EC-004 · MODULE 4 OF 22

AC vs. DC Electricity: Characteristics and Differences

Two regimes, one meter — and two completely different stories at every test station next to a power line.

EXTERNAL CORROSION TRACK | FOUNDATION TIER | ELECTRICAL BASICS FOR CP | ~30 MINUTES

BY THE END OF THIS MODULE

You'll be able to —

- Distinguish **AC and DC** by waveform, frequency, and where each shows up in CP work.
- Convert between **peak and RMS** voltage on clean sine waves using the 0.707 / 1.414 pair.
- Explain why CP requires DC: **fixed polarity, reference-electrode response, and ions in the electrolyte**.
- Recognize **induced AC on a pipeline** from a parallel power line and route it to its own work track — not to a rectifier adjustment.
- Apply **meter-mode discipline**: name the mode (V DC / V AC) in field notes; one conductor pair carries different readings in different regimes.

A TEST STATION NEAR A 138 KV CORRIDOR

You open the lid. The towers march in parallel.

Pipe header lead, Cu/CuSO4 half-cell pressed into moist soil, multimeter set to **V DC**. Black to half-cell, red to pipe.

−1.05 V

DMM · V DC · VS CU/CUSO4

The pipe meets the −0.85 V criterion with comfortable margin. CP is doing its job here.

SAME LEAD PAIR · FLIP THE METER

Now switch the meter to V AC.

6.5 V AC

DMM · V AC · SAME CONDUCTORS

> **Same pipe. Same soil. Same conductor pair.** Two completely different stories — and only one of them is a CP question.

Two readings. One conductor pair.

The mode is the answer.

WHAT WE'LL COVER

Two regimes, three jobs — and the meter mode that holds it together.

01

DC characteristics

Constant in one direction · where DC lives in CP

02

AC characteristics

Sinusoidal · 60 Hz · peak vs. RMS

03

Why CP requires DC

Polarity · reference electrodes · electrolyte response

04

AC on the pipeline

Inductive coupling · the 4 V AC threshold

05

Three measurement scenarios

Cabinet · test station · ripple

EC-004 IN THE RUNG

The hinge between the math and the hardware.

EC-001 named the **shapes** of CP circuits. EC-002 walked the **math** that runs inside them. EC-003 distinguished **V, I, and R** at the field-measurement level. Every one of those modules assumed something we never said out loud: **the current is DC.**

That assumption is correct, and it's load-bearing. CP is a DC technique. EC-004 makes the regimes themselves explicit — and adds the second story: how AC ends up on a pipeline that has nothing to do with the rectifier.

> **EC-005 picks up power and energy.** The deeper treatment of AC interference — coupling models, mitigation design, decoupling devices — lives in a later EC module dedicated to the topic.

SCOPE DISCIPLINE

What's in scope today, what's already covered, what's coming.

Topic	Where it lives	Status here
Series / parallel circuit shapes	EC-001	Named at reference level only
Ohm's Law calculation drill	EC-002	Referenced, not redone
V/I/R distinction at the meter	EC-003	Referenced, not redone
AC vs DC regimes & meter mode	EC-004 (here)	In scope
Power, energy, I^2R losses	EC-005 (next)	Forward-pointed
AC mitigation engineering	later EC module	Phenomenon named; engineering deferred

PART 1 OF 5

DC — constant in one direction.

WHAT DC IS

Steady level. Fixed polarity. Plotted against time, a flat line.

DC — constant

time →

AC — sinusoidal, 60 Hz

time → · one cycle = 1/60 s

DC sits at a steady value. AC swings sinusoidally above and below zero. Same axes, two regimes.

WHERE DC LIVES

Every part of the system that does protective work.

- **Rectifier output** — the (+) and (−) DC bus inside the cabinet, feeding the anode header and structure return. 12–50 V on V; up to 50 A on I.
- **Galvanic anode bonds** — magnesium or zinc anodes producing DC by simple electrochemistry. Tens of milliamps to a few amps.
- **Structure-to-soil potential readings** — the −0.85 V Cu/CuSO4 criterion is a DC voltage, read against a stable reference electrode.
- **Bond shunt readings** — millivolts DC across calibrated shunts, converted to amps via Ohm's Law.
- **Batteries** — coupon test rigs, monitoring gear, lab equipment.

WHAT YOU SET THE METER TO

DC mode reads steady levels. AC mode on the same conductors reads near zero.

22.0 V

V DC · RECTIFIER OUTPUT

−1.05 V

V DC · S-TO-S

A meter on AC mode looking at the same conductors will read close to zero — because pure DC has no alternation for the AC mode to register.

Every reading that judges protection.
Every reading that drives protective current.
All on the DC side.

PART 2 OF 5

AC — alternating, sinusoidal.

WHAT AC IS

Sine wave. 60 Hz in the US. 120 reversals per second.

One full cycle: rise from zero to a positive peak, fall back through zero down to a negative peak, rise back to zero. The number of cycles per second is the **frequency**. US utility AC: **60 Hz**. Two reversals per cycle × 60 cycles = **120 reversals per second**.

DC — constant

time →

AC — sinusoidal, 60 Hz

time → · one cycle = 1/60 s

TWO VOLTAGE NUMBERS, ONE WAVEFORM

Peak is the maximum. RMS is the equivalent steady DC.

$$V_{RMS} = V_{peak} \times 0.707$$

$$V_{peak} = V_{RMS} \times 1.414$$

So a 120 V RMS outlet has a peak of `120 × 1.414 ≈ 170 V`. A 240 V service: `≈ 339 V peak`. A 480 V three-phase line: `≈ 679 V peak`.

> **Catalog convention.** Nameplates and breaker ratings list AC voltages as RMS. When a tag says "120 V," it means 120 V RMS — not peak. RMS is the right number for power, current, and breaker sizing because it's the equivalent DC that delivers the same average power.

WHERE AC LIVES

Three places — only one of them on purpose.

Utility input

The AC service drop feeding the rectifier cabinet — 120 V or 240 V single-phase, 240 V or 480 V three-phase. AC is required here; it's what the transformer needs to operate.

Induced on the pipe

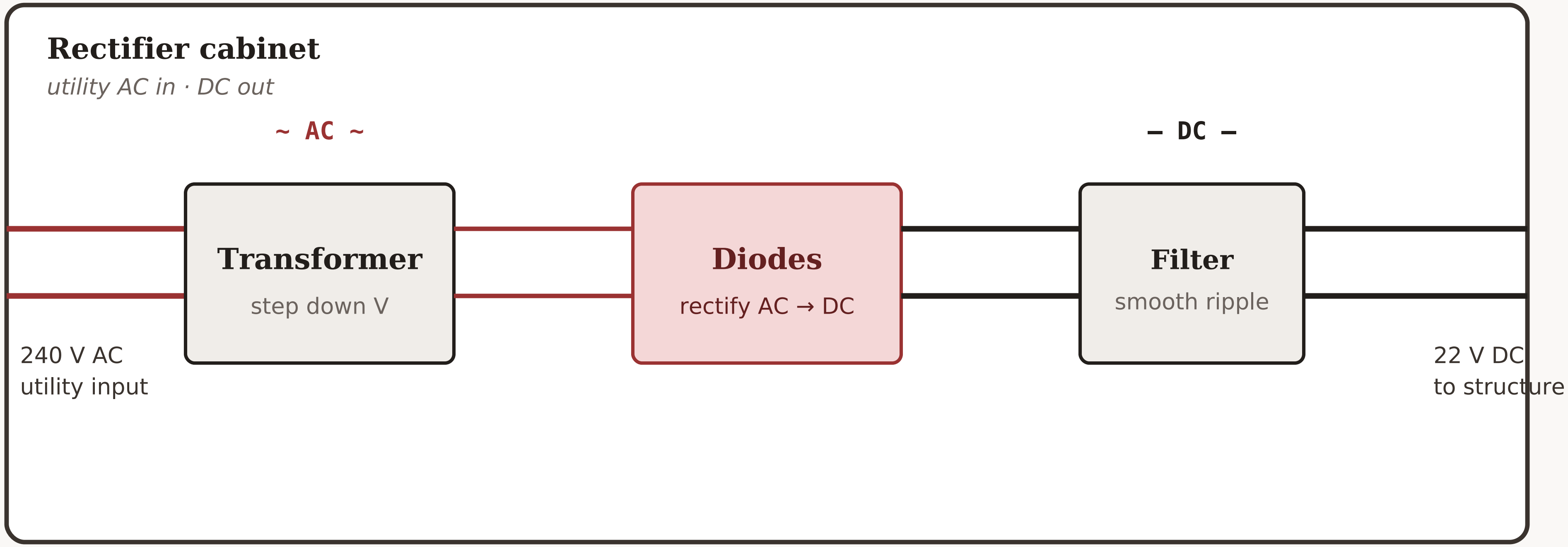
When a buried pipeline runs parallel to a high-voltage transmission line, the line's oscillating field induces an AC voltage and current on the pipe — incidental, not on purpose.

Ripple on rectified DC

The DC output of a rectifier carries a small residual AC component at twice the input frequency (120 Hz). Modern filtering keeps it small, but it's there.

THE RECTIFIER CABINET

One enclosure spans both regimes.



AC at the input lugs · transformer scales it · diodes flip every other half-cycle · filter smooths the result · DC at the output bus.

PART 3 OF 5

Why CP is fundamentally a DC technique.

REASON 1 OF 3

Polarity has to be fixed.

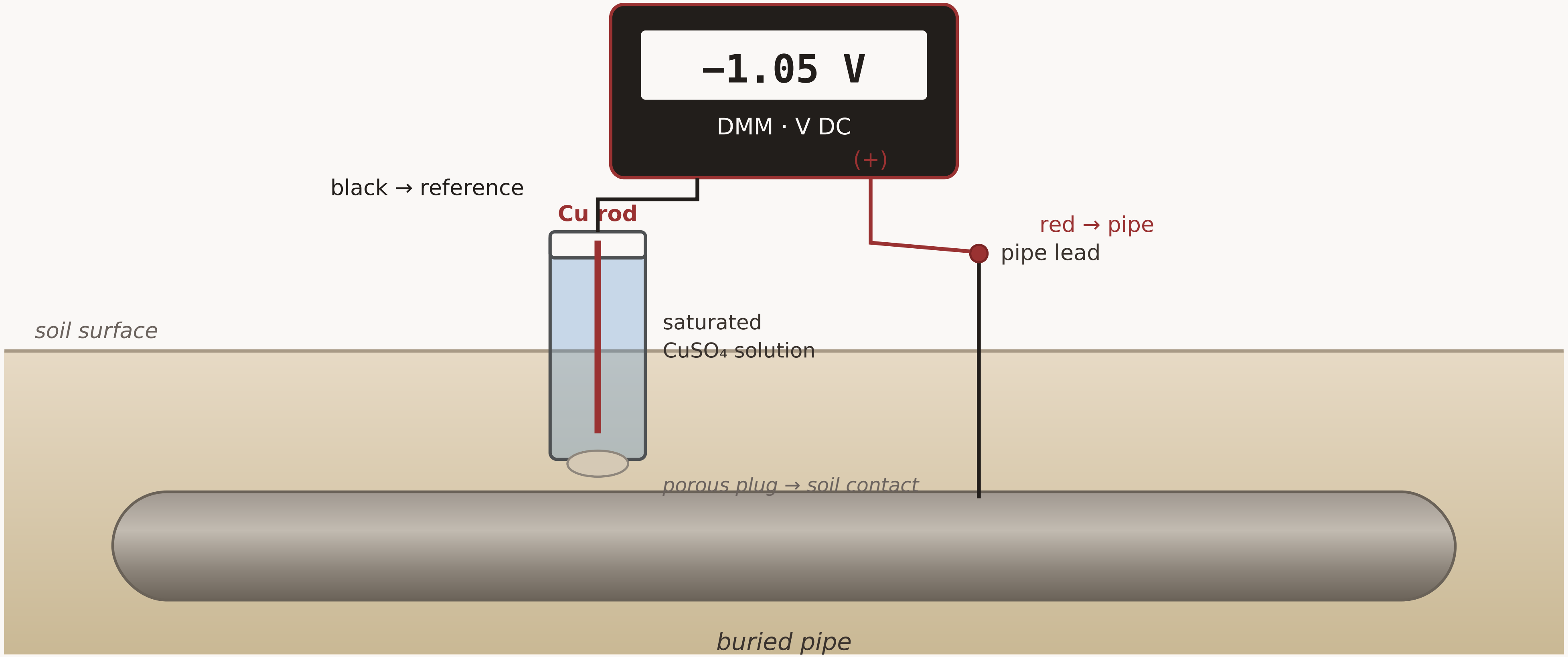
The whole point of CP is to make the structure the cathode of a deliberate electrochemical cell — push it to a more negative potential than it would naturally sit at, so the metal-loss reactions stop. That requires the structure to be cathodic **continuously**.

AC reverses polarity 120 times a second on a 60 Hz system. For 1/120 s the structure would be cathodic; for the next 1/120 s it would be anodic. **Anodic means metal loss** — exactly what CP exists to prevent.

No net protection from polarity that flips that fast. From the structure's point of view, that's no protection at all.

REASON 2 OF 3

Reference electrodes only read steady DC.



The Cu/CuSO4 half-cell sits at a fixed DC potential. The S-to-S reading is the difference between structure and that fixed reference.

REASON 3 OF 3

The electrolyte responds to direction, not magnitude.

Current through soil from anode to structure is a flow of **ions**, not electrons. Positive ions move one way, negative ions the other, and the electrochemistry at each electrode (oxidation at the anode, reduction at the cathode) only proceeds if the ions keep moving in their respective directions.

Reverse the polarity and the ions reverse — the chemistry the CP system was driving at the cathode unwinds during the half-cycle the polarity is wrong, and has to start over again.

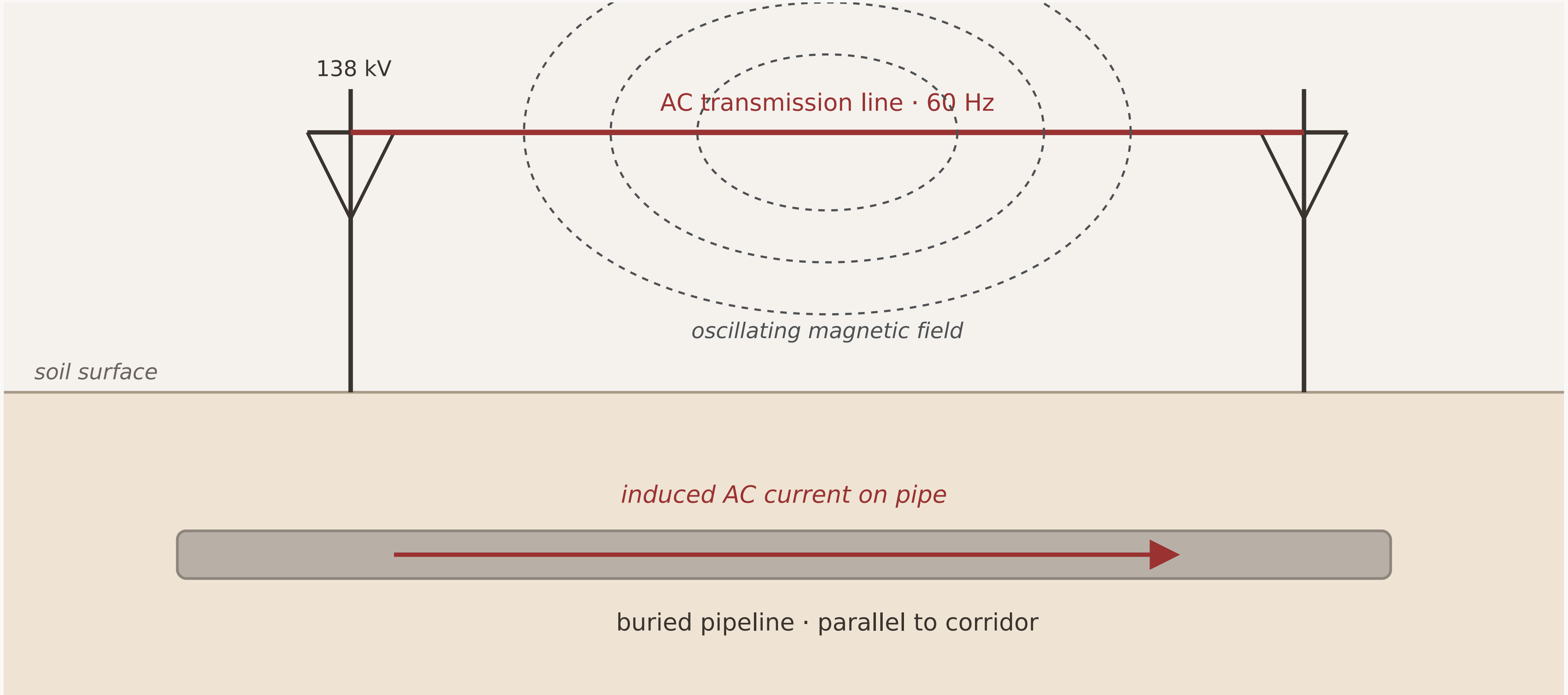
If the current averages to zero over time, it does no net protective work. AC averages to zero. CP requires net work in a fixed direction. The conclusion is unavoidable.

PART 4 OF 5

The second story — induced AC on buried pipelines.

WHERE AC ENDS UP ON A PIPELINE THAT HAS NOTHING TO DO WITH THE RECTIFIER

The pipeline acts like the secondary of a giant transformer.



Tens to hundreds of amps in the transmission line · oscillating magnetic field · induced AC voltage and current on the parallel pipe.

ABOVE THIS, AC CORROSION IS ITS OWN MECHANISM

The threshold rule of thumb.

~4 V AC

pipe-to-soil

V AC pipe-to-soil is the field reading. AC current density at coating holidays is the actual corrosion driver. At this level and above, conditions can support that — possible, not certain. Below: monitor. Above: investigate; mitigation is its own work track.

> **Personnel safety, too.** Industry standards generally treat **10 to 15 V AC and higher** pipe-to-soil as a worker shock hazard at above-grade flanges, valve boxes, and test stations. A few volts can be enough under wet hands; double-digit reliably is. Mitigation addresses both corrosion and safety.

WHY CP CANNOT FIX THE AC READING

More rectifier current does not change the induced AC.

The AC on the pipe is set by the geometry and loading of the nearby power line — distance, parallel run length, line current, soil resistivity, grounding. **None of those depend on the CP rectifier.** Pushing the rectifier output from 22 V DC to 28 V DC drives the structure-to-soil potential more negative — useful for CP — but does nothing to the AC pipe-to-soil reading.

AC interference is mitigated by separate work — gradient control mats, polarization cells, solid-state coupling devices, additional grounding at peak-AC locations. On its own track, with its own techniques, named in the references for the later EC module.

PART 5 OF 5

Three readings, three meter modes.

AT THE RECTIFIER CABINET

One enclosure, two regimes.

READING 1 · INPUT LUGS · V AC

240 V AC line-to-line

Utility service feeding the cabinet. AC by design — the rectifier needs AC at the input to drive the transformer.

READING 2 · OUTPUT BUS · V DC

22 V DC

Rectified output, on the cable to the anodes and structure. DC by design — the regime CP works in. Same enclosure, two regimes — the meter mode has to follow.

AT A TEST STATION NEXT TO A POWER LINE

The hook scenario, fully spelled out.

READING 1 · S-TO-S · V DC

−1.05 V DC

Structure-to-soil potential, more negative than −0.85 V. CP is working at this location. **This is a CP question; the answer is good.**

READING 2 · SAME LEAD PAIR · V AC

6.5 V AC

Induced AC from the parallel transmission line. At this level, conditions could support AC current density high enough at coating holidays to drive AC-induced corrosion — possible, not certain. **A different question, on a different work track. Both belong in the field notes.**

SAME CONDUCTOR PAIR, V DC AND V AC TELL DIFFERENT STORIES

Rectifier ripple as a cabinet-side health proxy.

READING 1 · OUTPUT BUS · V DC

22 V DC

Working DC level the rectifier is putting on the cable.

READING 2 · SAME BUS · V AC

0.4 V AC ripple (~1.8% of DC)

Residual AC after rectification, at 120 Hz on a full-wave bridge. Under ~5%: healthy filter. 10%+: investigate. A free diagnostic that fits in any cabinet visit.

KEY TAKEAWAYS

What sticks.

- **DC flows constantly in one direction** — flat-line waveform; rectifier output, anode bonds, S-to-S potentials, shunt readings are all DC.
- **AC reverses periodically** — sinusoidal at 60 Hz US standard; 120 reversals/sec; $V_{RMS} = V_{peak} \times 0.707$.
- **CP requires DC** — fixed polarity, reference-electrode response, ions in the electrolyte. AC averages to zero.
- **Rectifiers convert utility AC to DC** — transformer scales V; diodes flip every other half-cycle; filter smooths.
- **AC on a pipeline is a separate problem** — induced from parallel power lines; at ~4 V AC and above, conditions can support AC current density that drives AC-induced corrosion; CP does not mitigate it. 10–15 V AC and higher is also a worker safety threshold per industry standards.
- **Meter-mode discipline matters** — record the mode in field notes; one conductor pair carries different readings in different regimes.

WHERE THIS COMES FROM

References & further reading

- **AMPP CP 1 Cathodic Protection Tester Course Manual** — foundation treatment of AC and DC, peak vs. RMS, transformers, and rectification.
- **AMPP CP 2 Cathodic Protection Technician Course Manual** — extended treatment of rectifier operation, ripple, and rectifier types.
- **AUCSC Basic Course Manual** — companion treatment with utility-side context and AC interference introduction.
- **Peabody's Control of Pipeline Corrosion** — A.W. Peabody. Load-bearing DC framing alongside the pipeline-side AC story.
- **Corrosion Basics: An Introduction** — foundation cathodic protection alongside AC-on-pipelines.
- **AC Corrosion of Pipelines** — Brenna et al. Modern treatment of induced AC on buried pipelines.
- **Corrosion Engineer's Reference Book** — Baboian, ed. AC and DC fundamentals.
- **NACE/AMPP SP21424** — the standard governing AC mitigation engineering on pipelines.

UP NEXT IN THIS RUNG

EC-005 — Power and Energy in Electrical Circuits

Picking up the math: $P = V \times I$, I^2R losses in cables and rectifiers, energy in watt-hours, and how efficiency considerations shape CP system design.