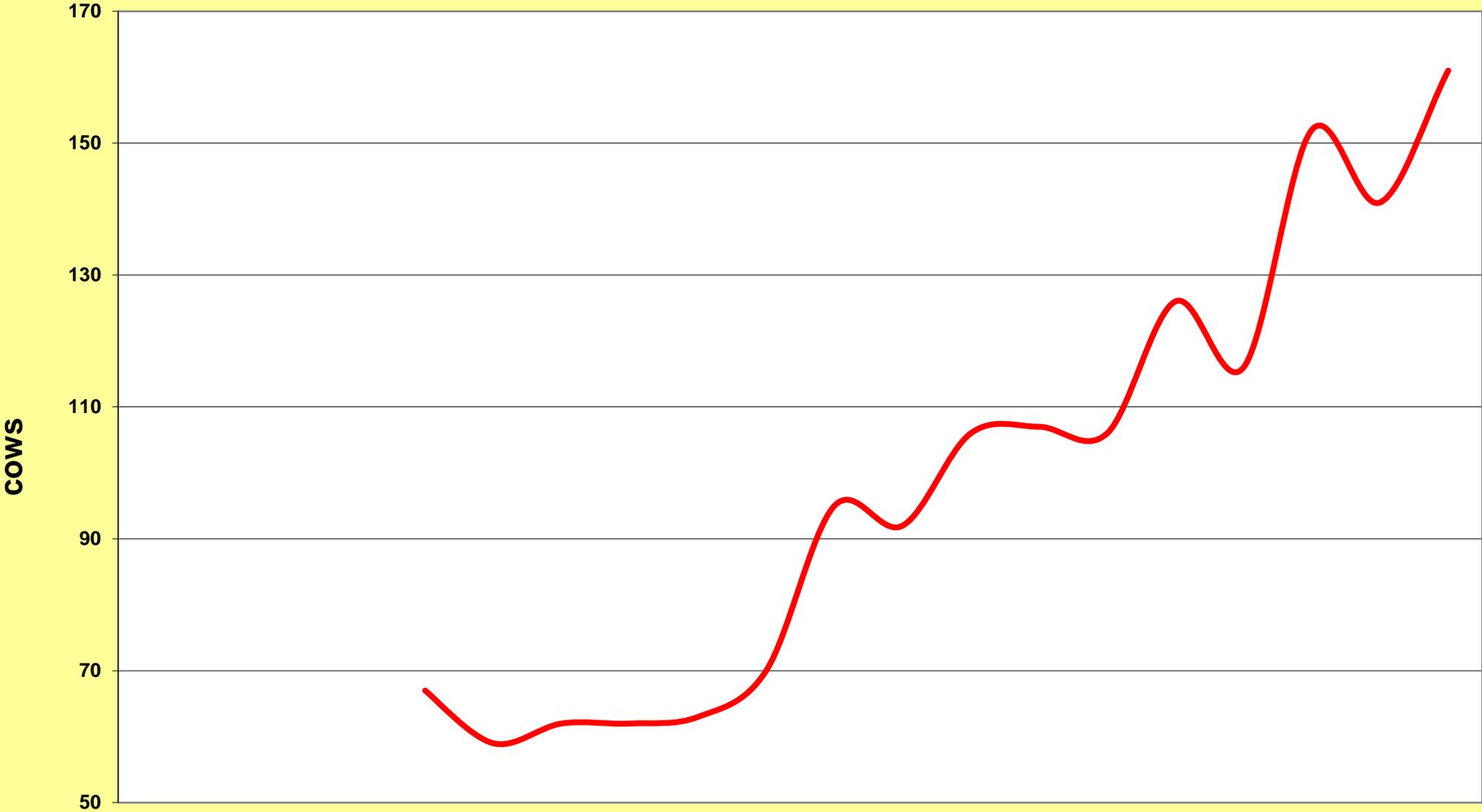


Midwest Rural Energy Council Workshop on
Advanced Topics in Stray Voltage
Investigation. March 2, 2016 in La Crosse, WI

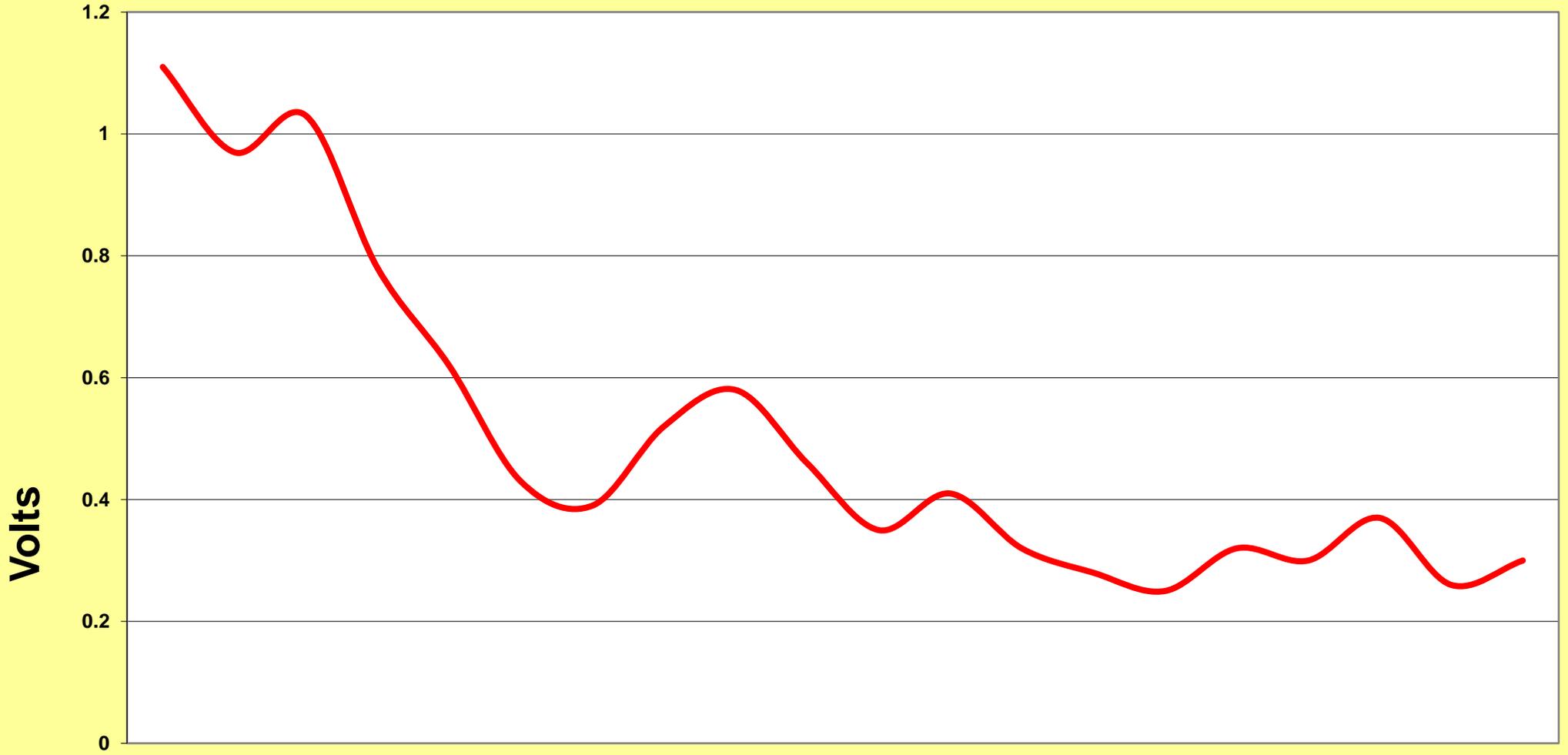
Farm Wiring Four Wire System Review

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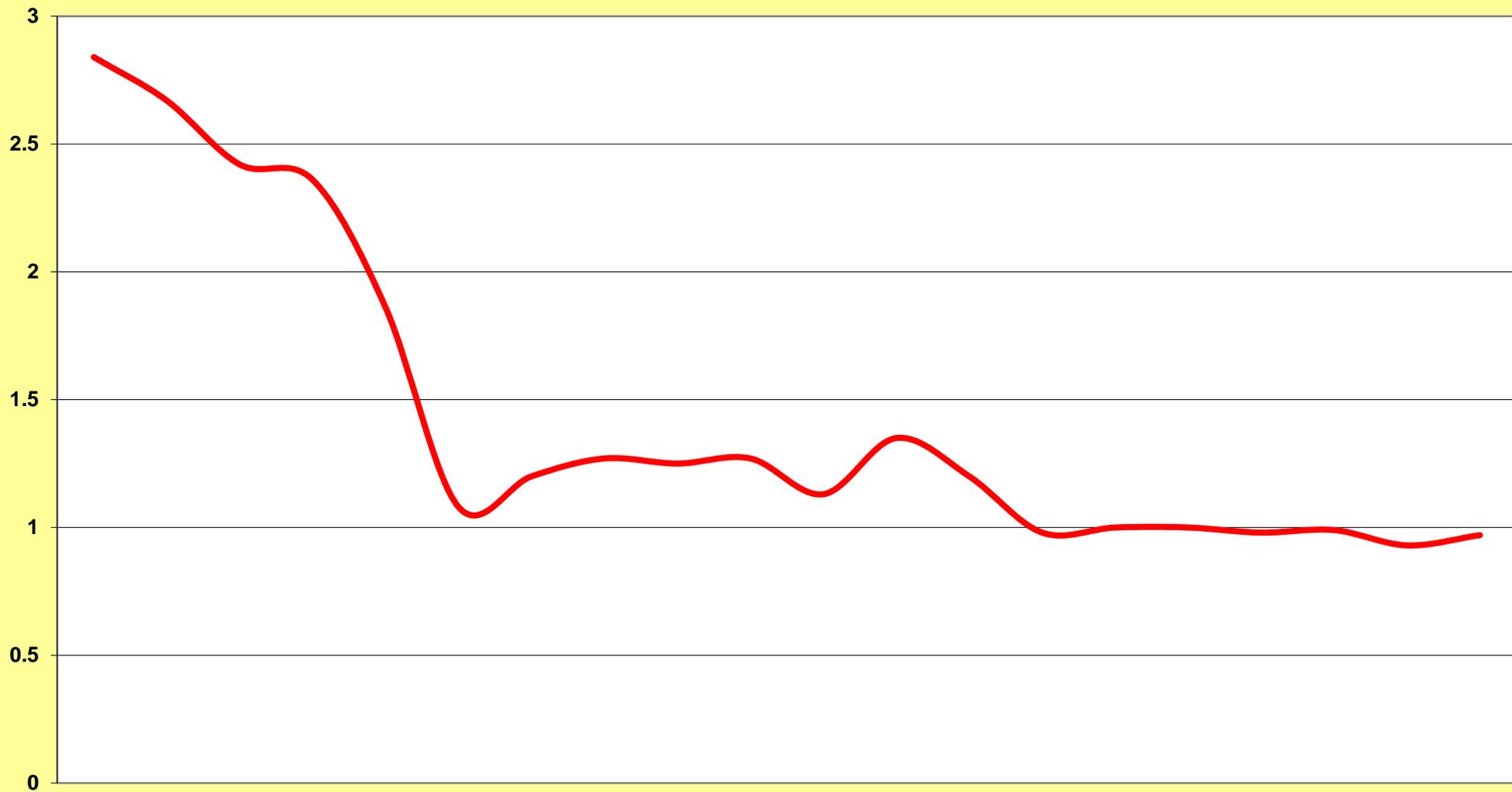
Herd size 25 year trend



Trend in cow contact voltage from all sources 25 year span, 79%

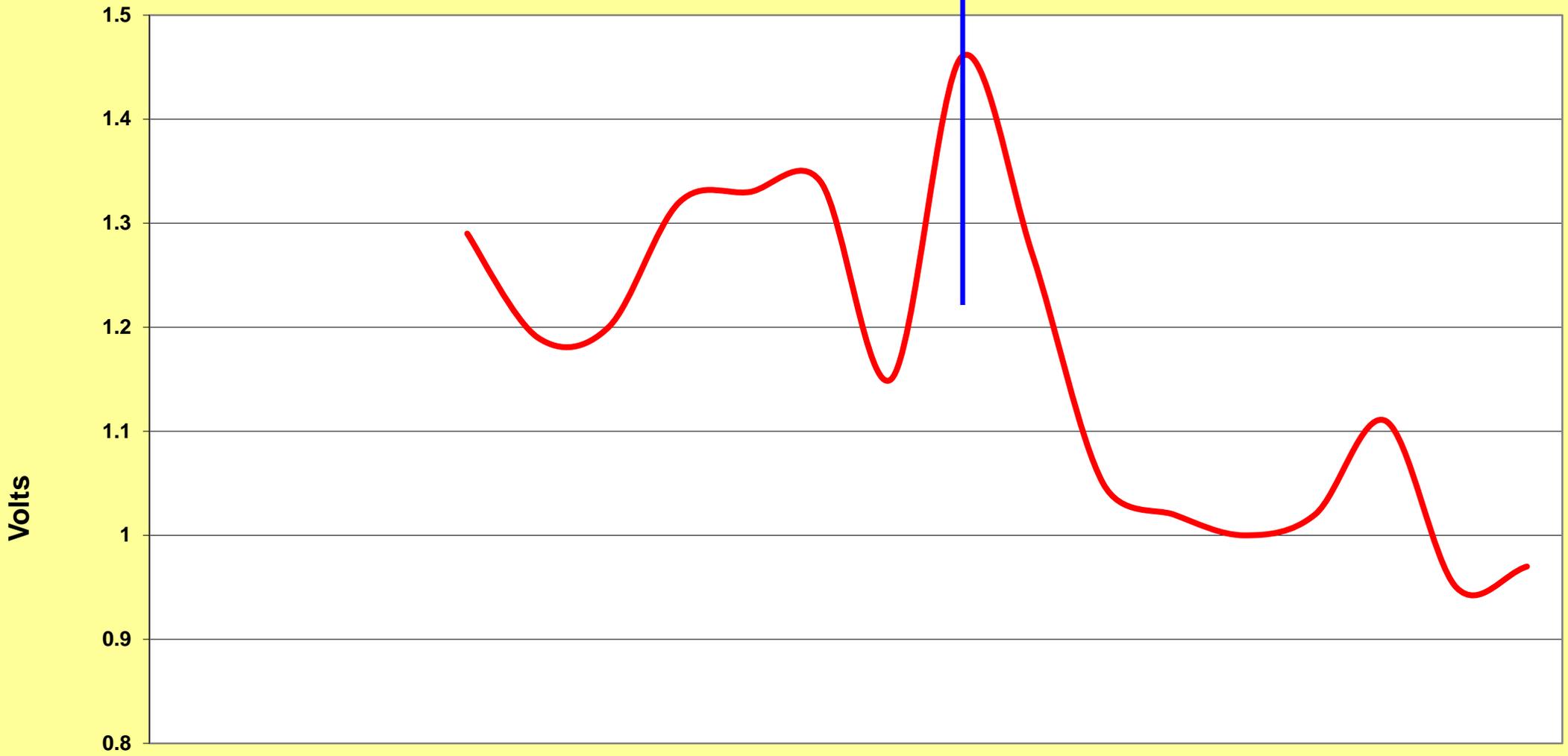


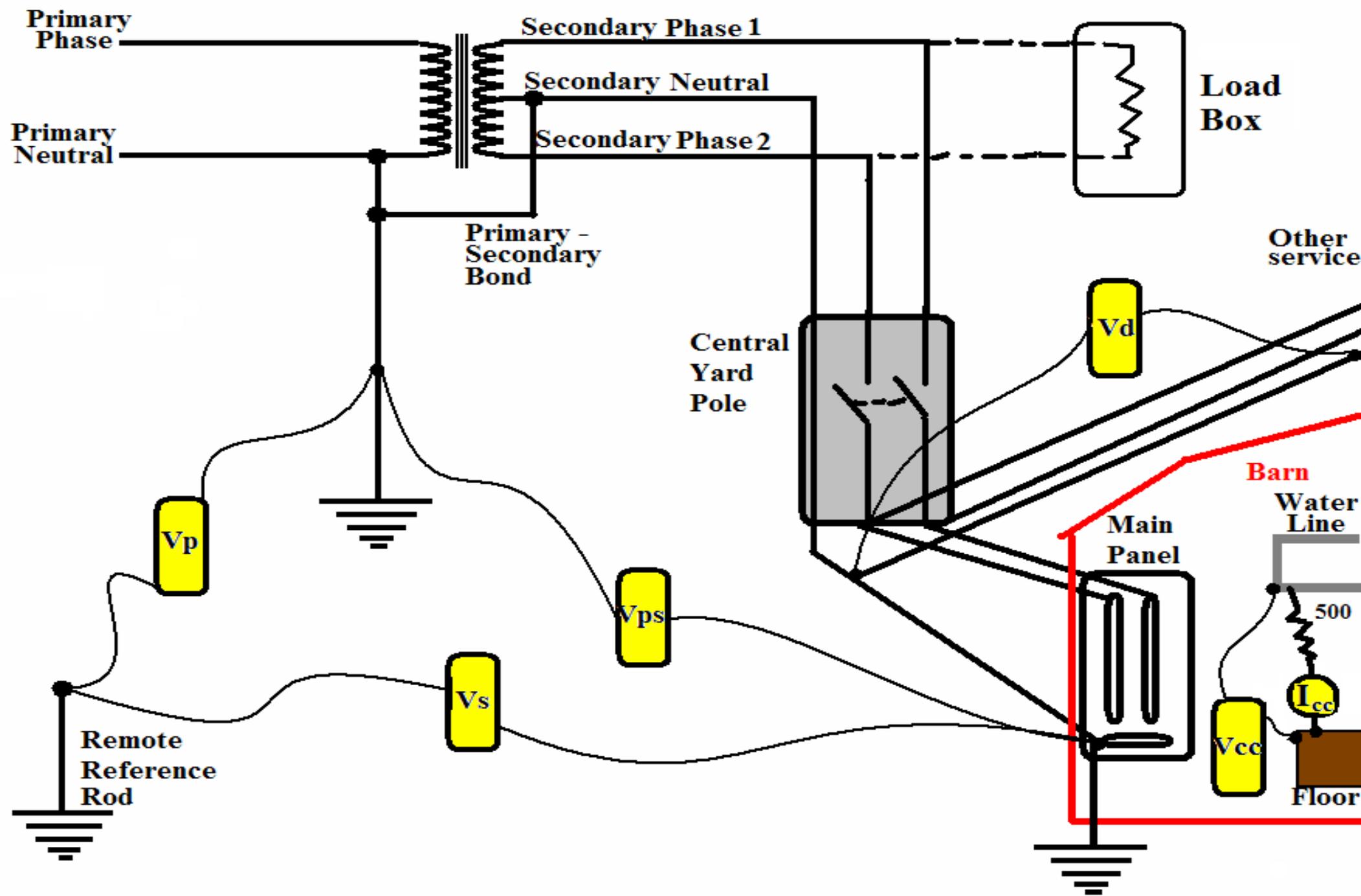
Trend in Vpnref at the transformer



Trend in Vsnref

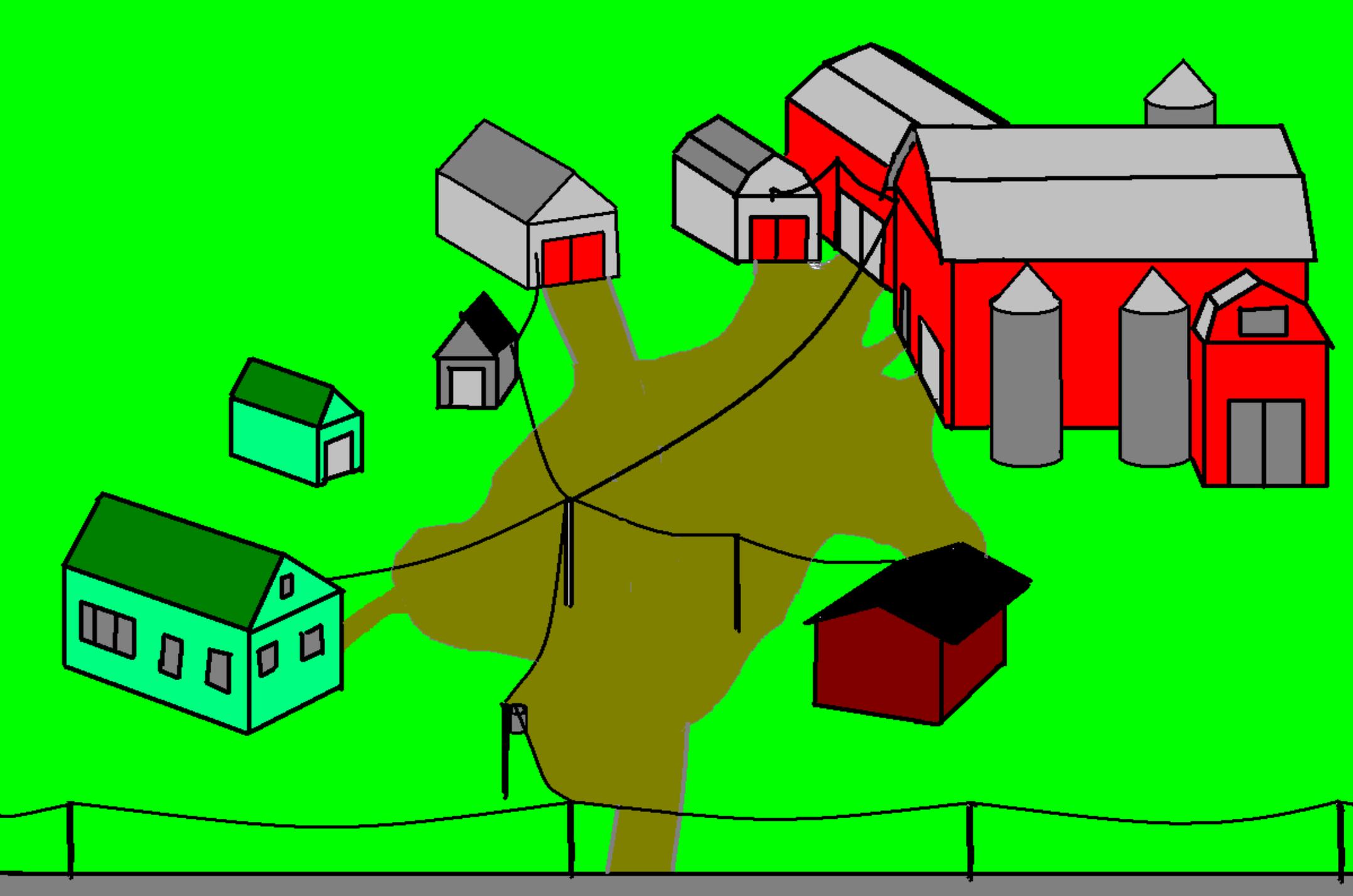
Farm rewiring pgm.

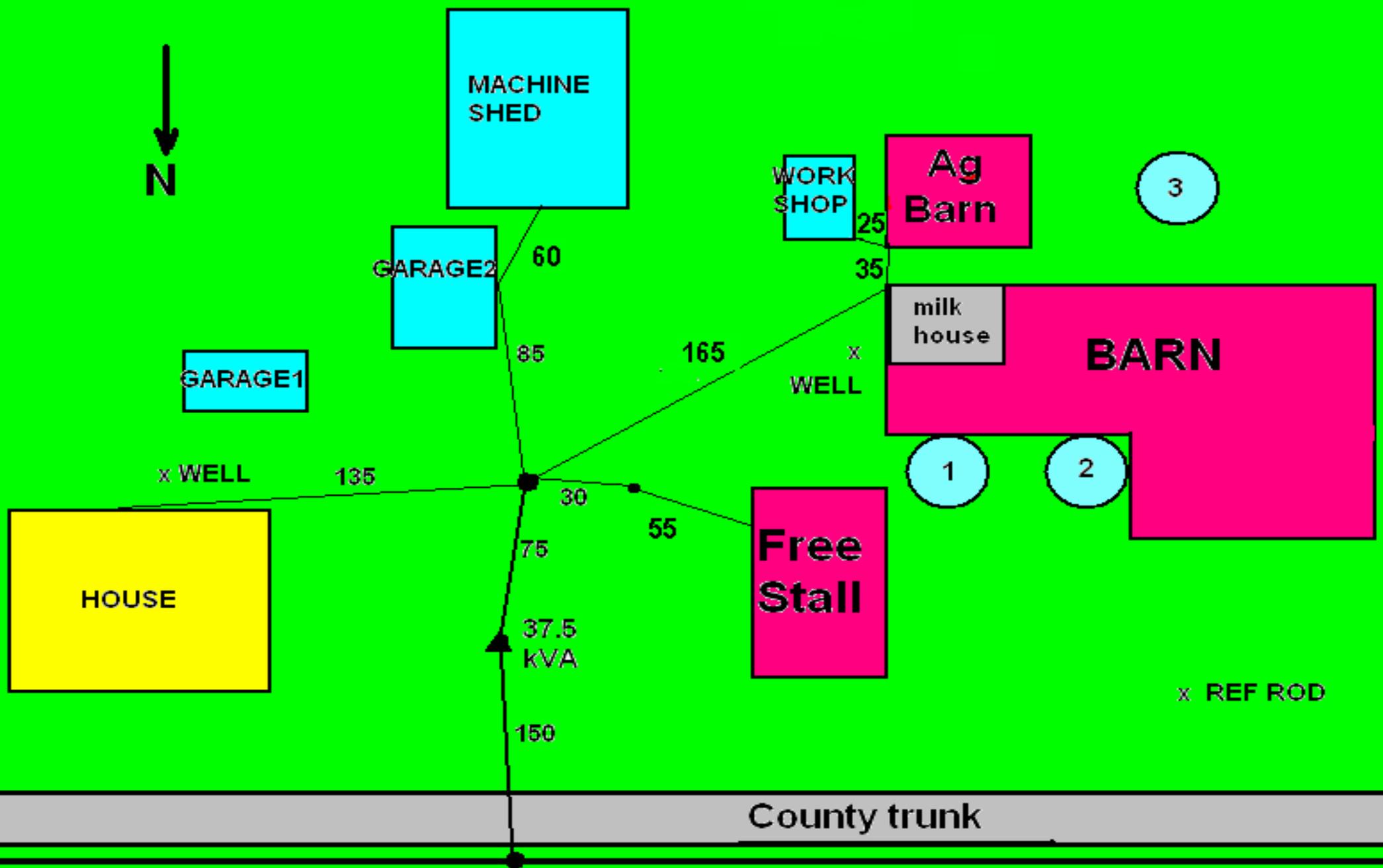




Fact:

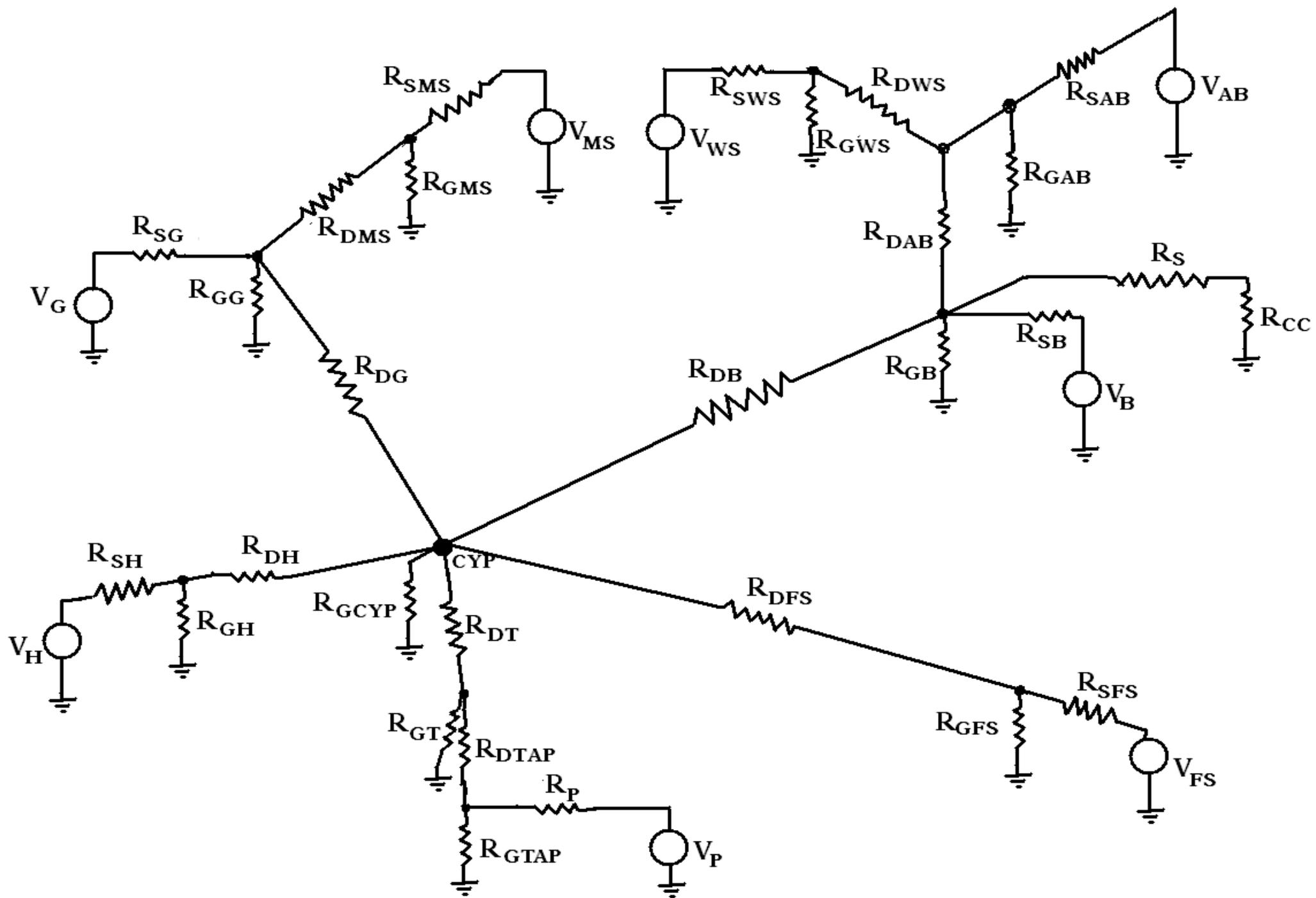
- Neutral-to-Earth Voltage exists on all electrical systems
- Neutral-to-Earth Voltage that reaches the animal environment is called Stray Voltage
- Fact: Voltage drop to one building will affect other buildings and the utility.





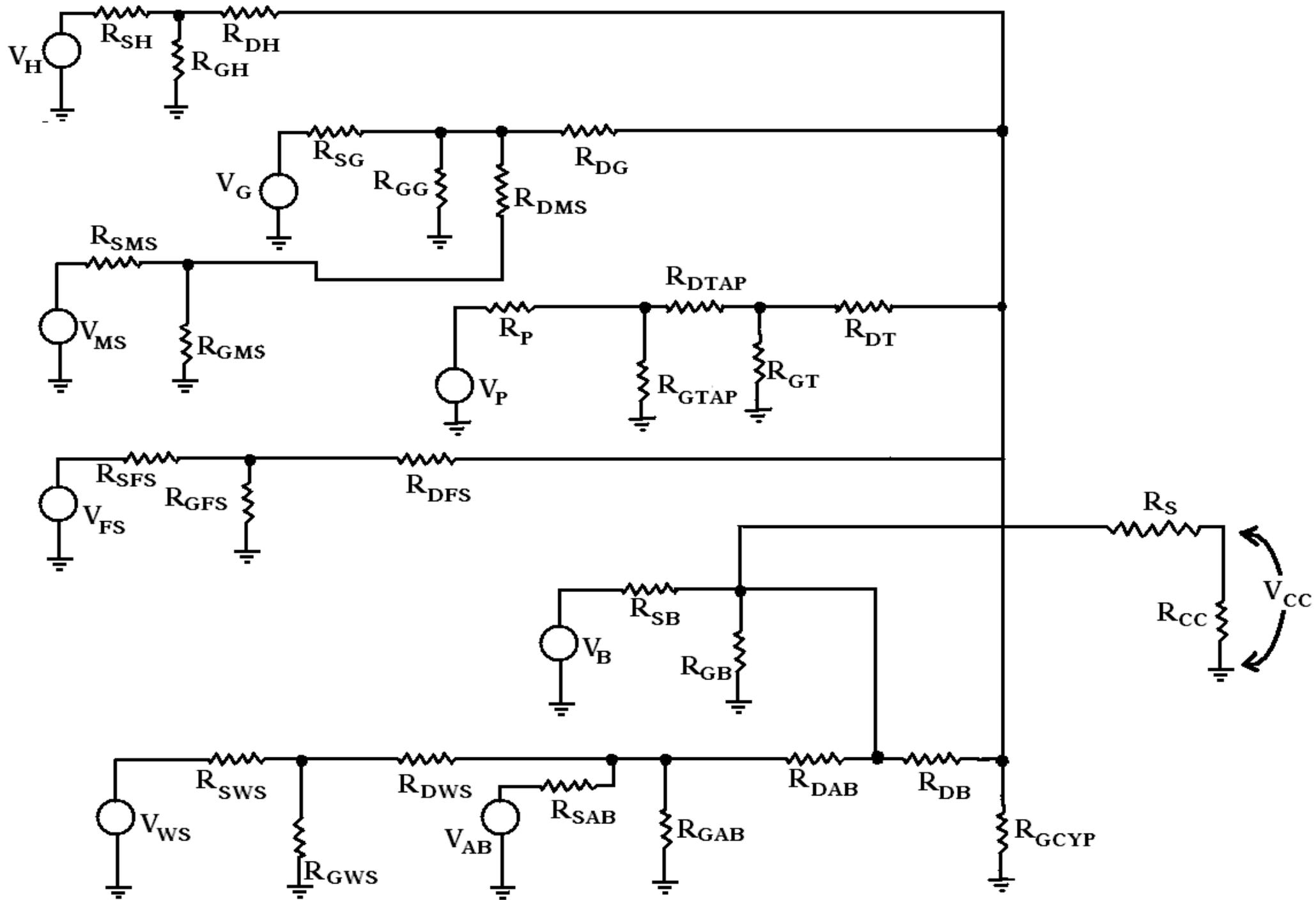
This is the view you see.....

- **We must look with a different perspective...**
- **We must see the neutral circuit as sources, resistances, connections and grounds.....**

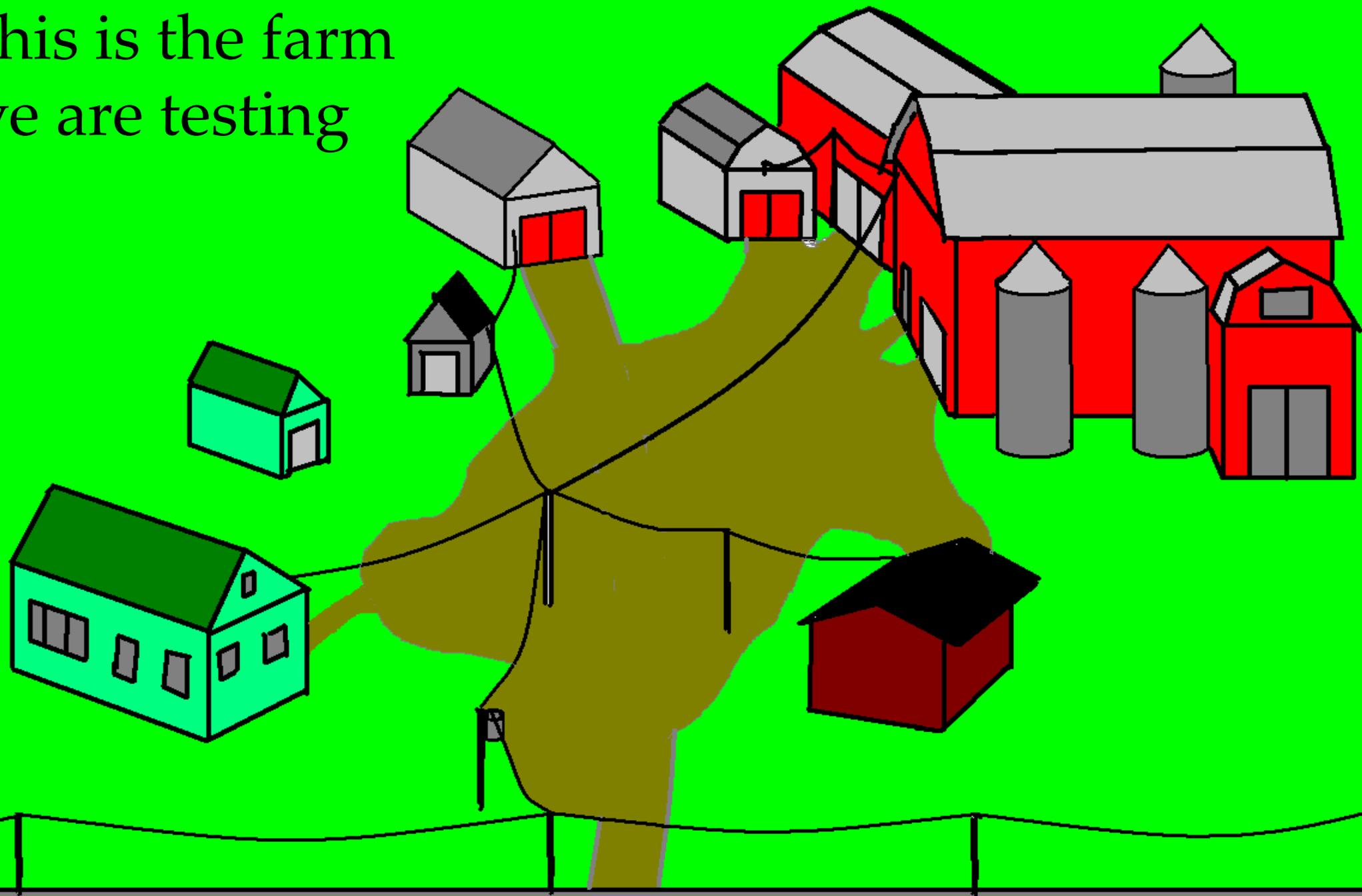


Re-assemble the schematic into a more functional form.

- The primary system and the secondary system on the left.....
- And the cow contact on the right.



This is the farm
we are testing



How effective is on-farm mitigation?

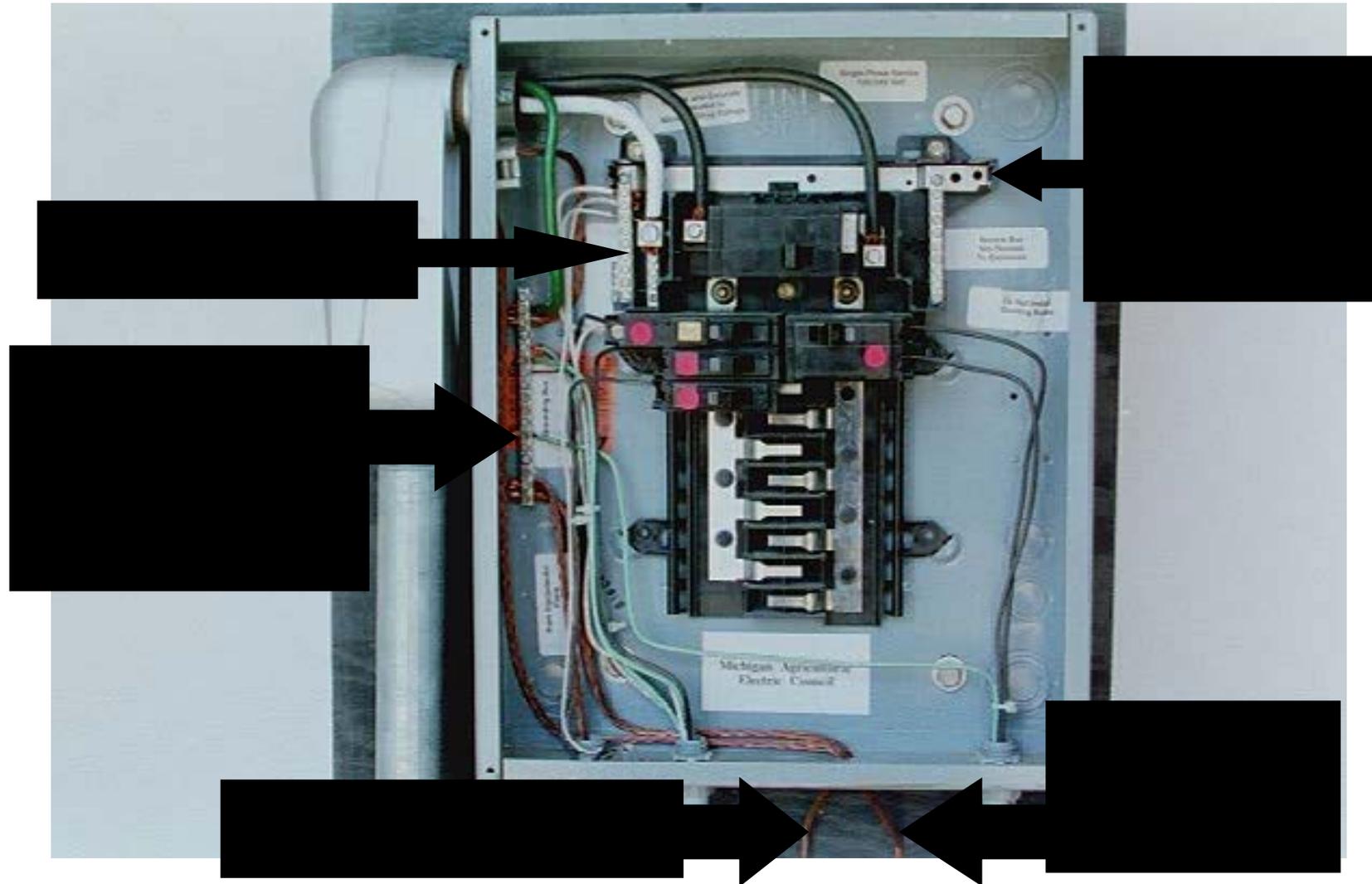
	No as-found EPP	As-Found EPP	No as-Found 4-wire	As-Found 4-wire
Average Icc	0.87 mA.	0.20 mA.	0.78 mA	0.39 mA.
N =	7254	939	6511	994

If both EPP and 4-wire were found, the average Icc was 0.19 mA. (N=360), If both were absent, the average Icc was 0.82 mA. (N= 5857).

Purpose: Four Wire Systems

1. The safest, least cost solution to the number one cause of stray voltage

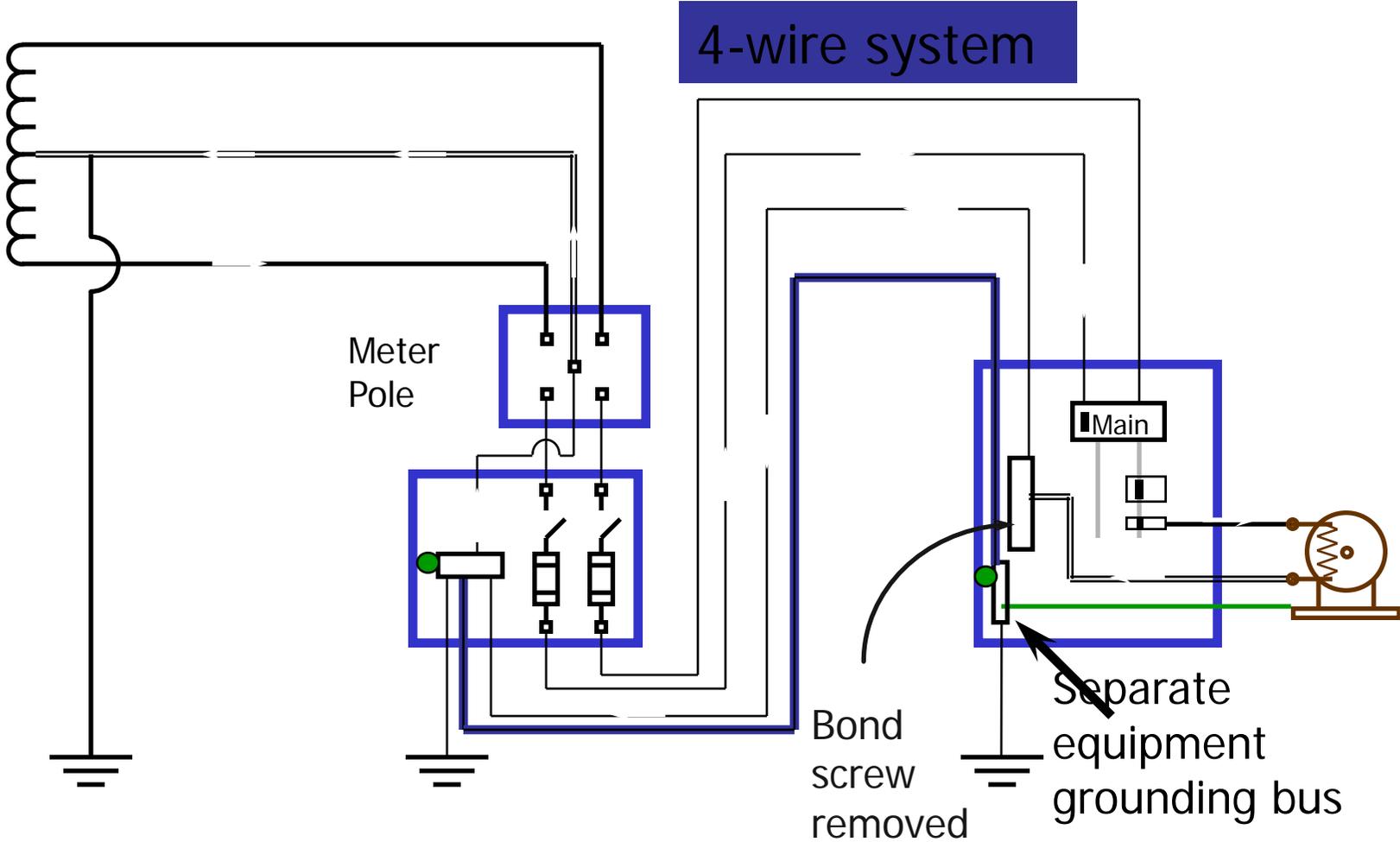
4-wire System Panelboard



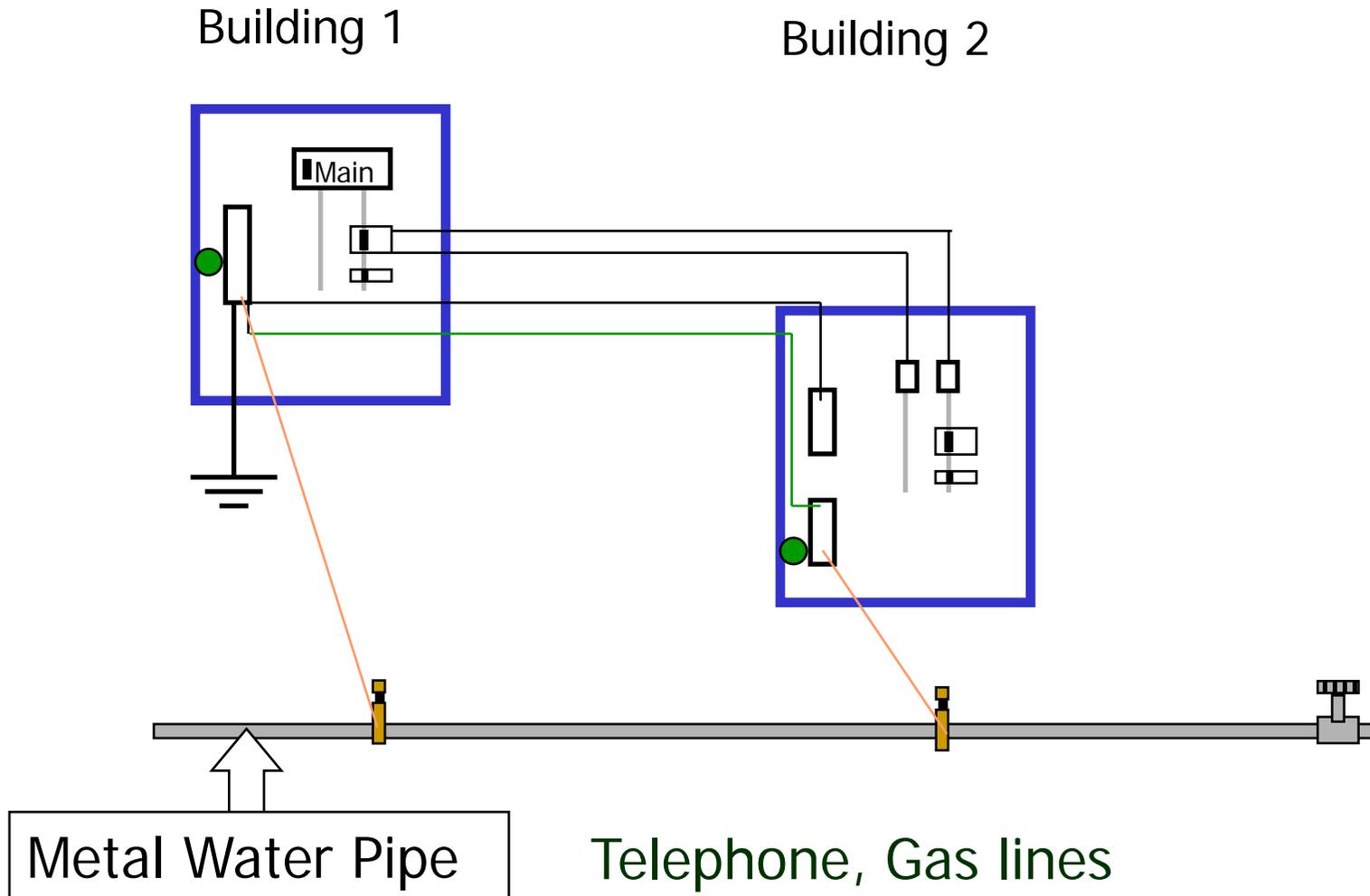
Four-wire vs three-wire feeders

- Supplying a subpanel in the same building
 - NEC requires the ground and neutrals to be maintained separate.
 - The grounded wire (the neutral) must be insulated and labeled white.
 - For agricultural buildings under *Art. 547* there must be a copper grounding conductor and if underground, the equipment grounding conductor must be insulated or covered

Separation of equipment grounding and neutrals



Supply to a separate building



Advantages of four-wire

- Reduces on farm source voltages at cow contact
- Eliminates 120 volt imbalance load problems
- Reduces secondary neutral current returning through the earth

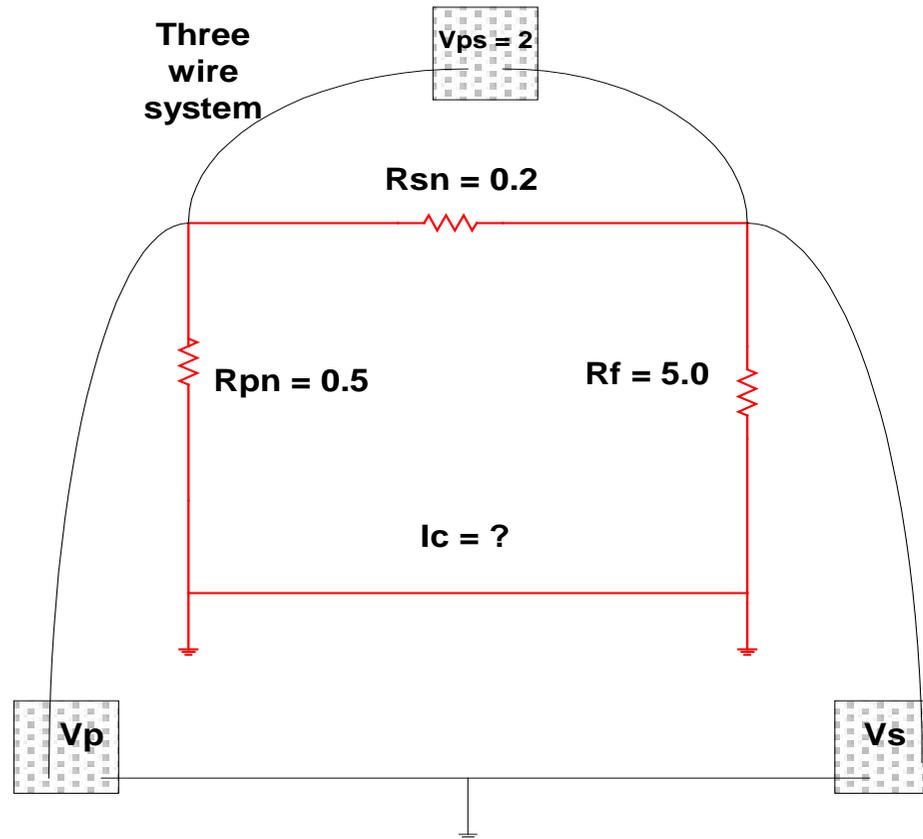
Disadvantages of four-wire

- A four-wire service is almost never wired correctly and to CODE.
- A four-wire service only corrects the on farm service or feeder being four-wired.
- Improper installation can cause voltages on equipment to increase.

ANY interconnection between equipment grounds and neutral can put a significant voltage where it can reach the animals or cause damage.

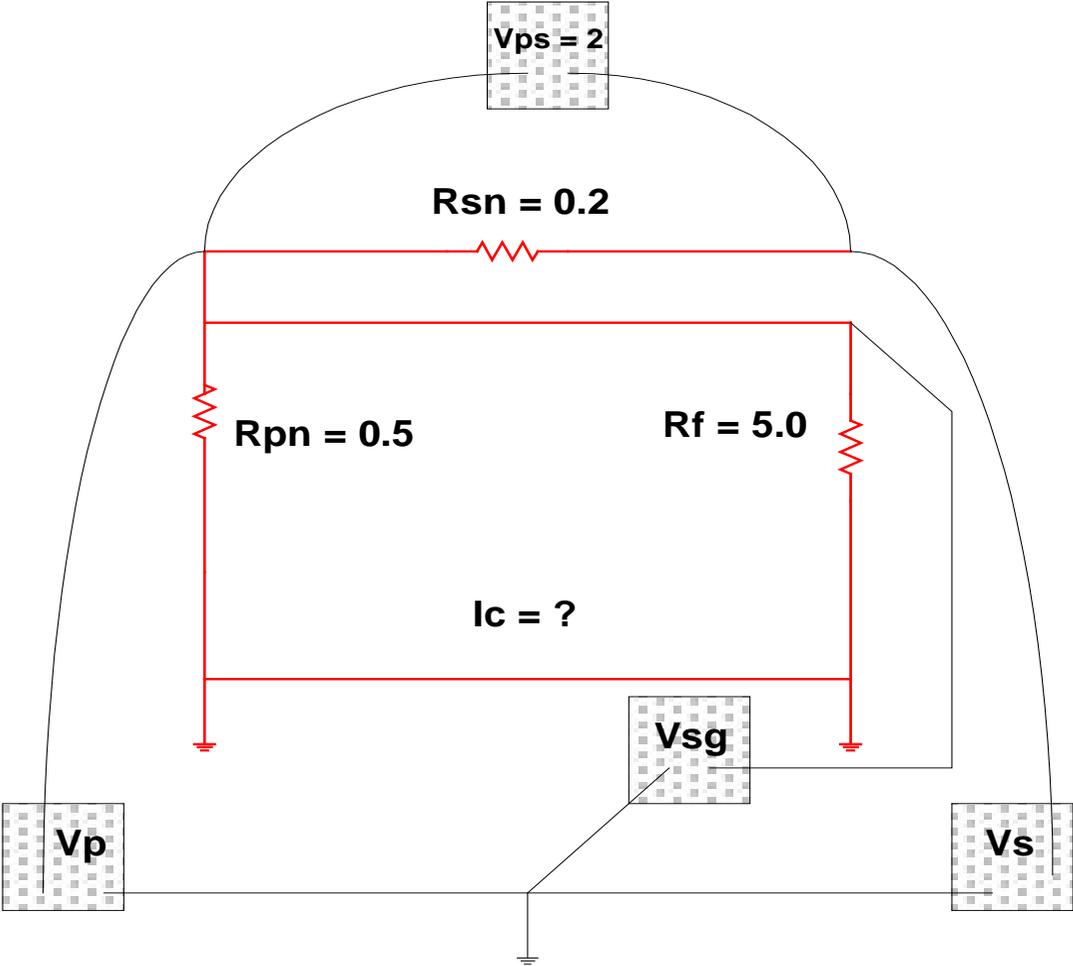
Three Wire System

- $V_p = 0.181$
- $V_s = 1.818$



Four-Wire System

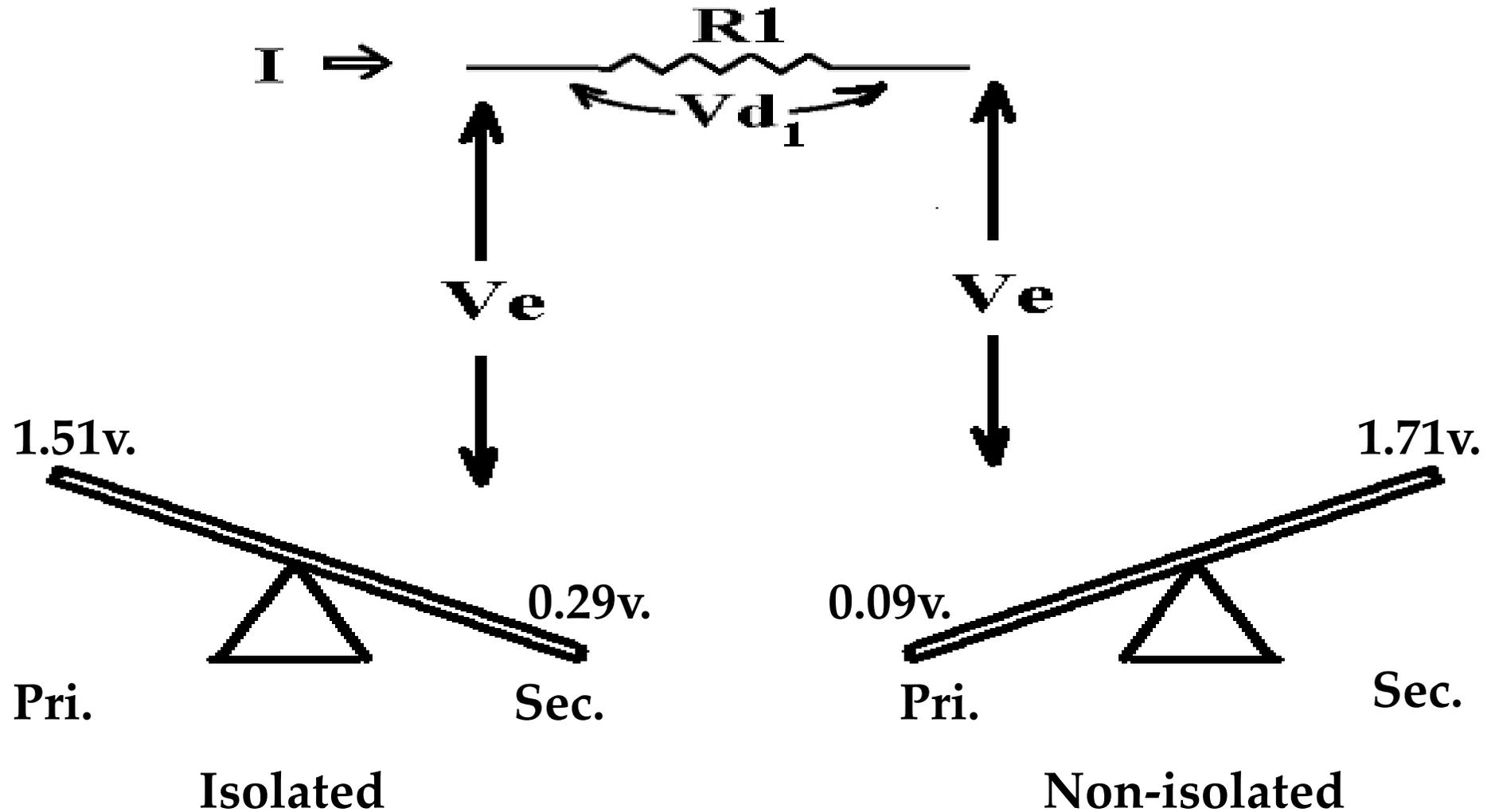
- $V_p = 0.0$
- $V_s = 2$



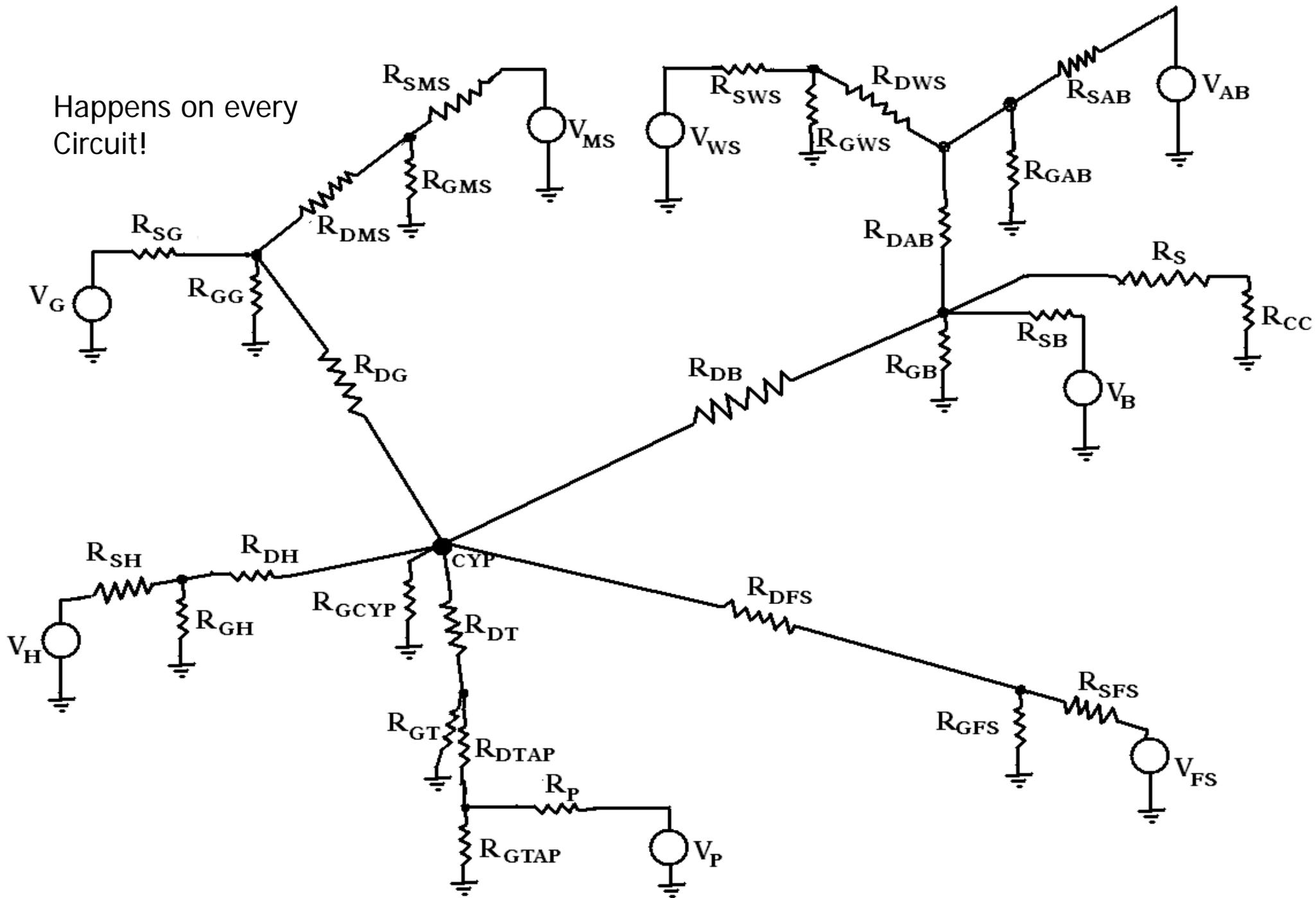
Warning

- **Separating the primary and secondary neutrals will shift the location of NEV from secondary neutral voltage drop at every service, feeder and branch circuit.**
- **V_p is never just V_p**

Example of teeter/totter effect:



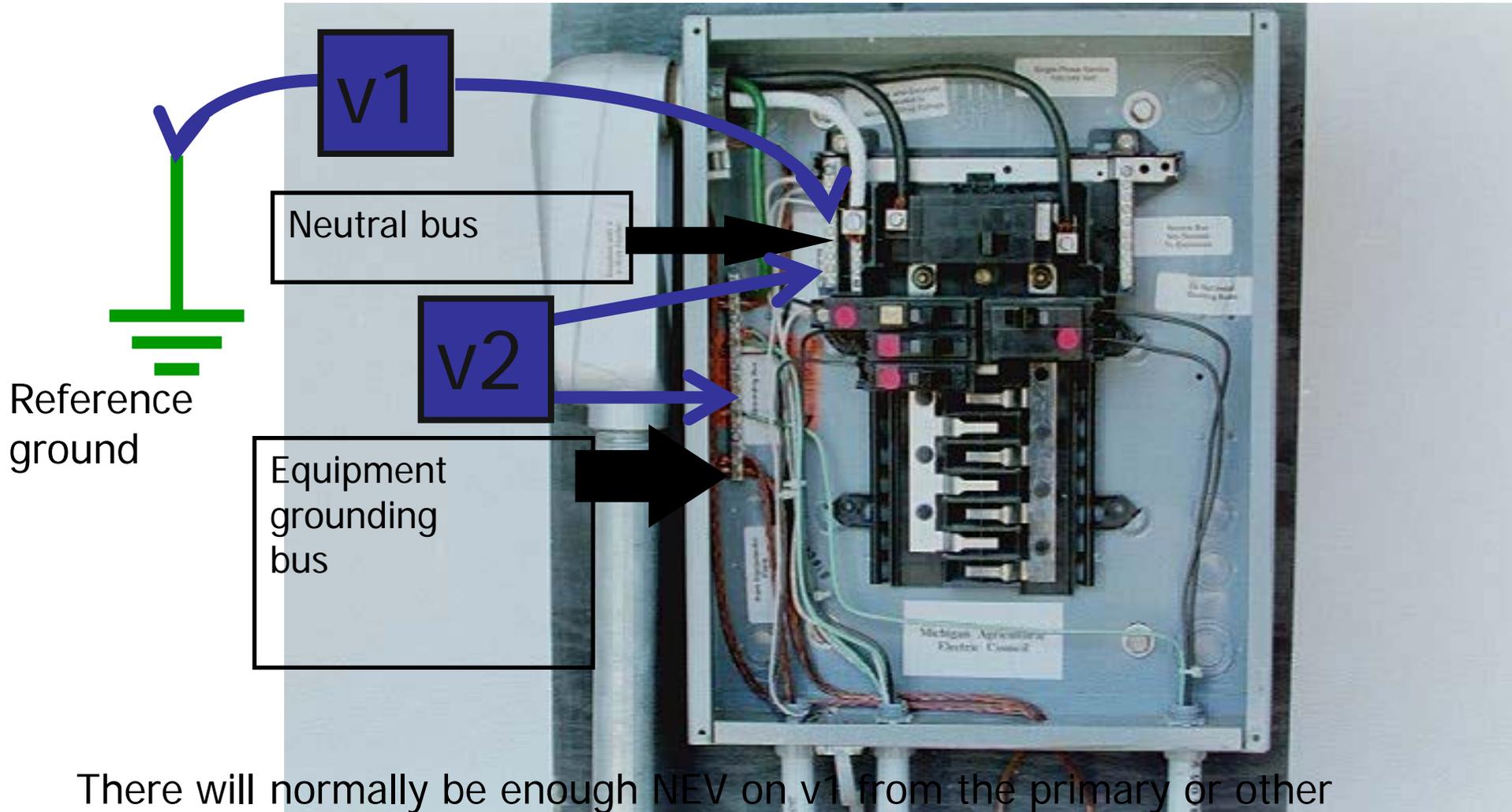
Happens on every
Circuit!



Think about this:

- What happens when you have interconnections?
 - Open neutral?
 - Unbalanced load current will flow through the interconnection. Interconnections are unintentional and not able to handle the job of a main bonding jumper. Fire?
 - Phase fault?

Testing Four-Wire Systems



There will normally be enough NEV on v1 from the primary or other buildings to use for test.

Testing 4-Wire (5-Wire) Systems for Interconnections

Do not:

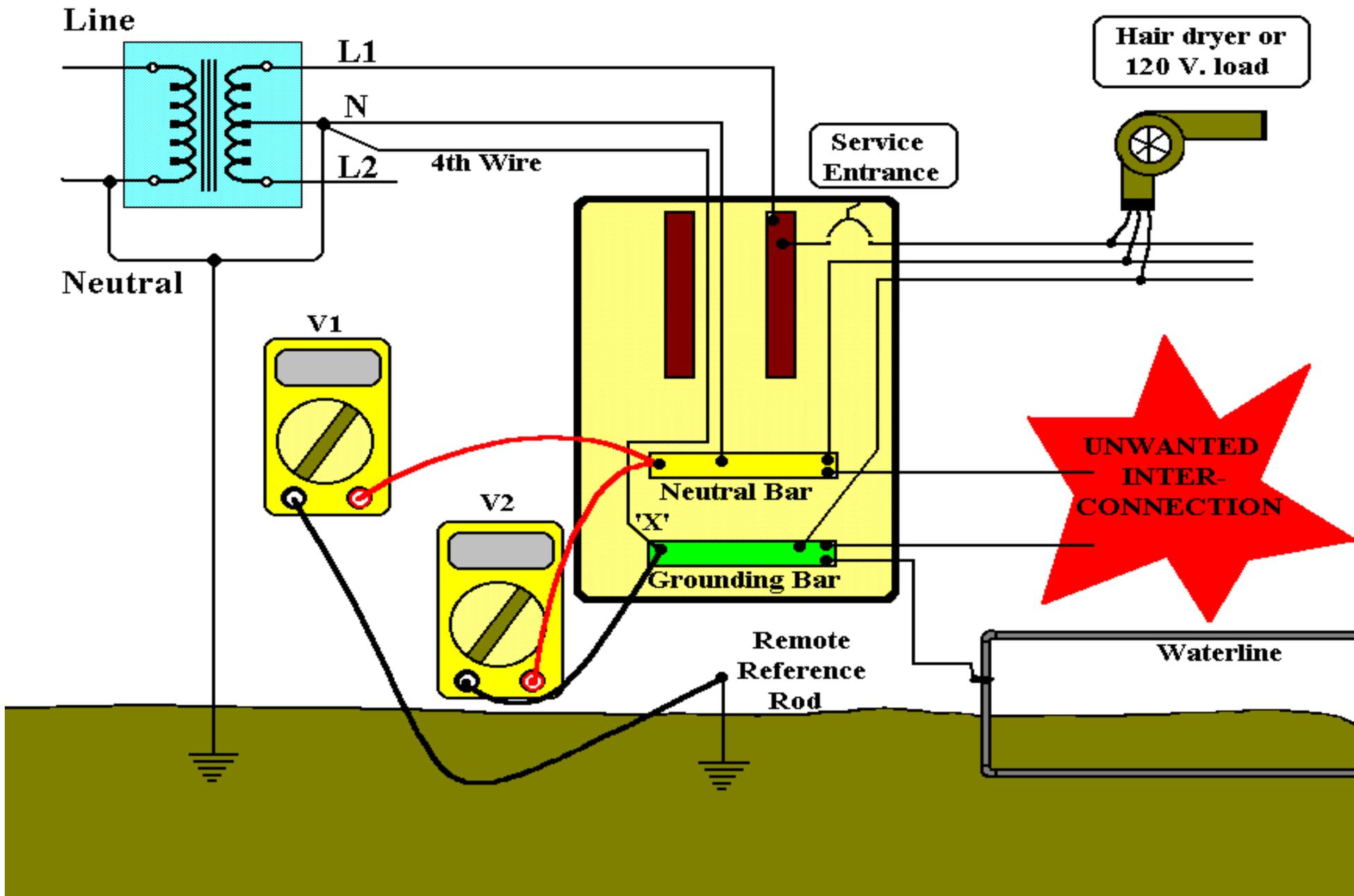
- Use a ohm meter to test for interconnections.
 - Ohm meter current is too small to swamp out noise on the system.
 - Circuit is too large.
 - Signal to noise ratio is unpredictable.
 - Meter not intended for this use.

Do not:

- Use a car battery to test for AC power system resistances or interconnections.
 - Current is too small to swamp out noise on the system.
 - Circuit is too large.
 - Signal to noise ratio is unpredictable.
 - Polarity problems occur.

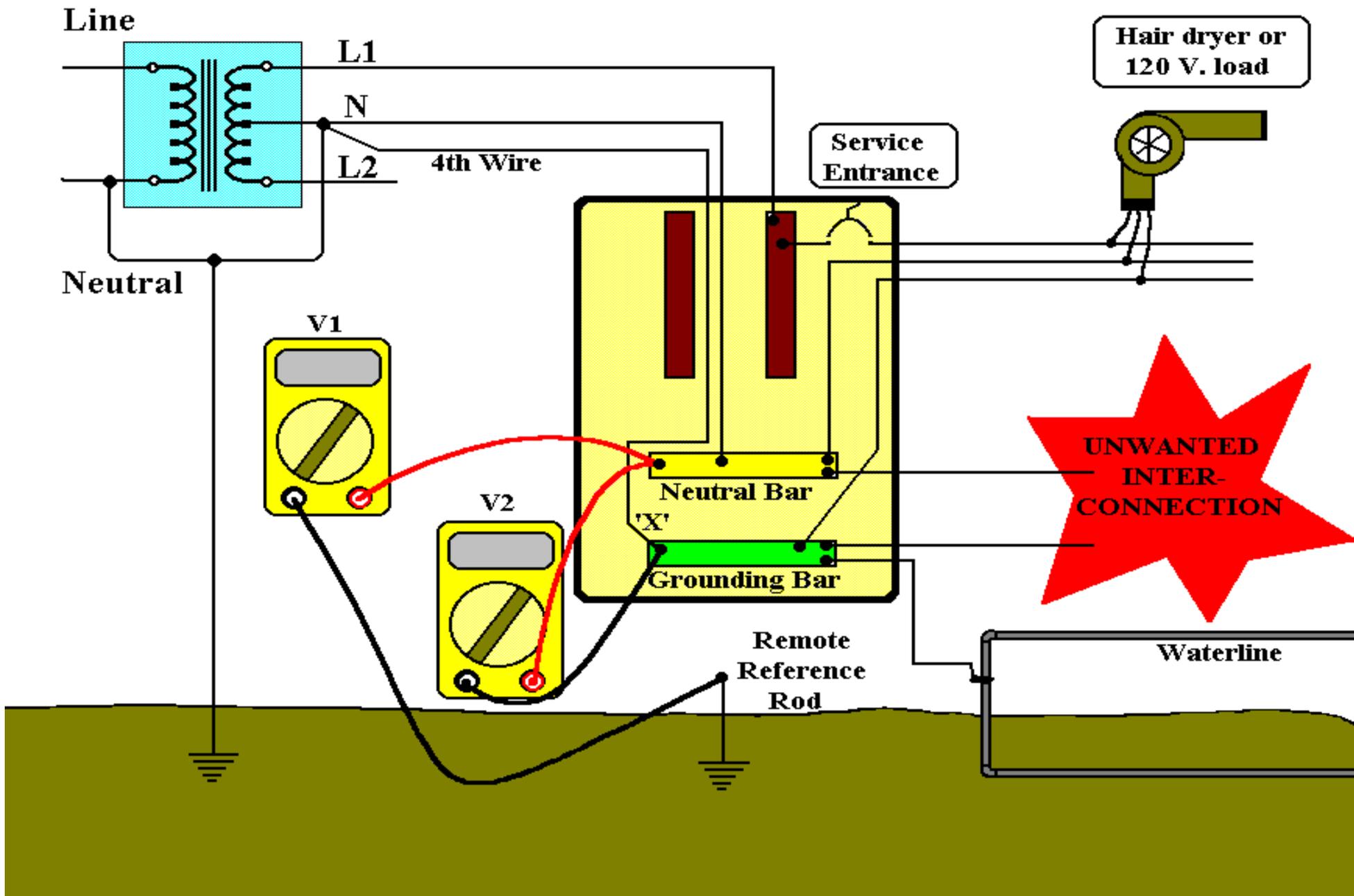
Do:

- Use a digital volt meter to test for farm wiring grounded and grounding system interconnections.
 - NEV is the source of interest so use it.
 - Input Impedance is very high.
 - Meter operates in the desired frequency range.



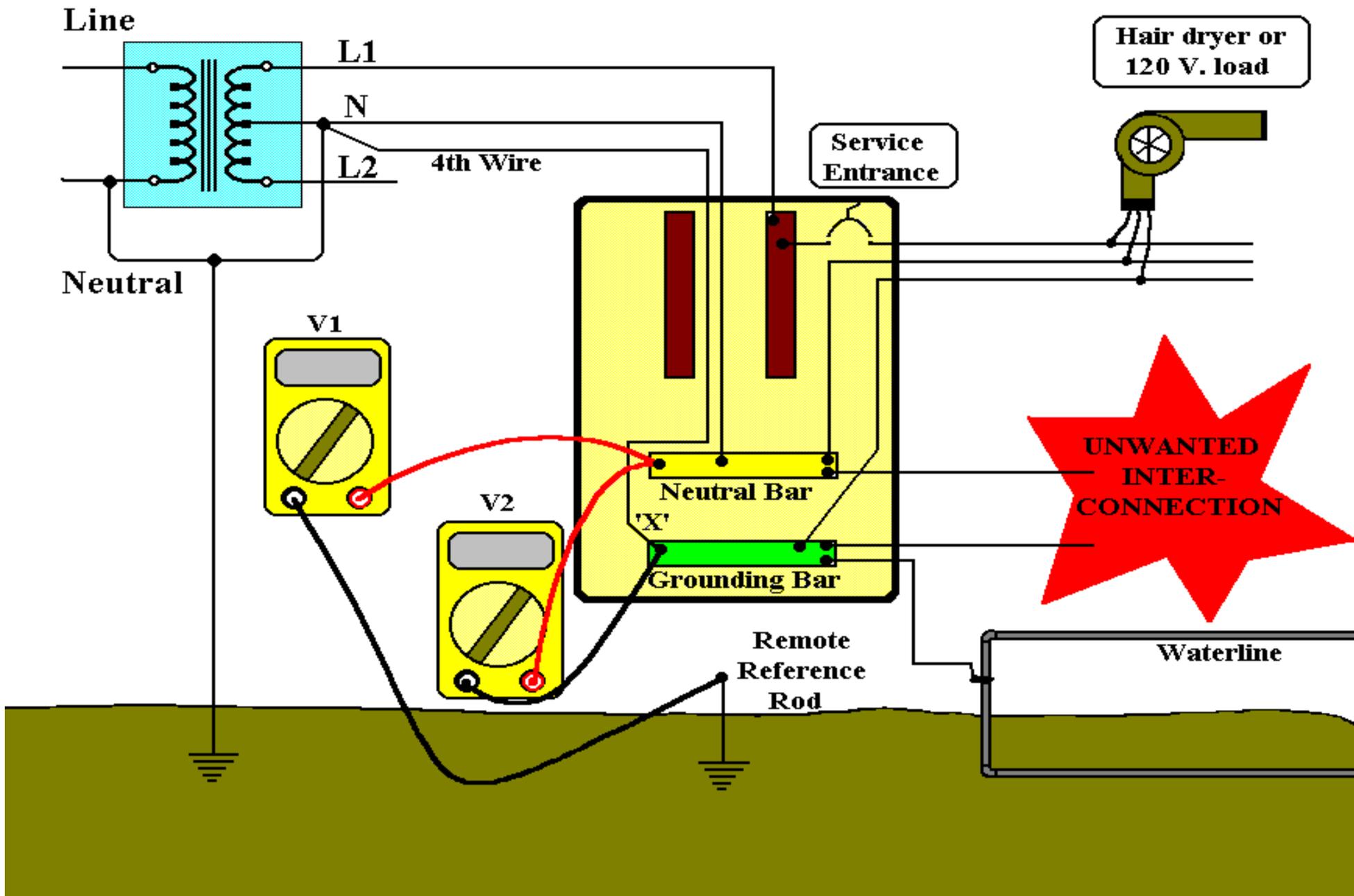
Testing Four-wire Systems

- 1. Remove all loads from the service equipment.
- 2. Connect two meters, each one to the neutral bar (v1&v2).
- 3. On one meter connect the second lead to a remote reference rod (v1).
- 4. On the second meter connect the second lead to the grounding bar (v2).



Testing Four-wire Systems

- Evaluate the separation of the grounded (neutral) and Grounding (fourth-wire) conductors by the following analyses:



Four-wire System Test

- A. If v_1 is much greater than v_2 there is an unwanted interconnection between the neutral and grounding wires. v_2 will be near zero if grounded and grounding conductors are connected.

Four-wire System Test

- B. Remove one outgoing grounding wire at a time until v_1 and v_2 read essentially the same.
- C. Find and separate the identified grounding wire/neutral interconnection.
- D. Continue to remove other grounding wires one at a time from the grounding buss to verify test results.

Final comments:

- Understand that every farm wiring system creates NEV.
- Never assume that the four-wire system is installed correctly.
- V_p is a combination of many sources.
- V_p s must be monitored to understand the source voltage on the farm.
- Secondary neutral voltage drop testing must be conducted properly.
- Primary changes alter source voltages on the farm.
- Eliminate interconnection.

QUESTIONS ?



•Not a proper four-wire