

Guide for Conducting a Stray Voltage Evaluation Under the MPSC Stray Voltage Rule¹

Introduction and Overall Purpose: This guide is intended to be used in conjunction with the administrative rules addressing animal contact current more commonly called stray voltage. This guide is written in a more casual format for ease in understanding the requirements in the MPSC stray voltage rules. This guide is not intended or suggested as a replacement for, or interpretation of, the actual rules.

Definitions: It is necessary to understand the meaning of several terms used in the MPSC Rule before conducting a stray voltage evaluation.

Stray Voltage is a voltage measured at an animal contact location with a nominal 500 Ω resistor across the input of the instrument.

Neutral-to-Earth Voltage is measured from a neutral wire or grounding wire to a reference ground. This is not an animal contact voltage. No shunt resistor is used.

Steady State voltage or current means a value that is the average over a 1-minute time interval. Hand-held meters generally do not provide a 1-minute average. Digital recording instruments generally can be programmed to provide averages over a given time interval. For the MPSC Rule, a digital recording instrument is required to be set at a maximum 1-minute averaging interval. If the term "steady state" is not used in the MPSC Rule, then the actual value of the measurement as determined using a hand-held digital meter is suggested, or a digital recording instrument can be used with an averaging interval set for 10 seconds.

Preventive Action Level is used in reference to an animal contact. This current is calculated by dividing the animal contact voltage as measured across a nominal 500 Ω shunt resistor by the measured value of the shunt resistor. Before starting the evaluation be sure to measure and document the actual value of the shunt resistor using a hand-held multimeter. The MPSC Rule does not require action to be taken by the utility unless the "preventive action level" is met or exceeded. That value is 2mA (0.002A).

Temporary Load (Load Box): This is a load applied at the secondary of the utility transformer, at the kWh meter location, or at the main farm electrical disconnecting means. This load is to be applied directly line-to-line and does not utilize the farm neutral conductor. A specific level of temporary load is not specified in the rule except that the temporary load is applied until the primary neutral-to-earth test voltage is achieved. If an adequate temporary load cannot be applied to achieve the conditions described in Rule 7(3)(e), then scaling is used as described in Rule 7(3)(g).

Utility Contribution is used in several locations of the MPSC Rule, but it is not in the list of definitions. Utility contribution is determined during the temporary load (load box) test. In Rule 3 (1) reference is made to a utility mitigative action threshold maximum level "utility contribution" to animal contact current of 1mA (0.001A). Rule 7(3) provides a protocol to determine utility contribution to animal contact current.

¹Prepared by the staff of the Michigan Agricultural Electric Council in cooperation with the Department of Biosystems and Agricultural Engineering, Michigan State University, East Lansing, MI 48824-1323.

Instrumentation: Hand-held digital meters generally indicate rms voltage and current. If the wave form is a true 60 Hz sine wave then the rms value is 70.7% of the magnitude of the peak value of the sine wave. The neutral-to-earth or stray voltage wave form may not be a true sine wave. The hand-held meter or recording instrument must be “true rms” indicating. The meter specifications must say “true rms” in order for a meter or recording instrument to be accepted as “true rms” indicating.

Digital recording instruments generally are used for a multitude of purposes and may record much more information than is required by the MPSC Rule. This other recorded data may be useful for diagnostic purposes. The MPSC Rule requires an average rms value recorded on 1-minute intervals. It is not uncommon for instruments to also record the maximum and minimum value that occurred during that 1-minute interval. These values may be useful for diagnostic purposes, but they are not relevant to implementing the MPSC Rule.

The MPSC Rule requires that digital recording instruments and hand-held meters be calibrated to factory specifications by a certified testing laboratory.

Remember that a digital recording instrument saves only one value over the pre-set time interval as the average of all values sampled during that time interval. If a load is turned on to increase the value for only 10 seconds, that higher value will be averaged with the lower values that occurred during the other 50 seconds of that time interval. The value saved by the recording instrument will not be the value that occurred during the 10 second test interval. When a digital recording instrument is being used for such testing, be sure to reset the averaging interval appropriate for the test. A 10 second averaging interval is suggested. An example where this may be necessary when conducting an evaluation under the MPSC Rule is when the farm power is disconnected and a temporary load (Load box) is applied at the transformer, meter, or farm electrical disconnect to test the primary neutral.

First Investigation: Rule 2 (1)

- usually initiated by the farmer or utility
- request is directed to utility

Response: The following action is required of the utility.

- Utility makes contact and schedules site visit.
- Make site visit and do whatever is appropriate to deal with farmers stray voltage concerns.

Purpose: Address farmer's concerns or questions by surveying the farm to determine levels of stray voltage and possible sources.

Procedure: Depending upon the situation, it is suggested that a neutral-to-earth voltage evaluation be conducted where burden tests are run to evaluate voltage levels that occur due to loading of the primary (temporary load) and secondary (120 volt load) neutrals. Either hand-held digital meters or a digital recording instrument can be used to gather data. For this type of evaluation it is suggested the averaging interval of a digital recording instrument be set at 10 seconds. Suggested measurements include primary neutral to reference ground voltage, barn panel neutral to reference ground voltage, primary neutral to barn panel neutral voltage, and animal contact voltage. If the farmer has reason to believe the source of a voltage may be intermittent, a digital recording instrument may be set. In cases where the primary and secondary neutrals were previously separated at the utility transformer, it may be desirable to measure the secondary neutral to reference ground voltage at the transformer as well as the voltage between the primary and secondary neutrals at the transformer.

Required by MPSC Rule: Determine stray voltage levels (AcV). Measure and record stray voltage at any animal contact location suggested by the farmer, as well as at all other locations where animals will potentially make contact with a neutral voltage. Do not make measurements at any location where personnel may be exposed to physical danger but, note why such a measurement was not taken. When making animal contact location voltage measurements, it is suggested the measurements be made with and without a shunt resistor at each location. Both voltages help evaluate which animal contact location is the one that is most probable to expose the animals to the maximum current. This determination is required if the farmer requests further investigation.

End Result: The objective should be to answer the farmer's questions, determine stray voltage levels (MPSC requirement), and reduce stray voltage to an acceptable level if in the judgment of the utility the stray voltage level needs to be lowered. If the stray voltage level is low, hopefully convince the farmer that stray voltage is not an issue. If alterations are made to the electrical system either at the farm or on the utility system, a repeat set of measurements should be taken to verify that an acceptable change in the level of stray voltage has occurred. If the farmer is not satisfied with the result, a request can be made to proceed to Rule 2 (2).

Second Level of Investigation: Rule 2 (2)

- Step 1 must have been completed.
- Must be requested by the farmer.
- Request is directed to utility.

Required by MPSC Rule: A specific protocol must be followed to determine the level of animal contact current.

1. The level of animal contact current shall be determined from measurements of animal contact voltage across a nominal 500Ω resistor.
2. The protocol in Rule 7 shall be followed:
 - a. Identify all animal contact locations, documenting voltage measurements at each location with and without a 500Ω resistor across the voltmeter input.
 - b. Select an animal contact location that is the most probable location to produce the highest animal contact current. Divide the animal contact voltage (AcV) by the value of the shunt resistor to get a probable worse case animal contact current at that location.
 - c. Establish a reference ground.
 - d. Set up animal contact test location (alternate location may be necessary).
 - e. Set the digital recording instrument to record steady state voltage for 72 hours. The instrument is required to record the primary neutral (if available) to reference ground voltage, barn panel neutral to reference ground voltage, and animal contact voltage.
 - f. Examine animal contact point voltage graph and select highest steady state voltage during 72 hours. Record value and exact time (1 minute intervals).

- g. Examine the graph for primary neutral to reference ground voltage (NpEV) and document the NpEV voltage at the exact time that the maximum animal contact voltage occurred which is the highest animal contact voltage measured during 72 hours.

Exact time the highest animal contact voltage occurred _____

Primary neutral-to-reference voltage at same time _____ V (NpEV)

- h. Calculate the steady state animal contact current.

highest steady state animal contact voltage during 72 hrs. _____ V

value of shunt resistor _____ Ω

divide voltage by resistance and multiply by 1000 _____ mA
 (Steady state animal contact current)

Note (from Rule 3) if steady state animal contact current is less than 2 mA, continue investigation at the discretion of the utility. If greater than or equal to 2 mA, proceed to step i. 

- i. Conduct temporary load (Load box) test. (See definition) A temporary load is applied at the transformer, meter, or farm electrical disconnect that does not apply current to the secondary neutral. If possible apply temporary load until the primary neutral-to-reference ground voltage (NpEV) is achieved that occurred at the same time as the highest animal contact current during the 72 hour measurement (AcV).

If a recording instrument is used, set it for 10 second average
 Hand-held voltmeter is permitted.

Measure:	NpEV	AcV
Farm power off	_____ V	_____ V
Temporary load on	_____ V	_____ V
Temporary load off	_____ V	_____ V
Change of voltage	Δ _____ V (Δ NpEV)	Δ _____ V (Δ AcV)

- j. If the level of primary-to-reference voltage determined in Rule 7(3)(g) cannot be achieved, then calculate an AcV by scaling. Scale the voltage using Δ NpEV to determine AcV when NpEV is equal to the voltage determined during the 72 hour test.

- k. If mitigation is undertaken by the utility, re-run temporary load (Load box) test to determine new values.

Measure:	NpEV	AcV
Farm power off	_____ V	_____ V
Temporary load on	_____ V	_____ V
Temporary load off	_____ V	_____ V
Change of voltage	$\Delta \frac{\text{_____}}{(\Delta NpEV)} \text{ V}$	$\Delta \frac{\text{_____}}{(\Delta AcV)} \text{ V}$

- l. If mitigation is undertaken by the farmer, and the utility is aware of such mitigation, the utility may repeat the 72 hour recording.

Action Required (Rule 3): Based upon the results of the previous testing the following actions shall be taken:

1. Action by the utility is required if the steady state animal current (calculated) from all sources meets or exceeds 2 mA, AND the utility contribution to steady state animal contact current exceeds 1 mA. (Rule 3(1)). Utility must commence action to mitigate utility contribution to animal contact current to 1 mA or less. 
2. Utility determines if communication service provider facilities provides pathway for some or all of the animal contact current. Utility requests action to be taken by the communication service provider. Commission can be asked to intervene if a dispute arises between the electric utility and a communication service provider over the issue of contribution to animal contact current. (Rule 3(3)) 
3. The utility should re-run the temporary load (Load box) test to verify that their action(s) reduced utility contribution to animal contact current to 1 mA or less. (NOT STATED in Rule)

Third Level of Investigation (Rule 4):

- All previous steps were completed.
- Request appointment of experts. A formal complaint for this action is not required.
- Farmer or utility may make request appointment of experts.
- Request directed to Commission.

Required by the MPSC Rule: The investigation by appointed experts is carried out under the direction of the MPSC.

1. If requested, the Commission may appoint 3 to 5 experts to investigate the complaint and report findings. (Rule 5(1))
2. Experts prepare a report which is submitted to: (Rule 4(1))
 - (a) Commission
 - (b) Farmer
 - (c) Utility

3. Requirements of the report by expert team.
 - (a) Report submitted within 30 days. (Rule 5(4))
 - (b) Report confined to scope of these rules. (Rule 5(2))
 - (c) Report may suggest corrective action. (Rule 5(4))
 - (d) Experts can be cross examined at any hearing. (Rule 5(4))

Action Required: Corrective action is not specified in the Rule. Presumably the Commission will issue an order for any necessary action to be taken by the utility and/or the farmer. (see first sentence of Rule 5(4)) The report shall be received in evidence if a formal complaint is filed.

Final Step (Rule 6):

- All previous steps were completed.
 - Farmer must file a formal complaint to Commission requesting a contested case hearing.
1. Commission issues a decision. (Rule 6(1))
 2. If decision is directed to utility, action must be taken to mitigate conditions to the satisfaction of the Commission. (Rule 6(2))
 3. If no decision is directed to utility, then no further action by the utility is required. (Rule 6(3))