

# Neutral Isolators for Stray Voltage Mitigation

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# Stray Voltage

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- Normally refers to the neutral-to-earth voltage (NEV) that can exist in a dairy facility
- Some or all of this voltage can also exist between:
  - Metallic structures and ground
  - Cow contact points and ground
  - Between cow contact points

# Stray Voltage Sources

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- On Farm
- Off Farm

# Typical “On Farm” Sources

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- Unbalanced 120V loads
- Insulation leakage in electrical equipment
- Improper wiring
- Cow trainers, electric fences, etc.
- Switching large electrical loads
- High resistance grounds

# Typical “Off Farm” Sources

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- Primary neutral-to-earth voltage caused by:
  - Under sized neutrals
  - High resistance neutral connections
  - High resistance neutral grounds

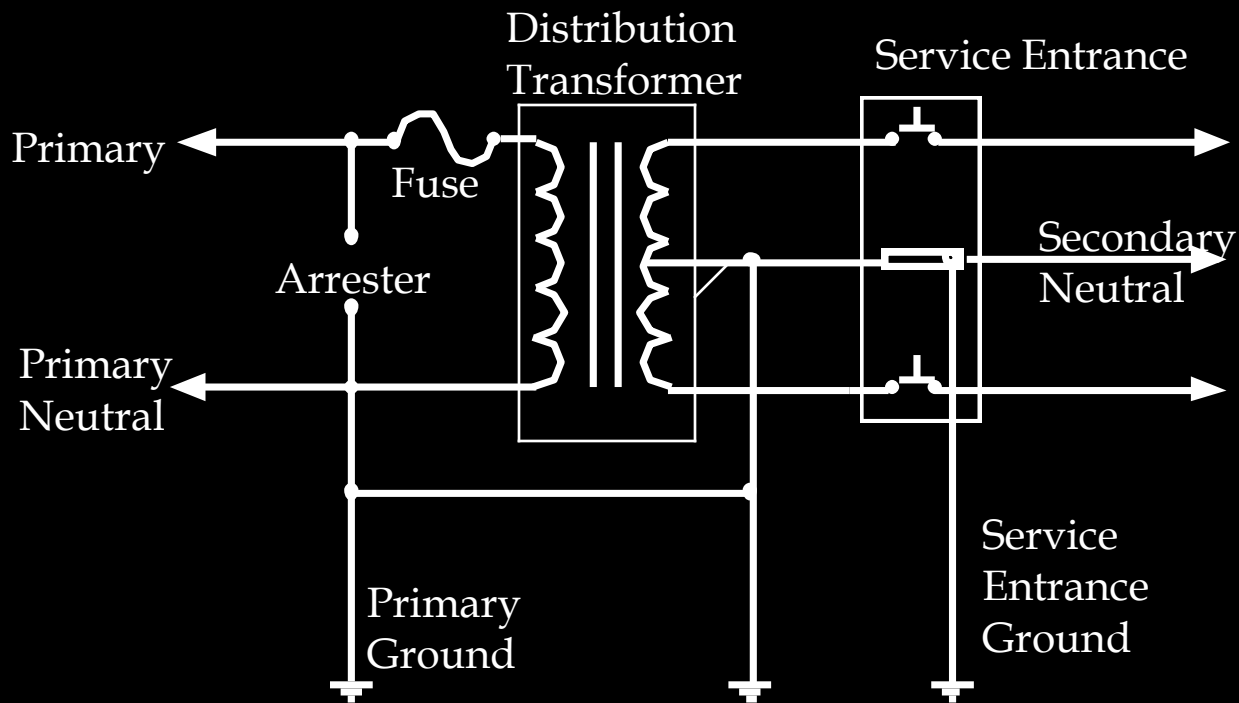
# Off Farm Neutral-To-Earth Voltage

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- Contributes to On-farm neutral-to-earth voltage
- Should be minimized (mitigated) when necessary

# Typical Single-Phase Transformer Installation

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# 1982 - 1984

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- 1982 – Initial recognition by DEI that off-farm source of NEV must be mitigated (Wis. Pub. Service)
- Neutral Isolator concept proposed to WPS
  - Initial ac fault tests conducted on WPS system
- Initial NIs then built and evaluated in a hi-power test lab
  - With support from WPS, WPL(Alliant), and NSP(XCEL)
- NI first introduced March 1983
- 1984 edition of NESC added Section 97D2 allowing isolation



# Functions of a Neutral Isolator

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- Minimize the power utility contribution to on-farm stray voltage
- While retaining the safety aspects of solidly connected primary-to-secondary neutrals

# Functions of a Neutral Isolator-cont.

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- Under “Normal” conditions, primary and secondary neutrals are isolated
- Under “Abnormal” conditions, primary and secondary neutrals are re-connected
  - Abnormal condition: Any condition that causes the voltage across the isolator to exceed a predetermined threshold (e.g. AC fault, lightning)

# Neutral Isolator

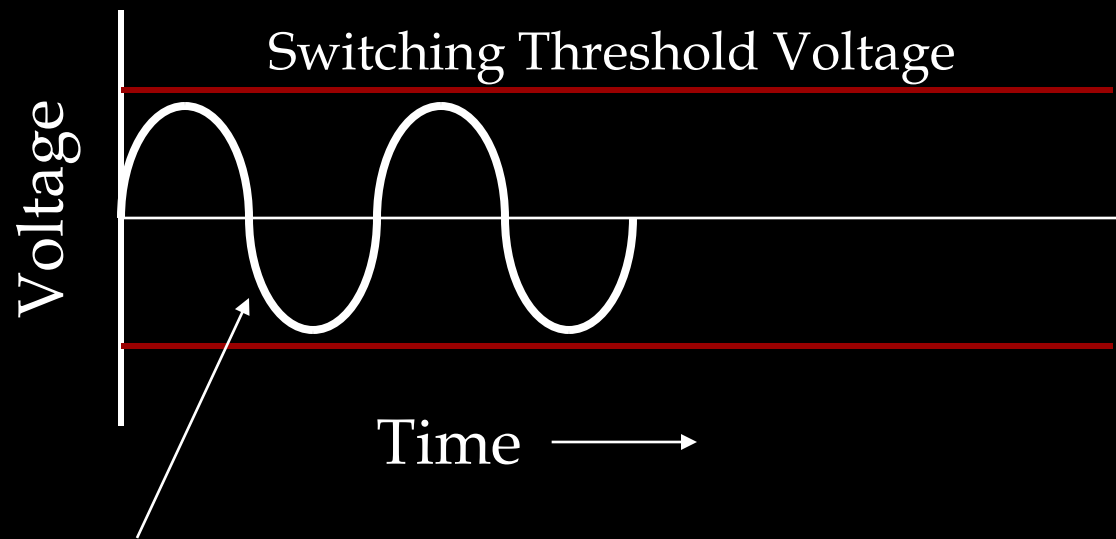
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- A voltage triggered switch
- If “V” < switching threshold,
  - Switch open, neutrals isolated, no current flow
- If “V” > switching threshold,
  - Switch closed, neutrals connected, current flows
- Threshold voltage: 36Vp (25Vrms) initially, since 1996, 45 Vp (32 Vrms)

# Neutral Isolator Operation

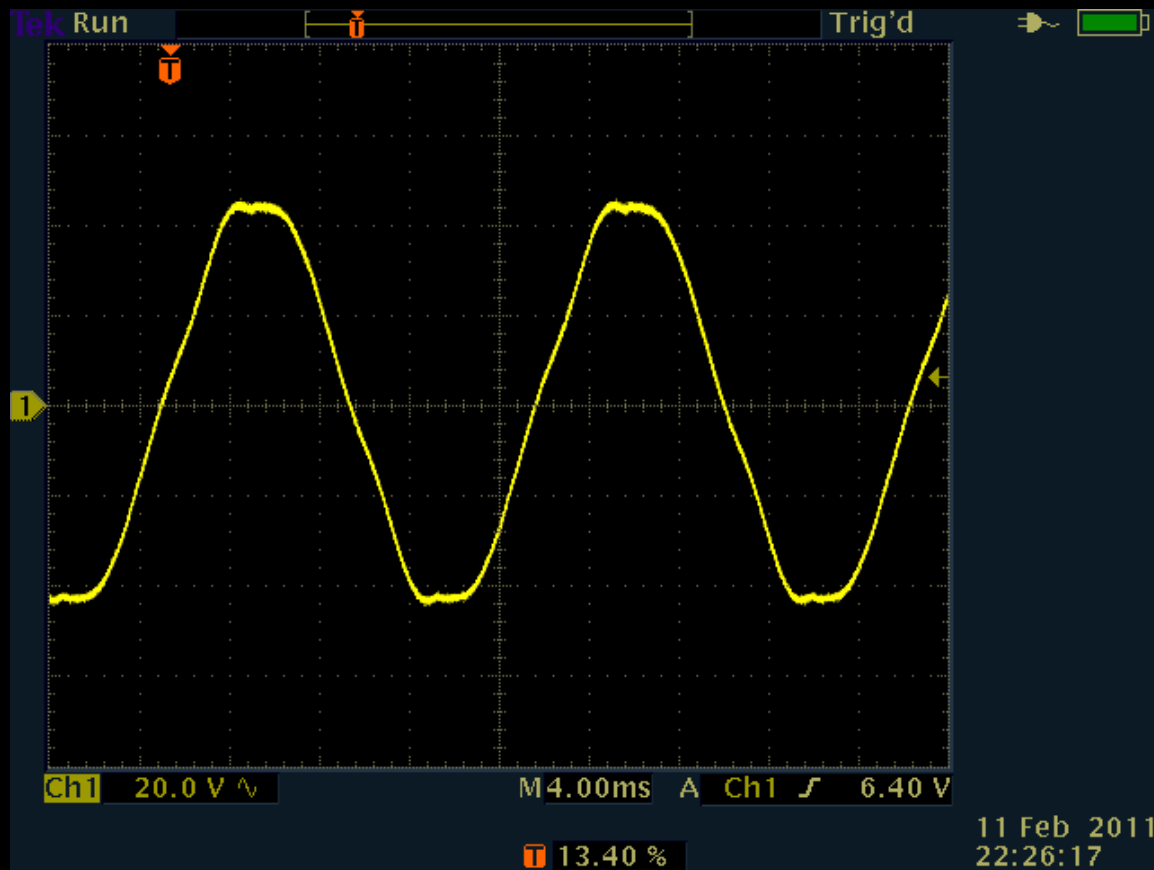
## Voltage < Switching Threshold

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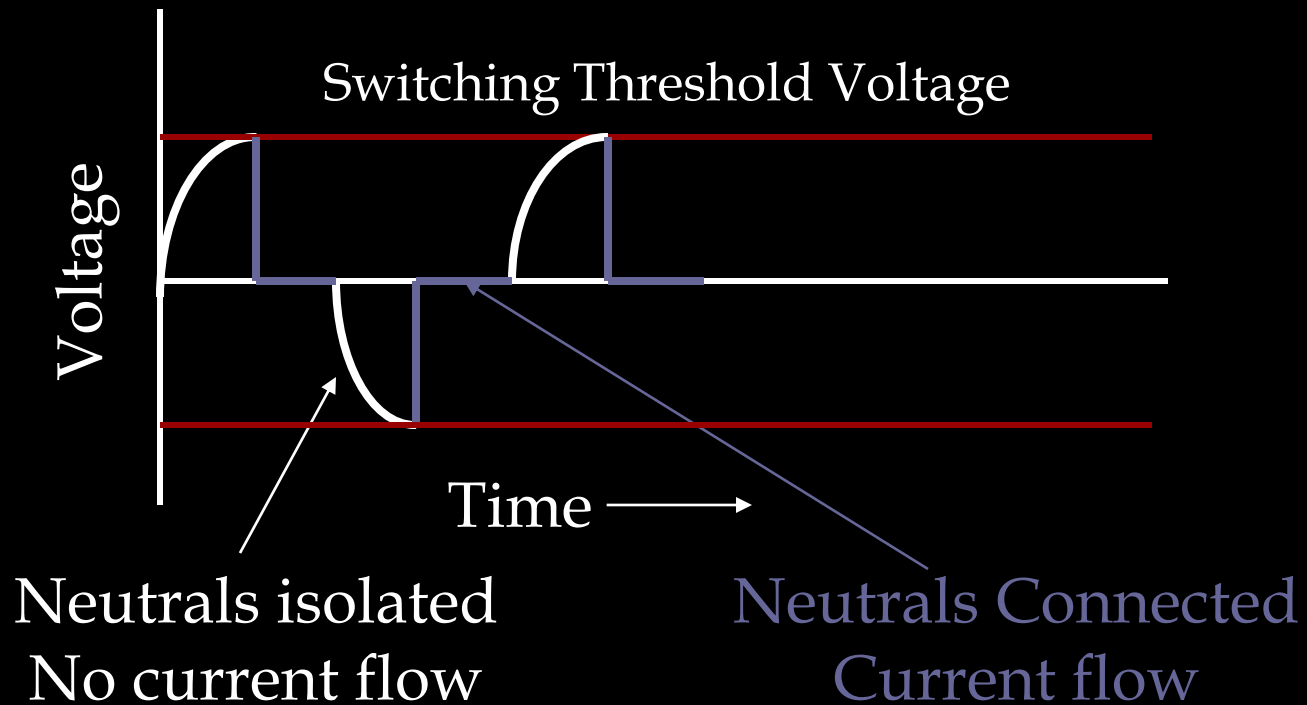
- Neutrals isolated at all times
- No current flow

# Neutral Isolator Operation Voltage < Switching Threshold

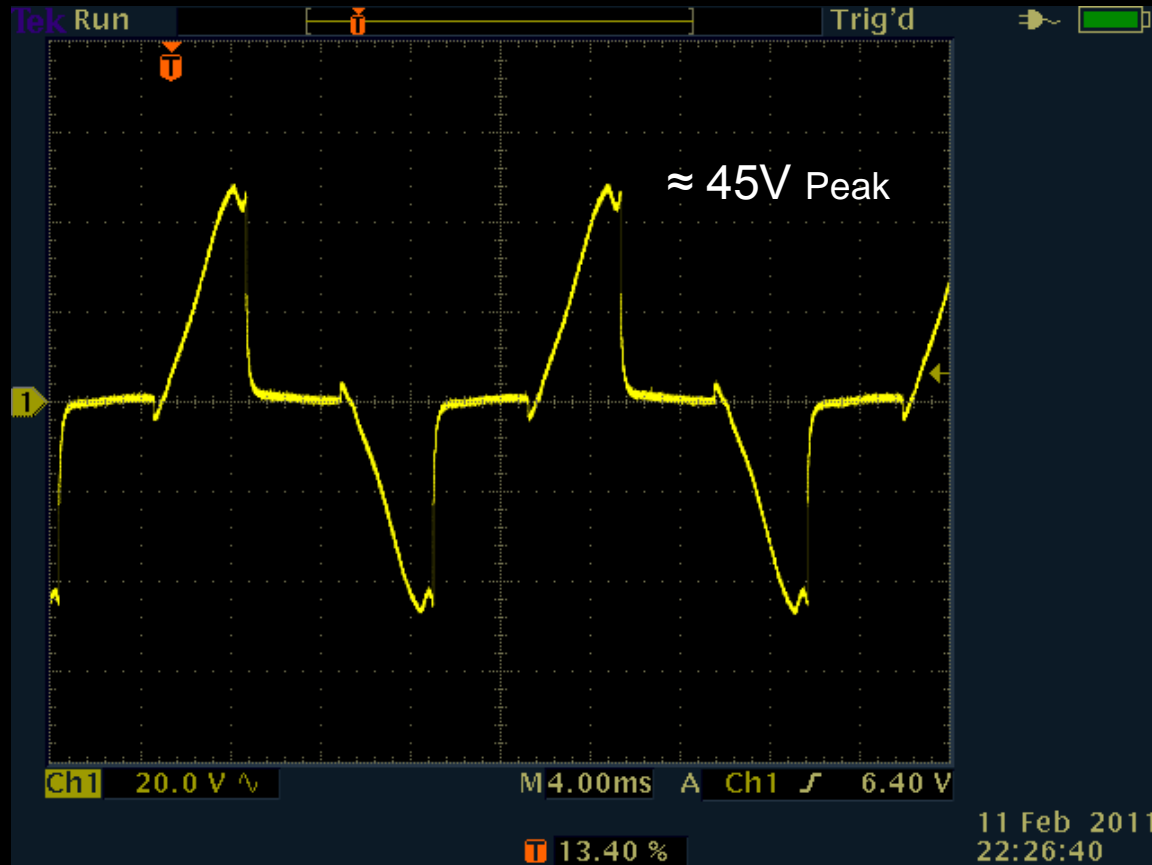


# Neutral Isolator Operation Voltage at Switching Threshold

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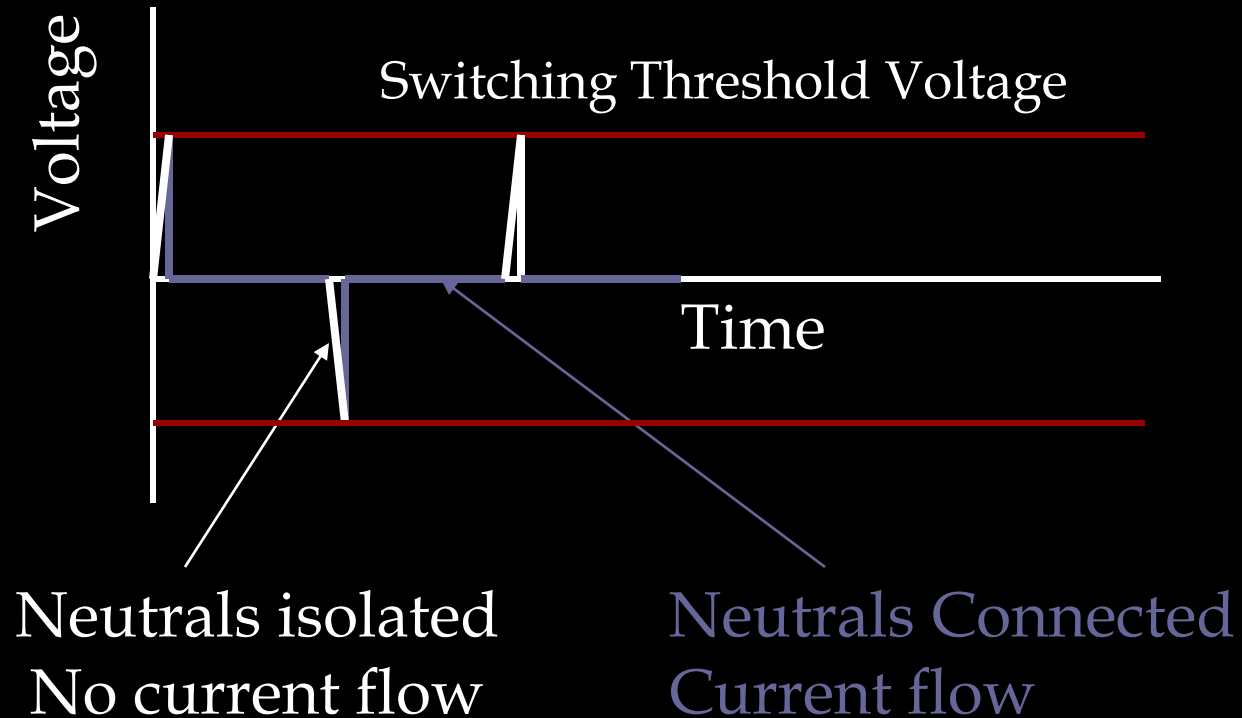
# Neutral Isolator Operation Voltage at Switching Threshold



# Neutral Isolator Operation

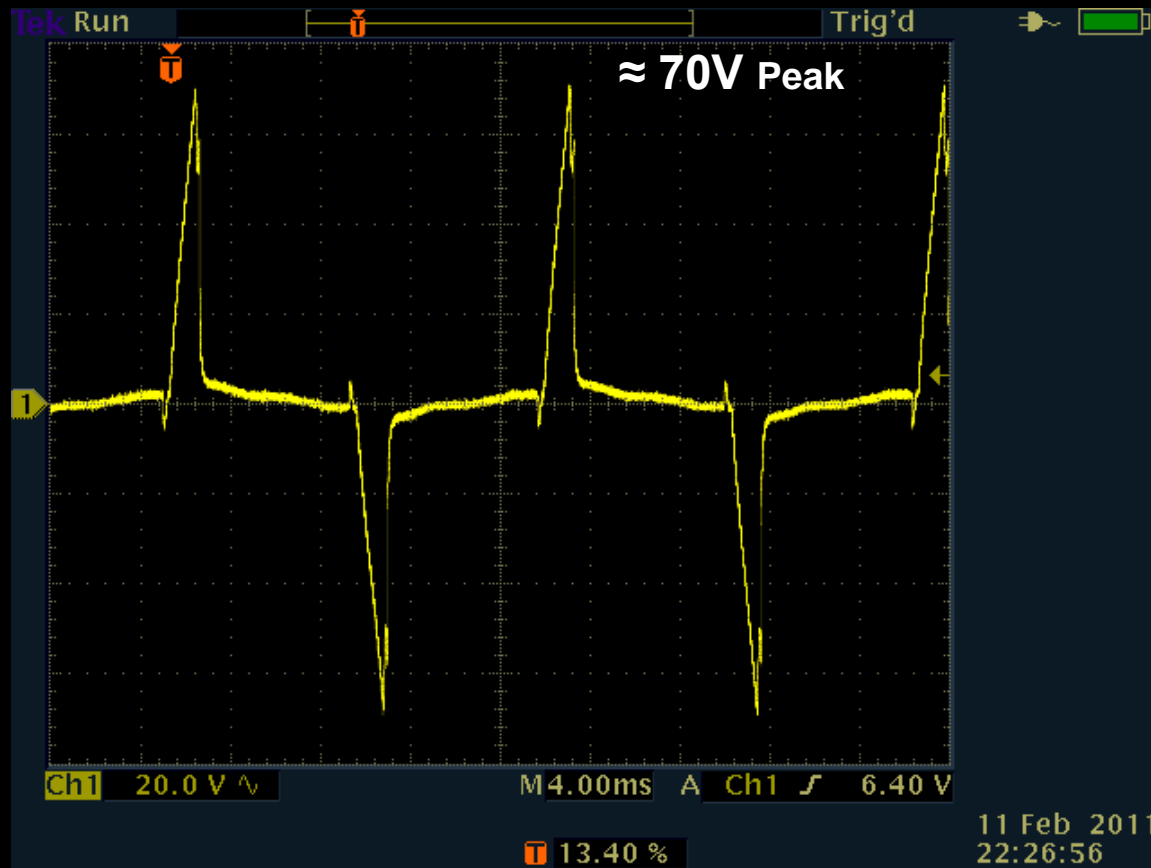
## Voltage $>$ Switching Threshold

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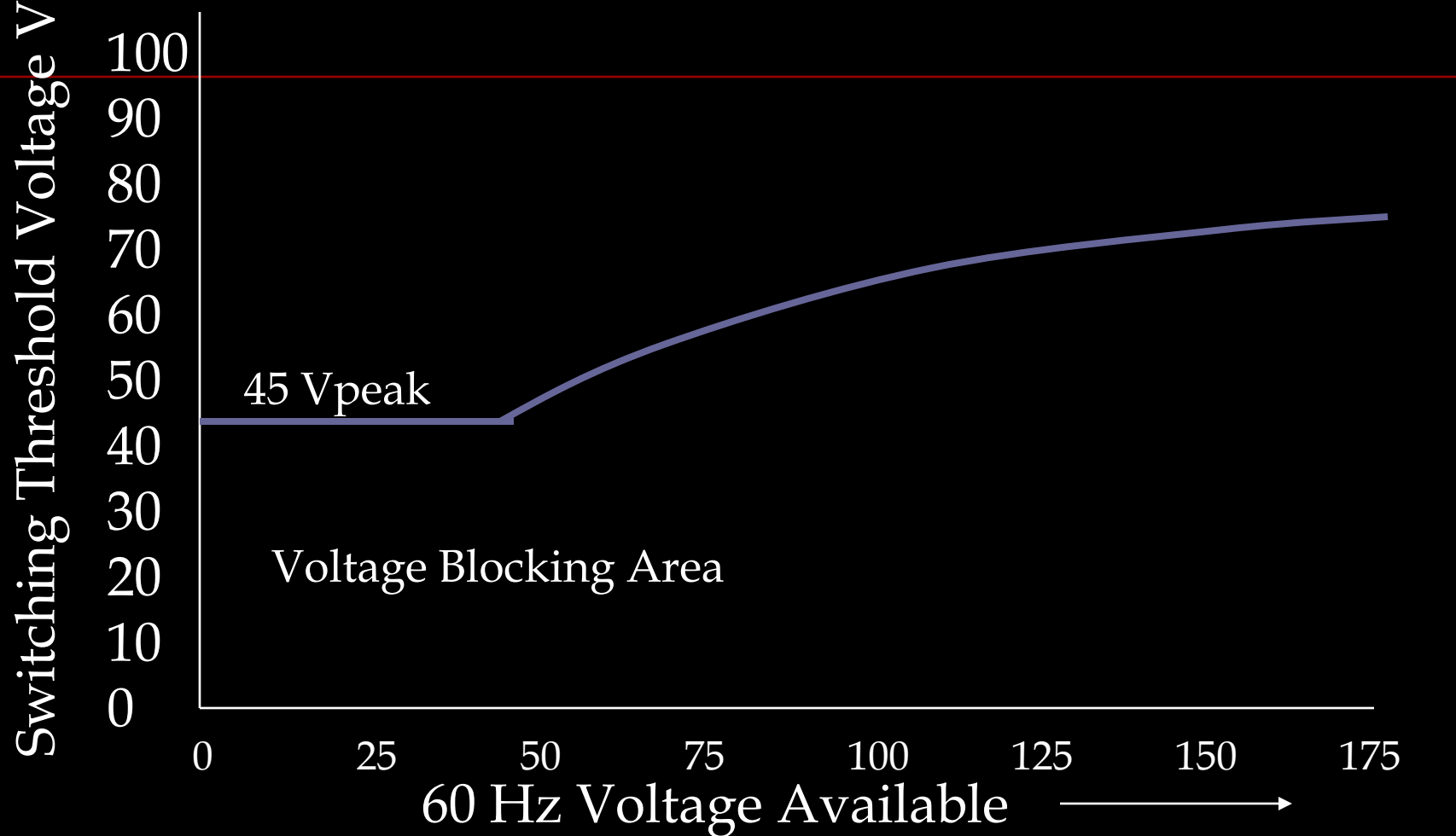




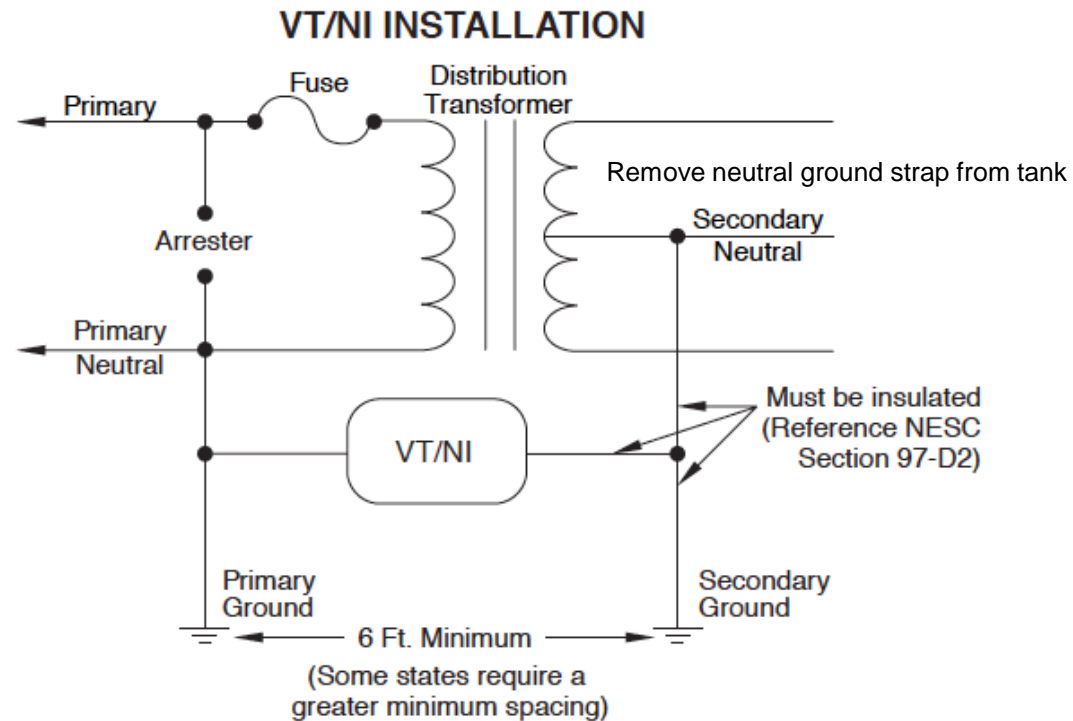
# Neutral Isolator Operation Voltage > Switching Threshold



# VT/NI Switching Threshold 60 Hz Conditions



# Primary-to-Secondary Isolation



Note: Remove bond between secondary neutral and transformer tank.

# Typical Installation

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# 1996

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- Major review by Wis. PSC
- Acceptable stray voltage criteria reviewed
- Some groups wanted an isolating device with a 300 V threshold to block transients
- Utilities and phone companies objected – safety?
- Compromise: A variable threshold isolator
- VT/NI Introduced in late 1996

# Wis. Stray Voltage Criteria

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- 2 ma limit between cow contact points\*
- 1 ma allocated to on-farm sources
- 1 ma allocated to off-farm sources
- Off-farm limit must be met independent of on-farm contribution

\* Limit based on 500 Ohm cow ( $2 \text{ ma} = 1 \text{ volt}$ )

# Wis. Stray Voltage Criteria

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- If utility cannot meet 1 ma criteria:
  - A neutral isolator can be installed for 90 days to address the problem
  - A PCS waiver is required for more than 90 days
- If a utility meets 1 ma criteria:
  - Farmer can request an isolator at his expense and leave it installed, but only if farm wiring meets code

# VT/NI Ratings

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## ■ AC Fault Current

- 3200A @ 1 cycle
- 2400A @ 3 cycles
- 1900A @ 10 cycles
- 1700A @ 30 cycles

## ■ Lightning Current

- 30kA crest (8x20 waveform)



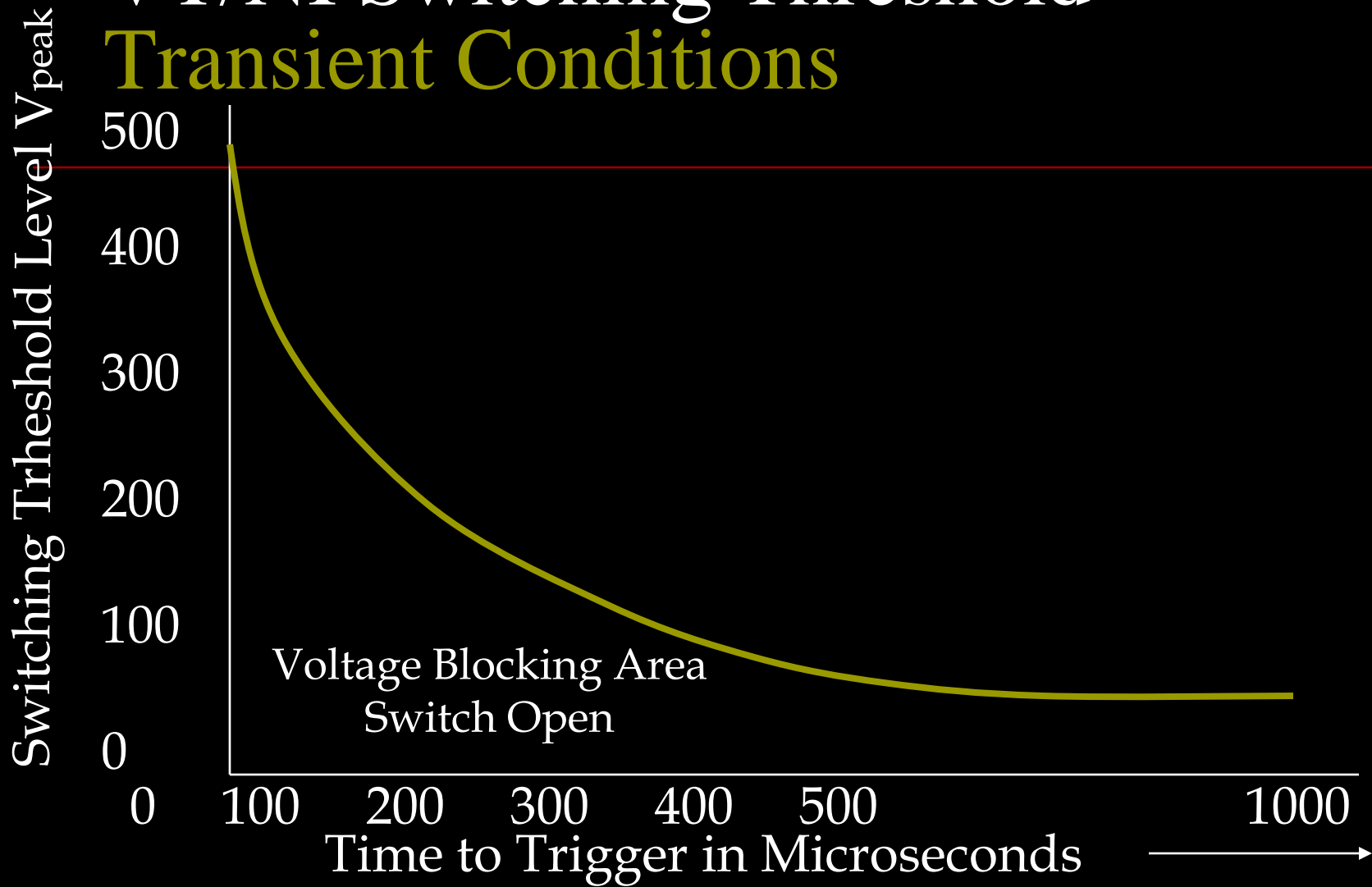
# VT/NI Ratings

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- Distribution Voltage – 15kV, 25kV, 35kV
- Response Time: 1-2 microseconds
- Failure Mode: Shorted
- Switching Threshold Voltage: See Graphs
- Typical AC impedence when “V” below switching threshold, > 2 Megohm

# VT/NI Switching Threshold

## Transient Conditions



# Switching Threshold-Original NI

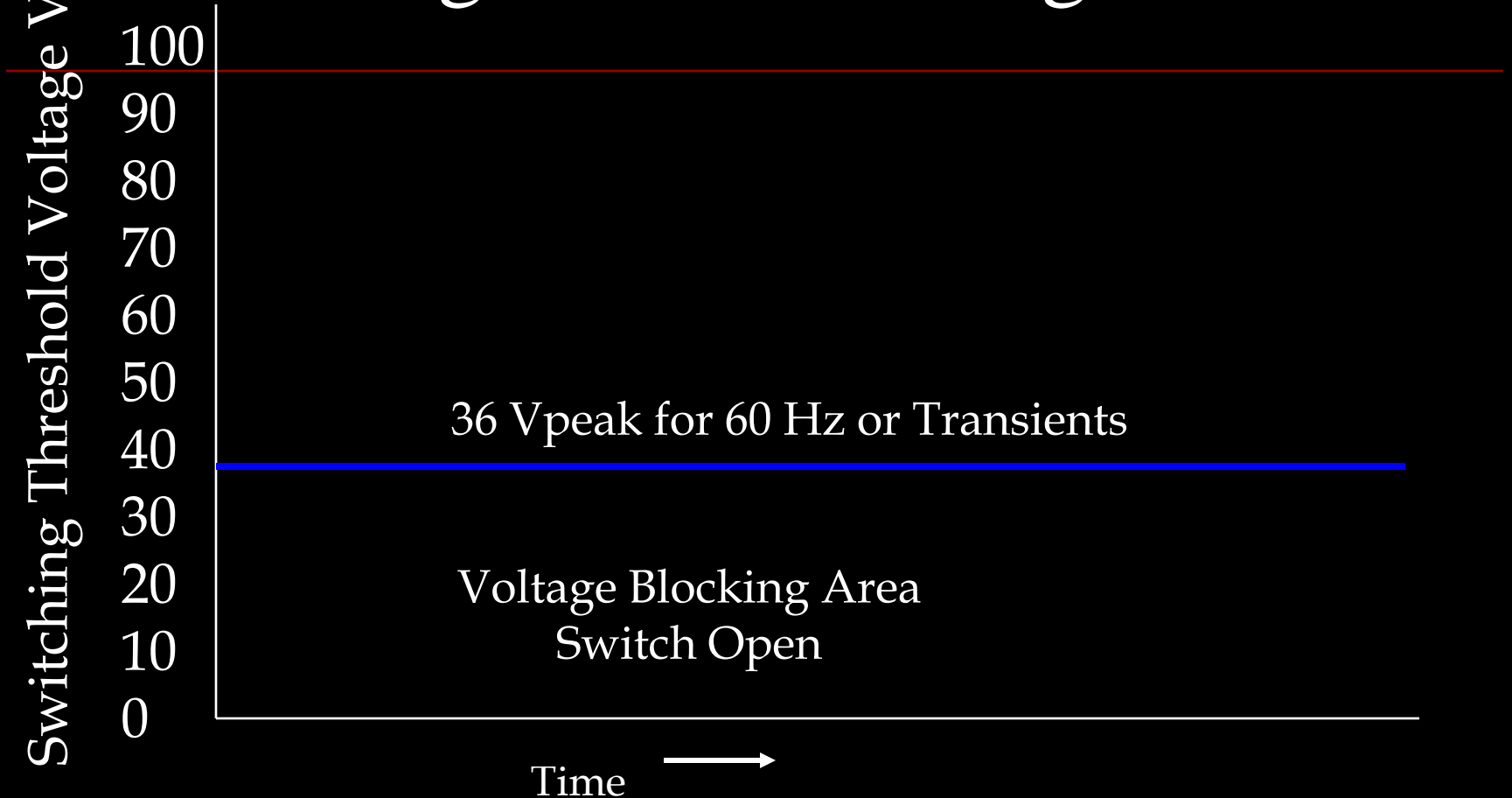
Switching Threshold Voltage  $V_{Peak}$

100  
90  
80  
70  
60  
50  
40  
30  
20  
10  
0

36  $V_{peak}$  for 60 Hz or Transients

Voltage Blocking Area  
Switch Open

Time



# Jan. 1, 2009 Design Change

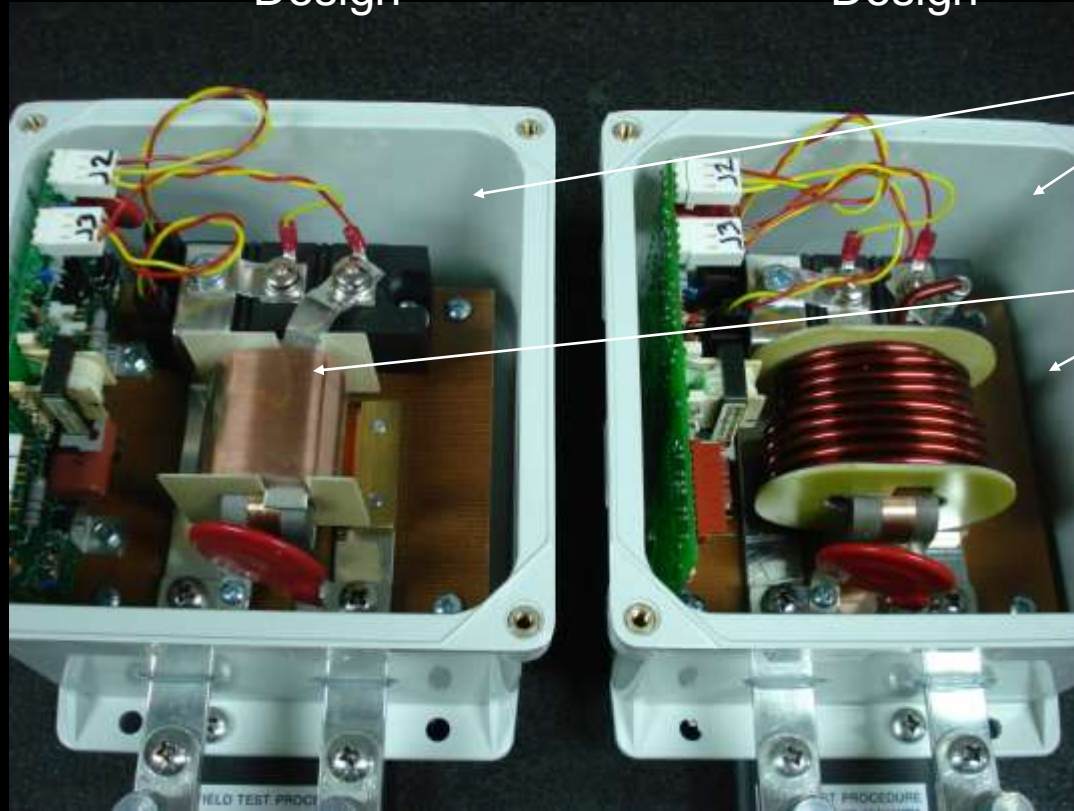
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- New thyristor with higher di/dt rating
- New inductor (higher  $\mu\text{H}$  value to reduce di/dt seen by thyristor)
  - Above changes made to improve immunity to lightning caused failures
- New visual identification to highlight change

# Internal Change

Prior  
Design

Revised  
Design



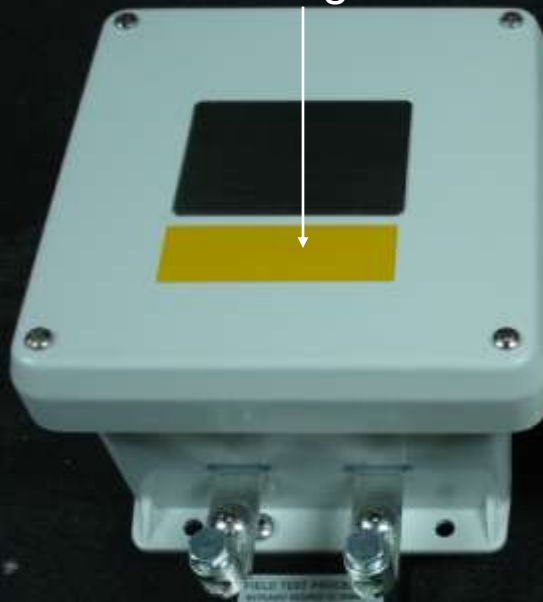
Thyristor

Inductor

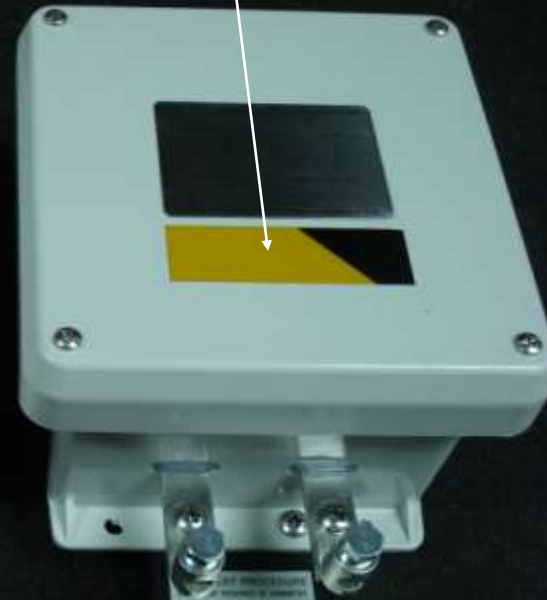
# External Visual Change

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Prior Design



Revised Design



# Field Testing Procedure

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- Isolate one terminal from circuit
- Measure resistance between terminals
- If  $R \gg 5,000$  Ohms, unit O.K. (R typically several hundred thousand ohms or higher)

# Summary

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- Neutral Isolators first introduced in 1983
- For power utilities for farm application only
- Intended to be installed until utility can correct the problem by other means
  - Often left installed upon user request
- Never intended or sold for other uses (e.g. shocks by swimming pools, hot tubs, etc.)



# References

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- PCS of Wis.
  - Report on Dairyland Isolator Device, May 20, 1998
  - Findings of fact, conclusion of law, and order, July 16, 1996
- DEI brochure on Variable Threshold Neutral Isolator

# Dairyland Electrical Industries

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