Overview Of Isolation Methods

Isolation Methods Using Smart Decouplers

- Decouplers are products that:
  - Selectively provide isolation or continuity between two points in accordance with a set of rules
  - May distinguish between ac and dc, a requirement for many applications
- Rules may be based on voltage and/or current or other parameters

Where Are Smart Decouplers Used?

- Power utility customers serving:
  - Farms, residential
  - The “corrosion industry” (gas/oil/chemical pipelines and associated stations/equipment, refineries, etc.)
  - Marinas
- Within a power utility:
  - DC isolation and ac grounding of underground transmission cable sheaths (pipe-type, lead jacketed, submarine)
  - To keep dc current out of transformers
  - To replace “arc gaps” when transmission cable sheaths are single-point grounded to prevent circulating currents

Common Smart Decouplers Characteristics

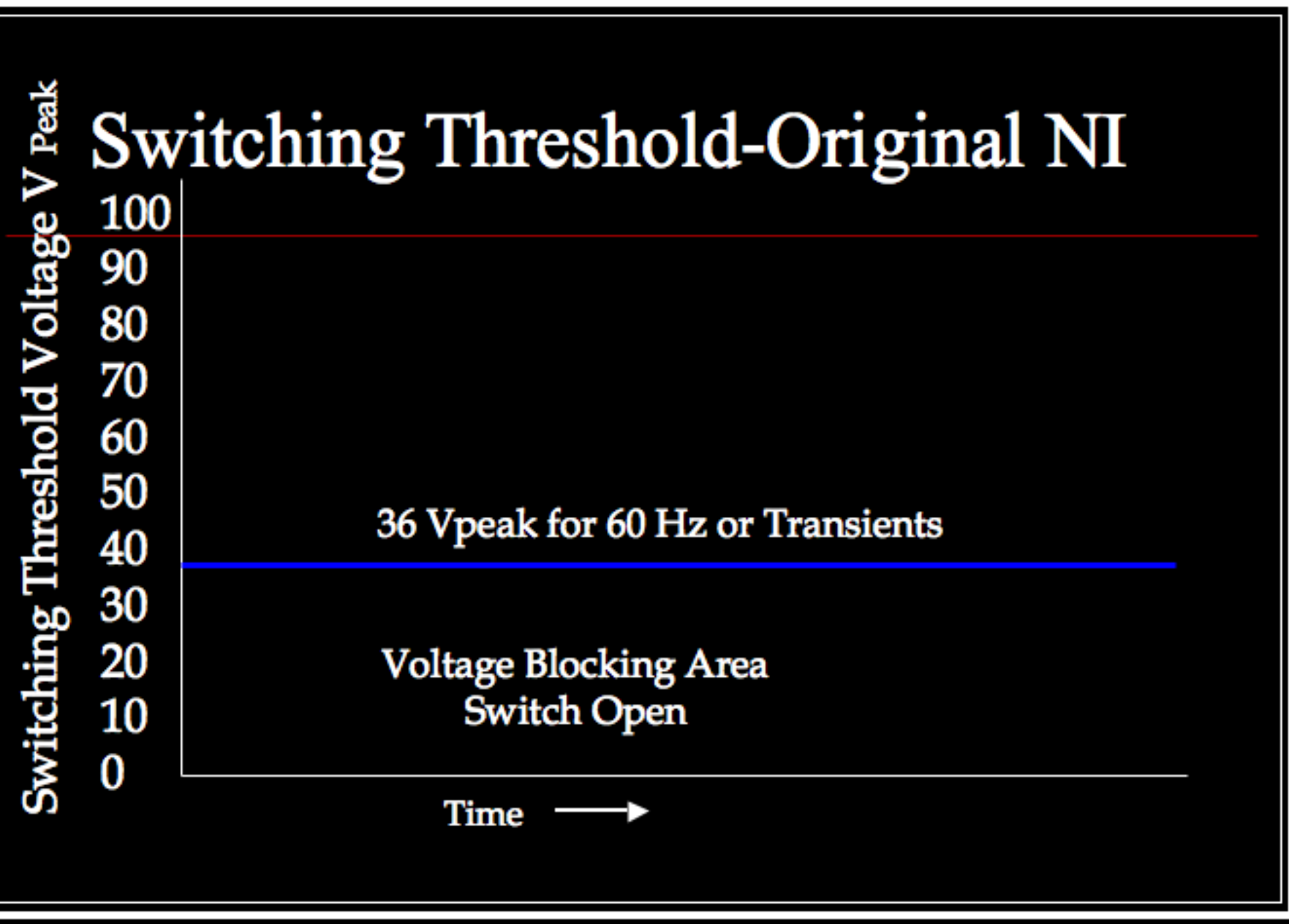
- Type 1
  - If Vac+Vdc <$V_{Threshold}$, Open circuit to ac and dc,
  - If Vac+Vdc >$V_{Threshold}$, Short circuit to ac and dc
- Type 2
  - If Vac+Vdc <$V_{Threshold}$, Open circuit to dc, short circuit to ac.
  - If Vac+Vdc >$V_{Threshold}$, Short circuit to ac and dc
- Type 3
  - If Vac+Vdc <$V_{Threshold}$ AND Iac < $I_{Threshold}$, Open circuit to dc, short circuit to ac.
  - If Vac+Vdc >$V_{Threshold}$ OR Iac > $I_{Threshold}$, Short circuit to ac and dc.

Type 1 Decoupler: Characteristics/Common Names

- Characteristics
  - If Vac+Vdc $<V_{Threshold}$, Open circuit to ac and dc,
  - If Vac+Vdc $>V_{Threshold}$, Short circuit to ac and dc
- Common names
  - Neutral Isolators: $V_{Threshold}$ = 45 V_{Peak} @60 Hz, Higher for transients with high di/dt
  - Over-Voltage Protectors: $V_{Threshold}$ = 2 to 3 V_{Peak} typical
  - Ring Gap Alternative
  - DC Blocking Device

Type 1: Neutral Isolator

- $V_{Threshold}$ = 45 V_{Peak} @ 60 Hz typical
- Used to minimizes on-farm voltage from voltage on a power utility primary neutral
- Provides an open circuit between primary and secondary neutrals in normal operation
- Reconnects primary and secondary neutrals in event of a primary to secondary transformer fault or other transient event (e.g. lightning)
- May have a fixed or variable $V_{Threshold}$


Switching Threshold-Original NI
Switching Threshold Voltage V Peak
100
90
80
70
60
50
40
30
20
10
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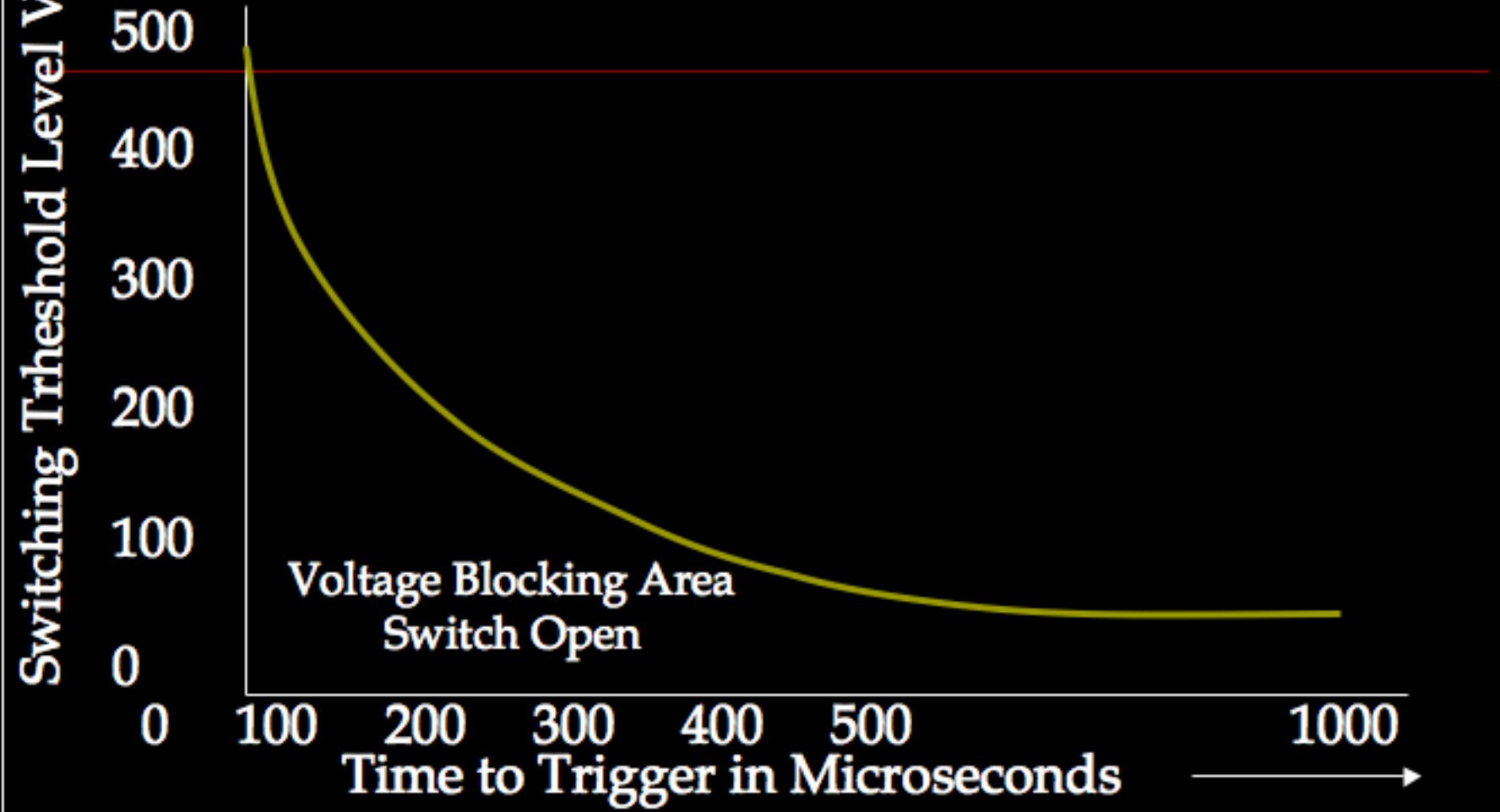
36 Vpeak for 60 Hz or Transients
Voltage Blocking Area
Switch Open
Time

VT/NI Switching Threshold

Transient Conditions



Type 1: Neutral Isolator

- Typical installation
- Detailed presentation on neutral isolators presented in separate break-out sessions

Type 1: Over-Voltage Protector

- $V_{Threshold}$ = 2 to 3 V_{Peak} typical
- Commonly used for over-voltage protection of insulated joints in cathodically protected pipelines
  - Insulated joints are used to separate pipeline into segments for cathodic protection
  - Used to prevent insulation failure and arcing that could cause an explosion if a combustible gas present or short out the CP system
- Must be certified for use in hazardous locations for most applications, Class I, Div. 1 or Div. 2
- Designed to limit voltage to very low levels (less than ≈ $5V_{Peak}$ for ac faults, < $150V_{Peak}$ for lightning

Type 1
Over-Voltage Protection Applications

- OVP, Class I, Div. 2 Explosion proof enclosure required
- OVP2, Class I, Div. 2 Not explosion proof, sealed & non-arcing
- Used only where no ac voltage is present under normal operating conditions

Type 1
Over-Voltage Protection Applications

- Protection of insulated joints in airport refueling systems. Installed in below grade vaults.

Type 1 Ring Gap Alternative

- $V_{Threshold}$ 750V typical
- Iac Fault Rating: 30kA for 30 cycles typical
- Used to replace arcing type ring gaps when single-point grounding underground transmission cable sheaths
- Used to limit sheath voltage rise at open point
- Single-point grounding is used to increase cable ampacity by eliminating heating caused by circulating sheath currents if sheath is grounded at both ends
- Unit may include built-in diagnostics

Type 1 Ring Gap Alternative

Type 1 Ring Gap Alternative

Type 1: To Prevent DC Current From Distribution Transformer Windings

- Stray DC current in transformers windings can saturate the core, cause heating, and cause harmonics that can affect a user's electrical equipment
- DC source may be:
  - Ground return current from an HVDC system operating in mono-polar mode
  - From an impressed current cathodic protection system

Type 1: To Prevent DC Current From Distribution Transformer Windings

- Solution: Install a DC Blocking Device
  - Rated for transformer primary current
  - VThreshold must be greater then max. dc voltage expected
  - For one recent application:
    - $V_{Threshold}$ = 25VPeak
    - Iac Cont. = 30A
    - Iac Fault = 5kA @ 30 cycles
    - $I_{Lightning}$ = 30kA Peak
    - Device presently being evaluated

Type 2 Decoupler: Characteristics/Common Names

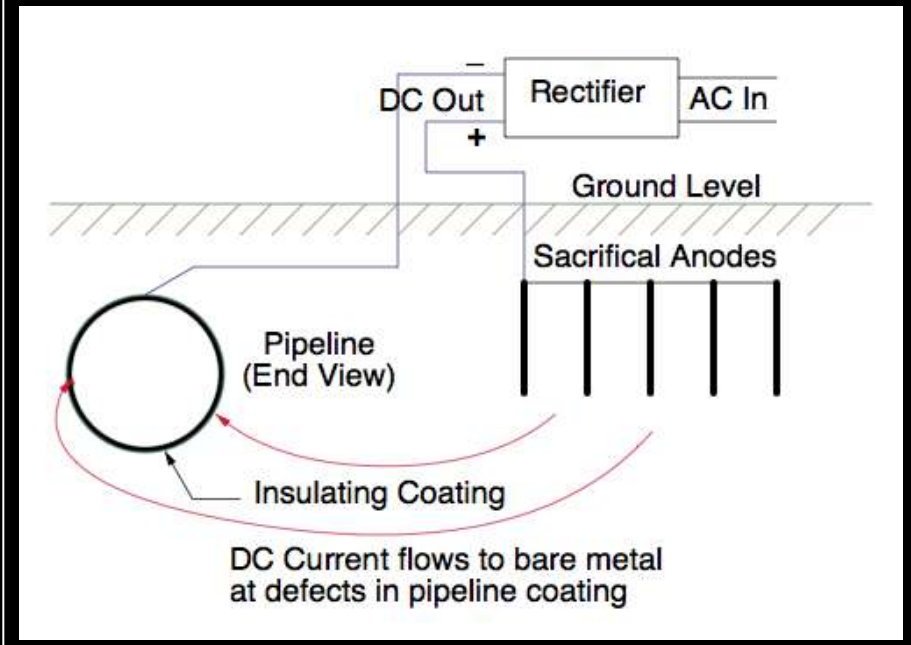
- Characteristics
  - If Vac+Vdc <$V_{Threshold}$, Open circuit to dc, short circuit to ac.
  - If Vac+Vdc >$V_{Threshold}$, Short circuit to ac and dc
- Common names
  - Polarization Cell Replacement (PCR)
  - Solid-State Decoupler (SSD)
  - Galvanic Isolator (GI)
- The most widely used decoupler

Type 2: Where Used

- Primarily used in corrosion protection applications
- Used where ac continuity and/or ac grounding is required while preventing the flow of dc current
- Many applications:
  - Require certification for use in the grounding path of electrical equipment (NEC Sec. 250)
  - Require a hazardous location listing

Corrosion Protection Basics

- Typical impressed current CP system



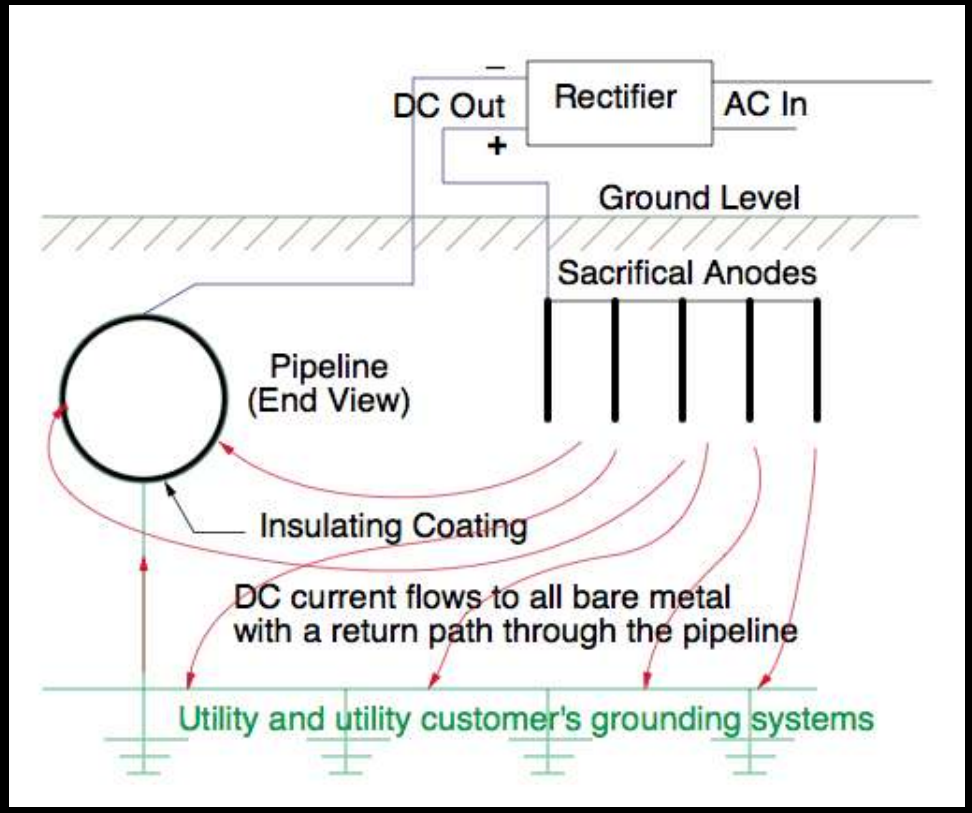
Corrosion Protection Basics

- Most pipelines are well coated (insulated)
- When isolated from electrical grounding systems, minimal dc current protects many miles of pipeline
- Pipelines with CP have electrical equipment (e.g. motor operated valves, monitoring systems, etc.)
- Electrical equipment must be grounded per NEC
- Grounding system is bare copper

Corrosion Protection Basics-cont.

- If equipment is directed bonded to a grounding system:
  - CP system tries to protect grounding system
  - CP coverage area is reduced
  - CP current demand is increased
  - Required CP on pipeline is often not achievable

Corrosion Protection Basics-cont.



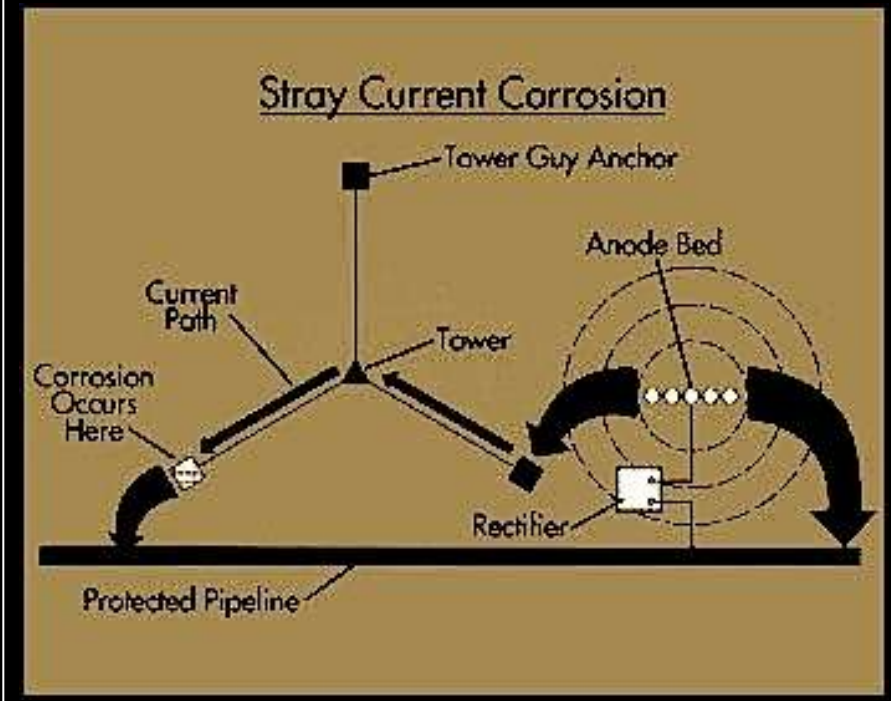
Old Solution When Cathodically Protected Pipelines Were Grounded

- Install more and larger rectifiers and anode beds
  - To brute force required CP levels
  - With significantly increased dc current
  - High dc current can contribute to dc current/voltage on users secondary systems (e.g. add to stray voltage)
  - High dc current can cause corrosion issues for power utility
- Install an insulated joint on each side of equipment to be grounded

Problems Caused By DC Current In A Grounding System

- Corrosion occurs where dc current flows from metal into an electrolyte (e.g. earth)
- All metals have a corrosion rate per unit of dc current
  - Example: Steel corrodes at a rate of 20#/A/yr
- DC current on a utility grounding system may find a lower resistance path back to the rectifier by exiting to earth and returning via the pipeline (e.g. at guy anchors)
- Metal corrosion occurs at current exit points

Stray Current Corrosion Example



Modern Method For Grounding A Cathodically Protected Pipelines

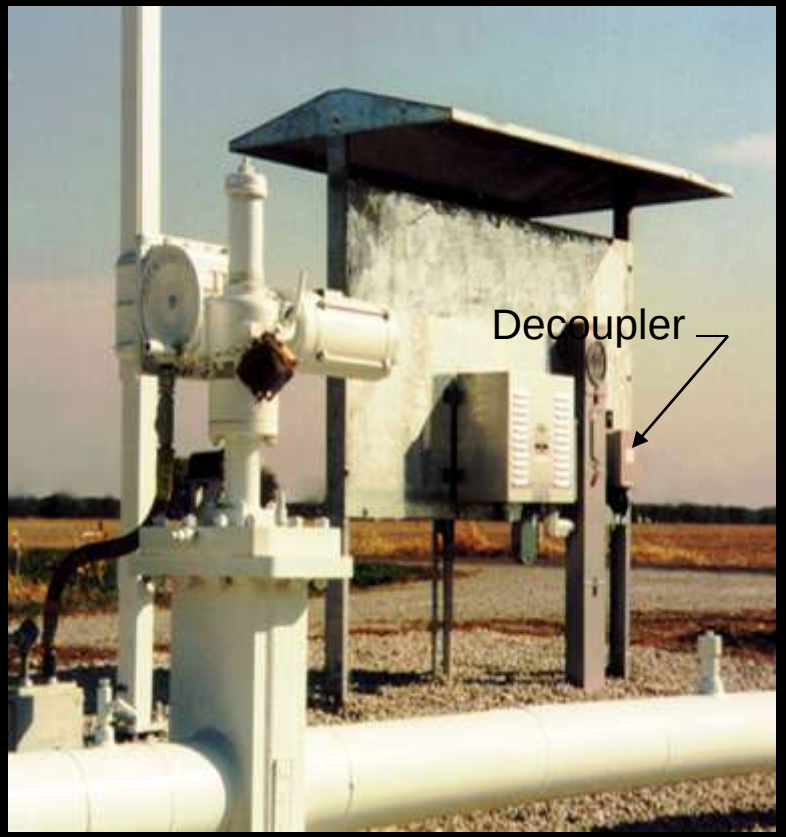
- Ground through certified decouplers
  - Complies with NEC
  - No affect on pipeline CP levels
- Most common products used:
  - PCR (Polarization Cell Replacement
  - Solid-State Decoupler (SSD)
- Typical Ratings:
  - $V_{threshold}$ = 2V to 3V
  - AC fault current: 2kA to 15kA @ 30 cycles
  - Lightning: 75kA to 100kA

Type 2:
Typical Applications

- Grounding electrical equipment integral to a CP system (e.g. motor operated valves, etc.)
- DC isolate regulator and metering stations from power utility grounding system
- Grounding pipelines to mitigate induced ac voltage to safe levels
- Provide over-voltage protection from lightning and ac faults where ac voltage is present

Type 2:
Motor Operated Valve Application

- Motor grounded through a decoupler
  - Provides ac grounding and dc isolation
  - Complies with NEC
  - No insulated joints required
  - Pipeline CP levels are unaffected



Type 2:
Fuel Storage Tank Application

- Tank bottom cathodically protected
  - Tank has electrical equipment
  - Requires ac grounding with dc isolation from station ground to achieve required CP levels

Type 2:
Lead Jacketed Power Cable Application

- Cable jacket;
  - Must be cathodically protected
  - Must be ac grounded without affecting CP levels
  - High fault current ratings required

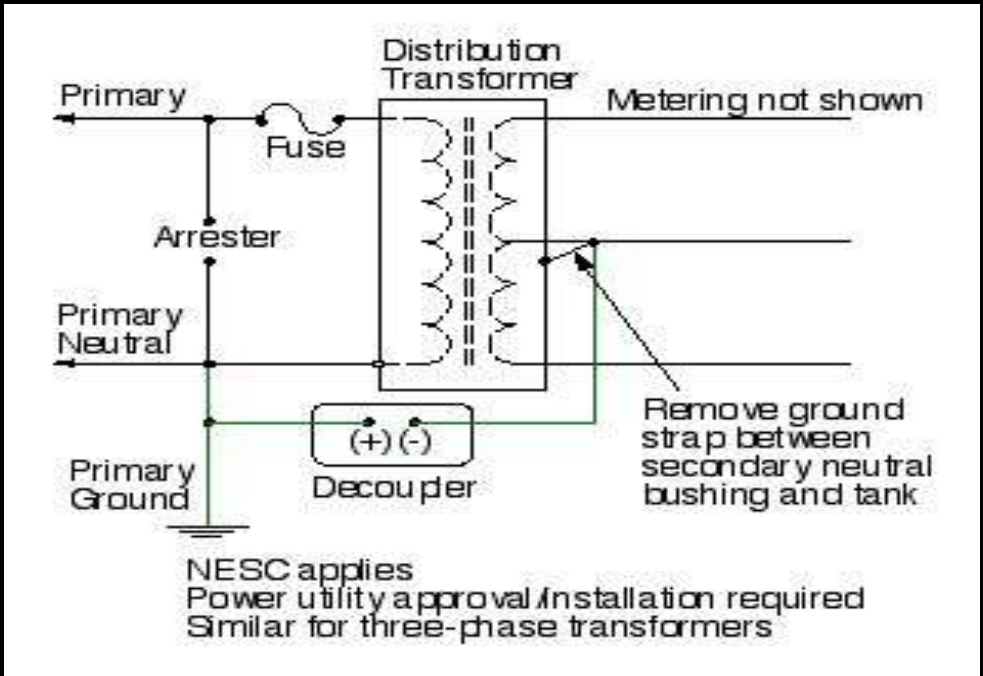
Decoupler

Type 2:
DC Isolation of Pipeline Stations:
Metering and Regulator Stations

- The user and utility grounding systems are normally bonded together
- Pipeline CP systems can usually protect their pipeline even when bonded to their station grounding system, but not when also bonded to the power utility grounding system
- Users find it highly desirable to dc isolate stations from the power utility grounding system

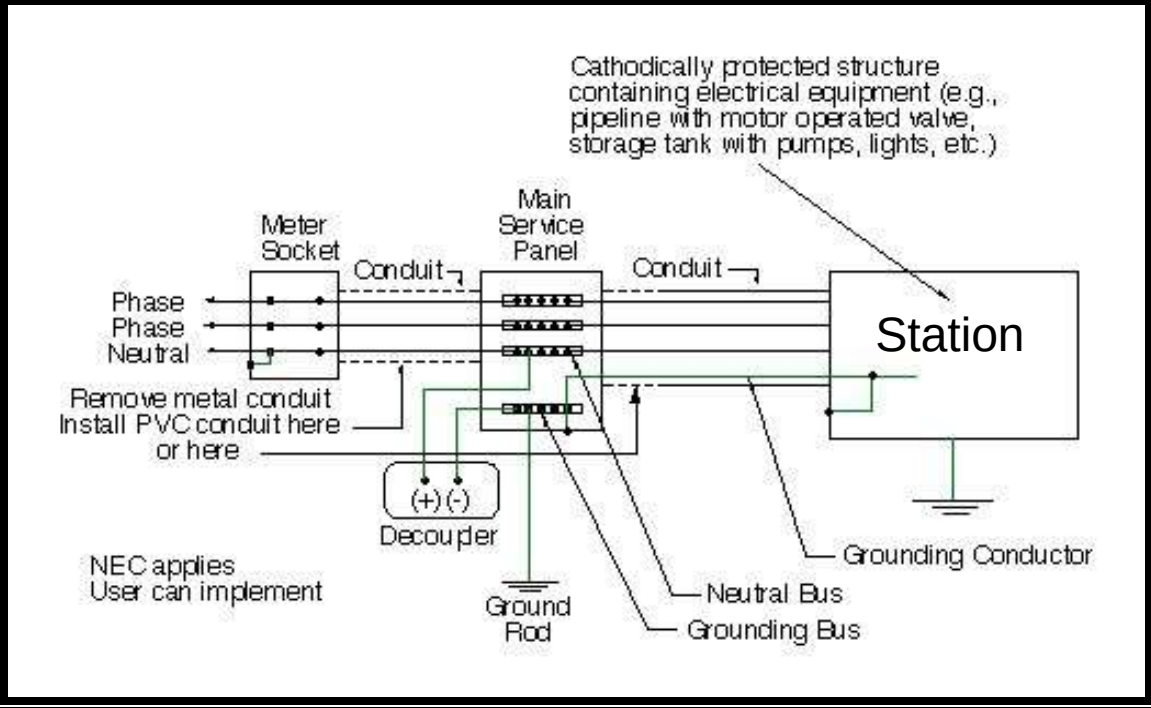
Type 2:
Station DC Isolation: Option A

- Installation identical to that of a neutral isolator
- AC continuity between grounding systems retained



Type 2:
Station DC Isolation: Option B

- Installation on secondary side of transformer
- AC continuity between grounding systems retained



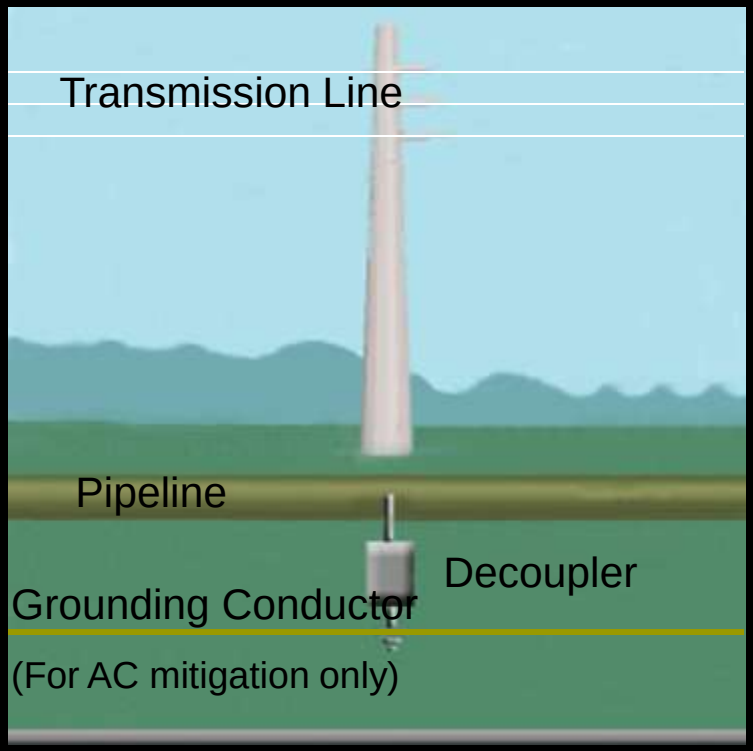
Type 2:
AC Voltage Mitigation

- New pipelines are increasingly forced into power line corridors
- New power lines are increasingly forced into pipeline corridors

Type 2:
AC Voltage Mitigation

- Pipelines in power line corridors pick up induced ac voltage (From few volts to >100V)
- Exposed pipeline voltage to earth must be ≤15V for safety (NACE SPO177-2007)
  - Often <<15V to prevent ac corrosion on buried pipelines
- AC voltage typically mitigated by bonding pipe to an isolated grounding system at intervals
  - Grounding loads voltage source, voltage is reduced
  - Current shunted to ground: From few amps to >100A

Type 2:
AC Voltage Mitigation



Type 2:
Typical Decouplers For AC Voltage Mitigation

Type 2:
Typical Decouplers For AC Voltage Mitigation

Type 2: Galvanic Corrosion Prevention

- Galvanic Corrosion-Four essential elements required
  - An anode
  - A cathode
  - A conducting environment for ionic movement (electrolyte)
  - An electrical connection between the anode and cathode for the flow of electron current.
- The anode is consumed. The cathode is protected.
- A galvanic isolator is commonly used to break the dc electrical connection to prevent corrosion while complying with a required ac connection (usually an electrical code requirement)

Type 2:
A Typical Galvanic Corrosion Cell

- A boat connected to ac shore power in a marina

Type 2: To Prevent Galvanic Corrosion In Boats

- Install a galvanic isolator (GI) in series with the shore cord grounding conductor
  - Certified GIs meet ABYC A-28 Code grounding requirement
  - Galvanic corrosion of boat metals eliminated
- $V_{Threshold}$ 1 V_{Peak} typical

A Caution Regarding Marinas

- Absolutely never swim in a fresh water marina that provides ac power to boats!
- Until recently, galvanic isolators for boats were allowed by the applicable standard to fail “open circuit”
- With a failed open GI, in the event of a fault the current return path is through the water which causes a voltage gradient that can paralyze a swimmer in the water
- Numerous drowning deaths occurred in marinas before it was realized that this was the cause
- Current GIs must meet the NEC requirements (safety grounding assured even if the GI fails)

Type 3 Decouplers Typical Applications

- Characteristics
  - If $V_{ac}+V_{dc} < V_{Threshold}$ AND $I_{ac} < I_{Threshold}$, Open circuit to dc, short circuit to ac.
  - If $V_{ac}+V_{dc} > V_{Threshold}$ OR $I_{ac} > I_{Threshold}$, Short circuit to ac and dc.
- AC grounding/DC isolation of pipe-type transmission cables
- Blocking DC in large power transformers
- In above applications, a steady-state ac current limit may be reached before the voltage limit

Type 3:
Pipe-Type Transmission Cable Application

- Cable pipe must be cathodically protected
- Cable pipe must be ac grounded without affecting CP levels
- $V_{Threshold}$ typically 12.5V_{Peak} or 20V_{Peak}
  - Primarily to keep stray dc current from accessing the cable pipe, such as from dc rail systems
- $I_{Threshold}$ typically 30A, 60A, or 90A rms
- AC fault current ratings: Up tp 54kA rms @ 30 cycles
- Lightning current ratings: 50kA, 75kA

Type 3:
Pipe-Type Transmission Cable Application

Type 3:
Blocking DC In Large Power Transformers

- DC Source: Ground return current from HVDC system
  - HVDC system: 2000MW @ +/-500kV India Power Grid
- $V_{Threshold}$ = 650V_{Peak} Primary, 700V_{Peak} Back-up
- $I_{Threshold}$ = 150Arms
- Fault current rating: 40kA @10 cycles, 1 sec. delay, followed by 40kA @10 cycles, 50 Hz
- Lightning current rating: 75kA (8 x 20 µsec)

Type 3 Decoupler
Blocking DC In Large Power Transformers

- AC transformers in a DC to AC converter station

Type 3:
Blocking DC In Large Power Transformers

Typical Work Practices

Typical Work Practices

Summary

- Decouplers:
  - Can address a wide range of problems
  - Most are used in cathodically protected systems
  - Most applications require a “fail-safe” design (i.e., fail “shorted” and still meet all current ratings)
  - Can accommodate virtually any current and voltage rating required