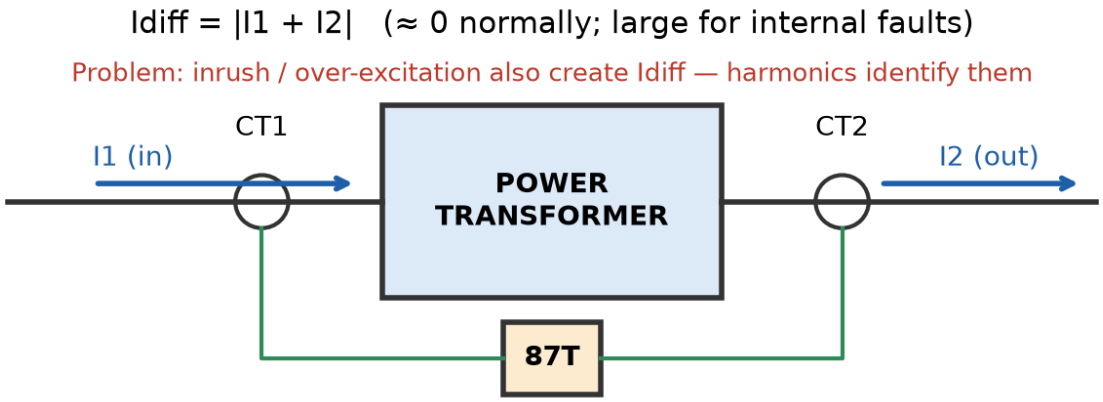
2nd & 5th Harmonics in Transformer Differential Protection

A visual guide for protection engineers — 87T inrush and over-excitation restraint

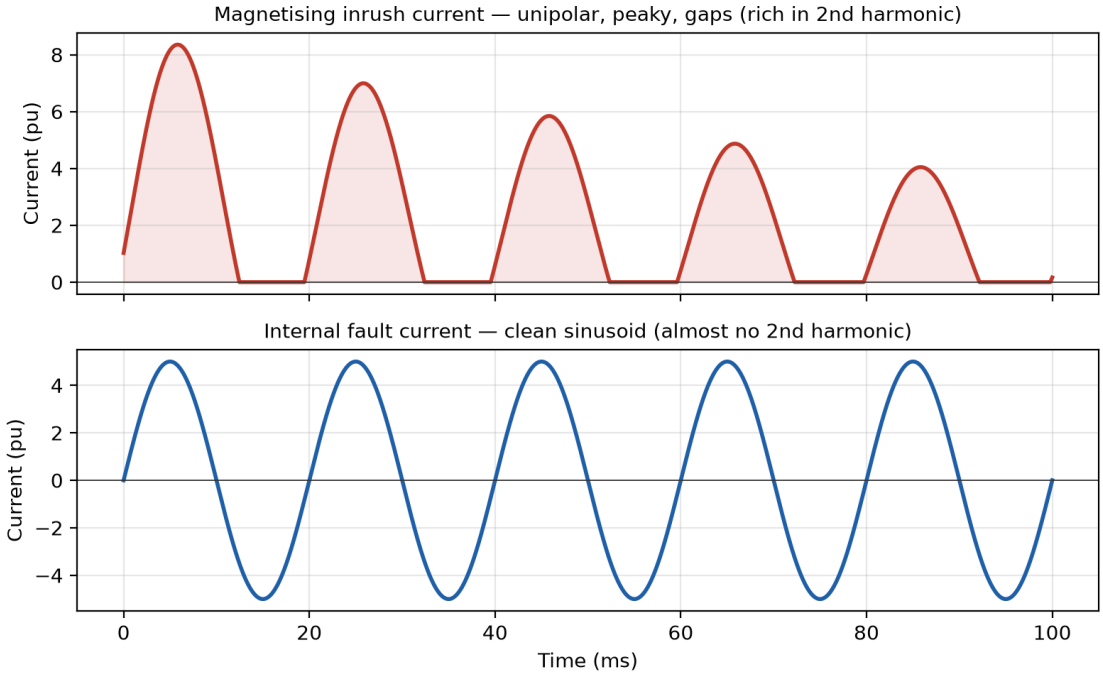
1. Why harmonics are needed

A differential relay (87T) compares current entering and leaving the transformer. Normally Idiff ≈ 0. But two **non-fault** events make a large current flow on one side only, so the relay sees a false differential: **magnetising inrush** and **over-excitation**. Each has a harmonic fingerprint that a real fault does not have.

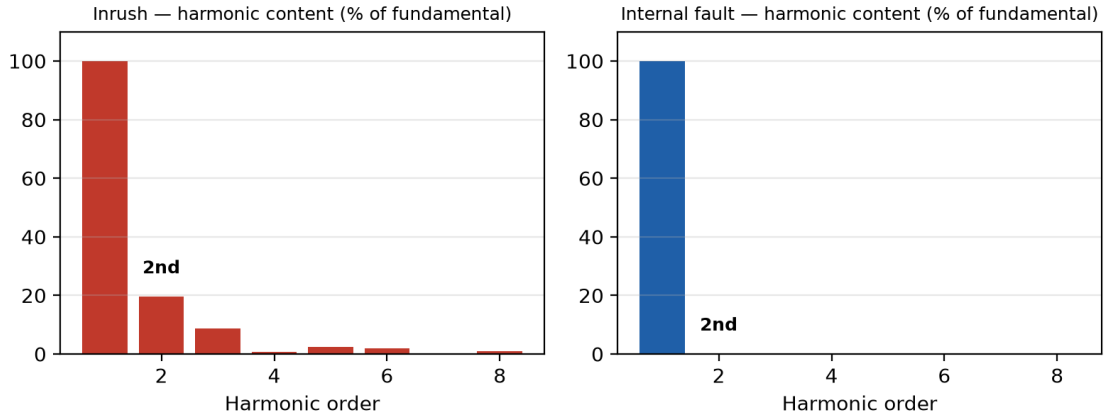


2. The 2nd harmonic — inrush restraint/blocking

When a transformer is energised (or voltage recovers after an external fault), the core can saturate asymmetrically. The magnetising current can reach **5–10× rated** and flows on the source side only. The waveform is unipolar, with gaps near zero — mathematically a lot of DC and **2nd harmonic (100 Hz on 50 Hz systems)**.

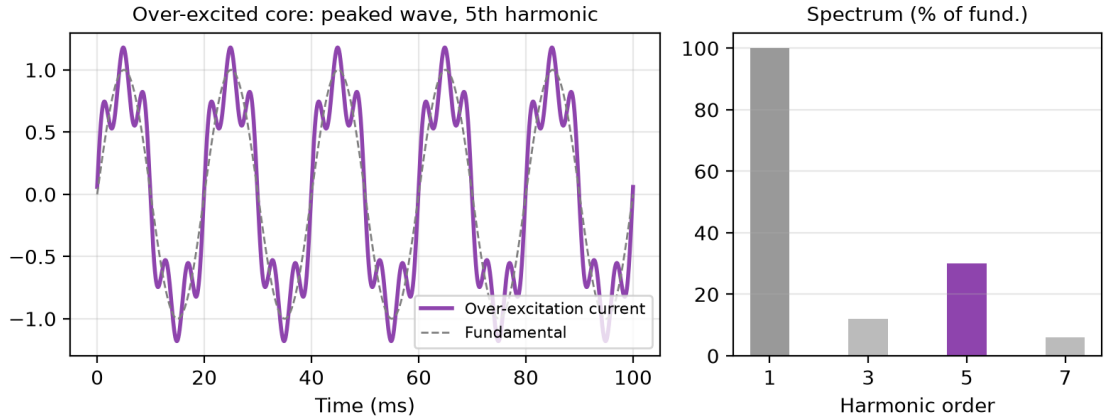


Typical inrush has 15–60% second harmonic; our sample waveform gives about 20%. An internal fault current is close to a pure sine with very little 2nd harmonic.



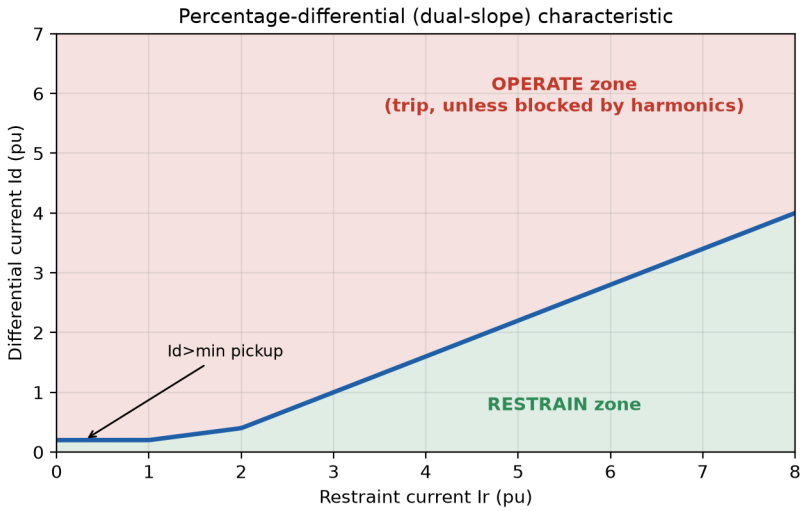
3. The 5th harmonic — over-excitation blocking

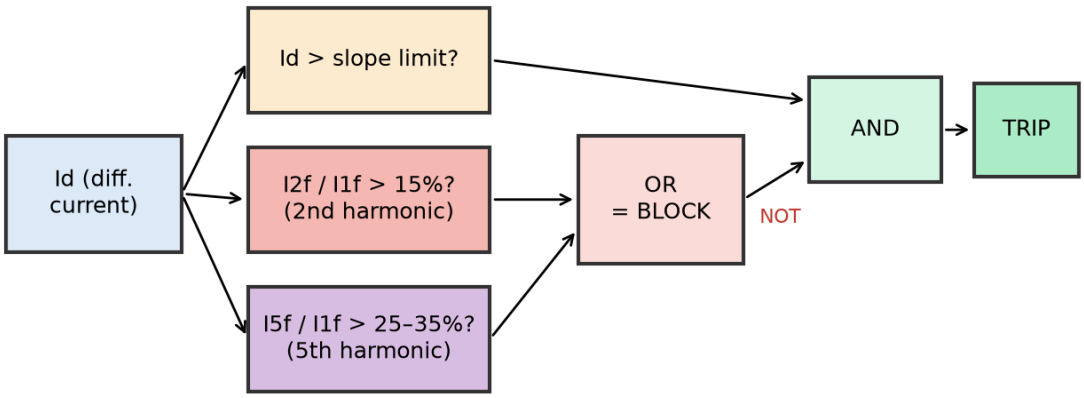
Over-excitation happens when V/Hz is too high (e.g. load rejection, high system voltage, low frequency). The core saturates symmetrically in both half-cycles, so the current has **odd harmonics only**, and the **5th (250 Hz)** dominates (the 3rd is mostly trapped in delta windings). This current is real but harmless in the short term, and flows on one side only, so Idiff appears.



4. How the relay uses them

The relay computes Id and Ir and applies a percentage-differential characteristic. In parallel, it filters (DFT) the 2nd and 5th harmonic from Id and divides by the fundamental. If a ratio exceeds its setting, tripping is blocked/restrained.





5. Quick comparison

	2nd harmonic	5th harmonic
Detects	Magnetising inrush	Over-excitation (V/Hz)
Frequency (50 Hz)	100 Hz	250 Hz
Cause	Asymmetric core saturation on energising / recovery	Symmetric core saturation from high flux
Typical setting	15–20% of fundamental	25–35% of fundamental
Action	Block / restrain 87T	Block 87T (and alarm via V/Hz 24)
Danger of ignoring	Nuisance trip on energisation	Nuisance trip; possible overheating if sustained

6. Practical notes

• **Blocking modes:** per-phase, cross-blocking (any phase blocks all three) or 2-out-of-3 — cross-blocking is the most secure for inrush.

• **Fault during inrush:** modern relays add waveform-based/gap-detection logic and an unrestrained high-set element (Id >>, ~8–10×In) that is *never* blocked by harmonics, so heavy internal faults still trip fast.

• **CT saturation on external faults** is handled by the restraint slope, not by harmonics.

• **Settings caveat:** modern low-loss cores can give inrush with 2nd harmonic below 15%; the long-line or CT remanence cases may need lower settings — verify against the relay manual (e.g. SEL-387, ABB RET, Siemens 7UT) and commissioning tests.

• **Testing:** inject 2nd/5th harmonic superimposed on fundamental on one phase and confirm the block asserts at the set percentage.