system	80% - 100%	$500+
Installing VTNI[7]	80% - 100%[9]	< $5
Saturable reactor filter[8]	30% - 80%[9]	< $2

Source: Kinectrics 2008; Table 4.6.

Notes:
1. Cost depends on number of loads on the circuit to be adjusted.
2. Assumes 5 km line; cost is less if rebuilding is not needed.
3. Cost depends on the number of ground rods to be added.
4. Cost varies by line length and number of customers
5. Cost varies by size of neutral ($900 - $5,700/km) and length replaced.
6. Depends on circuit length and the number of circuits sharing the poles.
7. Cost varies by device used and installation conditions.
8. Installed at the service panel.
9. Lower if primary NEV is over 10 V.

As shown on Table 7-1, the range of both effectiveness and cost is quite wide both from one measure to another and for individual measures depending on the characteristics of the location. The cost of buying and installing a specific device in order to address a given situation is relatively easy to estimate, but the same situation could

[101] Kinectrics 2008; p. 25.

also be addressed using measures involving system alterations or upgrades, costs could vary considerably.

The use of one or more measures to address a given stray voltage situation, or a number of similar circumstances on the same distribution line would require a detailed assessment of not only present conditions and circumstances, but expected future load growth (or shrinkage), the potential for distribution connected generation, etc.

7.10 On-farm Approaches to Prevention & Mitigation

In addition to the 'saturable reactor filter' mentioned above, some practices have been generally accepted as effective means of preventing stray voltage problems on the farm.[102] These include:[103]

Preventing and reducing stray voltage due to on-farm sources can involve a variety of installation and maintenance activities

- Re-wiring old 'three-wire' farm systems to include a grounding system and separate secondary neutral, with wires sized to ensure existing and new loads are adequately served;
- Ensuring a sufficient number and quality of groundings at service entrances, on secondary lines where used and for all electrical equipment;
- Using 240 volt motors and 'soft-start' motors to minimize momentary voltage 'spikes' (transients) when motors are turned on;
- Adopting regular maintenance routines for the farm neutral and grounding systems in order to identify and repair damaged wires and connections before problems arise;
- Ensuring new wiring and equipment installations are executed by qualified personnel familiar with the stray voltage phenomenon and inspected in accordance with electrical codes and safety codes;

[102] This list is not intended to be exhaustive.
[103] Information immediately below is based on *Investigation on the commission's Own Motion into the Practices, Policies and Procedures Concerning Stray Voltage for Electric distribution Utilities in Wisconsin*; Docket 05-EI-106; Public Service Commission of Wisconsin; August 10, 1989 (PSCW 1989); p. 19.

In addition, there are a number of approaches to remedying existing stray voltage situations, including:[104]

- Installing an equipotential plane in the barn floor to ensure the entire floor has the same voltage potential;
- Using watering devices made of non-metallic material, or that are not required to make firm contact with grounded metallic components;
- Avoiding the use of electric heating elements in the watering devices;
- Providing good drainage at watering devices to minimize floor surface wetness; and
- Ensuring 120 V farm loads on single phase secondary systems are ‘balanced’, that is, operated so as to minimize current on the secondary neutral conductor.

[104] Information is based on Reinemann 2008; p. 45; and pp. 49 - 50.

8 Review of Approaches in Other Jurisdictions

The purpose of this section is to describe the main elements of various approaches that have been taken in selected Canadian and U.S. jurisdictions to address farm stray voltage. Much of the information provided here is from a report prepared for Board staff by BDR NorthAmerica Inc. entitled *Regulatory Approaches to Addressing the Impact of Stray Voltage on Farm Operations* (cited here as BDR 2008).[105] Other information sources are referenced where used.

In Canada, each utility determines its own approach to farm stray voltage

At present, Canadian distributors are unregulated with regard to farm stray voltage. Rather, distributors either develop internal standards and procedures, or address farmers' complaints on a case by case basis. For example, in British Columbia, the use of an isolation device is a standard remediation measure used by B.C. Hydro where excessive farm stray voltage has been found. An Alberta distributor indicated that isolation devices can be installed if other approaches do not resolve the problem. Hydro Québec regards them as a temporary measure installed while other measures are considered.

In the U.S., regulators have adopted a variety of measures and approaches

In the U.S., a number of regulators have examined the farm stray voltage issue over the years. Of the jurisdictions examined for the purpose of this report, four (Wisconsin, Connecticut, Idaho and Michigan) have elected to regulate distributors.[106] The first of these to do so was the Public Service Commission of Wisconsin (PSCW) in 1989; the most recent was Michigan's Public Service Commission, which passed rules in 2007. All four jurisdictions have not adopted exactly the same regulatory framework or implementation approach. Other U.S. regulators have chosen different measures, and not all jurisdictions have adopted a compulsory approach.

[105] This Discussion Paper section has been prepared by Board staff and is for general information only. This section is NOT intended to replace the report prepared by BDR. BDR's report should be relied upon in the event of any perceived discrepancy between the information provided in this section and BDR's report. The full report (with an Executive Summary in French) is available on the Board's Farm Stray Voltage web page.
[106] All subsequent references to U.S. jurisdictions that regulate distributors with regard to farm stray voltage refer to these four states.

The discussion that follows compares the various approaches to addressing farm stray voltage with respect to nine related subject areas, each of which could be involved in developing a framework for addressing farm stray voltage in Ontario:[107]

A comprehensive approach to farm stray voltage involves a number of related issues

1. Distributor action targets & thresholds
2. Investigation procedures and costs
3. Training/certification requirements
4. Customer response procedures
5. Regulatory reporting requirements
6. Remediation options
7. Dispute resolution processes
8. Providing information to farm customers
9. Alternative approaches to implementation

8.1 Distributor Action Targets

Since stray voltage by definition involves points that animals can contact, it is logical that all four U.S. jurisdictions that addressed farm stray voltage through regulation adopted an approach based on a measurement that must be taken on a customer's farm. In 1989 the PSCW adopted a stray voltage standard of 0.5 V (or 1 mA) in "cow contact" (i.e. milking, feeding and watering) areas as the 'level of concern' beyond which distributors must take "corrective or mitigative" action.[108] At the time, no distinction was made between distributor and on-farm contributions to stray voltage. The Connecticut Dept. of Public Utility Control (DPUC) adopted the same standard in 1995.

Three U.S. states adopted targets for utility contributions to overall stray voltage measured at animal contact locations

In a 1996 Order, the PSCW differentiated between on-farm and distributor contributions to overall stray voltage in animal contact areas; and revised its 'level of concern' upward to 2 mA (or 1 V) based on updated research (including the findings of studies documented in USDA 1991) which indicated that 2 mA is "well below where a cow's

[107] The BDR report contains cross-jurisdictional comparison tables, including a detailed set of appendix tables.
[108] PSCW 1989; p. 34.

behaviour or milk production would be harmed."[109] Both Idaho (in 2005) and Michigan (in 2007) adopted this more recent Wisconsin stray voltage standard, which consists of two parts:

1) An *overall* threshold of 2 mA (or 1 V equivalent[110]); and
2) A maximum *distributor contribution* of 1 mA (or 0.5 V equivalent) beyond which "the utility must reduce its contribution to 1 mA or below".[111]

The DPUC, as mentioned above, requires distributors to take remedial action if overall farm stray voltage is found to be at or above 0.5 V or 1 mA. They must *also* do so if primary NEV measured at the farm exceeds 1 V. The rationale for this additional standard was that measuring distributor contributions to ACV requires a "painstaking approach". Capping primary NEV, on the other hand, was a relatively simple way to "alleviate most stray voltage concerns."[112]

It should be noted that there are differences across jurisdictions in terms of the scope of the applicability of farm stray voltage regulations. Some seem to be applicable only to dairy farms, while others encompass other livestock species:

- The Idaho Public Utilities Commission (IPUC) 'Stray Voltage Rules' "are applicable to dairy producers, public utilities and all persons or entities involved in any way in the measurement or remediation of stray current or voltage within Idaho."[113]
- Connecticut's 1995 Decision specifies that each distributor is to "send stray voltage information annually to the dairy farmers in their service territory" and dispatch their Stray Voltage Team to "conduct

[109] *Investigation on the Commission's Own Motion into the Practices, Policies and Procedures Concerning Stray Voltage for Electric Distribution Utilities in Wisconsin: Findings of Fact, Conclusion of Law and Order* (Docket #05-EI-115); July 16, 1996 (PSCW 1996); p. 32.
[110] Equivalent values in Volts are calculated using Ohm's Law and assume 500 Ohms as the value for animal + contact resistance.
[111] PSCW 1996; p. 32.
[112] Connecticut Department of Public Utility Control, *DPUC Investigation into Stray Voltage on Dairy Farms*; Docket No. 94-05-35; June 30, 1995 (DPUC 1995); p. 9.
[113] Idaho Public Utilities Commission; *Rules for the Measurement of Stray Current or Voltage (the Stray Voltage Rules)*; Title 61; Chapter 1; IDAPA 31.61.01.000 (IPUC 2005); sec. 001.

investigations on dairy farms"[114] and the Protocol appended to the Decision specifies that the "level of concern for stray voltage" used is "measured at cow contact locations".

- Wisconsin's 1989 Order applies to electric utilities that have "a distribution system which serves dairy or other confined livestock farms".[115]
- Michigan's Administrative Rules define a distributor action standard as "animal contact current" of 2 mA or more, where "animal" is defined as "vertebrates including, but not limited to, dairy and beef cattle, sheep, swine, poultry and horses".[116]

8.2 Investigation Procedures & Costs

In the Canadian jurisdictions surveyed by BDR for the purposes of this Discussion Paper, approaches to stray voltage testing are determined by the distributors themselves.[117] As a result, distributor investigation procedures range from informal to standardized.[118]

Where performance standards are used, regulatory provisions suggest or prescribe an investigation procedure

Wisconsin, Connecticut, Idaho, and Michigan all have implicit or explicit regulatory requirements for farm stray voltage investigations. Connecticut has no specific test procedure; instead, distributors were to establish their own test procedures designed to meet the stray voltage action standards.[119]

Wisconsin and Idaho have standardized, multi-part testing protocols designed to identify: whether and where stray voltage is present; individual on-farm sources; and contributions from the distribution system. Michigan's testing protocol is similar, but it does not include a detailed evaluation of on-farm sources. Also, Michigan distributors are

114 DPUC 1995; pp. 6 – 7.
115 PSCW 1989; p. 36.
116 Michigan Department of Labor and Economic Growth, Public Service Commission; *Rules and Regulations Governing Animal Contact Current Mitigation*; Administrative Rules 2005-008 SOAHR; 2007 MR 3 – March 1, 2007 (MPSC 2007); p. 8.
117 BDR 2008; p. 5.
118 British Columbia and Hydro Québec, respectively, are examples; see BDR 2008; pp. 27, 29 - 30.
119 BDR 2008; Connecticut; p. 36; Idaho; p. 38; Michigan; p. 42; and Wisconsin; p. 52.

allowed to submit to the regulator for approval testing procedures of their own design.

It is noted that the stray voltage investigation procedures specified by regulators in Wisconsin and Idaho are the most elaborate of those reviewed for the purposes of this paper in that distributor personnel are required to visit a farm on two or more occasions to set up, monitor, acquire data from and then retrieve testing equipment. The cost of these investigations is about $4,000 per farm.[120]

Generally, distributors bear the cost of farm stray voltage investigations and recover the expenses through the inclusion of these costs in rates charged to customers.[121]

8.3 Investigator Training & Certification

Some jurisdictions have recognized that detailed technical measurement and testing requires qualified investigators

Some jurisdictions have recognized the necessity of training personnel undertaking farm stray voltage investigations. In Québec, the ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (Ministry of Agriculture, Fisheries and Food, or MAPAQ), Hydro-Québec and the Union des producteurs agricoles (Union of Agricultural Producers, or UPA) have combined resources to put on a free, two-day training course for electricians specializing in rural locales.[122]

Among the four jurisdictions that formally regulate distributors in relation to farm stray voltage, only Idaho has specified training and certification requirements for stray voltage investigators.[123] Anyone conducting a stray voltage investigation for consideration by the IPUC must be "a qualified testing professional", defined as one of the following:

[120] BDR 2008; p. 54.
[121] BDR 2008; p. 65. In Québec, farmers may be charged a nominal (up to $400) fee to cover the cost of an initial farm stray voltage study. See BDR 2008: p. 31.
[122] BDR 2008; p. 31.
[123] See IPUC 2005; Rule 31.

- A licensed *professional engineer* or *master electrician* who has at least 48 hours of IPUC-approved stray voltage training and who has been involved in no fewer than five stray voltage investigations;
- A *technician* who has completed at least 8 hours of IPUC-approved stray voltage training under the supervision of one of the above qualified persons and who has been involved in at least 5 stray voltage investigations.

Idaho also stipulates that only a professional engineer who otherwise meets the requirements to perform stray voltage testing as set out above is considered qualified to analyze the test data obtained in an investigation.

8.4 Customer Response Procedure

Whether formalized in a procedures manual or simply a function of a distributor's operational structure, all distributors respond to customer concerns or complaints using a procedure consisting of receiving a customer query; directing the query internally; and responding to it in a timely fashion. In some jurisdictions where farm stray voltage regulations have been enacted, elements have been added to this basic process.

Some jurisdictions have suggested or specified the steps distributors must follow when responding to a farmer's complaint

For example, Idaho requires that farmers submit farm stray voltage investigation requests to their distributor in writing and that distributors respond by completing an investigation within 14 calendar days of receiving the request.[124] Furthermore, distributors are expected to begin remediation efforts within 5 business days of completing the investigation.[125] In Michigan, distributors are required to begin remediation within two business days of test completion, or at a time "mutually agreed upon" between the customer and distributor.[126]

124 IPUC 2005; 022.02
125 IPUC 2005; 091.01
126 MPSC 2007; R460.2703

Information transmittal requirements may be included in the procedure to ensure the farm customer is informed as to the results of the distributor's investigation. For example, the Wisconsin farm stray voltage regulations stipulate that distributors must provide farm customers with a report on the results of their stray voltage investigation, including the results of key tests and the level, if any, of stray voltage found, the source of any current that exceeds the 'Level of Concern', recommendations about the farm's wiring, and a description of the remediation measures taken by the distributor.[127]

Noting that distributors in that state "appear to recognize the importance of good communications with the customer to both analyze and solve stray voltage concerns," the Wisconsin regulator suggested that distributors should involve farm customers in the investigation process so that customers would have confidence in the findings.[128] Unlike Idaho, however, the PSCW has not prescribed a complaint response procedure; rather, distributors are required to file their customer service policies concerning farm stray voltage with the PSCW, and update these filings whenever the policies are revised.[129]

8.5 Regulatory Reporting Requirements

Where distributors are regulated regarding farm stray voltage specific reporting requirements are uncommon

Of the U.S. jurisdictions that regulate distributors with regard to farm stray voltage, Connecticut and Michigan have no specific regulatory filing requirements, while Idaho requires that information be filed by the distributor and the farm customer only where a farm customer is petitioning the regulatory authority to resolve a dispute.[130]

In Wisconsin on the other hand, investor-owned distributors have been providing information on the results of their farm stray voltage investigations to the PSCW since 1988.[131] Data on first time investigations must be submitted to the PSCW every 6 months, and

[127] BDR 2008; p. 53.
[128] PSCW 1989; pp. 27-28.
[129] PSCW 1989; pp. 29.
[130] BDR 2008; p. 59.
[131] BDR 2008; p. 53.

each distributor must keep a database of all farm stray voltage related contacts and investigations. Information supplied to the PSCW is compiled in a database and analyzed periodically for regulatory policy performance evaluation and development purposes.[132]

8.6 Remediation Options

In some jurisdictions, the use of devices to isolate the distributor and farm grounded neutral systems is restricted, while in others it is encouraged

As described in section 7, devices that isolate the farm's secondary neutral grounding system from the distributor's primary neutral offer a relatively quick and low cost way of reducing a distributor's contribution to stray voltage by lowering dramatically the flow of current between the distribution system neutral and the farm system neutral. In Vermont, where distributors have voluntarily adopted a primary NEV threshold of 0.5 V, isolation devices are installed at the distributor's discretion, even if that threshold is not exceeded.[133] BC Hydro includes isolation as a standard remediation approach where testing reveals a stray voltage problem exists.[134] In Alberta distributors also use isolation devices at their discretion, while in Québec, the provincial utility regards them as a temporary (1 year) measure, to be replaced by a permanent solution when practicable.[135] Connecticut's DPUC explicitly requires that distributors install a neutral isolation device if an alternative approach cannot be implemented within 15 days of testing.[136]

Section 7 also noted that there are concerns about the use of isolation devices in that their use can increase the risk of shock hazard on the farm and/or increase NEV elsewhere on the distribution system. This concern is reflected in the PSCW's approach to the installation of primary/secondary isolation devices (e.g. VTNI). Such installations are subject to four conditions:[137]

1. The distributor must install the isolator at its own cost;

[132] The PSCW Rural Electric Power Services published analyses in 1995, 1998, 2006 and 2007.
[133] BDR 2008; p. 48.
[134] BDR 2008; p. 27.
[135] BDR 2008; p. 25 (Alberta); and p. 30 (Québec).
[136] BDR 2008; p. 37.
[137] BDR 2008; p. 53.

2. The stray voltage level is above the level of concern;
3. Isolation will not create unsafe conditions on the farm because of lack of grounding or increase the primary neutral to earth voltage on the distribution system to unacceptable levels; and
4. The isolator remains in place for no more than 90 days, beyond which the distributor must request an extension from the PSCW.

In this way, Wisconsin's farm stray voltage regulatory regime promotes investments by distributors in system upgrades, which in 1989 included the need to replace outdated and inefficient steel conductors and 'split-bolt' ground wire connectors which had been used extensively until that time. In addition, if warranted on the basis of analyses of specific lines, upgrading conductors or increasing operating voltages were also to be considered.[138] It is noted, however, that subject to the above conditions, Wisconsin allows isolators to be installed permanently at the request of farm customers.

Typically, the cost of meeting their farm stray voltage related regulatory obligations are recovered by distributors through rates

Generally, costs associated with complying with farm stray voltage standards are recovered by distributors through rate adjustments. In Wisconsin, where distributors are allowed to meet their regulatory obligations by investing in mitigation measures on the farmer's property, the installation and maintenance expenses may be recovered through rates, but ownership of any equipment installed is transferred to the farmer.[139]

8.7 Dispute Resolution

In most of the jurisdictions surveyed, including all four of the U.S. jurisdictions that regulate farm stray voltage, if a dispute arises between a farm customer and their distributor with regard to farm stray voltage that cannot be resolved, the customer may submit their

[138] PSCW 1989; p. 17. Wisconsin distributors spent an estimated $1.5 billion on distribution system improvements over the past 20 years. See BDR 2008; p. 54.
[139] BDR 2008; p. 54.

complaint to the regulator for adjudication.[140] Within this general framework, there are minor differences in approach.

In Idaho, farm customers dissatisfied with the results of their distributor's investigation and remediation efforts can file a formal petition with the IPUC requesting a review.[141] The contents of the filing must include certain background information, a description of the alleged actions of the distributor that were not in compliance with the *Stray Current and Voltage Remediation Act* and of the remediation actions (if any) undertaken by either the distributor or the dairy farmer. The filing must be accompanied by a copy of the report prepared by the distributor regarding the results of their investigations on the farm.

Regulators adjudicate disputes between farm customers and distributors with varying levels of procedural formality

A similar but less formal process is followed in Michigan, where farm customers are also expected to notify the Public Service Commission if their stray voltage concerns are not addressed to their satisfaction.[142] Wisconsin farmers are also to appeal issues that could not be resolved with their distributor to the PSCW.[143]

Québec offers a different approach. Since the provincial Ministry of Agriculture (MAPAQ) is the 'single window' farm stray voltage service provider/coordinator, customers who are not satisfied with the results of the investigation or, where required, of Hydro Québec's remediation efforts can address their concerns to MAPAQ.[144] From there MAPAQ will pursue the matter with Hydro-Québec if needed. It is the distributors' regulator, the Régie de l'énergie, which has the authority to examine consumer complaints about a decision rendered by the utility concerning conditions of service, would if necessary be the final arbiter of cases that cannot be resolved by MAPAQ.

[140] BDR 2008; p. 69.
[141] BDR 2008; p. 40.
[142] BDR 2008; p. 43.
[143] BDR 2008; p. 53.
[144] See BDR 2008; pp. 30 – 31.

8.8 Farmer Access to Information

In general, the efficiency with which a stray voltage concern can be dealt with may depend on how well farmers are informed as to:[145]

- What farm stray voltage is and how it might affect their livestock;
- What other factors that can have a similar affect on farm operations need to be investigated as possible causes;
- What conditions on the farm, including the customer's electrical system, can contribute to the stray voltage problems, and the remediation options available to address these;
- Sources of experienced help and expert advice; and
- The process whereby stray voltage concerns are dealt with by their distributor, including how disputes are to be addressed.

Providing farmers with access to up to date information is considered key in most jurisdictions that have examined the issue

Some jurisdictions, such as Connecticut, explicitly require distributors to provide farm customers with information on stray voltage on a regular basis.[146] A team approach, involving several stakeholder parties is used in Connecticut, Québec and Wisconsin. Two or more stakeholder parties may be involved in providing farmers with access to up to date information and assistance in resolving their stray voltage concerns, including:[147]

- Electricity distributors
- The government agency responsible for agriculture
- Industry associations representing livestock farmers
- The electric utility regulator
- Universities or other educational institutions

[145] BDR 2008; p. 69.
[146] DPUC 1995 (Appendix B).
[147] For the parties involved in each of these jurisdictions see (in the order mentioned) BDR 2008; pp. 35; p. 31; pp. 49 – 50.

8.9 Implementation Approaches

No Canadian jurisdiction currently addresses the issue of farm stray voltage through specific requirements of distributors as defined and enforced by a regulator.[148] The issue has not to date gained public profile with Canadian regulators through their customer complaint/dispute resolution processes.[149] Other factors that may have influenced the Canadian non-regulatory approach include the restricted mandates of regulators in some jurisdictions (for example, Nova Scotia and Manitoba), and the industry structure in some provinces. In British Columbia and Québec, for example, where most customers are served by a large, provincially-owned, vertically integrated utility, the utilities are in a position to recruit expertise, develop policies and procedures, and implement them across the province to address the problem.[150]

Regulators have chosen different ways to implement measures to address farm stray voltage

In the U.S. jurisdictions where regulators have established a farm stray voltage management framework, not all of the above-listed measures have been included, or have measures been implemented in the same way. Approaches to implementing regulatory measures vary from one jurisdiction to another and over time within the same jurisdiction. Not every measure is set forth as a compulsory requirement; some are expressed as guidelines, others as performance standards monitored by the regulator.

Utilities can be required to develop a specific type of measure or to adopt a measure the details of which are prescribed by the regulator

For example, the PSCW first investigated the farm stray voltage issue in 1987/88, setting out in 1989 the principles and distributor practices that, in the PSCW's view, would best address various requirements of a comprehensive approach to resolving stray voltage concerns.[151] Distributors were required to develop and submit to the PSCW their own individual approaches, taking these requirements into consideration, or provide the PSCW with "good cause why it should not

[148] BDR 2008; p. 5 and pp. 24 – 33.
[149] BDR 2008; p. 55.
[150] BDR 2008; p. 56.
[151] An order was issued in January 1989 (Docket #05-EI-106), and subsequently amended in August 1989, and July and September 1990. PSCW 1996 provides a synopsis of PSCW investigations.

do so."[152] However, in a 1996 decision the PSCW recognized that differences among the various distributor approaches could result in farmers not being treated equally across the state, so distributors were required to collaborate to develop a uniform stray voltage investigation and response procedure, and then file on an individual basis.[153]

The Connecticut regulator's 1995 Decision (and appended protocol) was intended to signal the start of a longer process of developing more detailed measures. Distributors were required to provide information and training to farmers and their own staff, and form a special farm stray voltage investigation team among their staff to conduct investigations, but the specification of investigation procedures was left to the discretion of individual distributors to be guided by a proposed consortium of distributors, state agencies and others established under the Decision.[154]

At the opposite end of the spectrum, the IPUC was required by legislation to establish a uniform and comprehensive set of rules that would apply to all Idaho distributors on a compulsory basis. However, distributor perspectives on key elements of the rules were obtained through the workshop 'negotiation' process used by the IPUC to develop them.[155]

[152] PSCW 1989; p. 36
[153] PSCW 1996; pp. 38 – 39.
[154] DPUC 1995; pp. 6 – 7. BDR 2008; p. 34.
[155] BDR 2008; p. 38.

9 A Farm Stray Voltage Regulatory Framework: Issues & Options

9.1 Introduction

Board staff expects that regulatory measures adopted by the Board in response to the Directive will apply to licensed distributors, and will focus on off-farm sources that are within the control of – and most appropriately addressed by – licensed distributors.

As noted in section 4, farm stray voltage can result from both on-farm and off-farm sources. Board staff recognizes that the remediation and prevention of cases of farm stray voltage that result from on-farm sources or from off-farm sources that are not within the control of licensed distributors may not be resolved through the Board's process. Resolution of these issues may require the involvement of a number of other bodies, such as the ESA and OMAFRA.

9.1.1 Board Staff's Initial View

Information provided in the report prepared by Dr. Reinemann suggests that farm stray voltage, measured as animal contact current (ACC) in excess of 2 mA or as equivalent animal contact voltage (ACV) in excess of 1 V could potentially have an impact on farm operations.[156] Information provided in the report prepared by BDR NorthAmerica Inc. suggests that a potential quality of electricity service issue exists where animals are exposed to 2 mA (or 1 V equivalent) and the distribution system is found to contribute more than 1 mA (or 0.5 V equivalent).[157] Staff therefore believes that an appropriate approach to addressing the issue would be based on a distributor remediation target designed to ensure that sources within the control of the distributor are not responsible for ACC (or equivalent ACV) in excess of 1 mA (or 0.5 V).

[156] D.J. Reinemann, Ph.D.; *Literature Review and Synthesis of Research Findings on the Impact of Stray Voltage on Farm Operations* (cited here as Reinemann 2008)
[157] BDR NorthAmerica Inc. *Regulatory Approaches to Addressing the Impact of Stray Voltage on Farm Operations* (cited here as BDR 2008)

Board staff accepts that farm stray voltage from all sources in excess of 2 mA ACC or 1 V ACV could potentially have an undue impact on farm operations. This is the first element in a potential basic farm stray voltage regulatory framework, as illustrated in Figure 9-1. After reviewing the various approaches taken to the regulation of farm stray voltage in other jurisdictions as described in the BDR report, Board staffs' view is that a 'distributor remediation target' is the second element of a potential regulatory framework.

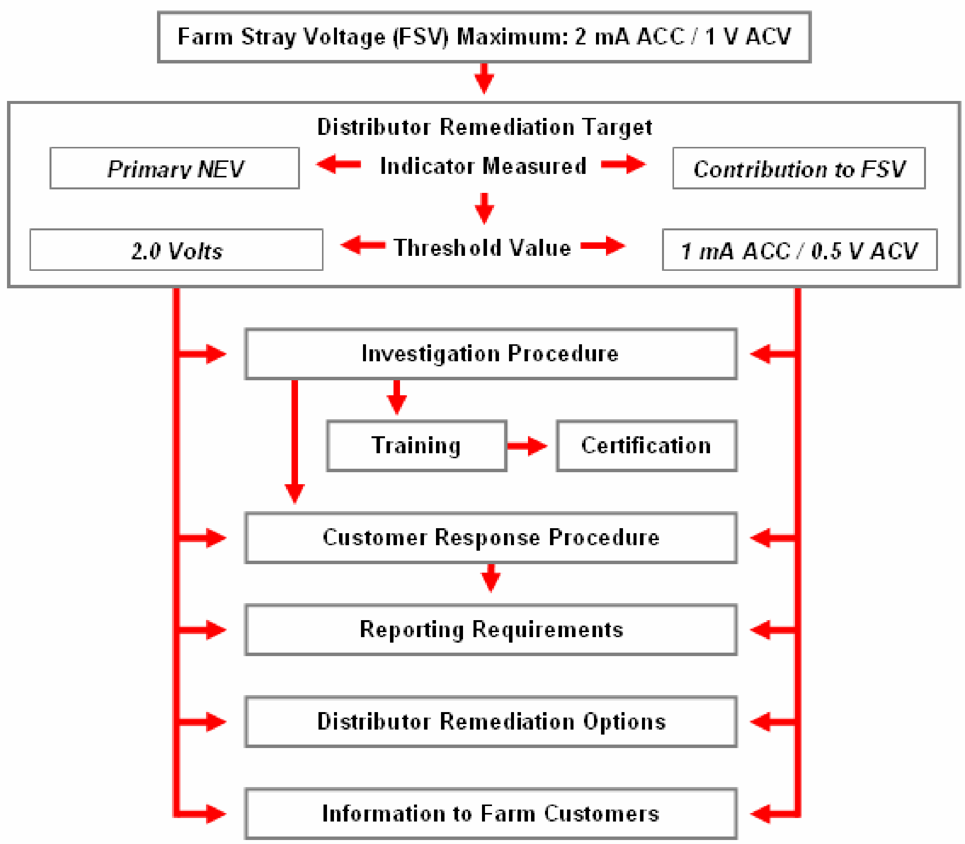

Figure 9-1: Potential Basic Regulatory Framework

As shown in Figure 9-1, the distributor remediation target consists of two parts: an *indicator* to be measured by the distributor and a *threshold value* beyond which the distributor could be required to take remedial action. Two alternative distributor remediation targets are shown: one based on primary NEV measured at the farm, the other on distributor contributions to ACC/ACV. Other alternatives are possible, but Board staff believes that these two approaches provide a useful starting point from which a potential basic regulatory framework can be constructed.

The regulatory framework set out in Figure 9-1 extends beyond the distributor remediation target to include several potential supporting elements. The need for, and nature of, such supporting elements may to some extent be dictated by the form of distributor remediation target adopted. For example, adopting a target that must be measured presupposes that some kind of procedure may be needed to take the appropriate measurements. If a procedure is needed, it could further be suggested that to ensure the procedure is executed properly, training may be required. And if training is needed, a certification process might be considered to ensure trainees meet a minimum standard.

9.1.2 Section Outline

The discussion below is organized as follows. For each element of the regulatory framework illustrated in Figure 9-1, a summary of related background information is provided, followed by a synopsis of how distributors in other jurisdictions deal with the matter, highlighting where regulatory approaches are used to guide distributor actions. Issues that should be considered when contemplating implementing the measure in Ontario are identified, as are options for dealing with these issues.

9.1.3 Approaches to Implementing Regulatory Measures

Regulators have adopted different approaches to implementing measures to address farm stray voltage. As discussed in section 3.2, there are alternative approaches that the Board could take, as well as a range of regulatory ‘tools’ that could be used.

The Board could establish objectives for distributors in the form of performance targets, procedural methods etc. but allow distributors the flexibility to comply with or achieve those objectives in the manner they consider most appropriate given their particular circumstances.

Alternatively, the Board could take a more prescriptive approach by establishing detailed requirements to be followed by distributors. The Board may wish to consider a mix of these approaches, where detailed direction is given by the Board for certain elements and distributors are given greater flexibility or discretion for some others.

9.2 Distributor Remediation Action Target Indicator & Threshold

This section considers the choice of "quality of electricity service" target that could be used to determine when remediation action by a distributor may be required to deal with a farm stray voltage situation. Based on approaches taken in other jurisdictions, this target consists of two parts: an *indicator* and a *threshold value*. As discussed below, the choice of indicator and threshold value could have a bearing on the need for, and form of, other elements to be included in the regulatory framework such as investigation procedures and related to this, investigator training.

9.2.1 Background Summary

In providing electricity service to farms, distribution systems can contribute to stray voltage appearing in animal contact locations. Other on-farm and off-farm sources can contribute to stray voltage at the same time. Studies show that the higher the level of stray voltage exposure, the greater the potential impact on an animal, and consequently, on farm operations. These studies also show that most dairy cows are not affected by exposures to animal contact current (or voltage) below 2 mA (or 1 V equivalent when measured using a 500 Ohm shunt resistor).

Historically, Ontario distributors have addressed farm stray voltage by focussing on the level of primary NEV at the farm, not on measured stray voltage *per se*. For example, Hydro One's internally established NEV standard is 10 V, with investigation "in a timely manner" required if primary NEV is 5 V or more so "improvements can be made before the 10 volt limit is exceeded".[158]

9.2.2 Approaches in Other Jurisdictions

Most of the jurisdictions surveyed for the purpose of this Discussion Paper do not have formal regulatory standards governing how distributors address farm customer stray voltage concerns. Instead, where stray voltage has been an issue, distributors have developed their own approach. There are, however, a few exceptions.

Utility regulators in Wisconsin, Idaho and Michigan recognize 2 mA or 1 V equivalent as a "conservative" or "preventative" level, above which action should be taken to ensure adverse impacts on farm operations are avoided. Recognizing also that stray voltage found on a farm can be the result of contributions from both the distribution system and on-farm sources, these regulators decided that distributors should be allowed to contribute no more than half - or 1 mA (0.5 V equivalent) - to the overall 2 mA (1 V equivalent) maximum. Connecticut has the same action target, but set the threshold at 1 mA of overall ACC. In addition, the Connecticut regulations require that primary NEV at the farm be no more than 1 V.

In Wisconsin and Michigan, farm stray voltage regulations are to apply to all livestock species. Idaho, on the other hand, has specifically limited the scope of application of their regulations to dairy farms.

In Canada, distributors have developed internal standards and procedures aimed at addressing stray voltage where it has been identified as a problem, whether on dairy farms or elsewhere. As in Ontario, the focus tends to be on the level of primary NEV at the farm, not on stray voltage *per se*. For example, Hydro Québec - like Hydro One - has an internal standard for maximum primary NEV of 10 V. Hydro Québec, however, considers 5 V to be a threshold beyond which remedial action to lower primary NEV is required.

[158] See Hydro One 2007b; p. 7.

9.2.3 Issues

Issue 1: Where ACC / ACV is found to be above 2 mA / 1 V, what electricity service quality indicator should serve as the trigger for distributor action?

Given the information provided above, distributors base their actions to address a given stray voltage situation on one of two target variables:

1. Neutral to earth voltage on the distribution system at the farm; or
2. The contribution of the distribution system to measured stray voltage on the farm.

Where U.S. regulators have addressed stray voltage, they have generally adopted the measured contribution of the distributor to overall animal contact exposure level as the basis for the distributor's obligation to remediate. This approach requires that a comprehensive investigation procedure be carried out by properly trained technicians, which means that costs - including training costs - associated with a relatively elaborate investigation must be considered. On the other hand, where distributor remedial action is based on primary NEV measured at the farm, the investigation procedure may be somewhat simpler and require less expertise with on-farm wiring and animal contact conditions.

Primary NEV has been used by Ontario distributors in the past as the benchmark guiding their approach to dealing with stray voltage. This approach is supported by information provided in section 4 as to how stray voltage can originate on the distribution system and why primary NEV can be a good indicator of the potential for stray voltage to appear on a farm.

Information has also been provided as to why primary NEV is not an accurate *predictor* of actual stray voltage levels, even in the absence of on-farm or non-distribution related off-farm sources. This variation is due to the fact that, at any given location, both primary NEV and ACC / ACV are a function of local conditions, including the type of soil, amount of moisture present, the condition and configuration of farm wiring, etc. Hydro One has suggested that farm stray voltage (from all sources) is typically between 40% and 60% of primary NEV.[159] This inconsistent relationship between stray voltage and primary NEV is the main drawback to accepting primary NEV as the trigger for distributor action. Therefore, the main difficulty with this approach might be selecting a practical primary NEV target level that will ensure stray voltage levels are acceptable in all cases (see Issue 2 below).

Options

Given the above discussion the following distributor remediation target indicators are suggested:

a) Distributors target primary NEV.

b) Distributors target the contribution of the distribution system to ACC / ACV on the farm.

Issue 2: What should the numerical threshold value be?

Given the background information summarized above, alternative numerical threshold values could be adopted as distributor targets. ACC of 2 mA or ACV of 1 V has been accepted in three U.S. jurisdictions as a conservative value *above which* adverse impacts on farm operations may begin to occur. On this basis, these same jurisdictions have determined that distribution systems may contribute at most half of this value - that is 1 mA ACC or 0.5 V ACV - and must undertake remediation measures if this threshold is exceeded. In Connecticut, the triggers for distributor action are 1 mA of overall ACC *and* 1 V primary NEV at the farm.

[159] Hydro One 2007b; p. 5.

On the other hand, where farm stray voltage regulations are not in place, distributors typically use primary NEV targets or threshold values. However, the variation in selected target value is fairly wide. Hydro Québec, for example, will take remediation measures on their system if primary NEV is above 5 V, while Vermont distributors will install an isolation device if primary NEV is above 0.5 V.

If the relationship between primary NEV and farm stray voltage was constant the issue would be resolvable based on known parameters. For example in Wisconsin, data shows that after controlling for on-farm contributions, ACV is *on average* about 25% of primary NEV.[160] If this relationship was true not just on average, but for *every* case of farm stray voltage in Ontario, and 0.5 V (equivalent to 1 mA) is considered an acceptable distributor contribution to stray voltage, then an appropriate primary NEV threshold would be 2.0 V (i.e. 0.5 / 0.25 = 2.0). 2 volts is toward the low end of the 0.5 to 5 V range noted above for Vermont and Hydro Québec respectively, so it could be argued that it represents a reasonable distributor remediation threshold value.

Options

Given the above discussion the following threshold values are suggested:

a) 2.0 V if distribution system NEV at the primary/secondary connection point at the farm is the action threshold.

b) 1 mA ACC or 0.5 V ACV if the distributor's contribution to stray voltage is the action threshold.

Issue 3: Should cow-based thresholds be applicable to all types of livestock farms?

[160] PSCW 2006; p. 18. This average value is calculated from data on secondary NEV measured during 'load box' tests, which involves restricting ACV sources to distributor contributions only. Therefore, during the load box test, primary and secondary NEV are almost the same.

Whether primary NEV or distributor contribution to ACC / ACV is adopted as the target indicator, and regardless of the numerical value of the action threshold or whether it is established as an objective or as a prescribed maximum, a decision must be made as to the scope of the measure's applicability. Jurisdictions that have established formal stray voltage regulations have adopted a distributor remediation action threshold based on the sensitivity of dairy cows to electrical current or voltage. Not all jurisdictions, however, apply the standard to *every* type of livestock farm.

Given the information provided in Dr. Reinemann's literature review and by farmers participating in this consultation, other livestock species that are kept in confinement such as poultry, swine and sheep can also be affected by stray voltage. It is noted that a relatively small number of studies have been undertaken to date on livestock species other than cattle. Consequently, the body of information upon which thresholds for other livestock species could be established may not be as robust as is the case for dairy and other cattle. The information does suggest, however, that other animal types are affected at generally higher exposure levels than are dairy cows.

Applying a threshold based on dairy cow sensitivity to animals that are less sensitive will result in the same remediation considerations and costs for other livestock farms as would apply to dairy farms. This could lead to higher costs than required to effectively address the impact of stray voltage on other types of farms. Meeting a dairy cow threshold would, however, provide an extra margin of 'insurance' for other types of farms where animal are less sensitive to voltage exposure.

<u>Options</u>

Given the above considerations, two alternatives are suggested for discussion:

a) Apply the numerical threshold to all livestock farms regardless of species.

b) Apply the numerical threshold to dairy and cattle farms only and adopt an alternative threshold(s) where other livestock species are involved.

9.3 Investigation Procedure

To determine if a remediation action threshold is exceeded, distributors will have to undertake some degree of investigation. This process should clarify, where relevant, the cause of the problem on the distribution system and identify the cost effective options available for remediation. Decisions as to the options mentioned above concerning the electricity service quality indicator will drive the content (steps involved, equipment needed and time required), and consequently the cost of the investigation procedure distributors use.

9.3.1 Background Summary

Farm stray voltage investigation procedures are not new to Ontario. OMAFRA and Ontario Hydro developed procedures describing investigation and remediation methods in the 1980s. More recently, Hydro One and the ESA have taken steps to update procedures manuals for use by distributors and electrical contractors.

Stray voltage investigation procedures manuals are useful because in order to identify and address stray voltage situations, certain measurements of voltage or current must be taken in a way that is technically sound and capable of producing accurate data. This is especially so where the measurement results can vary depending on the methods or instruments used. As well, whether utility actions are subject to requirements set internally or by a regulator, a practical method should be available whereby compliance with the requirements can be determined.

Based on a review of the farm stray voltage investigation procedures in use in Wisconsin, Idaho, and Michigan, it is clear that such procedures can be both detailed and technical in nature. At a minimum, whether for regulatory purposes or for distributors developing their own approach, Board staff suggests that a stray voltage investigation procedure should ensure that:

- The cost of investigations is transparent and consistent regardless of who performs the investigation or where it is carried out;
- The results of the investigations indicate clearly whether regulatory (or internal distributor) requirements are met;
- All investigations are carried out with the same degree of thoroughness and accuracy; and
- Re-testing permits initial results to be verified, or can confirm that remedial actions have achieved the desired result.

9.3.2 Approaches in Other Jurisdictions

In Canada, distributors are not regulated as to how they investigate suspected stray voltage cases, so they exercise discretion as to the nature and content of their stray voltage testing procedures. Some distributors have produced a formalized approach (similar to that used by Ontario Hydro as mentioned above) while others may take a less formal, case by case approach. Standardization may occur naturally where provincial utilities have a formal procedure and serve most if not all farm customers.

Despite the technical nature of farm stray voltage testing and analysis, not all jurisdictions have decided to impose a specific procedure on distributors. Idaho, for example, has embedded a standard procedure in its farm stray voltage ‘Rules’; Michigan distributors may use the procedure set out by regulation or develop their own procedure and submit it for approval; and Vermont – which allows distributors to set their own targets – also allows distributor discretion as to testing procedures.

Where a numerical standard applies to distributor performance, investigation procedures include tests designed to determine whether the standard is met. For example, investigation procedures used in Idaho, Wisconsin and Michigan are designed to identify whether and where stray voltage is present; and measure contributions from the distribution system. Where the three jurisdictions differ, however, is on testing for on-farm sources of stray voltage: Idaho and Wisconsin includes this in their procedures, while Michigan does not.

Regardless of the testing procedure used, in all jurisdictions reviewed for the purposes of this Discussion Paper distributors are responsible for the cost of any appropriate investigations they conduct. These costs are treated in the same way as any other prudently incurred distributor expense; that is, they are recovered by the distributor through customer rates.

9.3.3 Issues

<u>Issue 4: Should details of the investigation procedure be prescribed?</u>

Regardless of the target indicator or threshold value used, applying the same procedure to all investigations has several benefits: consistency of customer treatment; predictable costs (within a range dictated by conditions); ease of comparison across different tests carried out by different distributors; and repeatability (for validation/confirmation purposes).

Standardization could be achieved through a regulatory requirement or through a collaborative effort on the part of Ontario distributors to develop and take ownership of a ‘best practices’ investigation procedure that meets regulatory objectives.

Allowing distributors some discretion as to the extent to which the investigation procedure should be applied could result in lower costs. For example, in any given case it may be necessary to complete only a limited number of procedural steps to obtain sufficient information whereby the problem can be resolved cost effectively.

Options

There are a number of options and variants thereof that could be considered, such as:

a) Outline the goals and objectives of the procedure (e.g. measurements relevant to thresholds) and require that distributors design procedures that meet these goals and objectives.
b) Require that all distributors use a specific Board-approved procedure.

Issue 5: Should distributors be responsible for identifying on-farm stray voltage sources?

Since the sources of a given stray voltage situation can be either on-farm or off-farm, or both, all potential sources should be investigated in order to provide the basis for a comprehensive solution. Rural electricians with experience dealing with the diagnosis of on-farm sources of stray voltage could provide this service to farmers. Furthermore, strictly speaking, the distributor has control over, and could be reasonably expected to be responsible for only its own contributions to any stray voltage that may be present on a farm.

Some jurisdictions as a matter of policy require distributors to conduct tests to identify both on- and off-farm sources, while others do not. On-farm testing by distributors is clearly warranted (although not required) where (as in Wisconsin) distributors are allowed to substitute presumably less costly on-farm remediation for investments in modifying or upgrading their own systems.[161] Are there other reasons why distributors should be responsible for testing to identify specific on-farm sources of stray voltage, bearing in mind that distributors will incur the cost of investigations?

[161] BDR 2008; p. 53.

Options

a) Distributors are responsible only for investigating whether stray voltage exists and if so, the distribution system contribution thereto. However, distributors may conduct testing to identify on-farm sources at the request and expense of the farm customer.

b) Distributors are responsible for identifying sources of farm stray voltage including the distribution system and on-farm sources.

9.4 Training & Certification

It was mentioned in the introduction to the preceding section that decisions as to the electricity service quality indicator will drive the content of the procedure distributors use to investigate farm stray voltage complaints. This, in turn, will have an impact on the level of expertise that investigators will need to carry out the procedure efficiently and effectively; to ensure that the most cost-effective remediation measures are implemented; and to ensure that these measures have the desired result.

9.4.1 Background Summary

The proper identification, diagnosis and remediation of farm stray voltage problems can require considerable electrical expertise.[162] Investigators must be familiar with how electricity is used on modern farms, how animals interact with electrical equipment and grounded metal objects, and the animal contact locations most likely to be associated with problem levels of current exposure. Consequently, stray voltage investigations must be planned and executed with care, as measurements can vary depending upon how, when and where they are taken and as interpreting the data properly requires skill and experience.

[162] USDA 1991 has a ‘Warning’ notice aimed at dissuading non-experts from conducting investigations.

Farmers and distributors involved in the consultation agreed that distributor personnel are not always equipped with the skills and experience needed to carry out farm stray voltage investigations or determine the most appropriate measures for addressing a given situation. In recent years, a number of factors including a relatively low number of stray voltage complaints from farmers have resulted in a lack of knowledge on the part of utility professionals and farmers alike.[163]

Training may also be related to how prescriptive the investigative procedure is. Training would be more important where the diagnostic techniques are objectives-based and general in their design. Also, to the extent that the diagnostic techniques and steps are prescribed in a manual, specialized training may be less important.

The goal of training is to ensure that personnel doing farm stray voltage investigations have the expertise to take the measurements and analyze the data properly, and to consider and select an appropriate remediation measure or measures. Certification helps to ensure a minimum level of competence, as defined and evaluated by a recognized authority. A training requirement can exist in the absence of certification; and certification can be required in the absence of formal training programs.[164] Options for regulatory requirements for training and certification, therefore, are:

- Minimum training requirements;
- Minimum ‘hands on’ experience requirements;
- Certification by a recognized authority; or
- A combination of the above.

[163] OMAFRA 1998; Hydro One Networks Inc.; *Stray Voltage History at Ontario Hydro / Hydro One*; prepared by Williston Associates Inc.; 2007 (Hydro One 2007a).
[164] Certification could be awarded on the basis of job experience, passing a test, etc.

9.4.2 Approaches in Other Jurisdictions

With the exception of Idaho, training is mentioned most often in the context of providing rural electricians with instruction in diagnosing and dealing with on-farm sources (Québec, Wisconsin, Vermont). Idaho alone specifies the training and experience criteria whereby a person conducting stray voltage investigations on behalf of a utility can be considered "a qualified testing professional".[165] Moreover, with certain exceptions, the only professionals that Idaho recognizes as eligible to carry out testing (for IPUC-related purposes) are professional engineers, master electricians and technicians – each of which has its own certification requirements.

9.4.3 Issues

Issue 6: Should stray voltage investigators be specially trained?

Depending on the target indicator chosen (primary NEV vs. contribution to ACV), and whether on-farm sources are to be included, the investigation procedure can involve relatively complicated testing requiring considerable skill and some degree of familiarity with farm wiring and operating environments. Where accurate diagnoses and cost-effective distribution system remediation are potentially called for, personnel must be familiar with system characteristics and operations as well as with alternative remediation methods and their relative effectiveness in specific situations. Any difference in terms of training between an approach based on primary NEV versus one based on distributor contributions to ACV is, therefore, one of degree.

Training programs open to industry professionals (e.g. engineers, rural electricians, etc.) have been and are periodically offered elsewhere, but none are currently available in the province. Hydro One recently set up a facility capable of simulating stray voltage situations that will be used to train their staff to carry out stray voltage testing and remediation.

[165] See IPUC 2005; Rule 31.

The main drawback of a mandatory training requirement would be cost, especially if training can only be obtained outside Ontario. The primary benefit of mandatory training is the increased likelihood that tests and diagnoses will be accurate, and that remediation will be appropriate and cost effective.

The main drawback of not having a training requirement, which in effect means that distributors will exercise discretion over training, is the potential for inconsistency in the application of test procedures, in the selection of remediation measures and in the results ultimately achieved. This could result in a higher number of disputes between farm customers and distributors than may occur otherwise. The primary benefit of a discretionary approach is the potential for training costs to be comparatively lower, although any savings could be offset by increased costs associated with dispute resolution.

Options

In both options below, it is assumed that farm stray voltage investigators will be qualified professionals (e.g. electrical engineers, electricians, technicians).

a) Specialized training is recommended but not required; distributors may provide training opportunities for their personnel and recover prudently incurred costs through rates.
b) Specialized training is required and costs to satisfy the training requirement can be recovered through rates.

Issue 7: Should minimum training standards be specified?

“Training” can involve attending formal courses or field simulation exercises, or it could consist of accompanying an experienced professional on actual investigations, or both (like apprenticeship programs). Idaho is the only jurisdiction that has defined the qualifications for personnel carrying out stray voltage investigations for distributors, setting out specific numbers of training hours and investigations witnessed to be considered qualified.[166]

The benefit of stipulating minimum training standards is that it helps, just as a general training requirement does, to ensure that testing and remediation are carried out competently and cost effectively. Doing so also helps to make sure that all farm customers receive the same level of care. However, such standards do not guarantee that all individuals obtaining the required level of training will be equally competent in executing testing and remediation.

The benefit of allowing distributors discretion over training standards is the potential for cost savings especially where distributors have in-house personnel with considerable experience – but perhaps no formalized training – investigating and rectifying stray voltage situations.

Options

a) Recommend minimum training standards.

b) Establish minimum training standards.

Issue 8: Should investigators be certified?

While none of the jurisdictions surveyed require stray voltage investigators to be certified, an argument could be made that a person whose qualifications are recognized by an authoritative body like an educational institution, industry or professional association, or government agency provides a greater level of 'quality control' than minimum training standards or a general training requirement. Mandatory certification would also be consistent with – but not

[166] Idaho's 'Rules' also stipulate that the training must be approved by the regulator but do not state what criteria are used to make this determination.

necessary for - prescribing minimum training standards (Issue 7 Option b).

The main drawback of requiring certification is that it presupposes the existence of a party (or parties) recognized as an authority on stray voltage investigations and remediation. Therefore, the options posed below would only be relevant in the event that certification is available from a recognized authority.

Options

a) Recommend that stray voltage investigators be certified.

b) Require certification.

9.5 Customer Response Procedure

Regulatory choices concerning investigation procedures and personnel qualifications are affected by the remediation target indicator and threshold value that will trigger distributor action. Other features of the overall approach may not be influenced to the same extent, if at all. As noted below, the basic components of a customer response procedure do not vary by type of complaint. However, the details of the customer response procedure - if one is indeed required to deal specifically with customers' farm stray voltage concerns - may differ somewhat depending on the distributor remediation target indicator and threshold value.

9.5.1 Background Summary

Ontario distributors are required under their licences and the DSC to have and to document their customer complaint and dispute resolution processes and make this documentation available to customers. Typically, Conditions of Service documents describe in general terms how customer complaints and requests are received and handled internally, and the process whereby disputes are handled (see section 9.8.3). While distributors are required to record and report to the Board certain information about customer service complaints and service quality indicators, the Board has not established specific procedures, timelines or deliverables for handling most customer complaints.

Information received in the course of this consultation suggests that not all farm stray voltage-related requests are addressed using the same procedure, even by a given utility. Hydro One has indicated to Board staff that a standard customer response procedure has been drafted but has yet to be fully implemented internally. It is Board staff's understanding that in the past, interactions between farm customers and distributors have depended more on the skills and inclinations of the utility representative dealing with the customer than on defined procedures.

9.5.2 Approaches in Other Jurisdictions

Elsewhere, regulators have decided that certain elements of the response process need to be formalized. Some jurisdictions merely require that distributors develop a procedure and file it with the appropriate authority (e.g. PSCW in Wisconsin; Dept. of Agriculture in Vermont). Idaho is more prescriptive, first requiring that farmers submit written requests for stray voltage investigations to their utility, upon receipt of which distributors must respond with investigations and remediation within specific time frames.

Board staff notes that in Québec, farmers are encouraged to contact the provincial Ministry of Agriculture in advance of complaining to their distributor so that the Ministry can coordinate the overall response, and serve in the role of advocate on behalf of farmers not satisfied with the outcome of their distributor's efforts.[167]

9.5.3 Issues

<u>Issue 9: Should a special farm stray voltage customer response procedure be used?</u>

[167] BDR 2008; pp. 29 – 31.

The procedures Ontario distributors use to respond to customer complaints are determined by the individual distributors themselves and therefore may vary in certain respects. Some distributors will have different procedures for different types of complaints while other distributors may use the same approach for all types of complaints. Either approach could be capable of producing satisfactory outcomes for farm customers with stray voltage concerns, in which case a specific customer response procedure for farm stray voltage concerns may not be necessary.

Based on the approaches used in jurisdictions where distributors are regulated as to their responses to farm customer stray voltage concerns, farm stray voltage customer response procedures:

- Set out how customers should go about requesting a distributor's attention to a problem (e.g. in writing, by phone, etc.);
- Indicate target timelines for key activities (i.e. acknowledging the request, arranging for an information meeting, dispatching personnel to the farm, communicating results to the farmer and initiating remediation); and
- Describe how customers will be informed of the results of any investigation and the types of information that will be provided.

Drawbacks to establishing a procedure include delays created where customers and distributor personnel must adhere to the formal requirements, including the preparation of paperwork, obtaining sign-offs for deliverables, etc. Benefits include the documentation produced in the process that could be used by either party for future reference.

Of the main components of a customer response procedure mentioned above, only the target timelines might be directly affected by the choice of distributor remediation action target. However, timelines would also be affected by choices as to whether a prescribed procedure is to be used; whether on-farm sources are to be included in the investigation;

and by any restrictions on the range of remediation options available to distributors (see section 9.7 below).

<u>Options</u>

Assuming it is decided that a special customer response procedure is preferred, the following two options could be considered:

a) Require that distributors have a customer response procedure specifically for dealing with farm stray voltage requests.

b) Prescribe a customer response procedure that must be used by distributors when dealing with farm stray voltage requests.

9.6 Regulatory Reporting Requirements

As was the case with the customer response procedure, regulatory reporting requirements are not necessarily affected by the choice of distributor remediation action indicator. However, the volume of data managed and the complexity of data analysis required for regulatory purposes is much more likely to vary with the complexity and scope of the investigation procedure used. It is possible therefore, that one approach could be associated with somewhat greater data management requirements compared to another. However, it is unclear whether this difference would be significant enough to drive decision-making in relation to distributor reporting requirements.

9.6.1 Background Summary

The Board currently requires that distributors file various types of information on a periodic basis for a number of purposes including rate-making and service quality performance assessment. The Board requires that distributors maintain records of written complaints and remedial actions taken in response to these, but does not require distributors to keep statistics or databases on the number of customer requests by type, such as farm stray voltage requests. Consequently, information of a statistical nature on the incidence of farm stray voltage investigations and the results thereof were not available for the purposes of this consultation.

9.6.2 Approaches in Other Jurisdictions

Where performance standards have been adopted, regulators generally do not require distributors to make formal submissions of farm stray voltage related data. The exception is Wisconsin, where distributors have for almost twenty years been providing the regulator with details on the results of stray voltage investigations. Filings are submitted on a semi-annual basis and each utility is required to keep a database of all stray voltage related contacts and investigations.

9.6.3 Issues

Issue 10: What should distributors be required to do regarding farm stray voltage record-keeping and information reporting?

Information on the number and nature of requests from farmers regarding stray voltage, as well as on the results of investigations and remediation efforts can be useful to distributors for overall maintenance and upgrade planning purposes, and for gaining the maximum benefit of ‘lessons learned’ in terms of various remediation approaches. Such data also provides a basis for the Board to determine whether distributors are in compliance and for evaluating how well the regulatory approach is succeeding at addressing the issue.

Record keeping for analytical purposes involves certain expenses; the analysis of data, even for basic purposes, also involves costs. ‘Start up’ costs associated with record keeping can also be expected. The drawback to regulatory requirements regarding record keeping is the cost associated with record keeping and data analysis. Due to differences in size and number of farm customers, these costs may not affect all distributors in the same way.

Options

a) Specify the types of information distributors must keep on file regarding farm customer stray voltage requests, investigations, remediation efforts and outcomes so that the Board can obtain them by request.

b) Stipulate the information and analyses (e.g. summaries, analyses or copies of the detailed records) to be maintained by distributors and submitted to the Board in annual filings.

9.7 Distributor Remediation Options

Choices as to the distributor remediation target indicator and (but to a lesser extent) threshold value can have a bearing on the remediation options available to address a given case. For example, if primary NEV measured on the distributor's facilities at the farm is the trigger, then it can be expected that the primary remediation options would be those that address primary NEV measured at that point. If the distributor's contribution to ACC / ACV is the target indicator, these options, plus devices that restrict the passage of current from the primary neutral to the secondary system (but have no mitigating effect on primary NEV *per se*) would be eligible.

9.7.1 Background Summary

In the early years of Ontario's experience with farm stray voltage, a basic but effective form of primary/secondary neutral isolation was used as a temporary remedy where stray voltage was caused by the distribution system. The introduction of 'tingle voltage filters' represented a more permanent solution in that these devices block low levels of neutral current from being transmitted between the distribution system and animal contact areas.

Distributors now have a wide variety of options in the form of techniques and devices with which to achieve compliance with applicable standards. Some involve relatively costly and extensive modifications to the distribution circuit or portions thereof, while others consist of installing a solid state primary/secondary neutral isolation device, adding groundings or balancing the loads on 3-phase lines.[168] Generally, distributors require their personnel to determine the most economical approach that will achieve the desired result or benchmark where applicable.[169]

System upgrades such as increasing circuit voltages or replacing single phase with three phase lines tend to reduce primary NEV, and hence the potential for distributors to contribute to stray voltage appearing anywhere on a distribution circuit. In practice, investment in such upgrades is considered by distributors in the normal course of asset management planning, or when a connection impact assessment indicates that system upgrades would be required in order to connect a new load or distribution connected generation customer.

Cases of farm stray voltage, on the other hand, are typically located randomly on a distribution line: one farm customer may be affected, while neighbouring farms on the same circuit are not. In the absence of sufficient cases to warrant consideration of circuit-oriented solutions, remediation measures targeting local and even specific farm conditions may be the most cost effective.

9.7.2 Approaches in Other Jurisdictions

Due to the variability of conditions and hence the most cost effective remediation method in a particular case, all jurisdictions allow distributors to exercise discretion (within applicable safety and other regulations) when deciding what to do about a given stray voltage situation. The one exception to this general rule relates to the use of primary/secondary neutral isolation devices.

While this method of remediation can have implications for on-farm and distribution system safety and for primary NEV elsewhere on a

[168] See section 7.
[169] Hydro One personnel, for example, are to meet the utility's primary NEV standard by considering, in order of increasing cost: repairing defective splices etc; load balancing; adding ground rods. Hydro One 2007b; p. 15.

circuit, it is used in many jurisdictions. Wisconsin, however, has imposed certain restrictions on the use of isolation devices, but distributors are permitted to undertake remediation measures on the customer's electrical system or property, subject to the farmer approval.[170]

9.7.3 Issues

Issue 11: Should distributor discretion over the choice of remediation method be subject to restrictions?

Isolation Devices - Allowing the use of isolation devices could raise safety concerns, but distributors are responsible for ensuring that applicable safety standards are met, including those applicable where the installation of an isolation device on the distributor's system could have on-farm safety implications. Tests can determine whether installing an isolation device on the distributor's system is likely to result in higher primary NEV elsewhere in the vicinity of the farm and system modifications can be made to manage this effect.

The drawback to limiting the use of isolation devices to restrict the impact of the distribution system on stray voltage is the effect this has on costs. Situations could arise where an isolation device is the least costly method of remediation, even where additional measures must be taken to deal with safety and primary NEV levels elsewhere on the circuit. The result would be the imposition of a less cost effective solution, which presumably would have a relatively greater effect on customer rates.

A final consideration is that, strictly speaking, isolation devices downstream of the primary neutral grounding point at the farm do not reduce primary NEV on the distributor's system. Rather, they restrict

[170] Installation and maintenance costs for on-farm measures may be recoverable through rates. Assets are transferred to the farmer and so are not recognized as utility assets for rate-setting purposes.

the flow of current between the primary and secondary neutral conductors.

On-farm Remediation – In Ontario in the 1980s and 1990s, the main solution to stray voltage caused by the distribution system was the ‘tingle voltage (or Hammond) filter’. These were installed at the service panel in buildings where stray voltage was either found, or due to animal contact situations, could arise.

In Wisconsin, distributors are allowed to use on-farm remediation techniques in order to meet their own performance requirements. Some conditions apply and any assets installed on the farm become the farmer’s property. The extent to which this option was deemed necessary in light of restrictions on the use of neutral isolation is not clear. Nonetheless, even where no such restrictions exist, the ‘Hammond filter’ precedent suggests that on-farm remediation might be a less costly and/or more permanent solution to a given stray voltage situation than some types of system modification, such as adding ground rods.

Options

a) Require that distributors determine the safest, most cost effective remedy (or remedies) to a given stray voltage case, specifying where applicable which costs are eligible for recovery in rates.

b) Stipulate any restrictions on the use of certain remedies and the conditions under which they may be employed, specifying where applicable which costs are eligible for recovery in rates.

9.8 Meeting Farm Customers’ Information Needs

Choices regarding each of the above-mentioned candidate elements of an approach to addressing farm stray voltage will affect the types of information that could be made available to livestock farmers by distributors. However, the detailed content of the regulatory framework is not in and of itself a determining factor in relation to the question as to whether distributors should provide farm stray voltage related information to farmers.

9.8.1 Background Summary

At present, information on farm stray voltage can be found on the web sites of some but not all distributors with livestock farm customers. The Hydro One website, for example, has a Stray Voltage web page. The OMAFRA website is also notable for the detailed dairy-farm specific documents on the subject posted there. The OFA also provides information and commentaries on stray voltage to their members and the general public through various media.

While all of these sources are helpful, there is no ‘single window’ access to the variety of information that a farmer might need to assure a stray voltage concern is resolved in a timely and cost effective manner. In general, the efficiency with which a stray voltage concern can be dealt with may depend on how well farmers are informed as to:[171]

- What farm stray voltage is and how it might affect their livestock;
- What other factors that can have a similar affect on farm operations need to be investigated as possible causes;
- What conditions on the farm, including the customer’s electrical system, can contribute to the stray voltage problems, and the remediation options available to address these;
- Sources of experienced help and expert advice; and
- The process whereby stray voltage concerns are dealt with by their distributor, including how disputes are to be addressed.

9.8.2 Approaches in Other Jurisdictions

Distributors in Connecticut are required to provide stray voltage information to their farm customers on a regular basis. Other

[171] BDR 2008; p. 69.

jurisdictions either do not specify such requirements, or use a multi-party approach, thereby maintaining a high level of awareness among farmers, farm service providers and other stakeholders as to the nature and resolution of stray voltage concerns.[172]

9.8.3 Issues

Issue 12: What are distributors' responsibilities to farm customers in terms of providing information?

Farm Stray Voltage Information - Farm stray voltage can result from the normal operation of distribution systems. If farmers are unaware of the phenomenon, however, time and money could be lost ruling out other causes of observed symptoms.

This is not to suggest that stray voltage should be investigated first in every case. To the extent that certain combinations of symptoms and conditions are more likely to point to stray voltage as a probable cause, it would be useful if farmers and farm-related service providers were armed with basic information so that they would know when a call to their distributor is prudent. By minimizing requests for investigations where they are not needed, this approach could also avoid unnecessary distributor expense.

In short, Board staff suggests that both distributors and their customers would be well served if distributors provided livestock farm customers with basic information on stray voltage, including references to authoritative sources of more detailed information.

Customer Response & Dispute Resolution Process Information – As noted above, distributors are required to have customer complaint and dispute resolution processes. Ontario farmers have observed in this regard that neither process is generally well-known in the farming community.

[172] BDR 2008; p. 70.

It could be argued that the more customer-service related information is *actively* provided to relevant parties, the lower the long run costs of providing customer service. Farm customers are more likely to contact their distributor in the event of a suspected stray voltage situation if they understand a process is in place to address it. However, they will also be better equipped to cooperate with the distributor in the efficient resolution of the problem if it exists, thereby improving the overall efficiency of the process. Information on processes and procedures can also benefit farm customers in that timely access to customer response processes will help avoid losses related to impaired farm operations, and knowledge of dispute resolution procedures can help lower the costs of achieving a satisfactory outcome.

<u>Options</u>

a) Require distributors with livestock farm customers to provide access to information on farm stray voltage and customer response and dispute resolution procedures.

b) Specify the content and form and frequency of transmittal of information on farm stray voltage and related customer response and dispute resolution procedures to be made available by distributors to livestock farm customers where applicable.

9.9 Combining Measures & Options - An Illustration

To show how the various regulatory elements noted in Figure 9-1 and discussed above might fit together, Figure 9-2 depicts two possible approaches - along with accompanying elements - that could be combined into a regulatory framework to address farm stray voltage. While the farm stray voltage ACC / ACV maximum and the distributor remediation target indicator and threshold are ‘prescriptive’, as explained in section 9.1 the remaining elements can consist of features that are expressed as objectives or prescribed requirements. To demonstrate the variability possible, Figure 9-2 shows that prescriptive and objective features can be combined regardless of the distributor remediation target indicator and threshold value used.

A variety of other measures and accompanying features are possible. The purpose of this illustration is to stimulate discussion and written comment, to show the relationships among the different elements of an overall regulatory approach, and finally to demonstrate the potential for combining elements of the regulatory framework into different combinations and variations.

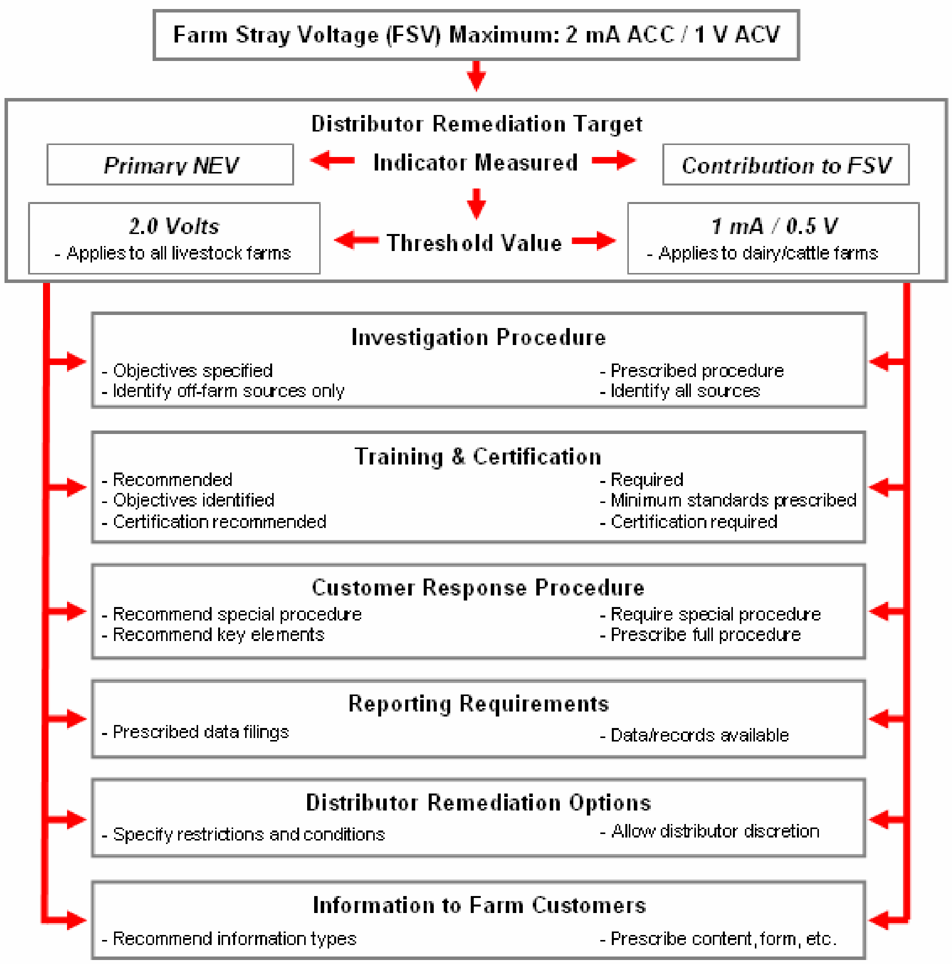

Figure 9-2: Farm Stray Voltage Regulatory Framework - Examples

Glossary

GLOSSARY

Ampere (A)	A measure of electrical current in a circuit
Animal contact current (voltage)	Electrical current measured in milliamperes (or voltage measured in volts) between two points that an animal could touch at the same time. The level is typically measured in amperes (or equivalent volts) using a shunt resistor of a specified resistance value to simulate the combined resistance of the animal's body and contact points.
The Board	Ontario Energy Board
The Directive	The Minister's Directive to the Board received June 22, 2007
Earth current	Electrical current flowing in the earth
Farm Stray Voltage	*Stray voltage* between two points that can be contacted simultaneously by a farm animal
Ground current	Electric current flowing on ground wires and ground rods
Milliampere (mA)	1/1000th of an ampere
Neutral Current	Electric current flowing on a neutral (return) conductor
Neutral to earth voltage	The level of voltage (measured in volts) between a neutral conductor ground wire and remote grounding point
Stray Current	An electric current flowing through an animal in simultaneous contact with two surfaces, each of which has a different voltage potential
Stray Voltage	A low (generally agreed to be 10 V or less) voltage potential between two points that can be contacted simultaneously
Tingle Voltage	*Stray Voltage*
Volt (V)	The unit of electromotive force representing the difference of potential that would carry one ampere of current against a resistance of one ohm.

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APPENDIX A - Order in Council & Minister's Directive

Ontario
Executive Council
Conseil des ministres

Order in Council
Décret

On the recommendation of the undersigned, the Lieutenant Governor, by and with the advice and concurrence of the Executive Council, orders that:

Sur la recommandation du soussigné, le lieutenant-gouverneur, sur l'avis et avec le con- sentement du Conseil des ministres, décrète ce qui suit:

WHEREAS it is desirable to improve the quality of electricity service in order to address certain issues related to stray voltage which are currently being experienced by the agricultural sector and, in particular, by farm customers.

AND WHEREAS the Minister may, with the approval of the Lieutenant Governor in Council, issue directives under section 27 of the *Ontario Energy Board Act, 1998* (the "Act") in order to direct the Ontario Energy Board (the "Board") concerning general policy and the objectives to be pursued by the Board.

AND WHEREAS, in recognition of the fact that one of the primary objectives of the Board, as contained in paragraph 1(1) 1 of the Act, is to protect the interests of consumers with respect to quality of electricity service, it is desirable that the Board develop its own processes, procedures and regulatory instruments to implement measures in order to address the issue of stray voltage as it is currently being experienced by farm customers.

NOW THEREFORE the Directive attached hereto, is approved.

Recommended: ______________
Minister of Energy

Concurred: ______________
Chair of Cabinet

Approved and Ordered: MAY 16 2007
Date

____
Administrator of the Government

O.C./Décret 1081/2007

MINISTER'S DIRECTIVE

TO: THE ONTARIO ENERGY BOARD

I, Dwight Duncan, Minister of Energy, hereby direct the Ontario Energy Board (the "Board") under section 27 of the *Ontario Energy Board Act, 1998* (the "Act") as follows:

1. The Board shall implement such measures which, in its own discretion, having regard to the objective related to quality of electricity service provided for under paragraph 1(1) 1 of the Act, are necessary to ensure electricity service to farm customers, in relation to "tingle" or "stray" voltage, is of a quality that does not unduly impact the operation of the farm.

	MAY 1 6 2007
Minister of Energy	Date