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 \( \text{Vac} + \text{Vdc} < V_{\text{Threshold}} \), Open circuit to ac and dc,
  - If \( \text{Vac} + \text{Vdc} > V_{\text{Threshold}} \), Short circuit to ac and dc

- **Type 2**
  - If \( \text{Vac} + \text{Vdc} < V_{\text{Threshold}} \), Open circuit to dc, short circuit to ac.
  - If \( \text{Vac} + \text{Vdc} > V_{\text{Threshold}} \), Short circuit to ac and dc

- **Type 3**
  - If \( \text{Vac} + \text{Vdc} < V_{\text{Threshold}} \) AND \( \text{Iac} < I_{\text{Threshold}} \), Open circuit to dc, short circuit to ac.
  - If \( \text{Vac} + \text{Vdc} > V_{\text{Threshold}} \) OR \( \text{Iac} > I_{\text{Threshold}} \), Short circuit to ac and dc.
Type 1 Decoupler: Characteristics/Common Names

- **Characteristics**
  - If \( \text{Vac} + \text{Vdc} < V_{\text{Threshold}} \), Open circuit to ac and dc,
  - If \( \text{Vac} + \text{Vdc} > V_{\text{Threshold}} \), Short circuit to ac and dc

- **Common names**
  - Neutral Isolators: \( V_{\text{Threshold}} = 45 \text{ VPeak} @ 60 \text{ Hz} \), Higher for transients with high di/dt
  - Over-Voltage Protectors: \( V_{\text{Threshold}} = 2 \text{ to } 3 \text{ VPeak typical} \)
  - Ring Gap Alternative
  - DC Blocking Device
Type 1: Neutral Isolator

- $V_{\text{Threshold}} = 45 \ V_{\text{Peak}} @ 60 \ Hz$ typical
- Used to minimize 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 $V_{\text{Threshold}}$
Switching Threshold - Original NI

- 36 Vpeak for 60 Hz or Transients
- Voltage Blocking Area
  - Switch Open

Switching Threshold Voltage V Peak

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0

Time →
VT/NI Switching Threshold

Transient Conditions

Switching Threshold Level $V_{peak}$

Voltage Blocking Area
Switch Open

Time to Trigger in Microseconds

0

100

200

300

400

500

1000

0

100

200

300

400

500

600

700

800

900

1000
Type 1: Neutral Isolator

- Typical installation
- Detailed presentation on neutral isolators presented in separate break-out sessions
Type 1: Over-Voltage Protector

- $V_{\text{Threshold}} = 2$ to $3 \ V_{\text{Peak}}$ 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 $\approx 5V_{\text{Peak}}$ for ac faults, $< 150V_{\text{Peak}}$ 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

Arcing Type
Ring Gap

Solid-State
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
  - $V_{\text{Threshold}}$ must be greater than the max. dc voltage expected
  - For one recent application:
    - $V_{\text{Threshold}} = 25$V Peak
    - $I_{\text{ac Cont.}} = 30$A
    - $I_{\text{ac Fault}} = 5$kA @ 30 cycles
    - $I_{\text{Lightning}} = 30$kA Peak
    - Device presently being evaluated
Type 2 Decoupler: Characteristics/Common Names

- **Characteristics**
  - If \( \text{Vac} + \text{Vdc} < \text{VThreshold} \), Open circuit to dc, short circuit to ac.
  - If \( \text{Vac} + \text{Vdc} > \text{VThreshold} \), 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.

- Rectifier
- AC In
- DC Out
- Ground Level
- Sacrificial Anodes
- Pipeline (End View)
- Insulating Coating
- Utility and utility customer's grounding systems

DC current flows to all bare metal with a return path through the pipeline.
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:
  - $V_{\text{threshold}} = 2\text{V to 3V}$
  - 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
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

NESC applies
Power utility approval, installation required
Similar for three-phase transformers
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 \( \leq 15V \) 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

- Transmission Line
- Pipeline
- Grounding Conductor (For AC mitigation only)
- Decoupler
Type 2: Typical Decouplers For AC Voltage Mitigation
Type 2: Typical Decouplers For AC Voltage Mitigation
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

- $V_{\text{Threshold}}$ 1 V $V_{\text{Peak}}$ 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
- $V_{\text{Threshold}}$ typically 12.5$V_{\text{Peak}}$ or 20$V_{\text{Peak}}$
  - Primarily to keep stray dc current from accessing the cable pipe, such as from dc rail systems
- $I_{\text{Threshold}}$ 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
- $V_{\text{Threshold}} = 650V_{\text{Peak}}$ Primary, $700V_{\text{Peak}}$ Back-up
- $I_{\text{Threshold}} = 150$Arms
- 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