Instant-Off (I-O) Measurements on Decoupled Systems

Important Considerations

What Is A Decoupler?

- A device that has a very low impedance to ac current but blocks the flow of dc current up to a predetermined voltage level, typically 2 to 3 volts for most applications
- Typical decoupler AC impedance: 10 milliohms
- Typical decoupler DC resistance: Megohms
- Grounding through a decoupler:
  - Virtually the same as direct bonding for ac, but
  - DC isolates the grounding system from the pipeline/CP system

Decoupler Voltage

- Determined by the following formula:
  - $V_{(Decoupler)} = V_{(DC)} + I_{(AC\ Peak)} \times X_C$
    where
    - $V_{(DC)}$ is the dc voltage across the decoupler terminals
    - $I_{(AC\ Peak)}$ is the peak steady-state ac current flowing through the decoupler
    - X_C = 0.010 Ohms, a typical decoupler ac impedance

Note:

$V_{(Decoupler)}$ is not a function of the ac voltage present before a decoupler is installed.

$V_{(Decoupler)}$ is only a function of the ac current available after a decoupler is installed.

Decoupler Voltage-cont.

- If $V_{(Decoupler)}$ is less than the decoupler design blocking voltage, the two points to which the decoupler is connected are dc isolated, but ac connected.
- If $V_{(Decoupler)}$ is greater than the decoupler design blocking voltage, the two points to which the decoupler is connected are dc and ac connected.
  - To limit the voltage under an ac fault or lightning condition
    - Max. voltage due to ac fault ≤ 10V peak
    - Max. voltage due to lightning ≤ 125V peak typical
    - Voltage across decoupler terminals

Common Decoupler Applications

- Grounding electrical equipment integral to a cathodically protected system (e.g., motor operated valves)
  - Decoupler must be third-party certified to meet “grounding requirements” of electric codes (e.g. NFPA 70 for U.S., CSA Code for Canada)
- Decoupling AC voltage mitigation grounding systems
- Decoupling gradient control mats
- Over-voltage protection (e.g. insulated joints)
- Station dc isolation from power utility grounding system
  - Regulator, metering, and compressor stations

Reasons For Decoupling

- Allows ac grounding/bonding per electric codes without affecting CP levels
- Eliminates unnecessary insulated joints
- Separates CP system design from other requirements
- Minimizes stray dc interference problems (e.g. dc rail systems)
- The galvanic potential of the grounding system material used becomes irrelevant
  - Alternative materials can be used for ac mitigation grounds and gradient control mats (e.g. copper vs zinc)

Factors To Be Aware Of When Decoupling

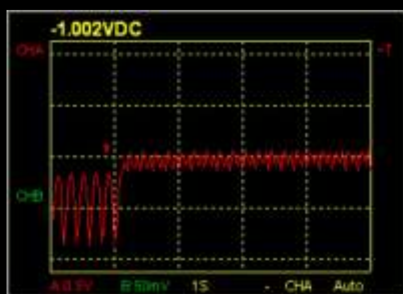
- Instant off CP measurements *may* be higher than the true value (i.e.more electronegative)
  - Measurement may appear acceptable, but pipeline may not be adequately protected

Instant-Off CP Measurements Precautions On Decoupled Systems

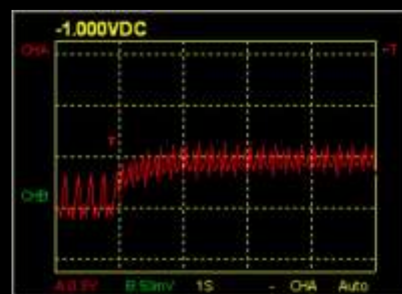
- A one-time voltage waveform analysis may be required with and without decouplers
- Measurement delay time may need to be increased relative to time of current interruption
- Decouplers may need to be disconnected for I-O measurements
- An alternate means of obtaining true CP readings may be required
  - If required measuring delay is not feasible/acceptable

Instant-Off Waveforms: Non-decoupled vs Decoupled Pipeline

- Measurements on a very short, poorly coated pipeline at a pipeline test site



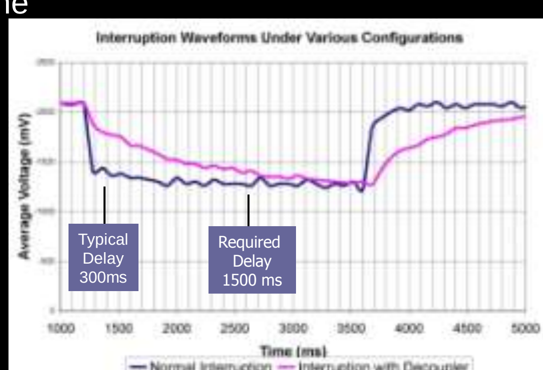
Non- Decoupled



Decoupled

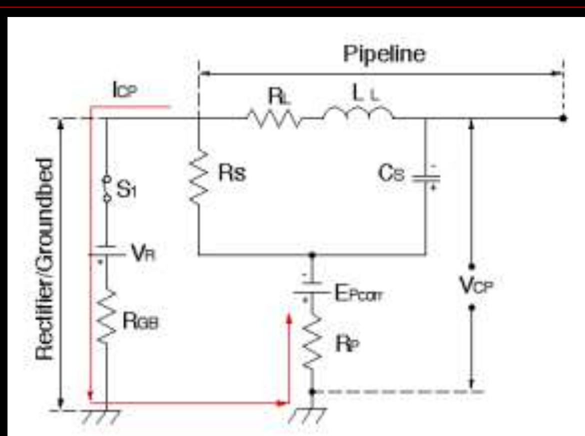
Instant-Off Waveforms On A Non-decoupled vs Decoupled Pipeline

- Measurements on a 6”- 40 mile, 16 mil FBE well coated pipeline



Why Does This Phenomenon Occur?

Schematic of Cathodically Protected Pipeline

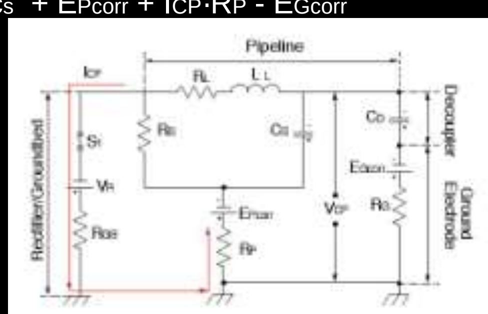


Acceptable Protection Criterion

- $E_{PCorr} + E_{Cs} \le -0.85V$ (-850mV polarized potential criterion)
- $E_{Cs} < -0.1V$ (-100mV shift criterion)
- To measure, $I_{CP} \times R_P$ must be eliminated or V_{CP} will be erroneously high

Schematic of Cathodically Protected Pipeline with Decoupler

- No dc current flows in path with decoupler
- $I_{CP} \cdot R_P + E_{Pcorr} + E_{Cs} = E_{Gcorr} + V_{CD}$
- $V_{CD} = E_{Cs} + E_{Pcorr} + I_{CP} \cdot R_P - E_{Gcorr}$

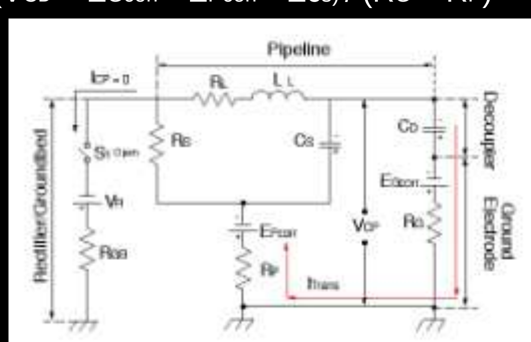


Events after Current Interruption

- V_{CD} must change by the I_{CP} x R_P component eliminated
- A transient current, I_{Trans}, must flow to effect this voltage change
- The circuit RC time constant determines the rate of voltage change across the decoupler (cannot be instantaneous)
- I_{Trans} x R_P causes a secondary IR voltage drop
- Until I_{Trans} has dissipated, an instant-off measurement will be erroneously high (too electronegative) due to I_{Trans} x R_P
- The I_{Trans} dissipation time may be beyond the measuring delay time

Schematic of Cathodically Protected Pipeline with Decoupler after Current Interruption

- $V_{CD} + E_{Gcorr} - I_{Trans} \cdot R_G - I_{Trans} \cdot R_P - E_{Pcorr} - E_{Cs} = 0$
- $I_{Trans} = (V_{CD} + E_{Gcorr} - E_{Pcorr} - E_{Cs}) / (R_G + R_P)$



Observations from Formulas

- $V_{CD} = V_{CP}$ (pipeline ON potential) - E_{Gcorr}
- V_{CD} may be zero, depending on grounding material used
- I_{Trans} will always exist when the rectifier is turned OFF on decoupled systems
- For an accurate measurement, the circuit time constant (TC) must be ≤1/5 of the measuring delay time
  - Example: If measuring delay time = 200ms, then TC ≤ 40ms

Parameters Affecting Circuit RC Time Constant

- $R = R_S + R_P + R_G - R_M$
  - R_S = shunt polarization resistance
  - R_P = coating resistance + soil path resistance to remote earth
  - $R_S + R_P$ = total resistance of pipe to remote earth
  - R_G = resistance of ac ground electrode to remote earth
    - R_M = mutual resistance between pipe and ground electrode (applicable if pipe and ground electrode are in close proximity, R_M not shown in schematic to simplify analysis)
  - The "R" parameters are not under the control of a decoupler designer
  - Modern pipeline coatings contribute to high "R" , especially on short and/or small diameter pipelines

Parameters Affecting Circuit RC Time Constant-continued

- C is primarily due to the decoupler capacitance, but Cs is not an insignificant factor
- The decoupler C value can be affected by design, but cannot be lowered enough to eliminate this measuring error in many applications
- C must be quite high to:
  - Shunt typical values of ac current to ground in ac mitigation applications without affecting CP levels (i.e. without rectifying ac)
  - Limit the decoupler dc voltage blocking level to reasonable values (i.e. decoupler costs increase with higher blocking voltage)

General Comments

- The I-O measuring phenomenon:
  - Is not unique to solid-state decouplers, also applies to polarization cells
  - Is not readily addressed by decoupler redesign as the decoupler "C" would have to be reduced to a value that would not meet other key decoupler requirements

Suggested Measuring Options

- Option 1:
  - First set interrupters to 10s ON, 2s OFF
  - Then, at several locations:
    - Record *on/off* waveforms with and without decouplers installed
    - Review waveforms to determine if a measuring error exists when decoupled
    - If a measuring error exists, determine if an increased measuring delay time would eliminate/minimize error
    - If feasible, increase measuring delay time and repeat tests to confirm.
    - If increased measuring delay time not feasible, consider Option 2

Suggested Measuring Options-continued

- Option 2:
  - Consider disconnecting decouplers for I-O measurements, but take safety precautions as the voltage may rise to an unsafe level (e.g. ≥15V)
  - But do not disconnect decouplers used for grounding electrical equipment integral to the pipeline as this would be in violation of the National Electric Code
- Option 3: Use coupons as an alternate means of obtaining accurate potential readings and use to adjust for errors in instant-off measurements

Summary

- Instant-off potentials on decoupled systems may be in error (too electronegative)
- These potentials are affected by key parameters not under the control of a decoupler designer
  - Pipeline length, diameter and coating resistance, soil resistivity, grounding electrode design and proximity to pipe, etc.
- Analyze *on/off* waveforms to determine if a measuring error exists and increase measuring delay time if feasible, or
- Use coupons as an alternate means of obtaining accurate potential readings

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