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Introduction

When cathodic protection (CP) is applied to a buried pipeline using **impressed current**, a **rectifier** converts AC from the grid to DC and drives protective current to the structure. In an ideal world the DC would be perfectly steady; in practice, rectifiers produce a small, periodic **ripple** at predictable frequencies (e.g., **60 Hz** for half-wave, **120 Hz** for full-wave, **360/720 Hz** for 6-/12-pulse three-phase units). Filters (capacitors and chokes) reduce the **amplitude** of ripple but not the **frequencies** themselves.

Because of this, it is common to see frequency content (e.g., 60 Hz, 120 Hz) superimposed on a nominally DC potential or current. **Seeing energy at 60 Hz or 120 Hz does not, by itself, prove external AC interference**—it may simply be rectifier ripple. The key questions are **source** and **significance**: *What is causing the frequency content, and is it hazardous to people or the asset?*

This guide explains how Iso-Smart acquires and analyzes field data to separate **rectifier-origin ripple** from **true induced AC** and to quantify risk. We combine:

- **Synchronized, high-resolution time-series** of potential and current (e.g., structure and/or coupons).
- **Spectral (frequency) analysis** to fingerprint dominant frequencies and harmonics.
- **Correlation** with operations and environment (rectifier tap changes, utility loading/switching, nearby energy sources, storms).
- **Dual metrics—Average (DC) and True RMS (TRMS)**, from which we compute **AC-only RMS** to isolate the magnitude of the AC component.

By interpreting the **waveform** (shape), the **spectrum** (which frequencies dominate), **consistency across locations**, and **when** changes occur, we can determine whether we are seeing harmless ripple or meaningful induced AC. We then compare measured values to **AMPP (NACE)** criteria for **personnel safety** (touch voltage) and **AC-induced corrosion** (AC current density with DC context) to guide mitigation.

Bottom line: frequency \neq interference by default. **Context determines cause and consequence.**

A note on “spectrum” (what the analysis shows)

A spectrum shows **how a signal’s energy is distributed across frequencies**.

- A **0 Hz** peak represents the **DC level** (the average).
- Peaks at **60/120/360 Hz**, etc., reflect periodic components (**ripple** and/or **induced AC**).
- Comparing **Avg vs TRMS** tells you **how much** AC rides on the DC; the spectrum tells you **which** AC frequencies are present and **how strongly**.

Purpose of Document

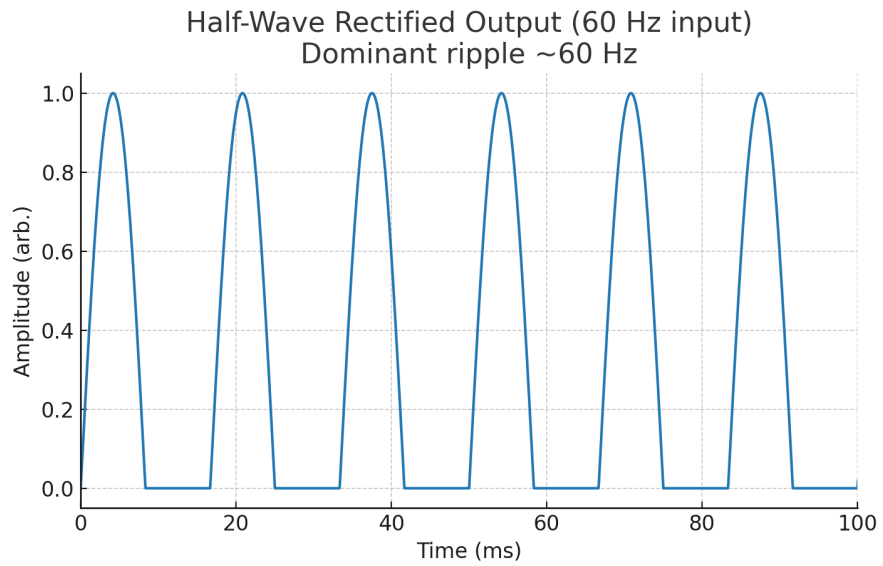
To illustrate why “DC” outputs from rectifiers often contain measurable **frequency components (ripple)**, how those components appear in both the **time** and **frequency** domains, and how **Iso-Smart** analytics help distinguish rectifier ripple from **induced AC** on pipelines and assess risk against **AMPP (NACE)** criteria.

Typical Rectifier Frequency Signatures

Let us look at examples of the typical output of common rectifiers in the CP industry.

Half-Wave

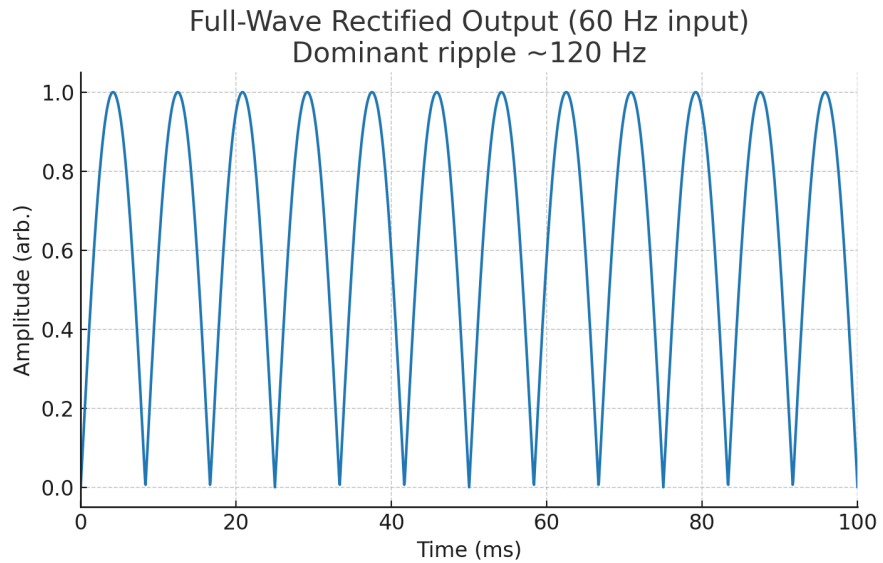
Figure 1



Rectifier Source	Dominant Ripple Frequency <i>(all assuming a 60 Hz system)</i>	Notes
Half-wave (single-phase)	60 Hz	Pulsating DC; strong fundamental + odd harmonics

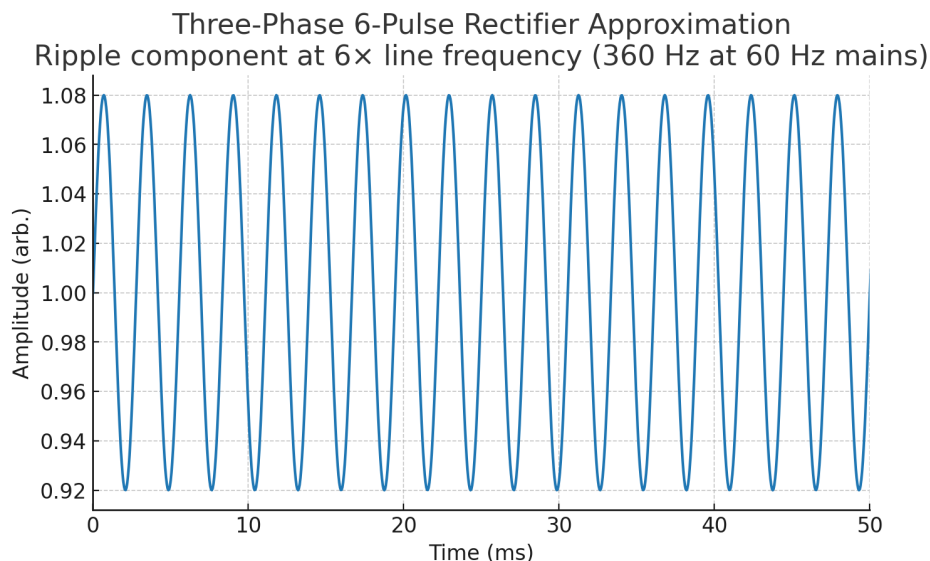
Full-Wave

Figure 2



Source	Dominant Ripple Frequency <i>(all assuming a 60 Hz system)</i>	Notes
Full-wave (single-phase)	120 Hz	Even harmonics common; DC offset + 2× line frequency

Figure 3

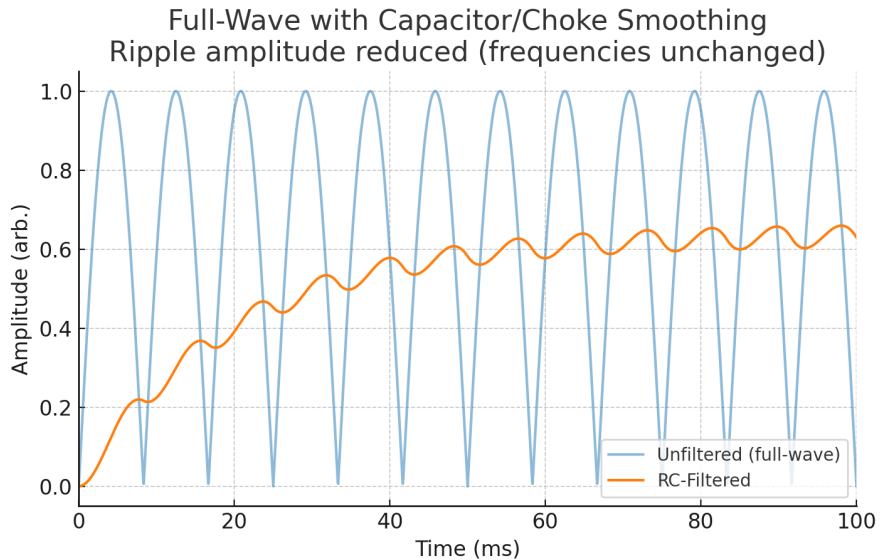


Source	Dominant Ripple Frequency <i>(all assuming a 60 Hz system)</i>	Notes
3-phase, 6-pulse	360 Hz	Ripple at 6x line frequency

Filtering (Capacitors & Chokes)

Smoothing components such as capacitors and chokes (inductors) reduce the amplitude of ripple in the time domain but do not change the underlying ripple frequencies produced by the rectification topology. See **Figure 4**. Heavier filtering lowers ripple magnitude while preserving the same spectral lines (e.g., 120 Hz for full-wave).

Figure 4



Frequency-Domain Examples

Let's look at examples of the frequency domains of these outputs from half and full-wave rectifications. Both for outputs with No AC Interference and **w/ 3-phase AC** Interference.

No AC Interference

Figure 5: Frequency Domain of **half-wave** output; 60 Hz fundamental with harmonics.

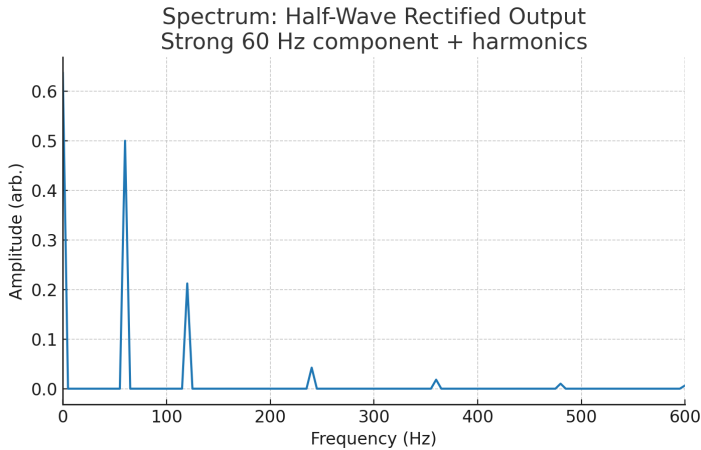
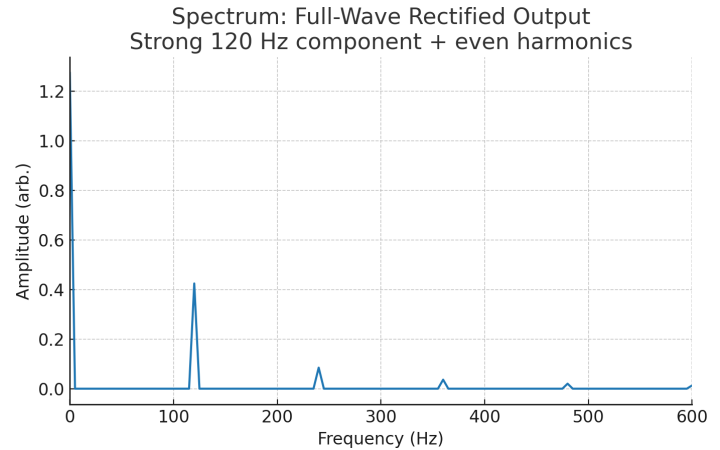
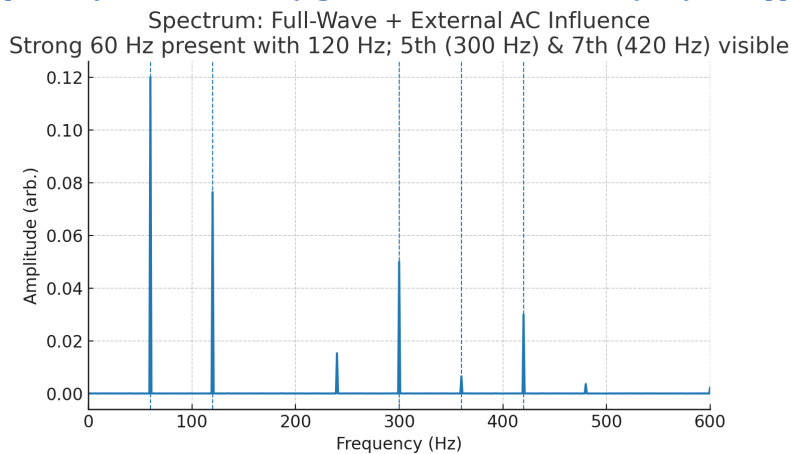


Figure 6: Frequency Domain of **full-wave** output; strong 120 Hz component with even harmonics.



w/ 3-phase AC Interference

Figure 7: Frequency Domain w/ external AC present; strong 60 Hz peak alongside 120 Hz; power-system harmonics (e.g., 5th = 300 Hz, 7th = 420 Hz) may also appear.



How Iso-Smart Distinguishes Ripple from Induced AC

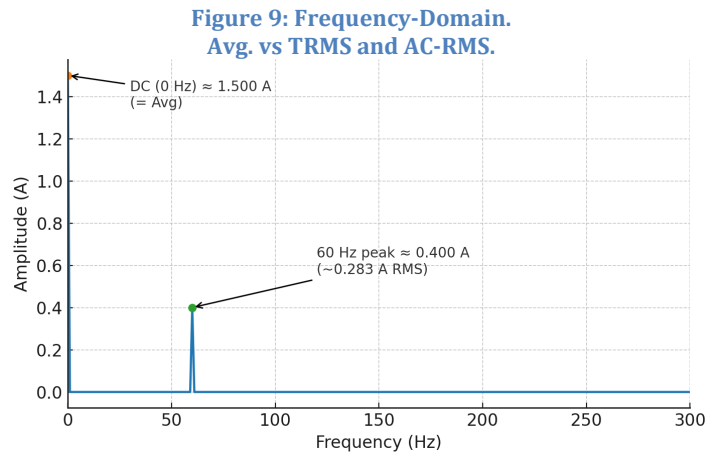
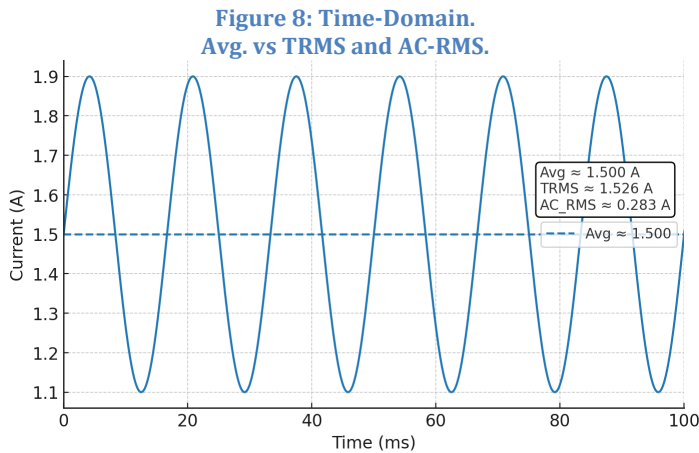
Iso-Smart collects synchronized, high-resolution time-series data of potentials and currents and applies frequency analysis to surface dominant frequencies and harmonics; like in the examples earlier. This makes it practical to separate **rectifier-origin ripple** from **externally induced AC**.

Key analytics and metrics

- **Average (DC mean):** The steady protective component (your baseline).
- **True RMS (TRMS):** Magnitude of DC **plus** any AC components.
- **AC-RMS (AC-only):** Computed, to isolate the AC magnitude independent of DC.
- **Frequency fingerprints:** Patterns help infer source, i.e., **120 Hz with even harmonics** → **full-wave rectifier ripple**; **strong 60 Hz (with power-system harmonics like 300/420 Hz)** → **likely grid coupling**.
- **Current density (with coupons):** Convert measured current to A/m^2 using coupon area to assess risk and mitigation impact directly against AMPP guidance.

Avg vs TRMS Example

For a measured interval with Avg ≈ 1.500 A and TRMS ≈ 1.526 A, the AC-only component is AC-RMS ≈ 0.283 A. A small gap (TRMS \approx Avg) implies minimal AC; a larger gap (absolute difference) between TRMS and Avg indicates meaningful AC content even when the DC (Avg.) looks stable. Reference to **Figure 8** and **Figure 9** for further explanation.



Instant-Off (IR-free) measurements (recommended)

- **What we do:** Temporarily **interrupt all CP sources** in a synchronized manner and record **ON vs OFF** windows.
- **What it shows:**
 - If the **120 Hz** component **collapses** during **OFF**, that points to **rectifier ripple**.
 - If **60 Hz** (and power-system harmonics) **persist** during **OFF**, that supports **external AC interference**.
- **How we use it:** We compute **Avg, TRMS, AC-RMS** in each window and, when coupons are present, **AC/DC current density** for direct comparison to **AMPP (NACE)** criteria (touch voltage for personnel safety; AC current density bands for corrosion risk).

IR-free Measurement Examples (all using full-wave output)

Figure 10: With the rectifier energized and no external AC coupling, the spectrum shows a large 0 Hz (DC) component, the average CP potential, and a clear 120 Hz line with smaller even harmonics (e.g., 240, 360 Hz). This is the normal fingerprint of **full-wave rectifier ripple**. The absence (or near absence) of a 60 Hz line indicates there is no meaningful induced AC from nearby power lines in this condition.

What to conclude / next step:

- Treat this as typical rectifier behavior.
- Quantify ripple via **AC-RMS** and confirm it is not affecting criteria checks. If ripple is excessive, consider rectifier filtering/maintenance; otherwise, no AC interference is indicated.

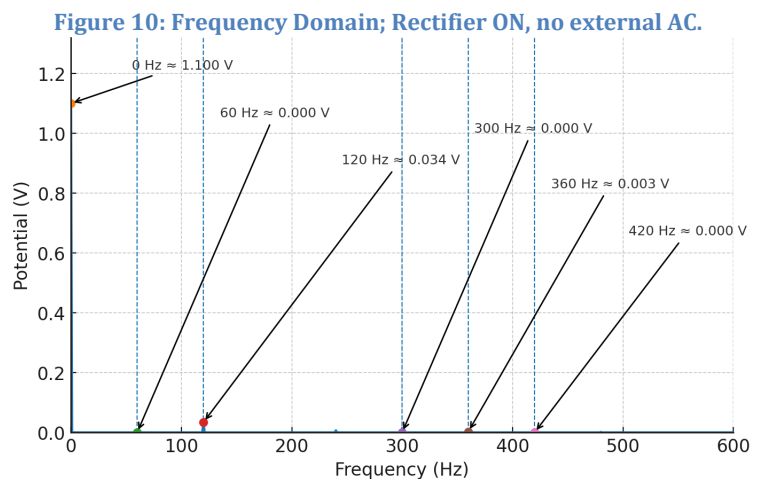


Figure 11: During a synchronized **Instant-Off (IR-free)** window, the rectifier ripple disappears, as expected, because the rectifier is de-energized. The **60 Hz** line is also not present, indicating **no external AC coupling**. Any tiny residual lines are measurement noise or local transients.

What to conclude / next step:

- Confirms that peaks seen in the ON state were **rectifier-origin ripple**, not interference.
- Use this OFF window to record IR-free potential for CP performance checks.

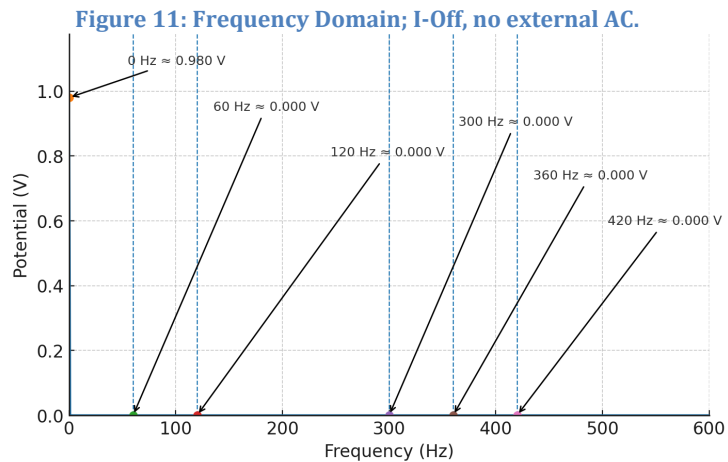


Figure 12: Here the rectifier’s **120 Hz** signature is still present, but a **strong 60 Hz** line appears with characteristic power-system harmonics (often **5th = 300 Hz, 7th = 420 Hz**). This mixed fingerprint—**60 Hz + 120 Hz**—suggests **external AC coupling** superimposed on normal rectifier ripple.

What to conclude / next step:

- Likely **induced AC** while the CP is ON.
- Compare **ON vs I-Off** spectra (**Figure 12 vs Figure 13**) to confirm attribution.
- Use **AC-RMS** (and coupon **AC current density** where available) to assess risk versus AMPP guidance.

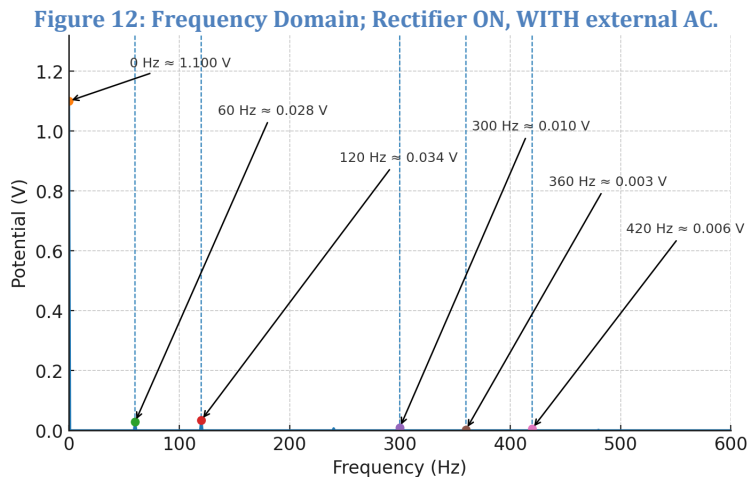
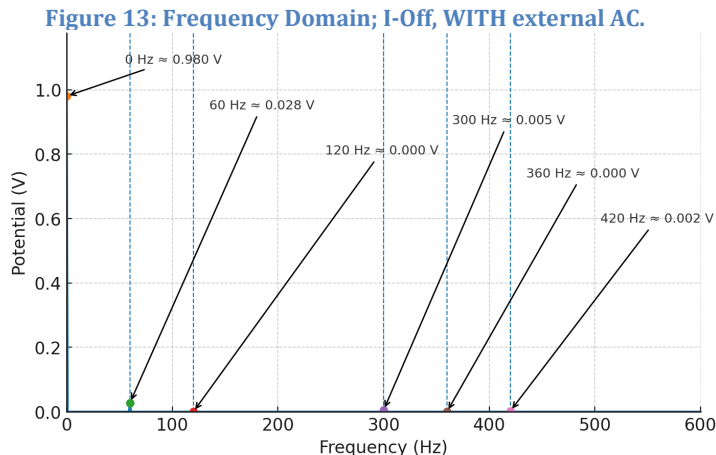


Figure 13: Interrupting CP removes rectifier ripple, yet the **60 Hz** component (and sometimes **300/420 Hz**) remains. Persistence during I-Off is a strong indicator of **external AC influence** independent of the rectifier.

What to conclude / next step:

- Diagnose as **induced AC** from nearby power infrastructure.
- Quantify magnitude with **AC-RMS** and, where coupons are present, compute **AC current density (A/m²)** to compare against **AMPP (NACE)** corrosion-risk bands.
- For personnel safety, evaluate **touch voltage** where applicable.



Computing Current Density

With coupons, Iso-Smart reports current and uses the known, exposed coupon area (A) to compute $J = I / A$ for both AC and DC components. This ties measurements directly to the criteria described in **AC-Induced Corrosion, Current Density (per SP21424)**.

Assessing Hazard Magnitude (AMPP/NACE Criteria)

Iso-Smart provides decision-grade metrics that map to widely used AMPP (formerly NACE) criteria for both personnel safety and AC-induced corrosion. Always consult and follow the latest AMPP standards and company specifications.

Personnel Safety, Touch Voltage (per SP0177)

Monitor steady-state AC touch voltage to below approximately 15 V (RMS) relative to local earth at above-ground appurtenances to limit shock hazard. Fault-condition evaluations require additional considerations per the standard.

AC-Induced Corrosion, Current Density (per SP21424)

Evaluate AC current density (A-AC) at representative coupons and consider the concurrent DC CP current density (A-DC). Typical guidance includes:

- If A-DC ≤ 1 A/m², maintain A-AC $< \sim 100$ A/m² on a 1cm² coupon.
- If A-DC > 1 A/m², maintain A-AC $< \sim 30$ A/m² on a 1cm² coupon.

These thresholds are applied to time-weighted average current densities and help classify risk and prioritize mitigation.

Suggested Workflow (as guidance)

1) Baseline:

- Record 48–72 hours to capture normal operations and review frequency domain analysis and Avg/TRMS/AC-RMS relationships.

2) Isolate variables:

- If possible, briefly adjust or de-energize a candidate rectifier, such as I-Off readings.
 - i) A collapse of 120 Hz (or 360 Hz) supports a rectifier-ripple hypothesis; persistent 60 Hz suggests induced AC (*assuming full-wave rectification*).

3) Compare locations:

- Induced AC tends to appear consistently along an affected corridor; rectifier ripple is localized.

4) Quantify impact:

- Use AC-RMS and AC/DC potentials and current density (with coupons) to judge risk, and trend improvement after mitigation.

Note: The example figures provided in this document are illustrative.

Iso-Smart generates site-specific plots and metrics using your live data to reach a confident diagnosis.