Do CTs Like DC? Performance of Current Transformers With Geomagnetically Induced Currents

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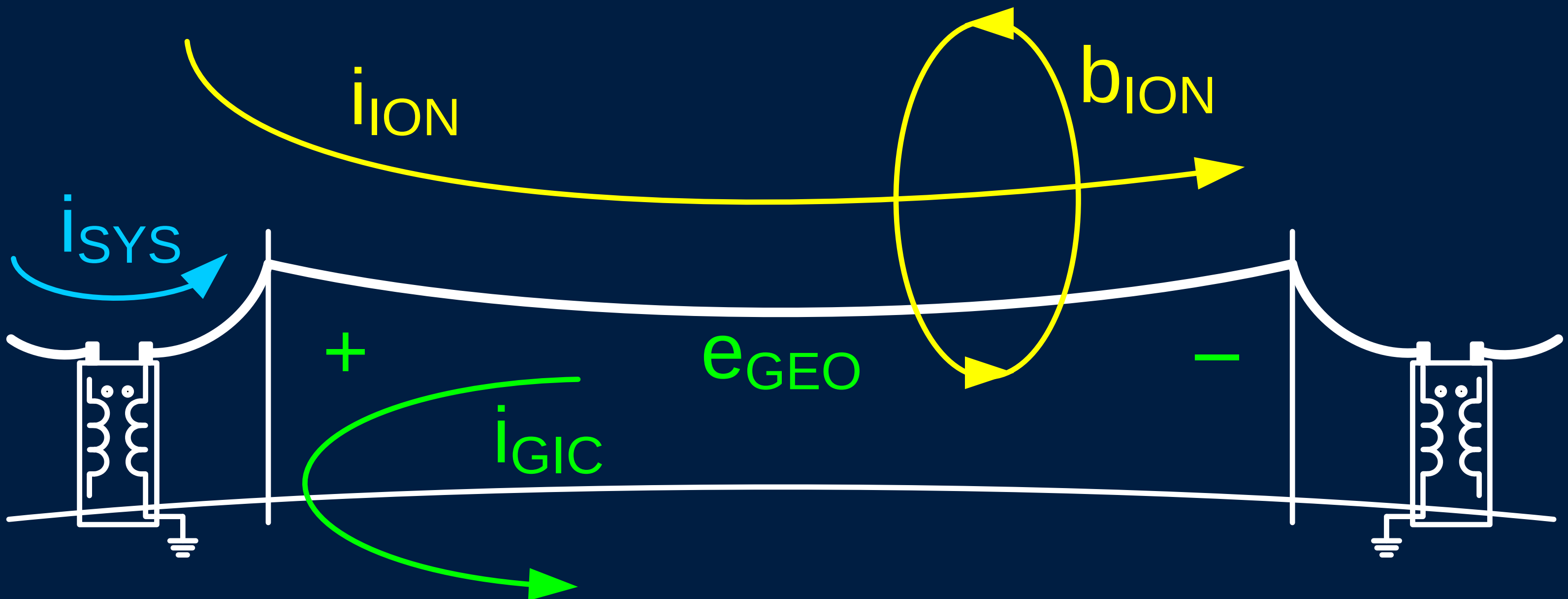
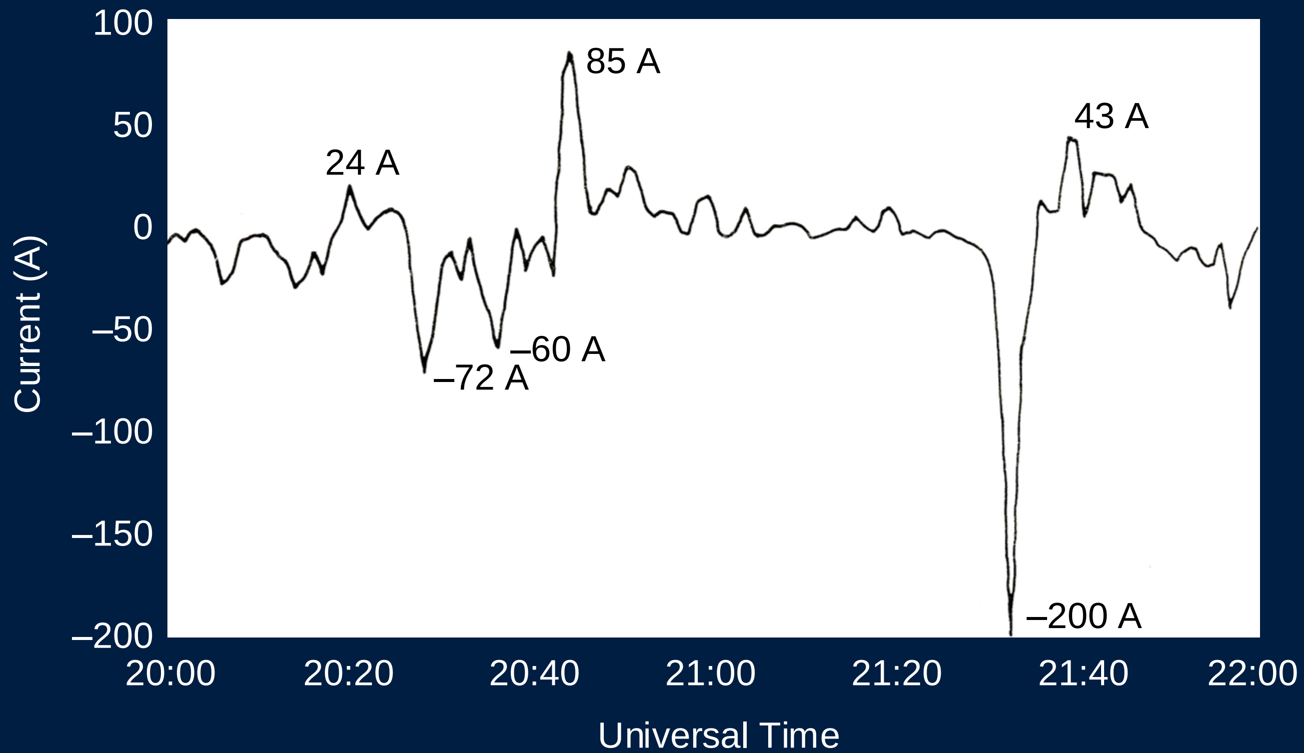
GIC Mechanism



- Solar storms → ionospheric current (i_{ION}) → magnetic field (b_{ION}) → geoelectric emf (e_{GEO}) → current flow (i_{GIC})
- GIC circulates between grounding points, added onto system frequency current (i_{SYS})

GIC Characteristics



GIC measured in a transformer neutral in Finland during a geomagnetic storm on March 24, 1991 [4]

- Changes very slowly – practically DC
- Up to 300 A primary in grounding point
- Splits equally between phases (100 A per phase)

GIC Concerns

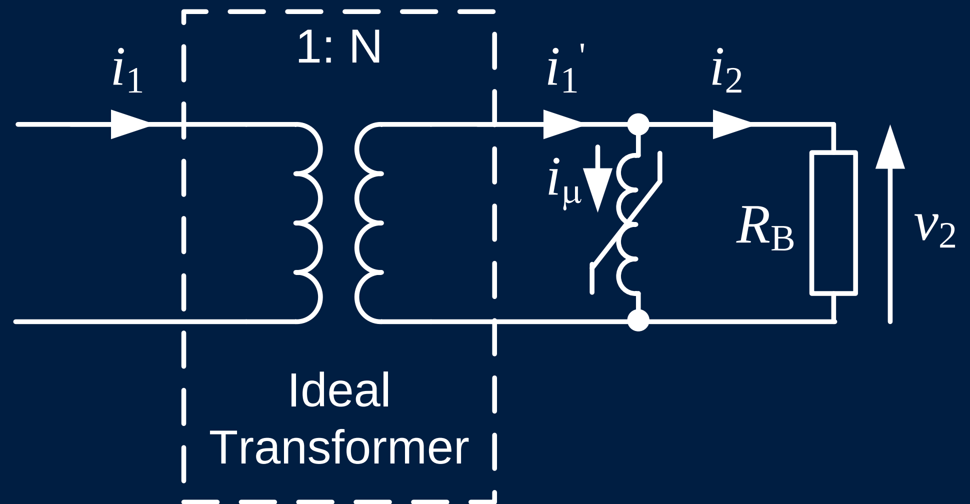
- Transformer thermal stress due to unique way of overexcitation
- Generator rotor thermal stress due to negative-sequence harmonics from GSU under GIC
- CT performance, protection, security, and dependability

CTs “Don’t Like” DC

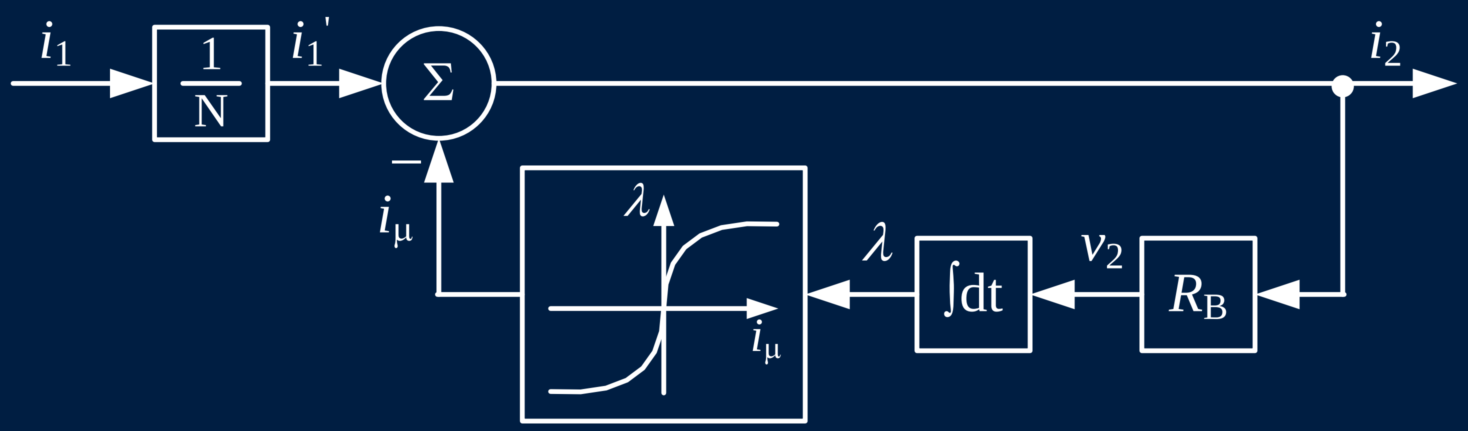
- Exponentially decaying component in fault current eventually saturates CT
- Hypothetical CT and protection concerns
  - Security of 87 elements
    (line, transformer, and bus)
  - Performance of line protection in general
  - CT thermal stress

CT Representation

Circuit Model

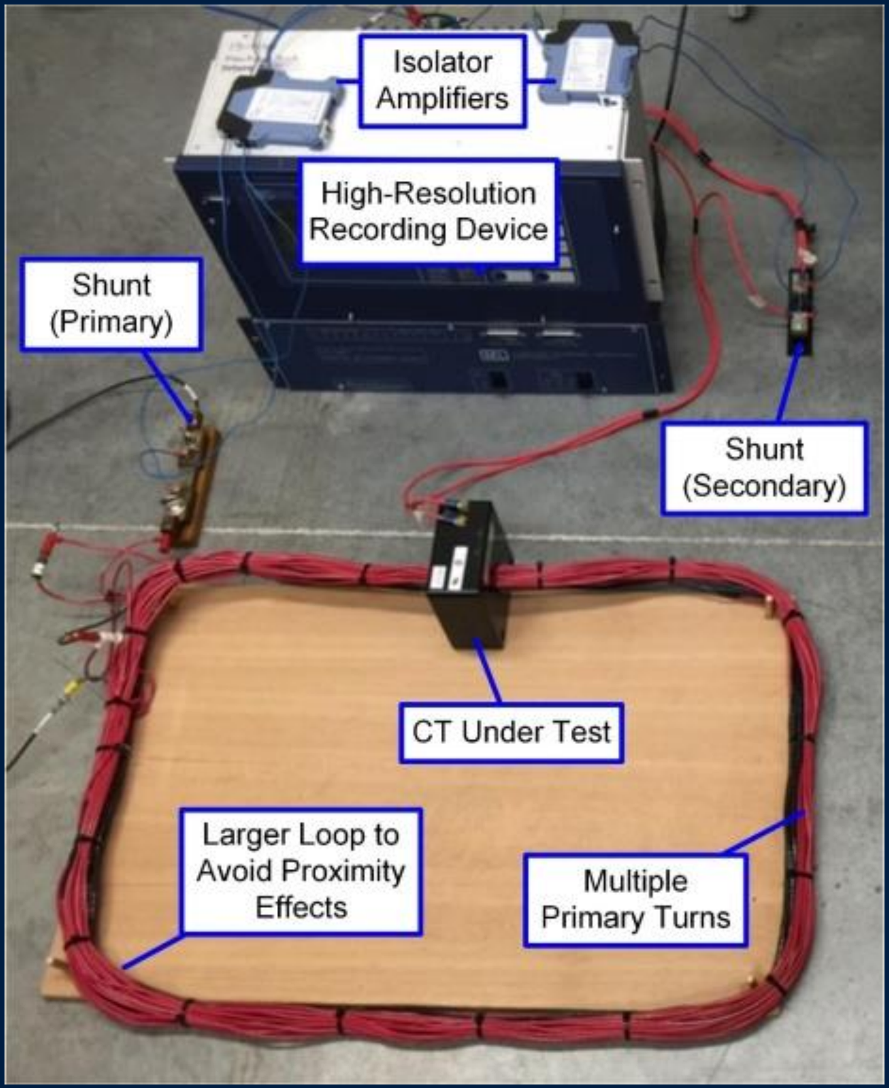


Signal Model

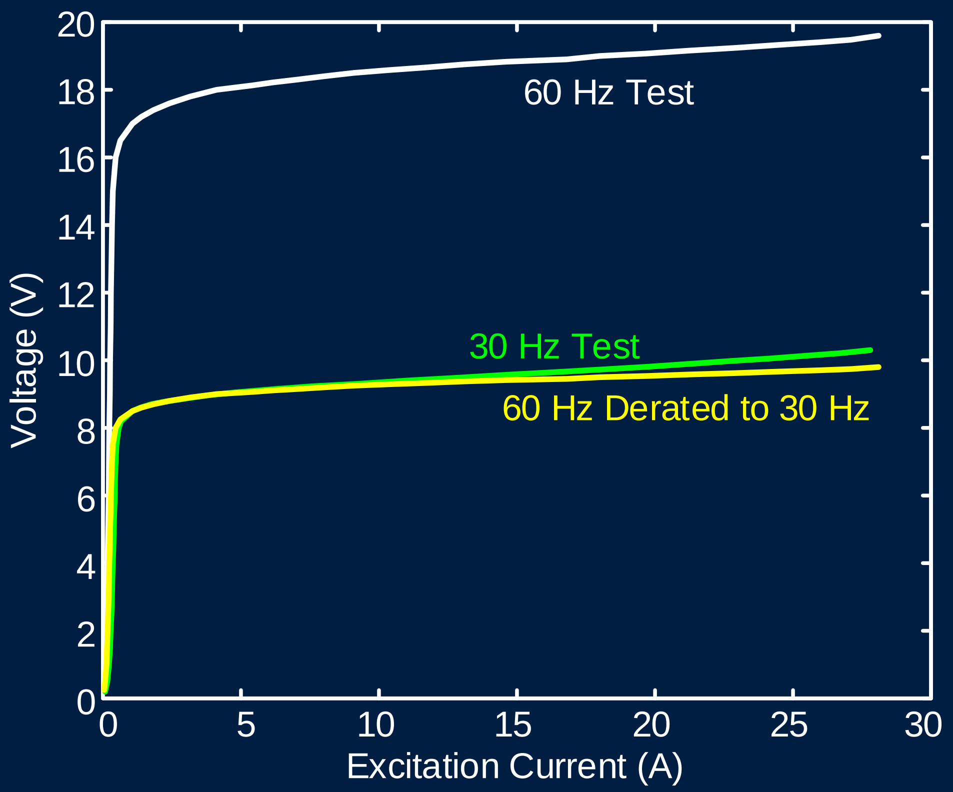


Physical 150:5 C10 CT Tests

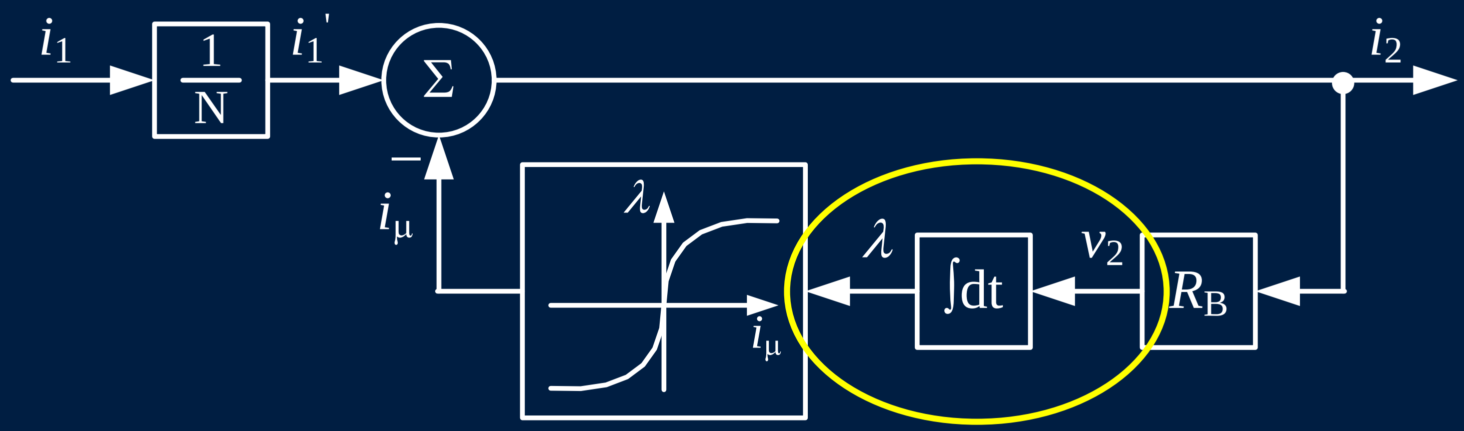
Laboratory Setup



Excitation Characteristic



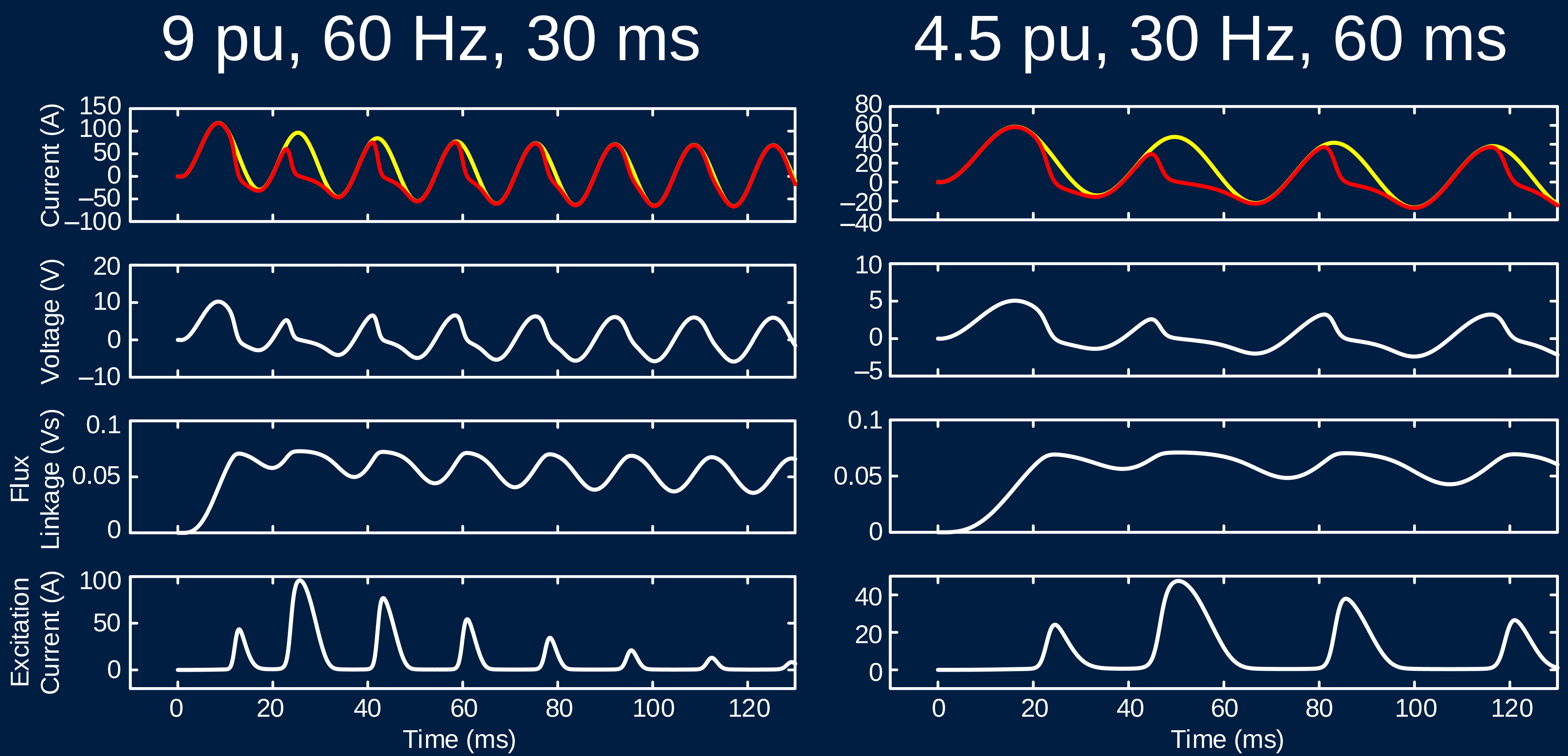
CT Response to Low Frequency



For a given current magnitude:

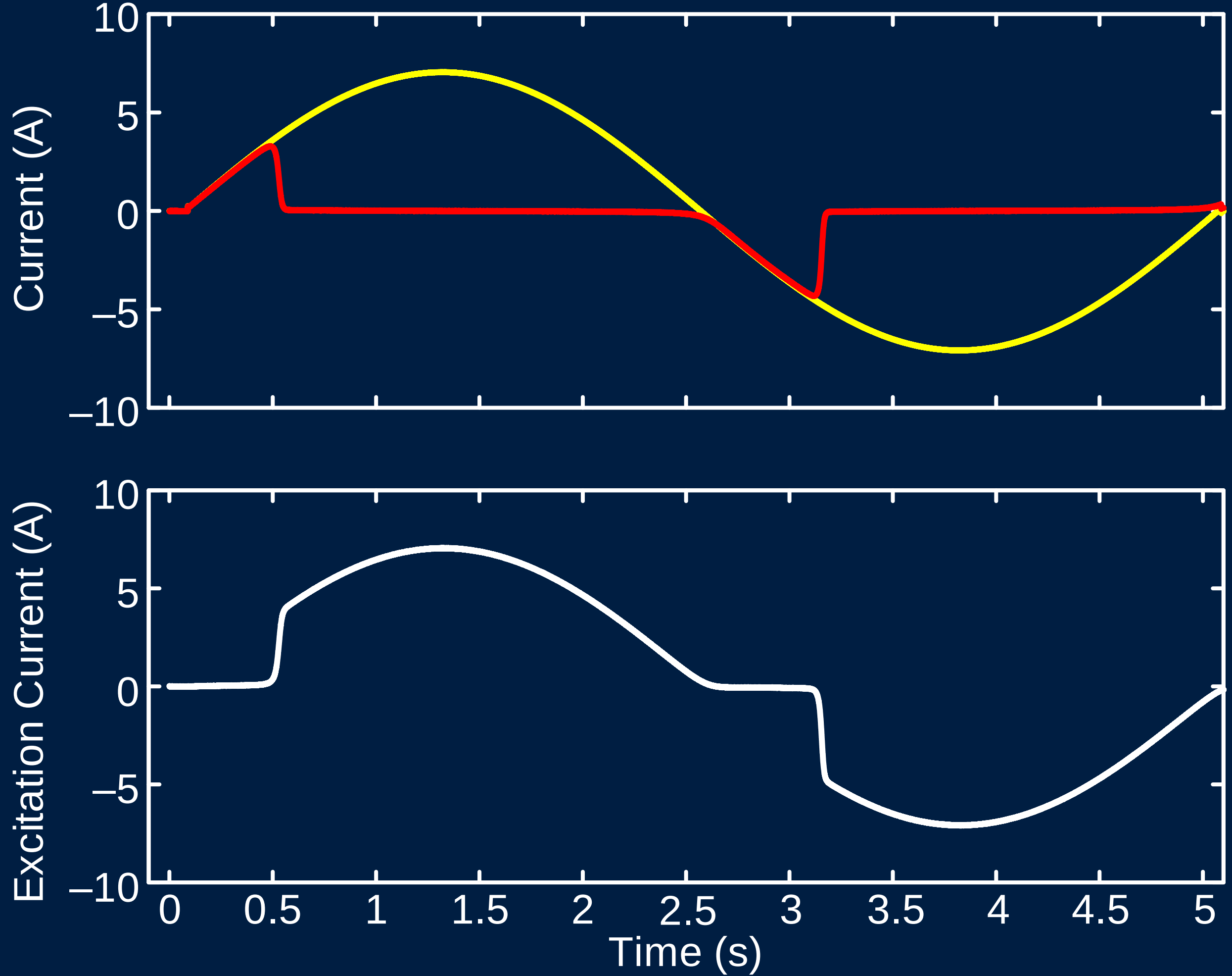
Lower the frequency → Higher the peak flux → Higher the excitation current → Higher the CT error

Frequency Derating



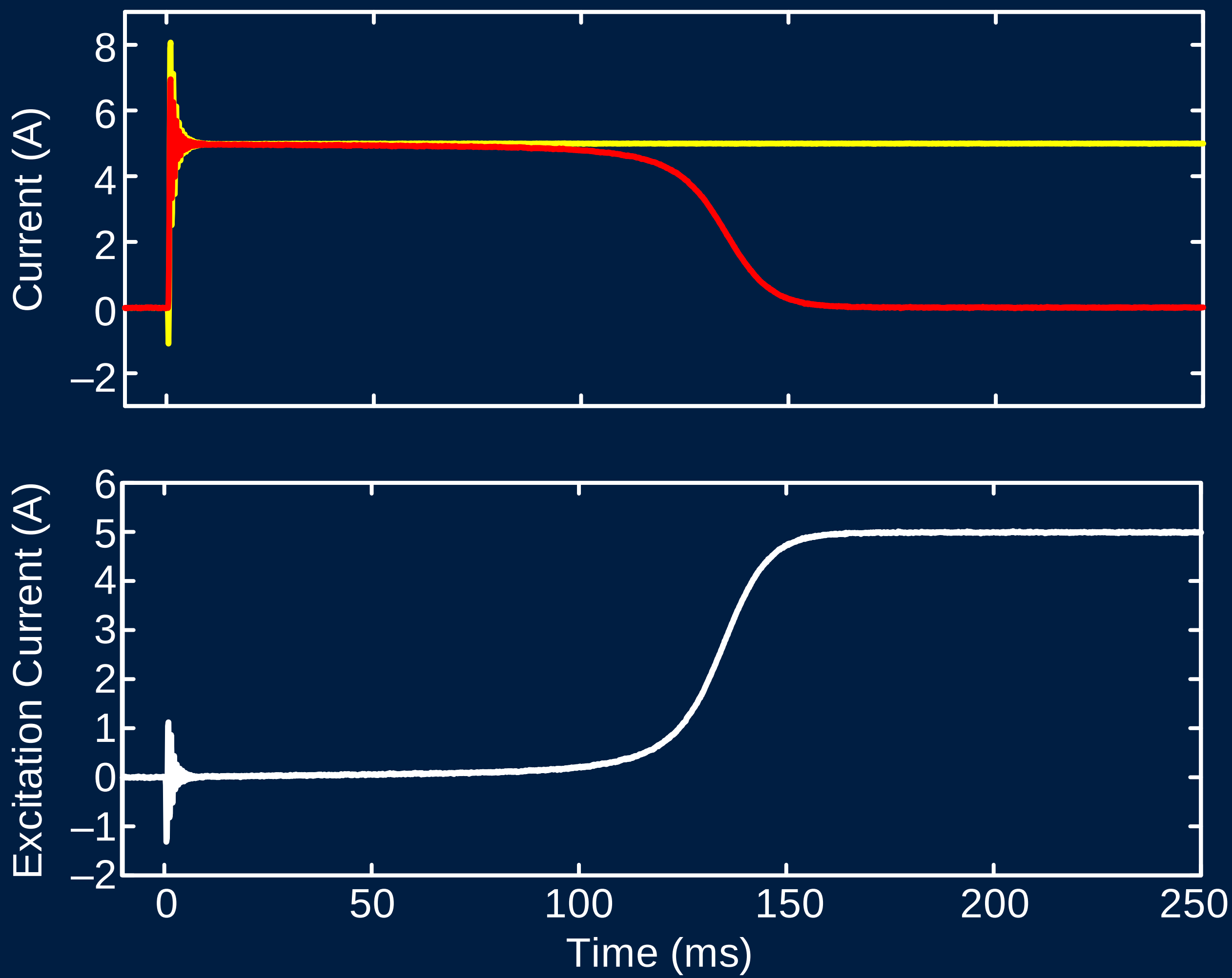
Half the frequency = half the current
(with the same errors)

CT Response to Low Frequency



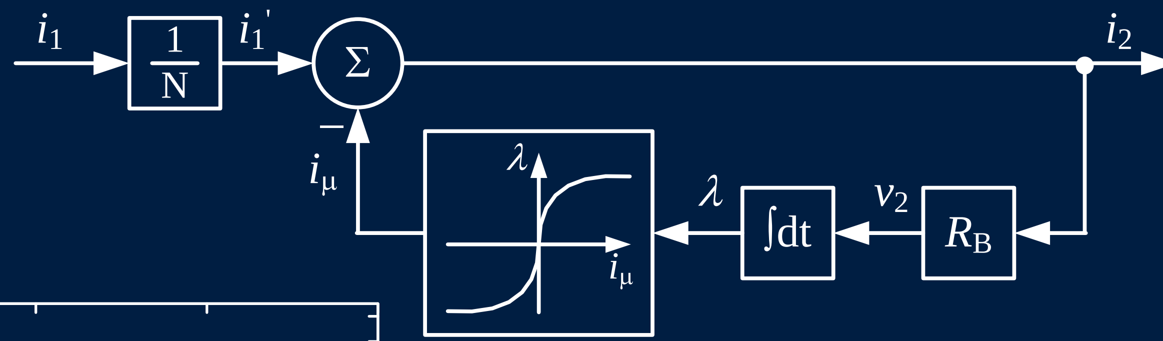
Laboratory test: 0.2 Hz, 150 A (1 pu)

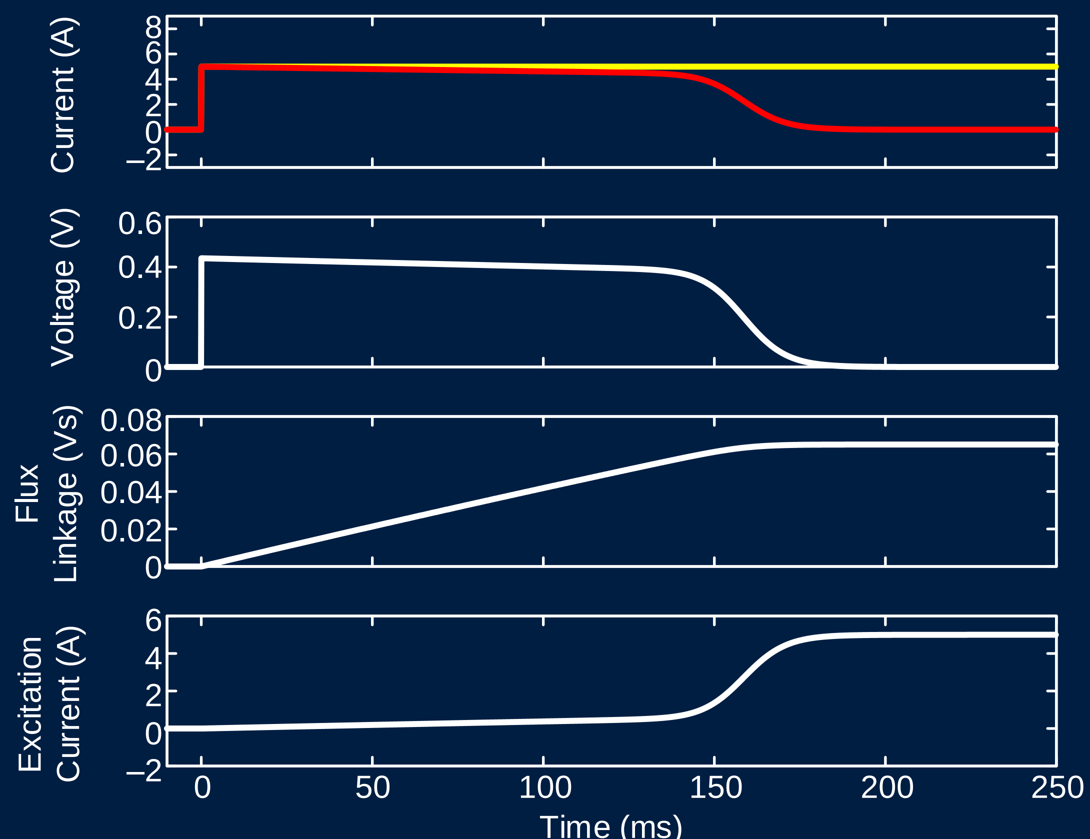
CT Response to DC

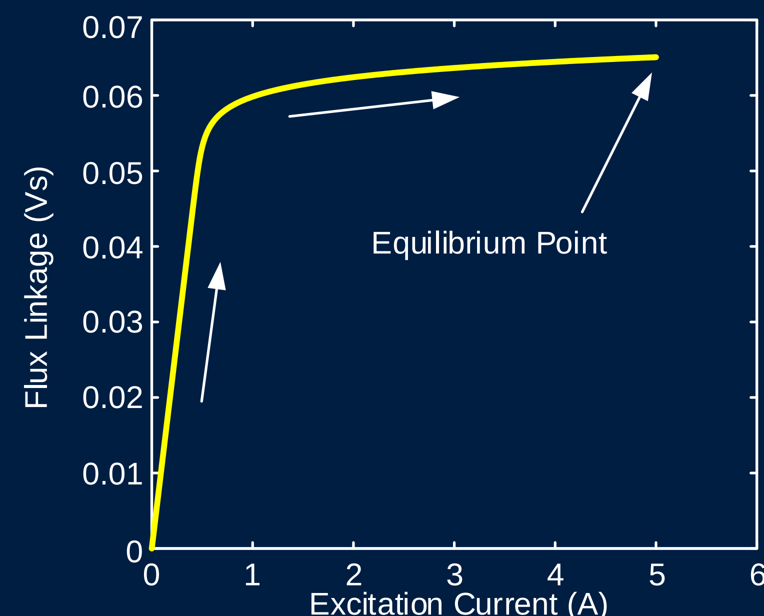


Laboratory test: 150 A (1 pu)

CT and DC Explained

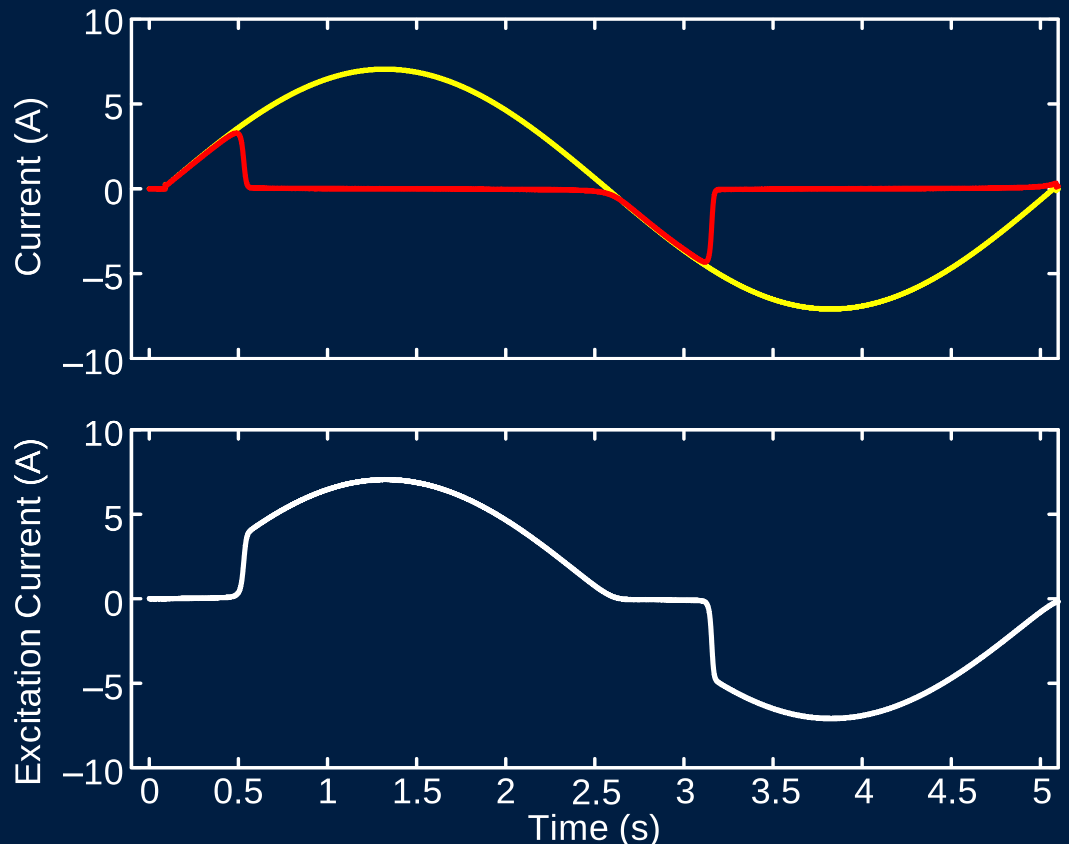




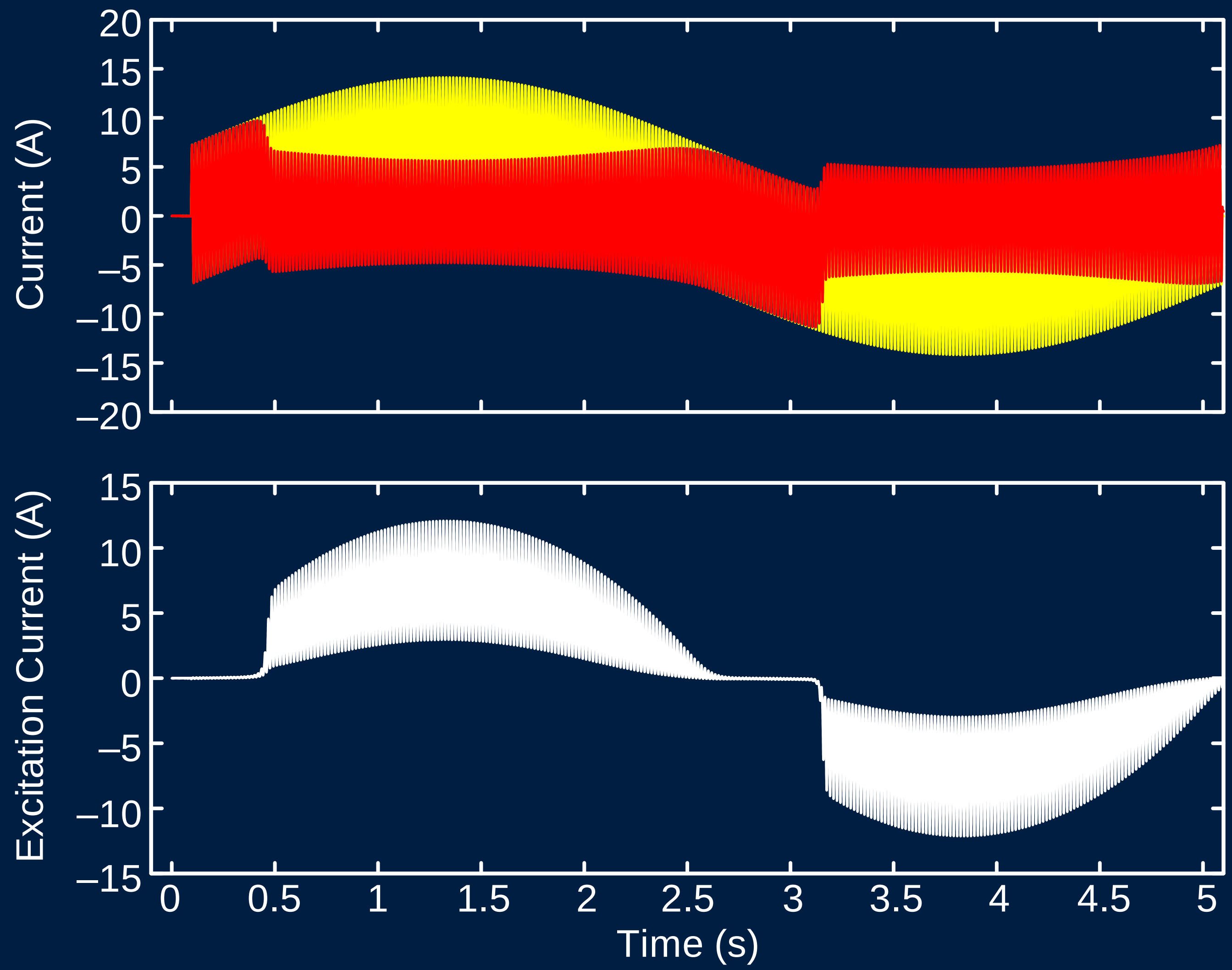


CT and Superposition

<u>Input</u>	<u>Output</u>
Near DC	No DC (“complete saturation”)
+	+
Rated AC	???

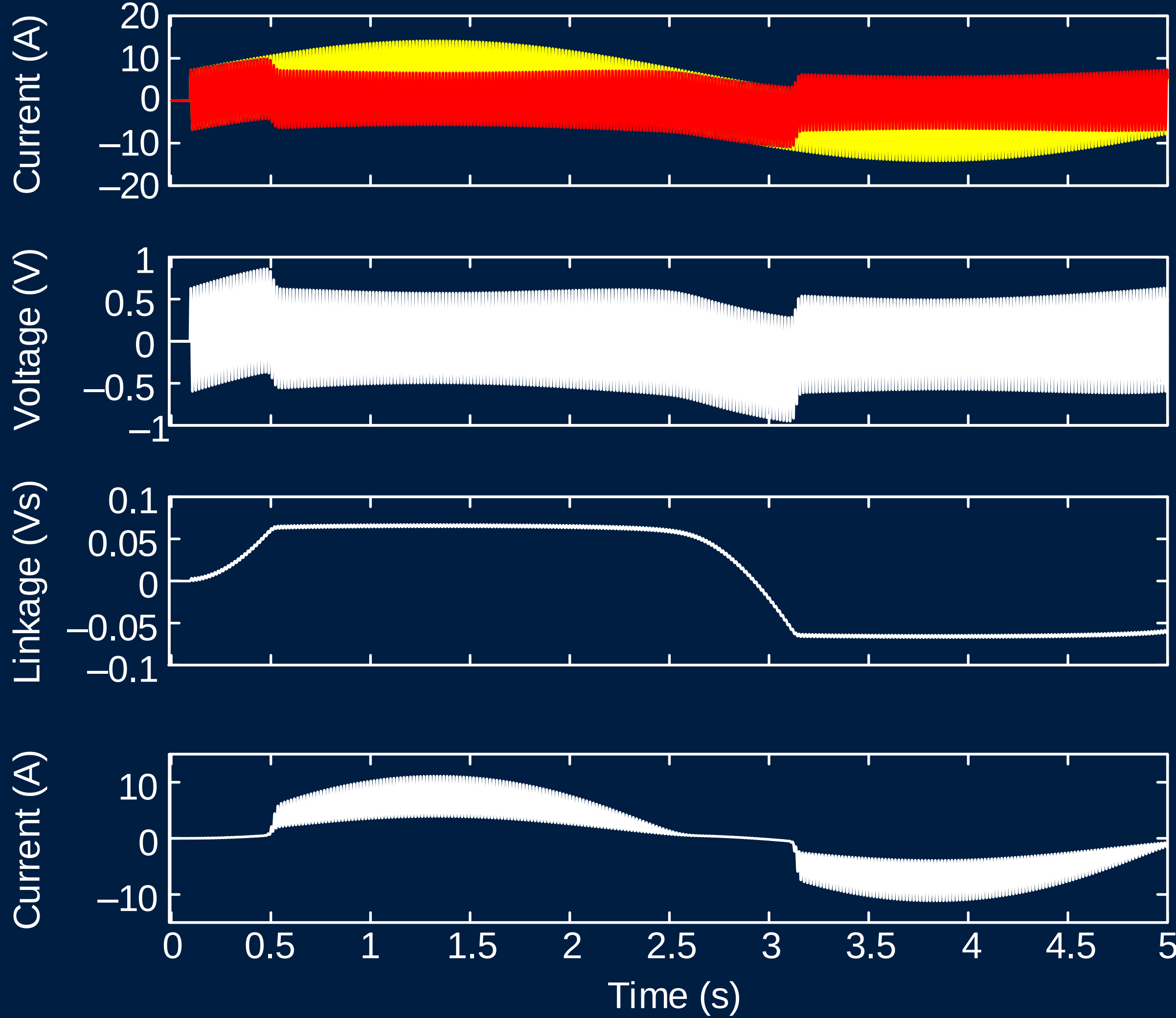


CT and Superposition



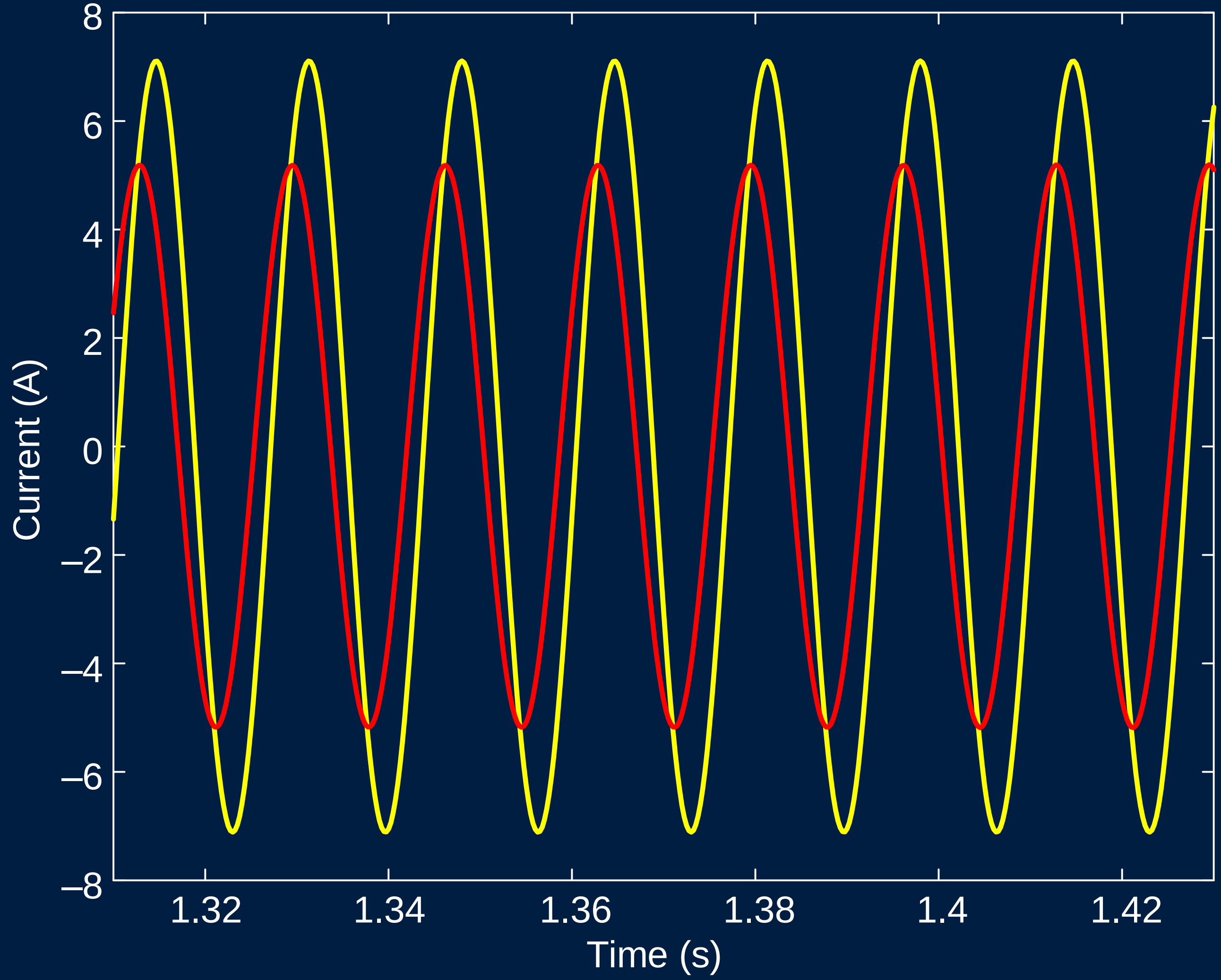
Laboratory test: (0.2 Hz, 150 A) + (60 Hz, 150 A)

CT and Superposition



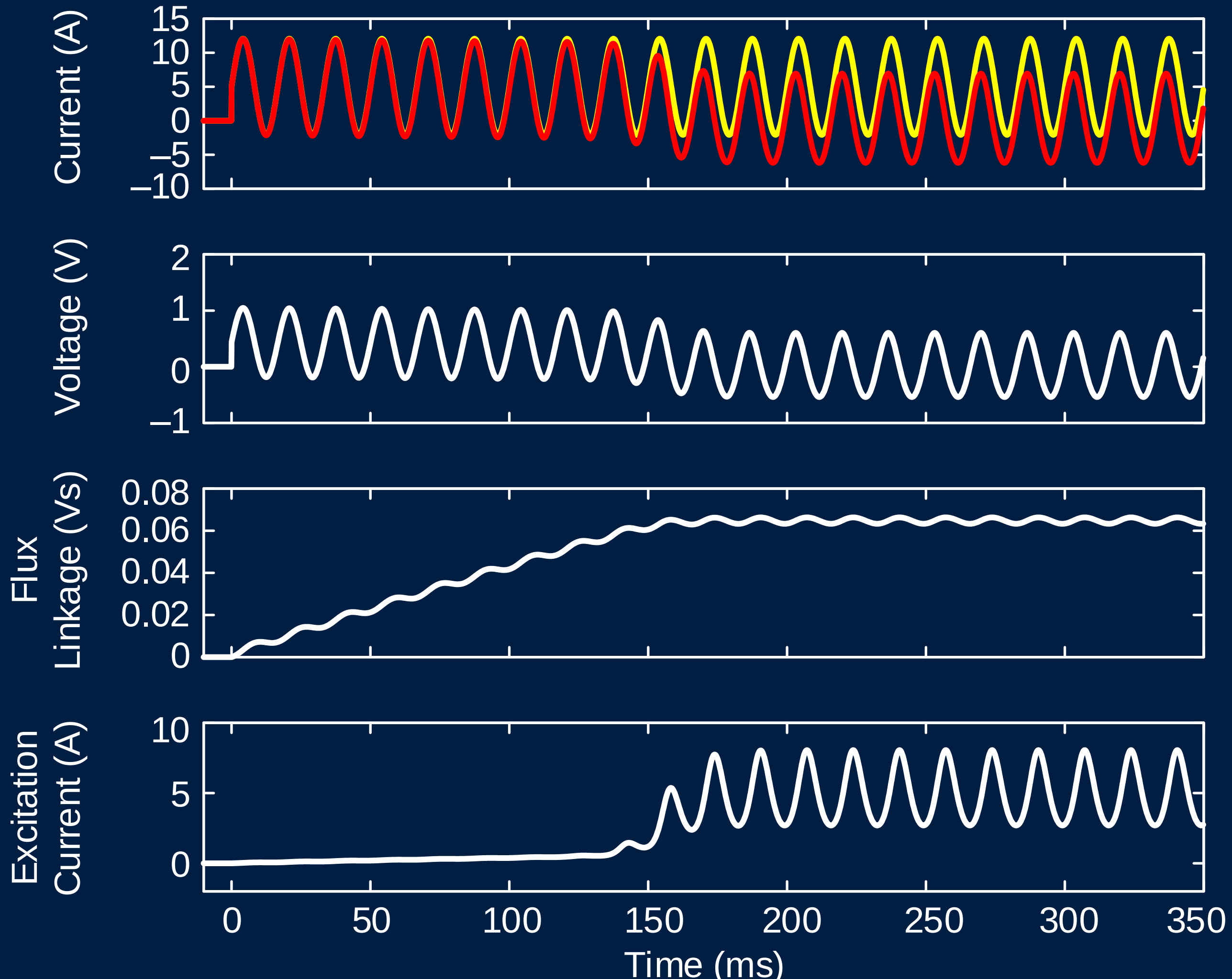
Simulation: (0.2 Hz, 150 A) + (60 Hz, 150 A)

CT and Superposition



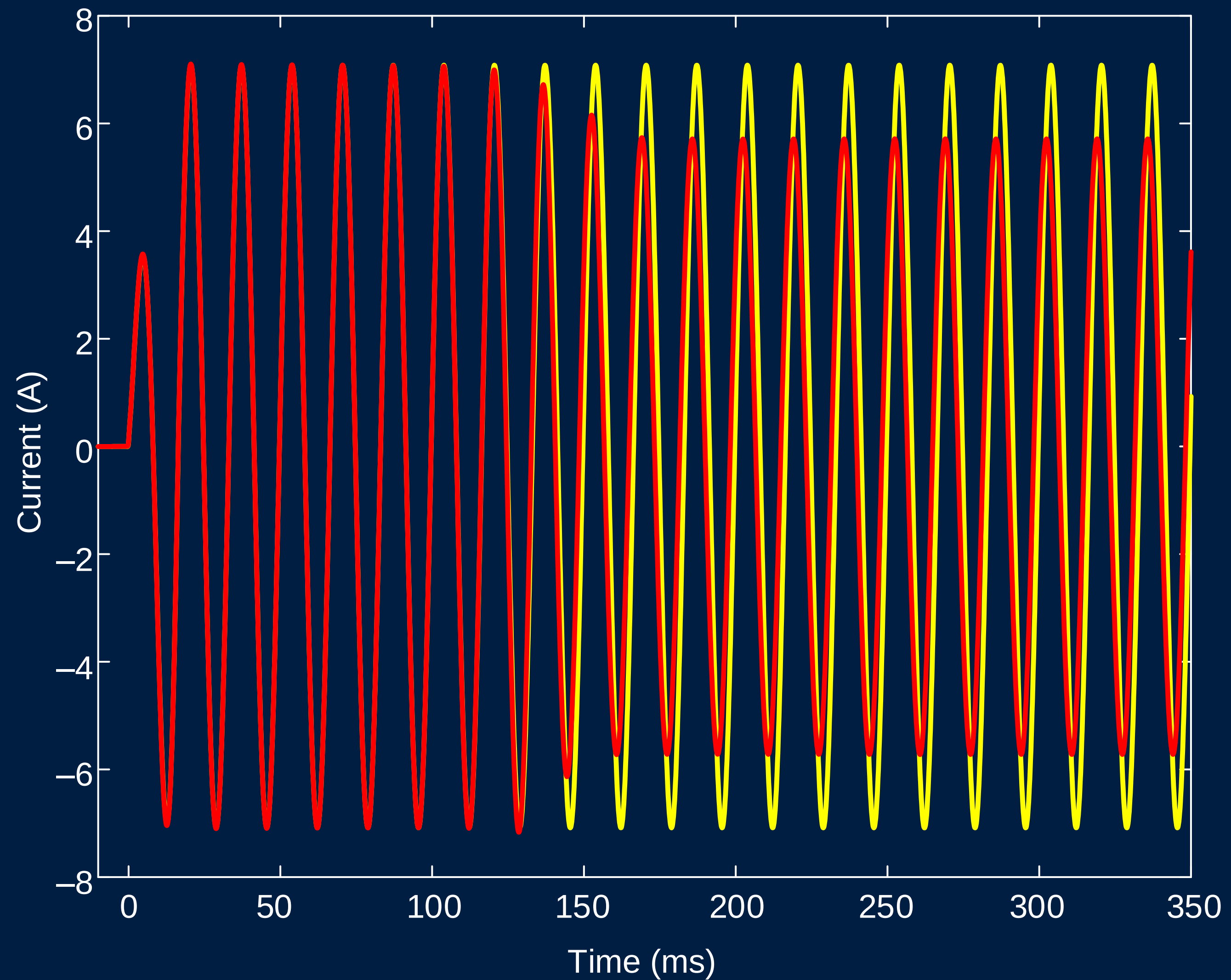
27% and 39° 60 Hz errors with 0.2 Hz current as high as 1 pu

CT and Superposition



Simulation: 150 A DC + (60 Hz, 150 A)

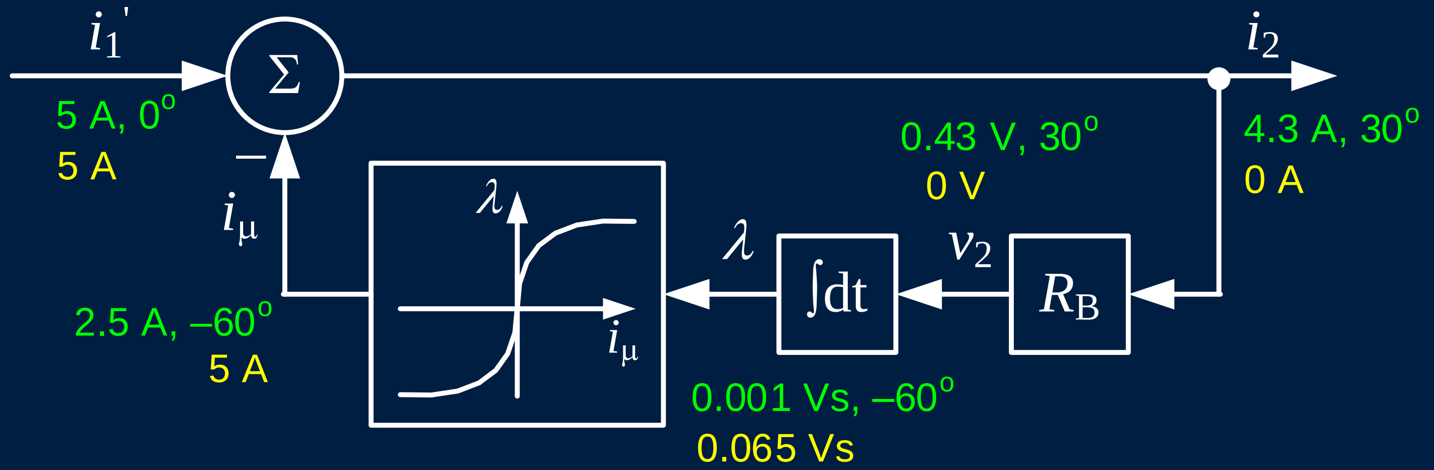
CT and Superposition

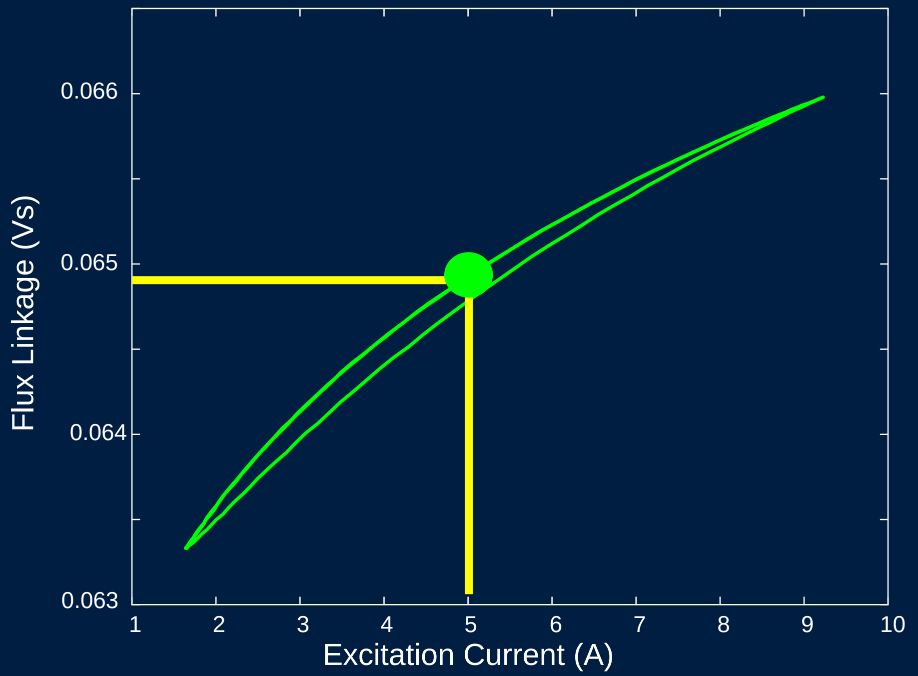


19% and 31° 60 Hz errors with DC current as high as 1 pu

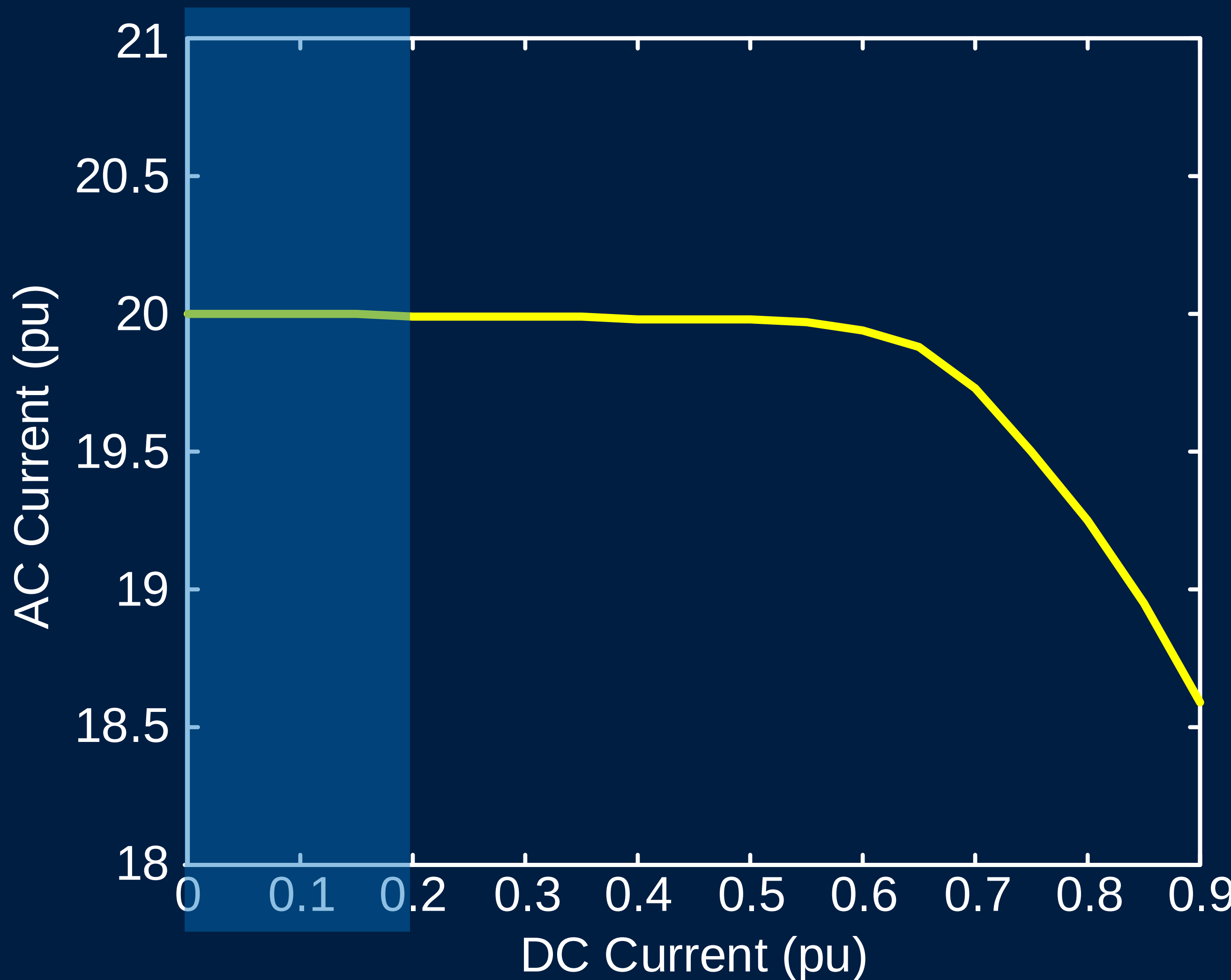
Explanation

AC RMS Values
DC Values





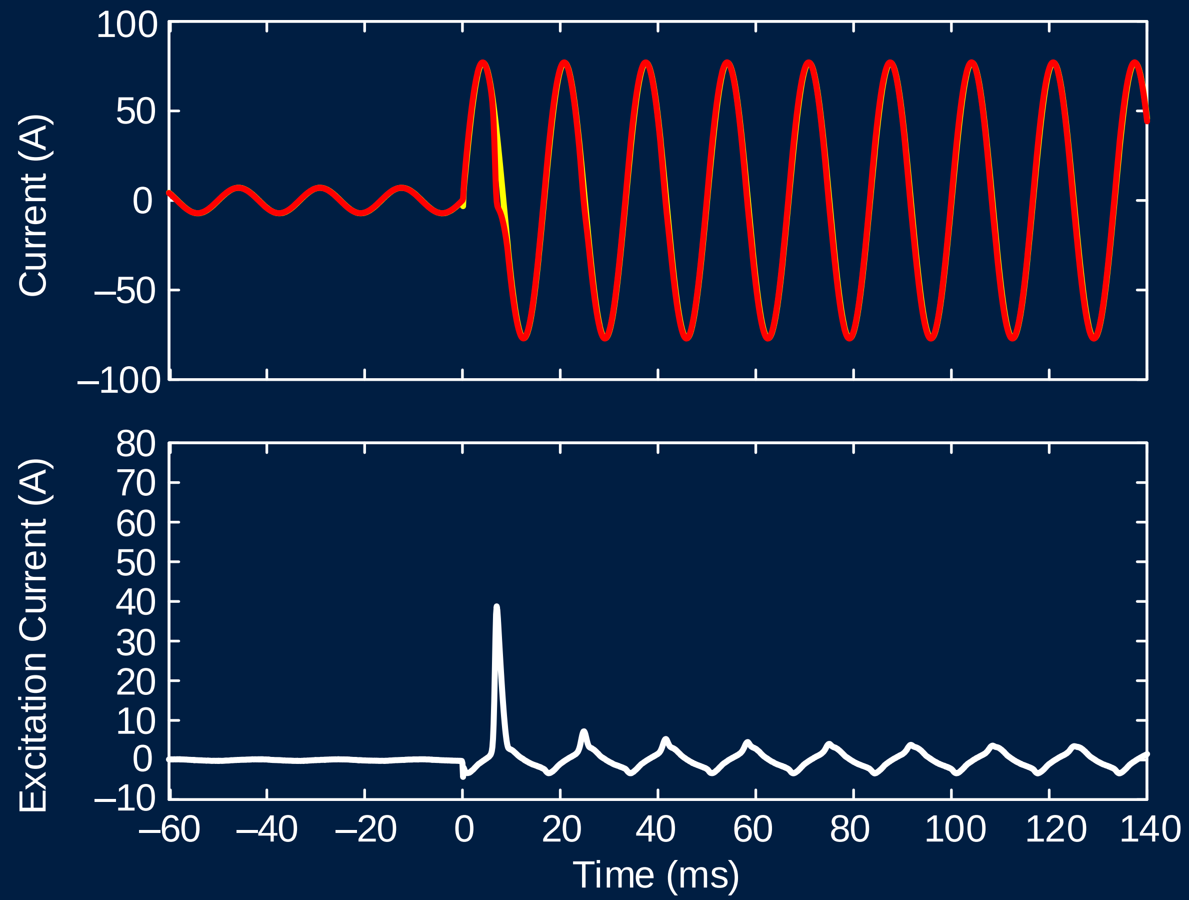
CT Derating for Symmetrical Current



GIC has no impact on CT in fault steady state

Transient CT Performance

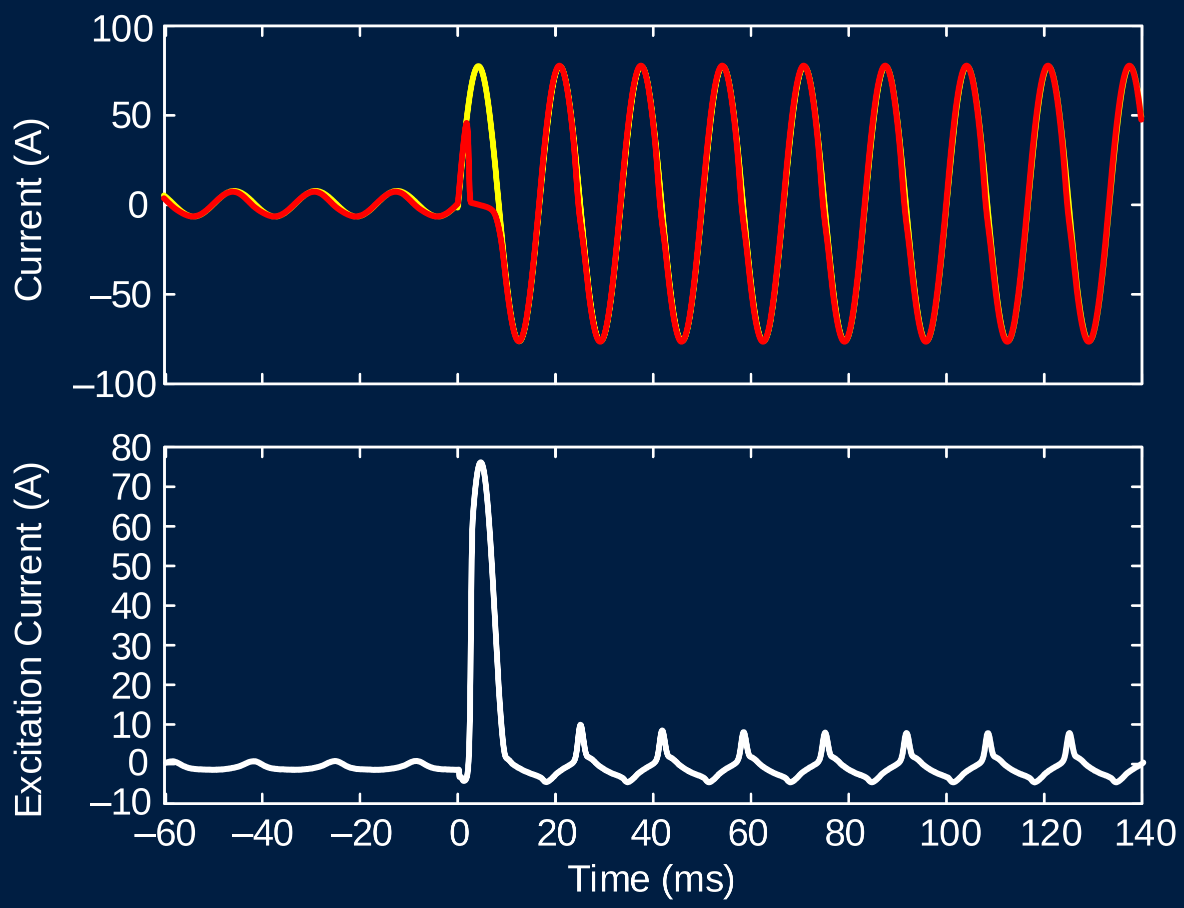
Without GIC



C10, 150:5 CT – fault current of 1.6 kA rms with prefault load of 150 A rms and no GIC current

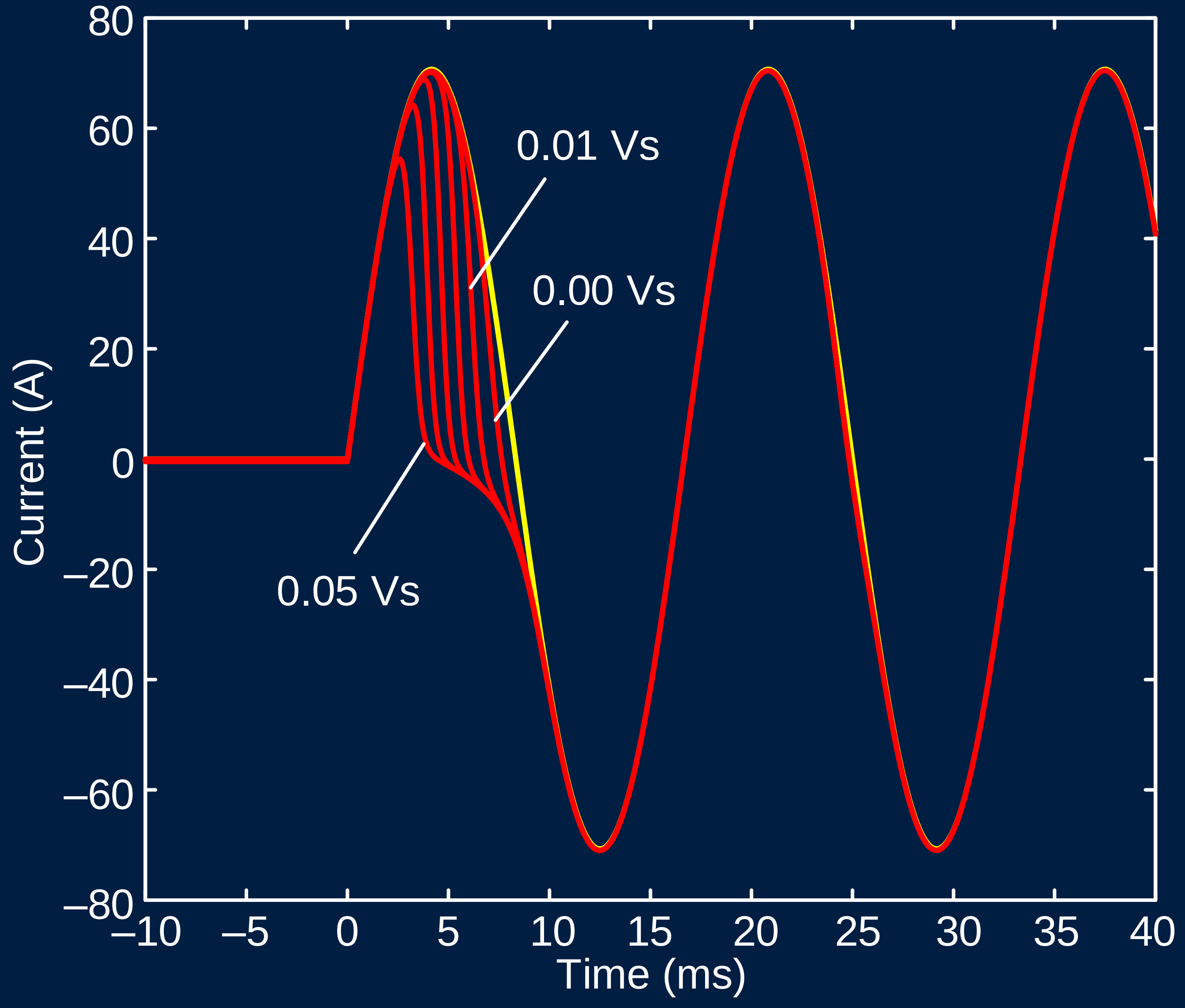
Transient CT Performance

With GIC

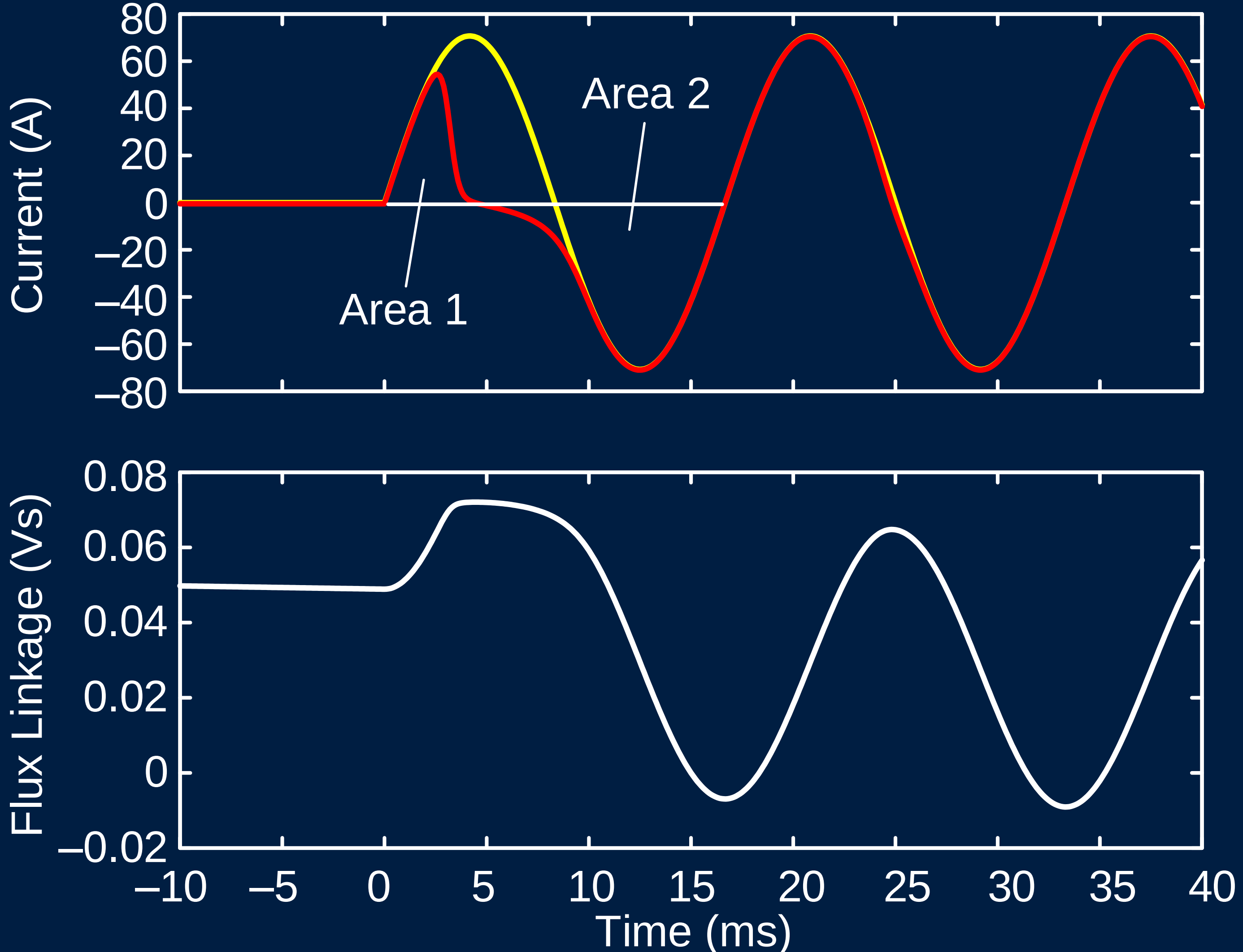


C10, 150:5 CT – fault current of 1.6 kA rms with prefault load of 150 A rms and 15 A DC GIC current

Impact of GIC Similar to Residual Flux



Why Does CT Recover?



CT Performance With GIC

- GIC has no practical effect on load or fault current measurement in steady state
- GIC has considerable effect on transient CT saturation during faults
- GIC impact is short-lived
- GIC and residual flux effects are very similar

What Does It Mean for Protection?

- No measurable impact of GIC on protection performance
  - Slower relays not impacted
  - Faster relays already deal with CT saturation
- No standing DC in secondary currents, no need to analyze protection input CTs
- No correlation between days of high GIC and UOs, according to our historical data

Conclusions

- Do CTs like DC?
  No, you cannot measure DC with CTs
- Do CTs mind DC?
  A little, standing DC impacts accuracy of AC measurement
- What is GIC impact on protection CTs?
  Very short-lived, similar to residual flux
- Is protection affected?
  No, if design considers other CT errors

Questions?