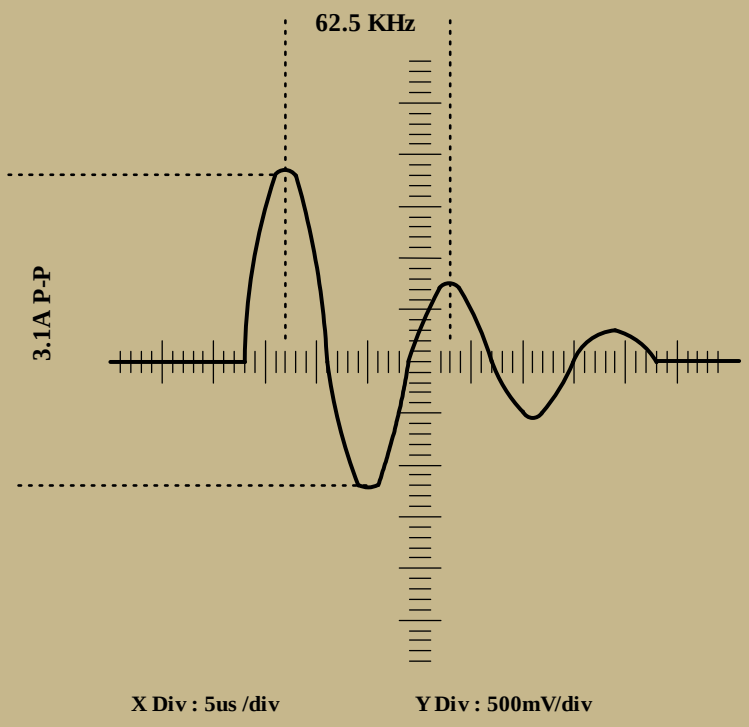
# Measurement Protocols




## The Analysis of Livestock Farms Electrical Networks

Agrivolt

A Nuvolt Corporation Inc. company

## About us

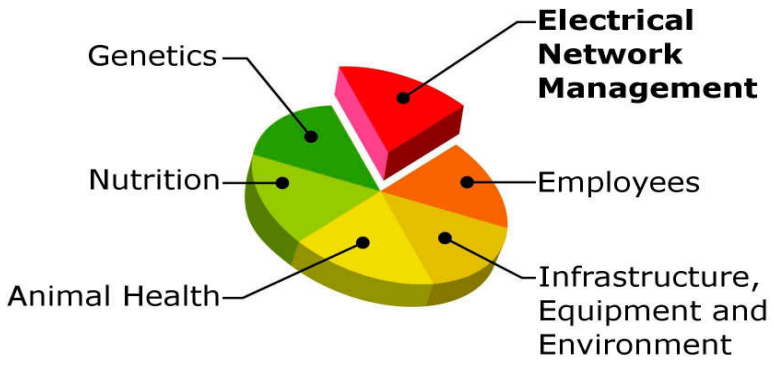
AGRIVOLT is an uncontested world leader, in the analysis of livestock farms electrical networks. The Company distributes specialized equipment for the neutralization of electric currents in the animal environment as well as Monitoring Systems for equipment and electrical network.

AGRIVOLT Inc. is a subsidiary company of Nuvolt Corporation Inc. which holds numerous international patents for various electrical equipment components and which is recognized for its research and development activities, particularly on the impact of electricity on herd performance and the prevention of defects on electrical networks.

## Agrivolt Measurement Protocols

As a result of its involvement with dairy, hog and poultry livestock farms, AGRIVOLT has developed methods of measurements, well adapted to the particularities of a farm environment, to evaluate the presence and quantity of current affecting herd performance. Agrivolt believes that the electrical network of a livestock farm must be managed since it affects herd performance and operation cost of the livestock entity.

**Management parameters of a livestock farm**



The very broad variety of electrical networks on livestock farms in North America, the growing number of electric distributions, the complexity and multiplication of livestock production equipment in a context where automation is a need, have led Agrivolt to establish a process of execution of measurements well suited to the configuration of the electrical networks of today's livestock facilities, in order to ensure to the evaluation a very high degree of accuracy. Agrivolt has standardized this measurement protocol into a computerized format.

AGRIVOLT's approach to create this measurement protocol is to establish the quantity of current which circulates on the grounding and bonding networks of a livestock facility during a 24 hours minimum period. Thereafter, AGRIVOLT identifies the sources and transmission modes to the animal and quantifies them.

**AGRIV0LT considers a power source only if it can be distinguished among several sources, if we can determine its transmission mode to the animal and finally if we can quantify it. Moreover, AGRIVOLT considers that no matter the power source, be it external (off farm) or internal (on farm), or no matter its frequency range, the impact on the animal would be the same.**

The Agrivolt measurement protocol excludes the use of a reference rod since our protocol is carried out in current. With a reference rod, measurements are in voltage. As it is the leakage current which generates a sudden increase in voltage, one can identify neither the source nor its transmission mode to the animal with a measurement in voltage. In the case of the distribution network of an Electric Utility without primary neutral, measurement with a reference rod is ineffective.

# Agrivolt's approach in 9 points

Agrivolt has developed a computerized measurement approach both unique and precise, utilizing the following steps:

1. A draft showing the locations of all the building of the livestock facility is made.

2. A draft of the electric diagram of neutrals and bonding networks of all the building of in the livestock facility is also made.

3. After reviewing the above, selection of the measurement protocol is made.

4. Implementation of the measurement protocol.

5. Transfer of data to the technical support team.

6. Technical validation of measurements by the technical support team.

7. Data analysis and strategic decisions of the file are made.

8. Preparation of the analysis and recommendation report.

9. Presentation of the analysis and recommendation report.

# Potential Sources of Current

Potential sources of leakage current are the basis of the AGRIVOLT measurement protocol. We first characterize the sources relative to livestock facilities as **External Sources** or **Internal Sources**. Moreover, the origin of these sources varies according to the type of electrical network. The electrical network of an Electric Utility with primary neutral, found in the majority of livestock facilities in USA and Canada, has different sources compare to an Electric Utility network without primary neutral as can be found, for instance, in California.

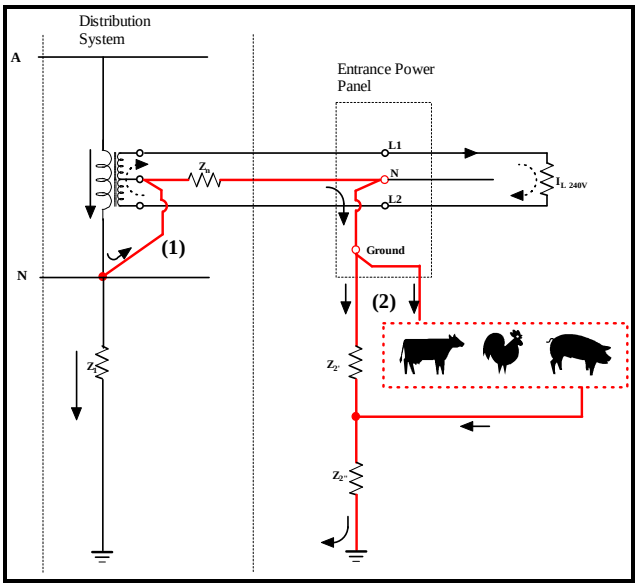
## 1- External Sources. Electrical network with primary neutral

*External Sources* are power sources whose origins come from outside the livestock facilities. The analysis of transmission mode of the leakage currents of external sources leads to a reclassification in three categories.

### A) Load return from 208 V to 600V

These are load returns originating from livestock buildings which circulate on the grounding and bonding networks of the livestock farm complex. When one power a load from a distribution transformer, part of the primary current return uses the neutral-ground bond (1) located at the center tap of the distribution transformer, to access the grounding and bonding network (2). The graph below illustrates the return pattern of that current.

Simplified diagram of an electrical network

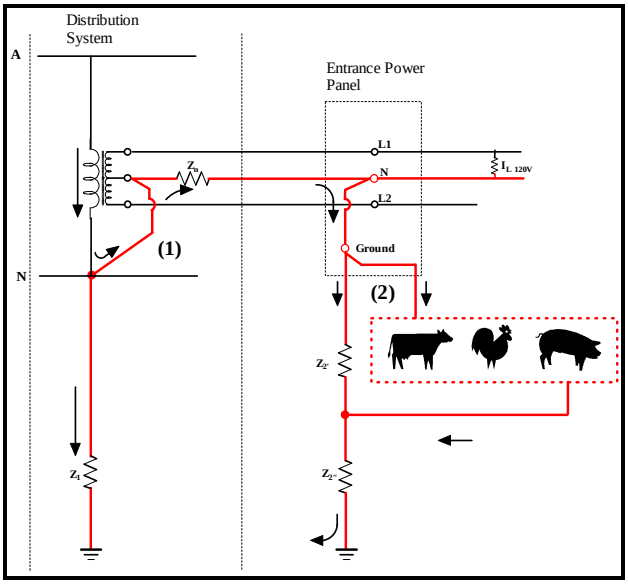



Current return from 208 to 600V Load

**B) The load return from 120V to 347V**

These are load returns originating from livestock buildings which circulate on the grounding and bonding networks of the livestock farm complex. These loads can be regarded both as external sources and as internal sources. Here, we consider them as an external source since the return of the primary current of this load uses the neutral-ground bond (1) located at the center tap of the distribution transformer to access, in portion, to the grounding and bonding network (2) of the livestock facilities. The graph below illustrates the return pattern of that current.

Simplified diagram of an electrical network




Current return from 120 to 347V Load



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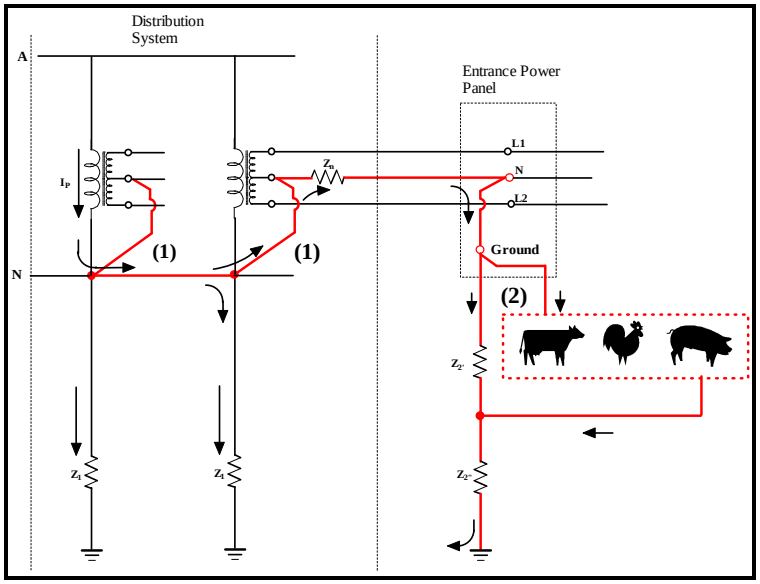
### C) Neighbouring load returns

These are returns generated by neighbouring loads of the farm which partly use the neutral-ground bond (1) located at the center tap of the distribution transformer to access the grounding and bonding network (2) of the livestock building. In the majority of cases, these returns come from the same Primary electrical network. The graph which follows illustrates the return of these neighbouring currents.

Simplified diagram of an electrical network

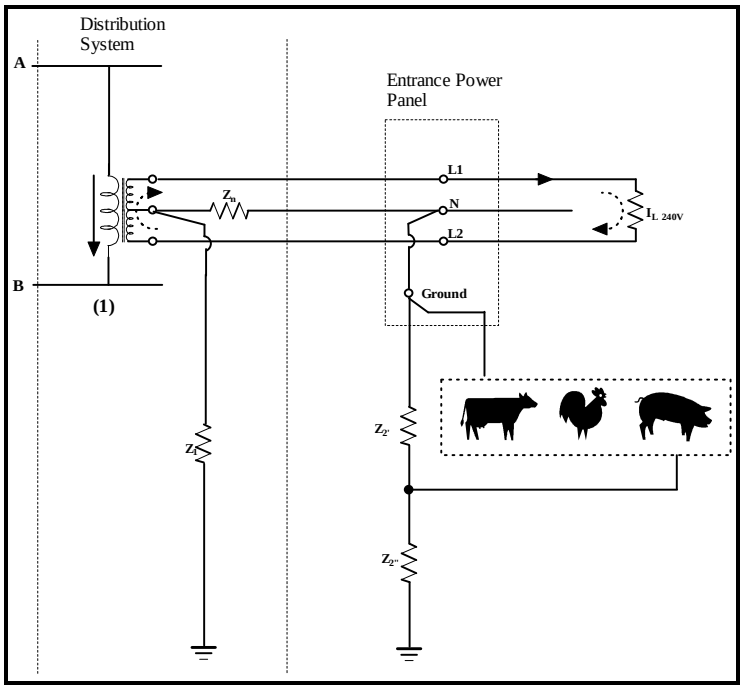



Return caused by neighbouring load

## 2- External sources: Electrical network without primary neutral

In a distribution network of this type, there are no External Sources. The distribution transformer does not have a neutral-ground bond on the Power Utility side (1). The graph which follows illustrates such a case:

Simplified diagram of an electrical network




No Load return

A network without primary neutral cannot generate any return current from external sources, because all the primary currents circulate in conductors which are isolated from the earth. In other words, there is no ground path.

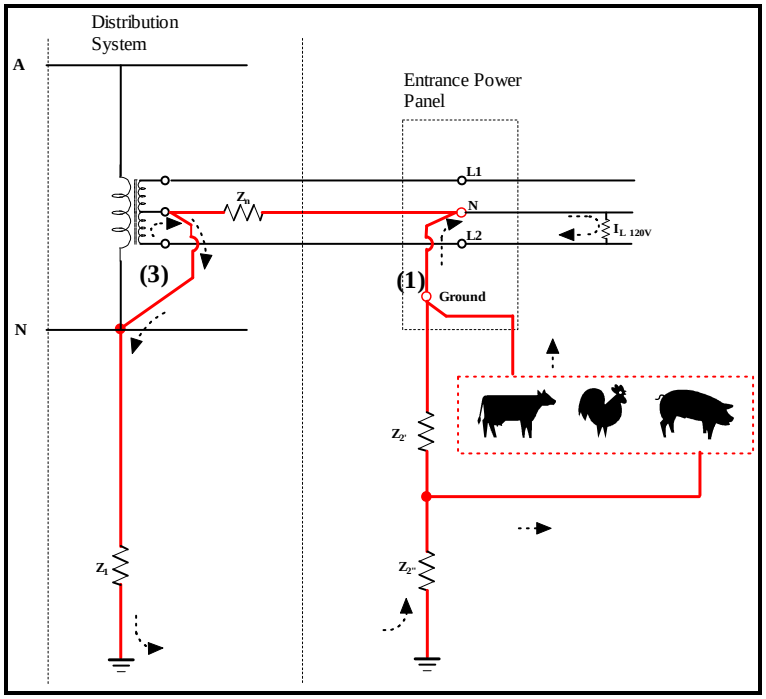
## 3- Internal sources

The internal sources of leakage current are as important as the external sources. They are multiple and variable in time.

### A) Load returns from 120V to 347V

We saw previously that part of the current from a 120 to 347V load which comes back to the grounding and bonding network can come from *external sources* through the neutral-ground (3) bond at the distribution transformer. We must mention that part of the return of an internal load from 120V to 347V can circulate on the grounding and bonding network. It is important to note that part of these loads is cancelled or added according to the polarity of the current; it is the residual portion which we can measure on the grounding and bonding network. The following graph illustrates a load return from a 120 to 347V network. The neutral-ground bond (1) at the main distribution is in direct relation with the grounding and bonding network (2) of the livestock building.

Simplified diagram of an electrical network



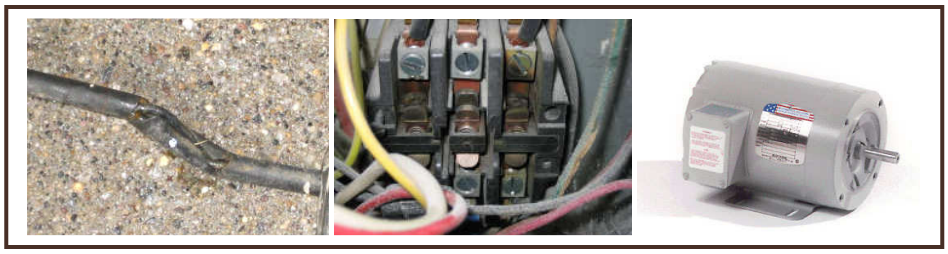

Current return from 120 to 347V Load

### B) Leakage currents at medium frequency

The leakage currents at medium frequency are electric currents whose frequency varies from 100 Hz to more than 100 KHz, which circulate on the grounding and bonding network of the livestock facilities. They are produced by medium frequency noise generating equipment such as variable speed drives, variable speed electronic fans, electronic ballast lighting, electric fences, dimmers, etc.

### C) Leakage currents generated by faulty equipment.

These are leakage currents from defective equipment: wiring, motors and starters and/or improper installation. The frequency of the leakage currents will vary from 60 Hz to more than 100 KHz, part of which circulates on the grounding and bonding network in the livestock facilities.

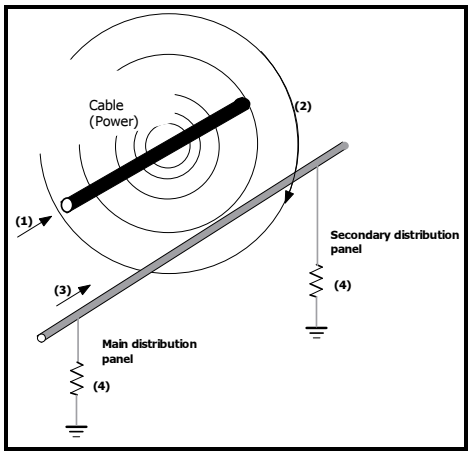


Equipment likely to generate leakage currents

### D) Current loops

A current loop occurs when the variation of an electric load of a conductor (1), induces a voltage (2) on a bonding conductor (3) because it is too close. A loop is then formed, because this conductor is bonded to ground (4). A small amount of voltage induced on a loop can generate an important current flow.

Simplified diagram of a current loop



# Measurement Protocol

## 1) Measurements of external sources

### A) Data recording

AGRIVOLT takes a measurement from an ammeter, located on the wires which connect the distribution transformer and the Main disconnect of the livestock building. The reading is carried out in differential mode for a 24 hour minimal period. The ammeter is connected to a data logger which records the data in real time during this period.

This reading in differential mode makes it possible to determine the minimum and maximum quantity of leakage current. This portion of leakage current represents the quantity of current which flow through the grounding and bonding network.

If there is a neutralization device separating the primary and secondary neutral, directly at the distribution transformer (VTNI, Ronk Blocker) we take two measurements, with and without the device.

### B) The ground resistance of the livestock facilities

AGRIVOLT developed an evaluation method of the ground resistance of a livestock building, from validated algorithm. By integrating the resistance of the main neutral conductor, covered distance, outside temperature, and taking into account the impact of motor start-ups on the electrical network. The computerized measurement protocol determines with a high degree of accuracy the equivalent resistance of a livestock building and, if necessary, the resistance of the distribution network of the Electric Utility.

C) **The calculation of the minimum and maximum voltage potential**

To evaluate the minimum and maximum voltage in a livestock building, we use the Ohm's law since two factors are known to us. Indeed, we know the resistance of the livestock building and the quantity of current flowing on the grounding and bonding network.

*Ohm's law: Voltage = Resistance X Current*

*Minimum Voltage = ground Resistance of the Building X Minimum current*

*Maximum Voltage = ground Resistance of the Building X Maximum current*

*Example : (Minimum) 3V = 3 ohms X 1000 mA*

*(Maximum) 4.5V = 3 ohms X 1500 mA*

**D) Impact of motor start-ups**

AGRIVOLT also takes in consideration the impact of motor start-ups, i.e. the sudden increase in the quantity of current on the grounding and bonding network during motor start-ups. In its evaluation of the voltage levels, this consideration is very important since we note several hundreds motor start-ups daily in a livestock complex. The relative importance of these motor start-ups is a function of several elements of the electrical network. As an example, the configuration of the electrical network, the primary and secondary level of voltage and the HP value of the motor, are important components which influence the raise of leakage current generated by motor start-ups. The impact of motor start-ups is measured by the ammeter connected to the data logger over a 24 hour period. To quantify the impact of motor start-ups, we again use the Ohm's law.

Example 1.5V = 3 ohms X 500 mA (increase current measured at motor start-up)

In this case the impact of the motor start-up is a sudden increase of 1.5V on the grounding network which is added to the maximum voltage that we calculated in point C). Thus the overall peak voltage with motor start up is: 4.5V + 1.5V = 6.0V.

## 2) Measurement of internal leaks

**A- Current generated by equipment defects at 60 Hz**

With a dedicated software that we have specially developed, we check the leakage current at each circuit breaker. Whatever exceeds 100 mA is identified as equipment to be fixed. Part of these leakage currents circulate on the grounding and bonding network of the livestock building.

**B - Current generated by equipment defects at medium frequency**

Using an ammeter connected to an oscilloscope, we measure, identify and determine the transmission mode of the source then characterizes and quantifies the electronic noise.

**C - Current loops**

The evaluation of the current loops requires first the control of leakage currents of external and internal sources. Thereafter, using a measurement in amperage, Agrivolt uses load start-ups to identify the source of the loop and determines its impact on the grounding and bonding network of the livestock facility.

# The analysis and recommendation report

Having completed the measurements and transferred the data to the technical support team, the analysis of the data begins with various exchanges between the team assigned to measurement and the support team. An analysis and recommendation report is then prepared. The report is divided into various sections:

- An executive summary which details the method of measurements and the results of measurements of external and internal sources.

- Specific and precise recommendations for each identified source.

- Supporting documents for each measured source specifying the scales, the frequencies used and time.

- Scientific data which justify our recommendations as for the sensitivity threshold of the animal and the impact of electricity on their performance.

- A quote for the neutralization of the sources.

To simulate the quantity of current likely to pass through the body of an animal, AGRIVOLT uses the following scientific data:

Perception Threshold to electricity for a pig, chicken or cow = 1 mA
Sensitivity Threshold to electricity for a pig, chicken or cow = 3 mA

Body resistance of a pig to electricity we use = 400 ohms
Body resistance of a chicken to electricity we use = 1000 ohms
Body resistance of a cow to electricity we use = 250 ohms

To determine a safety threshold at 60 Hz, we use Ohm's law.

*Safety threshold = Body resistance X Sensitivity Threshold*

| | |
|---|---|
| *Pig* | *1.2V = 400 ohms X 3 mA* |
| *Chicken* | *3 V = 1000 ohms X 3mA* |
| *Cow* | *0.750V = 250 ohms X 3mA* |

# Presentation of the analysis and recommendation report

AGRIVOLT realizes that the analysis of the electrical network of a livestock farm is complex and the measurements are not always obvious to understand. AGRIVOLT tries to simplify the topic as much as possible. In order to make sure of a good understanding of the protocol of measurement, we do a live presentation to the producer and his team of advisors.

## Cost of the analysis

The cost of the analysis of the electrical network of a Livestock producer is based on the following parameters:

• Evaluation of estimated time based on a summary description of the Livestock producer's electrical network, i.e. type of network, localization of the distribution transformer, localization of the electrical panel, number of panels with circuit breakers, number of circuit breakers, number of facilities, sending of a summary sketch of the electrical network, number and type of medium frequency generators.

• Evaluation of the travel and lodging cost.

• The shipment costs for the measuring equipment.

The cost of evaluation of the work is provided to the Livestock producer in a few minutes. Upon approval, a mandate is sent to the producer for signature.

## Voltage or current

Does one have to control voltage or current? Both have an impact on the animal's behaviour. A leakage current generates two phenomena; first a potential difference (Voltage) and second, a magnetic field. The equipotential grid, in its design, is a prime example of this. This equipment eliminates the differences in voltage but increases the quantity of current circulating in the grid and metal structures. The magnetic fields appear when the current flows; the higher the current, more important is the magnetic field. The literature shows that man and animal are both sensitive to magnetic fields.

To solve the negative impact of leakage currents, it is necessary to neutralize both voltage and current.

## The least resistance path

In North America, the distribution networks are configured so that the neutral current returns to there source by the neutral and/or the earth, to the substation. The current circulates according to the least resistance path. Therefore, it can go down from the neutral towards the earth, as it can go up from the earth towards the neutral.

## Return of current through the earth

A bond with the ground is essential for the safety of the users and the installations. The earth can contain only very little current (mA) per square meter. It is a known fact that these small currents can circulate through your property. To have a detrimental effect to your livestock, these currents must be present in significant quantity. Such a situation could be found when the neutral ground bond is present and becomes a path for the return of these current to the substation. Therefore, in this situation, the current is attracted and goes up towards the neutral through the grounding network of the facility, thus creating a more important circulation of current in the animal environment.

## Equipotential grid

The outcome with the equipotential grid is to maintain the metal structures and the floor of the building at the same potential (Voltage). This objective ensures the safety of the users against the risks of electrocution. An equipotential grid is an excellent ground which becomes the main point of entry or exit of the leakage current. It is normal to measure very high currents when we measure an equipotential grid. Its function is not so much to protect the animal from magnetic fields, but to limit the possibility that the animal perceives a shock between two points due to a difference of potential (voltage). In other words, the equipotential grid solves an important problem related to safety but creates another one which impacts directly the performance of the herd.

## Measurements at contact points

With an equipotential grid, measurement at contact points is confirming tiny differences in voltage between the metal structures and the floor. This voltage is always very weak in spite of the fact that several amps (current) circulate through the equipotential grid and the metal structures. The Ohm's law applies, on this basis, there is little amperage likely to pass through the body of the animal due to voltage potentials. In our experience, the true problem has more to do with the presence of an important magnetic field in the livestock's environment.

In our opinion, measurement at the contact points does not accurately represent all that can likely affect the animal.

## Location of the farm

The quantity of leakage current of external sources depends among other things, on the location of the farm in relation to the substation. When the 3 following situations are compared, one can better understand the significant difference in quantity of current which circulates on the grounding and bonding network of a livestock facility. First, if located at the end of the network, the load return seeks to use the earth as a return (the least resistance path), thus adding more leakage current in the grounding network of the farm facility. Second, a localisation in the middle of the network is the place best adapted to limit the quantity of current in the grounding network of the farm facility because the neutral offers a more favourable path for the current to return. Third, with a localisation at the beginning of the network, near the substation, the

leakage currents in the earth (return) tend to go back up on the grounding network of the facility to access the neutral network. This situation such as the end of the line increases the quantity of current in the environment of the livestock.

## Impact of grounding on leakage currents

All the electrical networks must be in conformity with the electric codes and applicable standards. Safety and reliability represent the basic criteria governing all facilities.

To think that one must reduce the number of grounds in order to control the leakage currents is false. Certain people will go so far they will jeopardize the safety and the reliability of their network for finally reducing very little amount of leakage current. However an increase in the number of grounds decreases the total resistance of the farm and has very little effect on the level of voltage, which therefore increases the quantity of leakage current.

## Copper belt around a building

The use of copper conductor not connected to the electrical network and buried around a livestock facility makes it possible to attract currents circulating in the earth (the least resistance path rule). The currents enter by an end of the belt and leave by the other end. The advantages for the protection of a herd are almost non-existent.

When the belt is connected to the building by the grounding network, it facilitates the return by the neutral, thus increasing the quantity of current which circulates on the grounding and bonding network and so it has a direct impact on the herd.

A measurement in voltage in such a context is generally very weak and is related to an error in the localisation of the reference rod. A copper belt has an important zone of influence, covering several feet (meters). To take a valid measurement, the reference rod must be several hundred feet (meters) away from this zone of influence.

## DC Voltage

The circulation of DC (galvanic) current in the network of an agricultural installation is common. The amplitude, however, varies in time according to the type of connection.

Galvanic currents are generated by the potential difference (voltage) between two grounds of an electrical network. These currents are generally stable or, at least, fluctuate very slowly in time. The amplitude can however differ from one farm to another. These currents can be attributed, among other things, to the galvanic effect of the soil where is established the earth electrode (chemical effect), to the telluric effect; under the influence of solar wind, the variation of terrestrial magnetic field produces differences of potential between distinct and far removed groundings. The circulation of D.C. current exceeding 40 mA on an livestock facility network is not common. The continuous DC voltage generally varies between 50 mV and 1000 mV. To be perceived, D.C. current must be 9 times higher in the body of the animal than AC current thus, from our point of view, galvanic currents are not very likely to affect a herd.

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