Distribution Harmonic Issues: Telephone Noise

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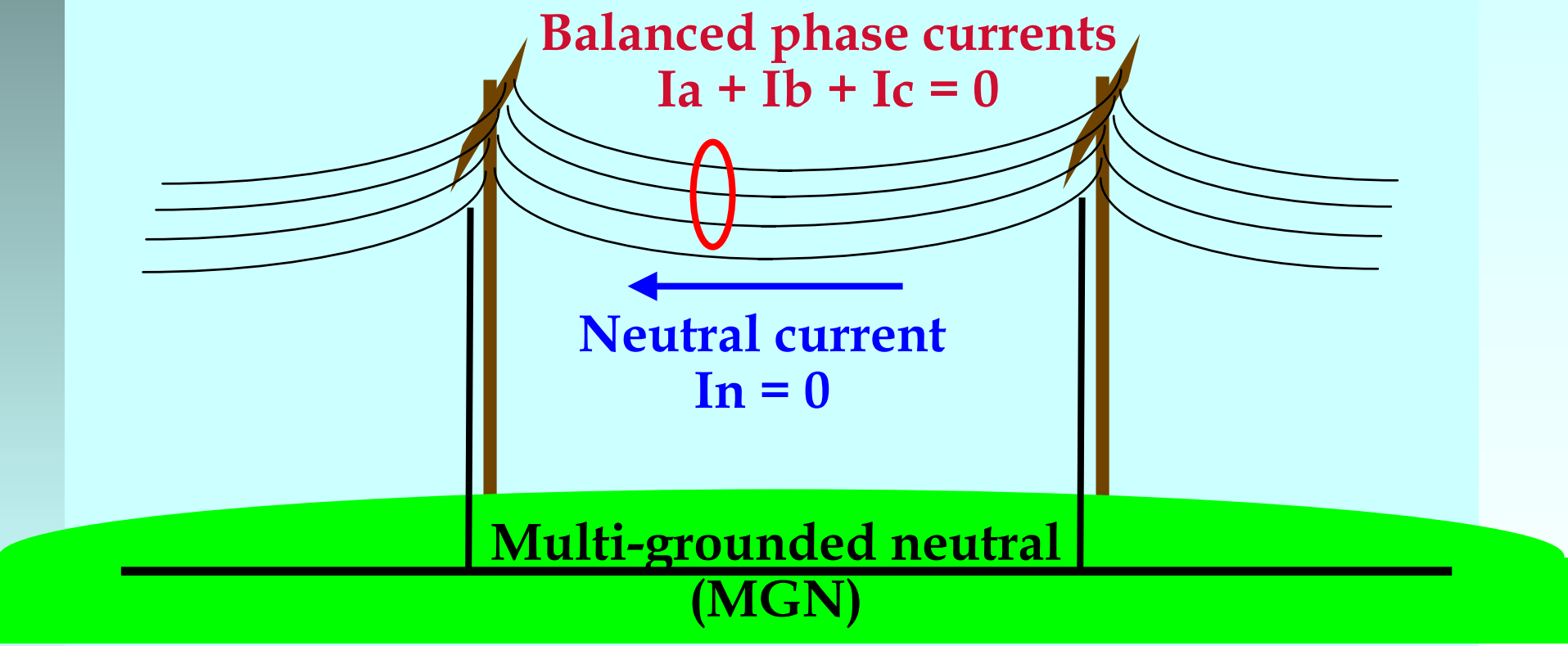
Balanced system, no harmonics



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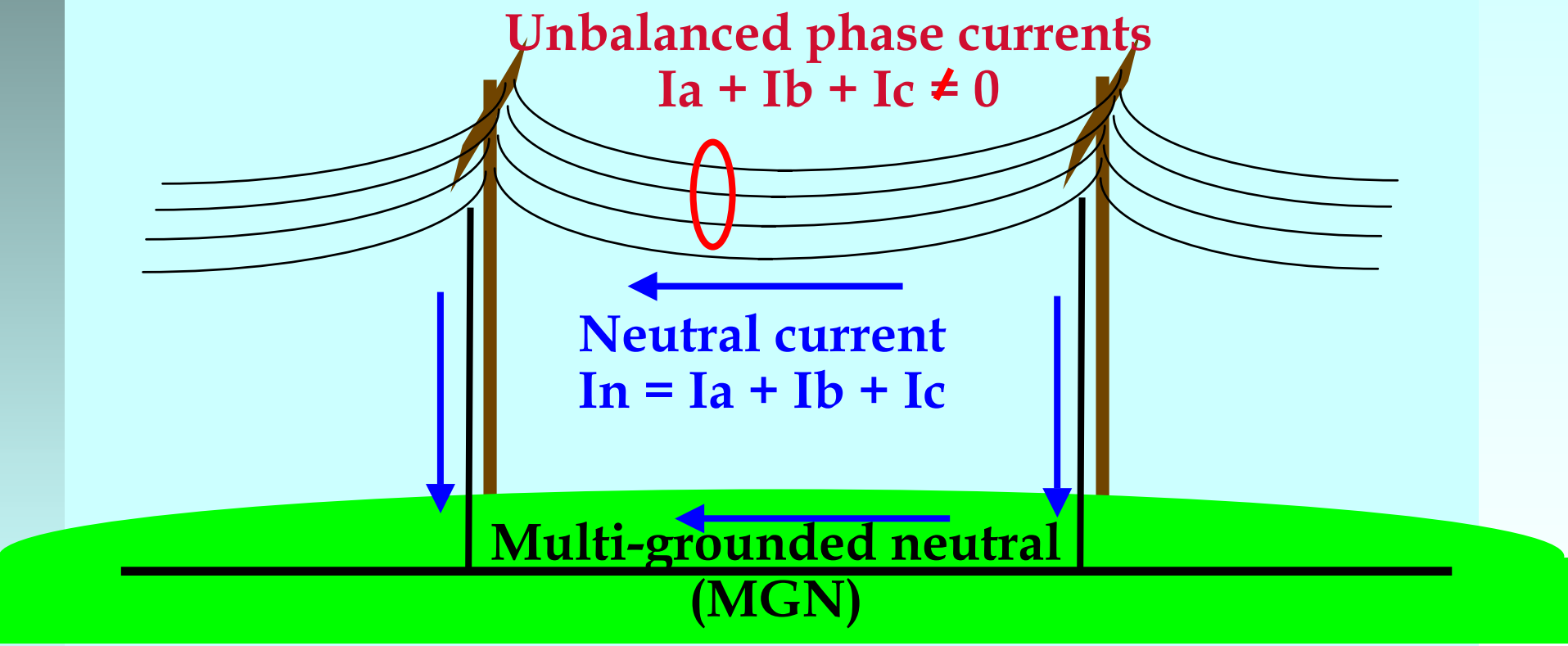
Unbalanced system, no harmonics



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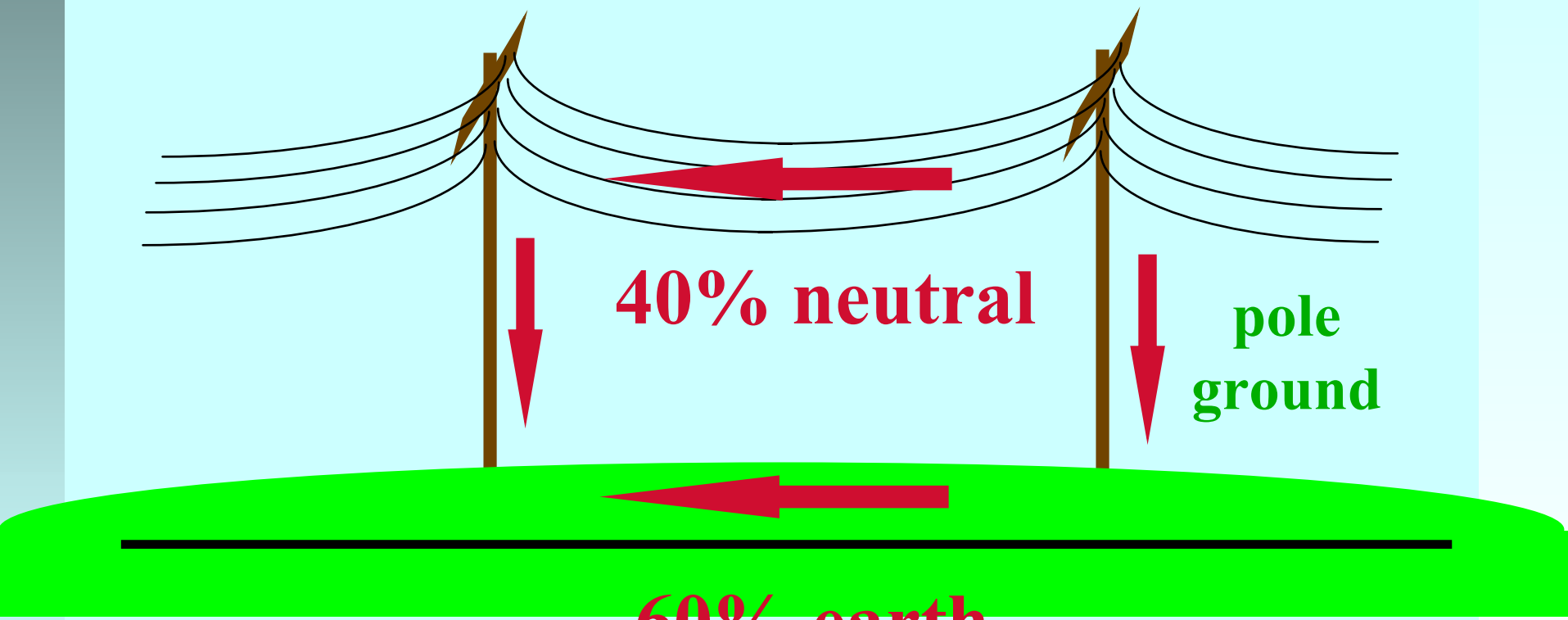
Return current



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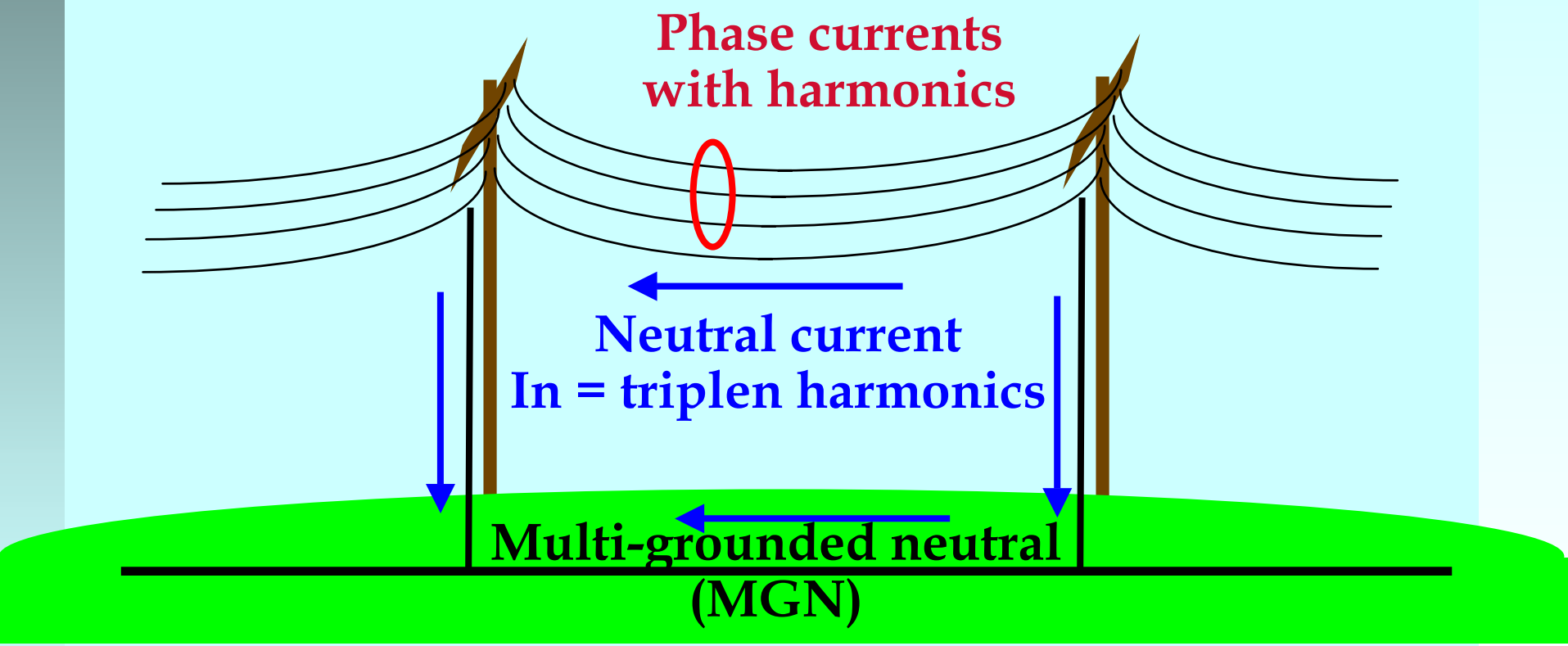
Balanced system, harmonics



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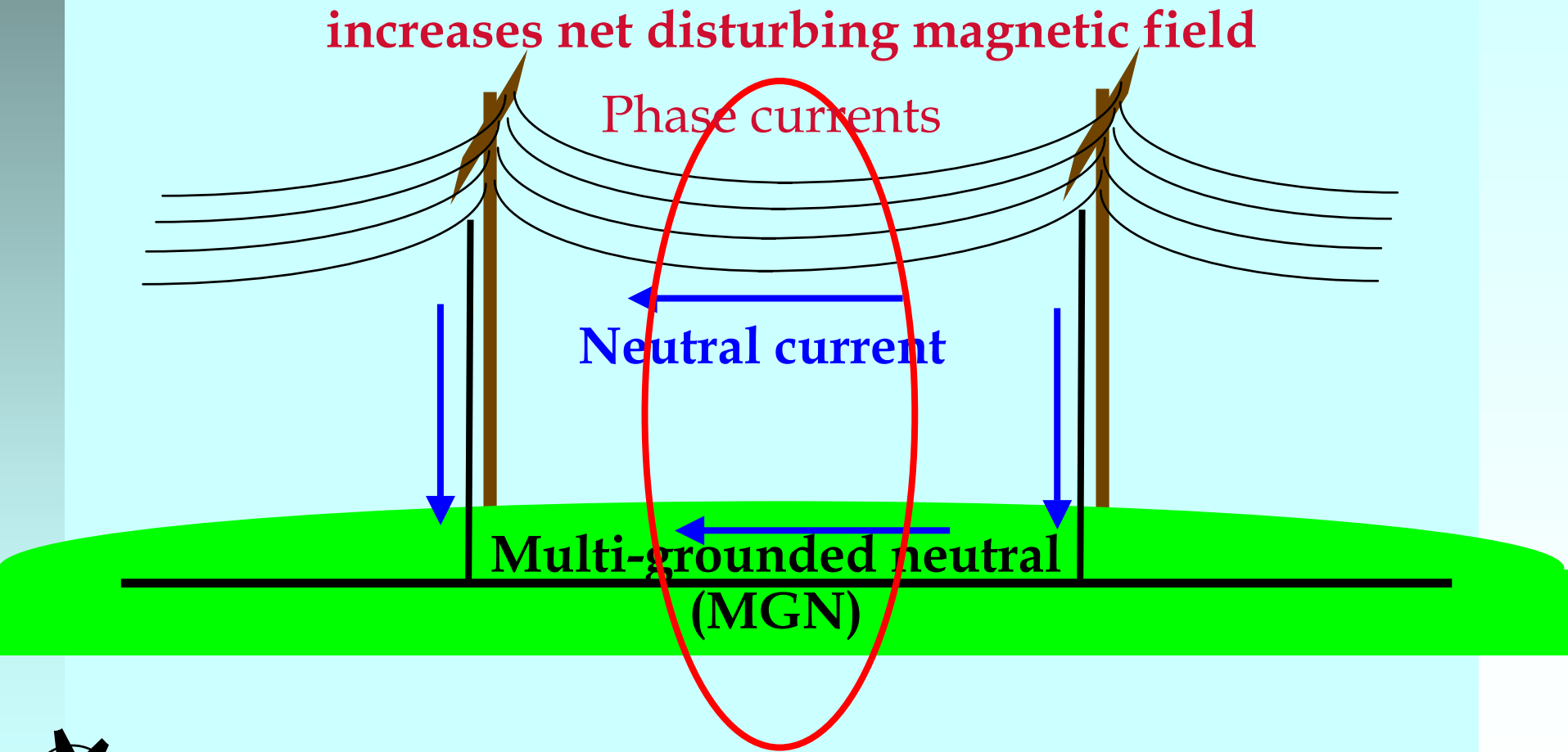
Neutral current flows in MGN



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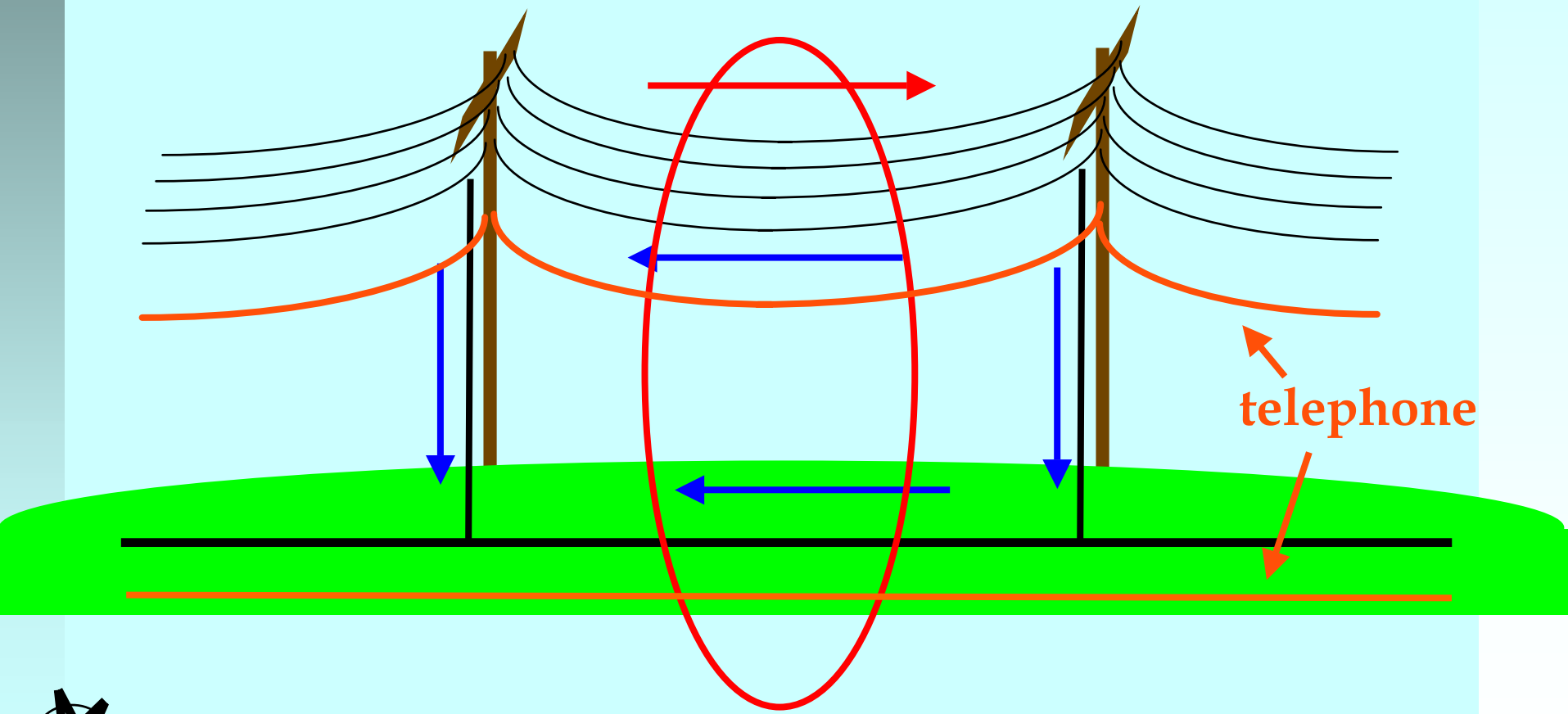
Net disturbing field couples with telephone conductors, induces noise



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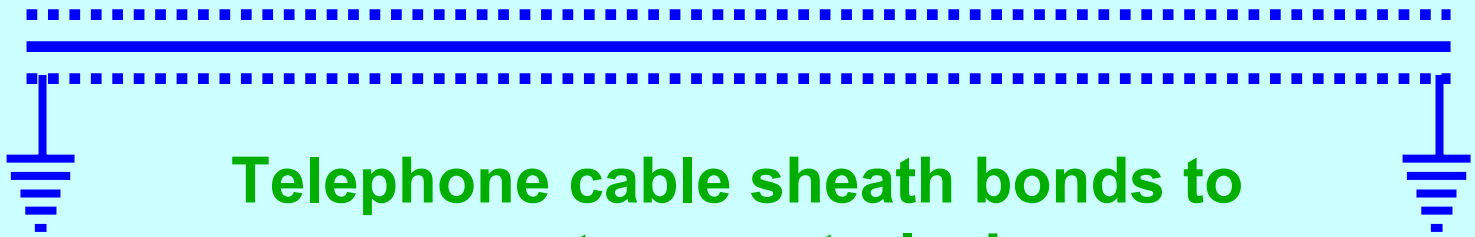
Shielding

Number of phase conductors changes

Feeder changes direction



Telephone cable sheath bonds to power system neutral wherever exposure changes.

Other devices and techniques help, but none can completely mitigate high noise levels.

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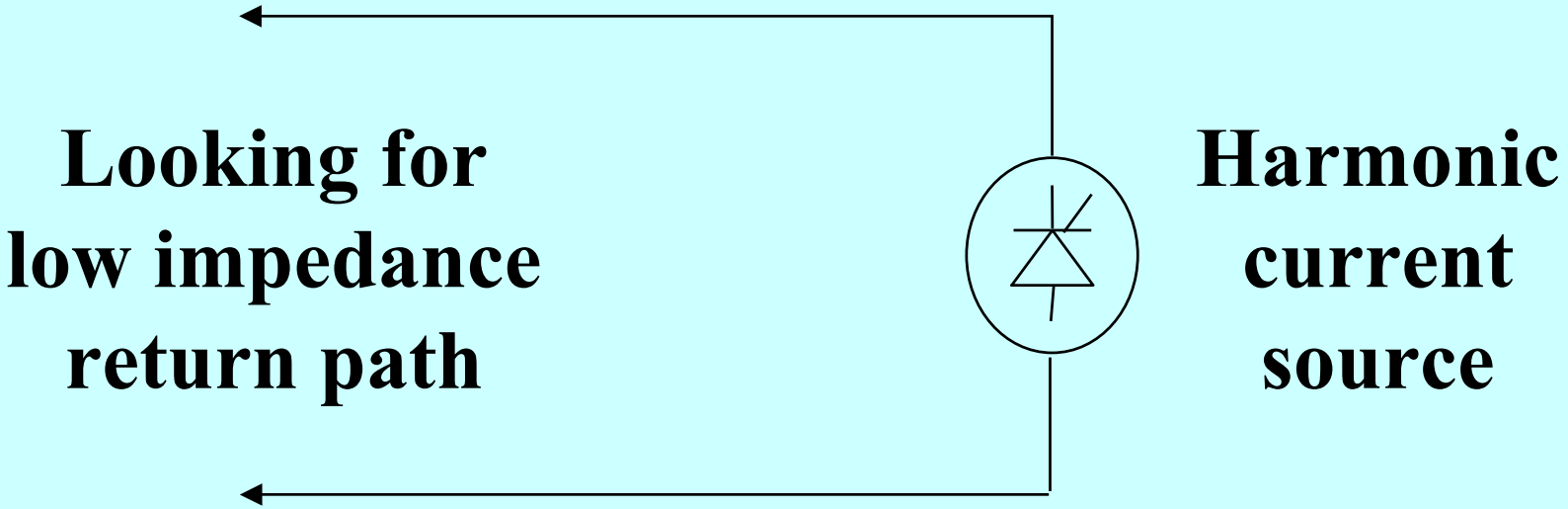
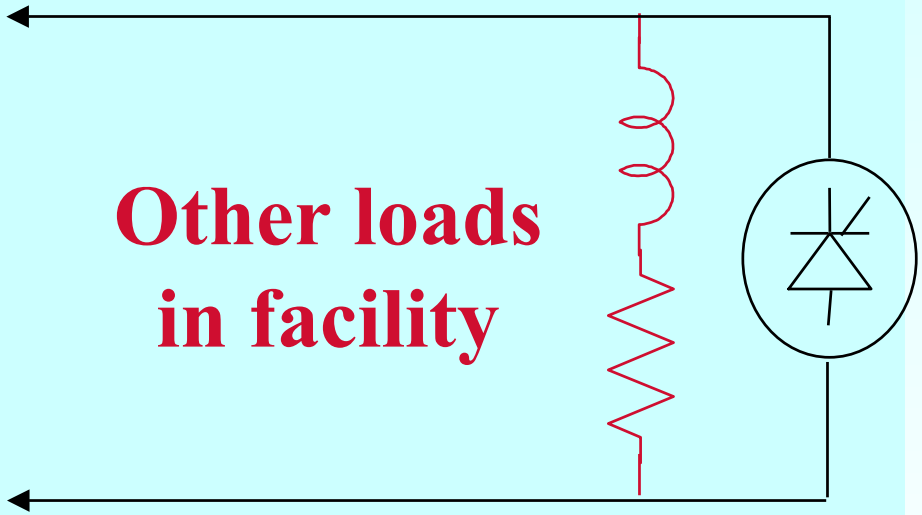
Harmonic current flows from and returns to its source:



Harmonic return path

Inductive:
$X = 2\pi fL$
increases
with frequency

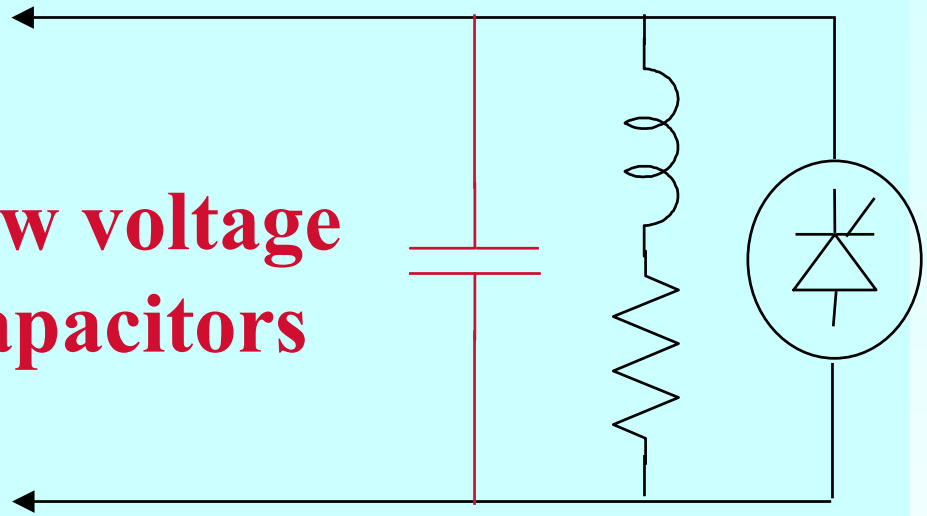


Capacitive:

$$X = \frac{1}{2\pi f C}$$

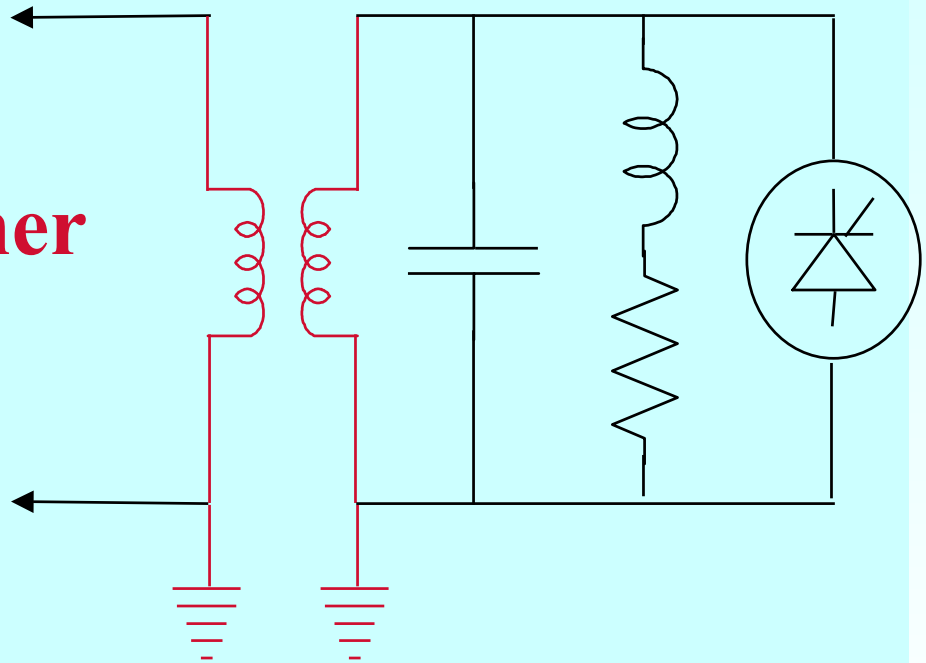
decreases with frequency

Low voltage capacitors



First ground

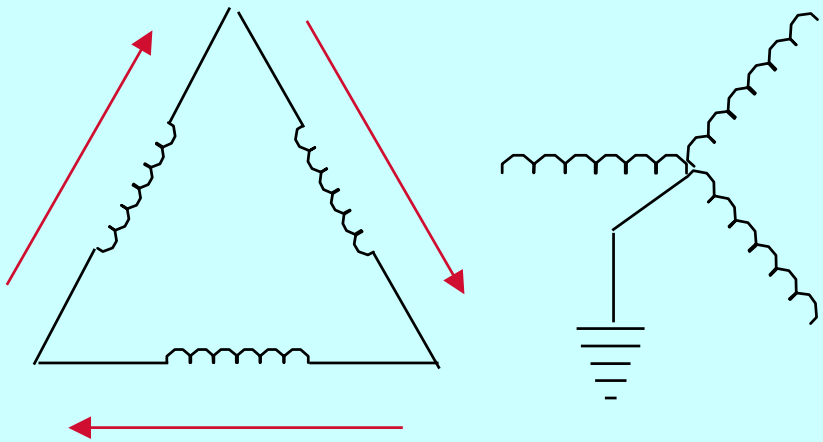
Transformer (high Z)



Delta-Y transformer

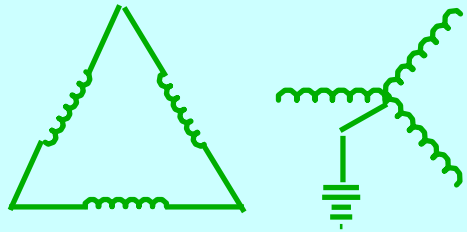
Balanced 3rd, 6th, 9th ... harmonics circulate in delta winding

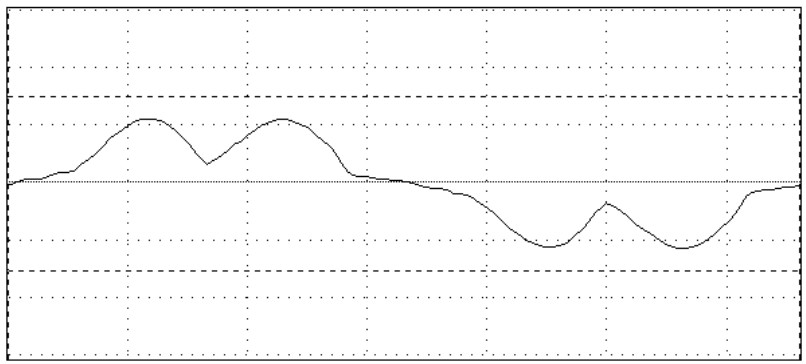
Reduced triplen harmonics

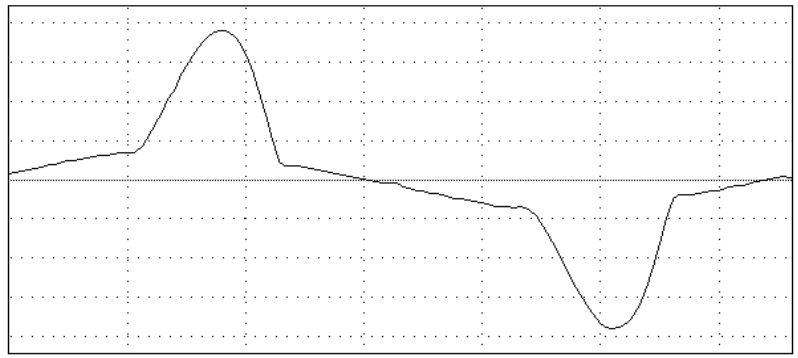


Harmonic source

Delta - Y transformer







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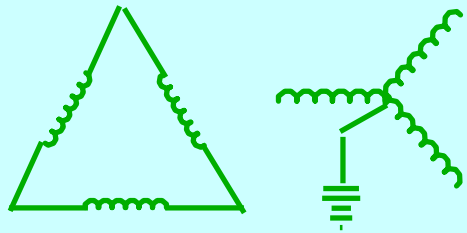
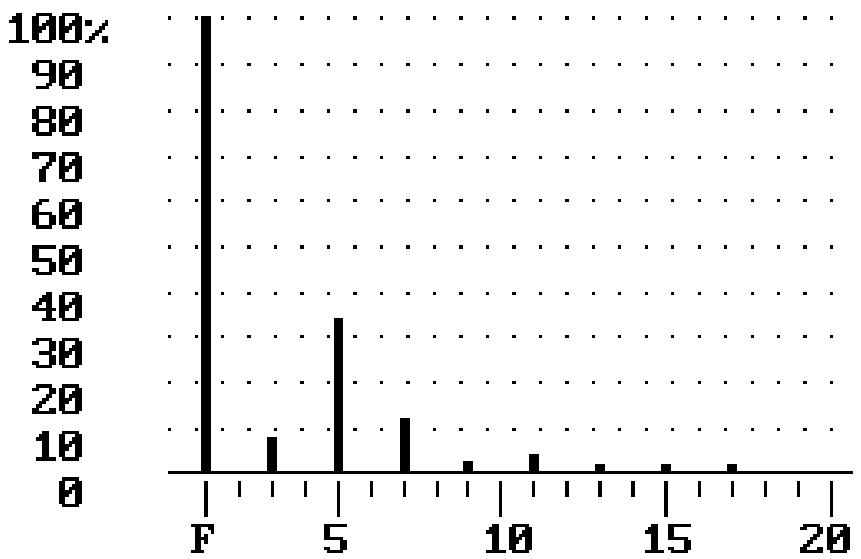
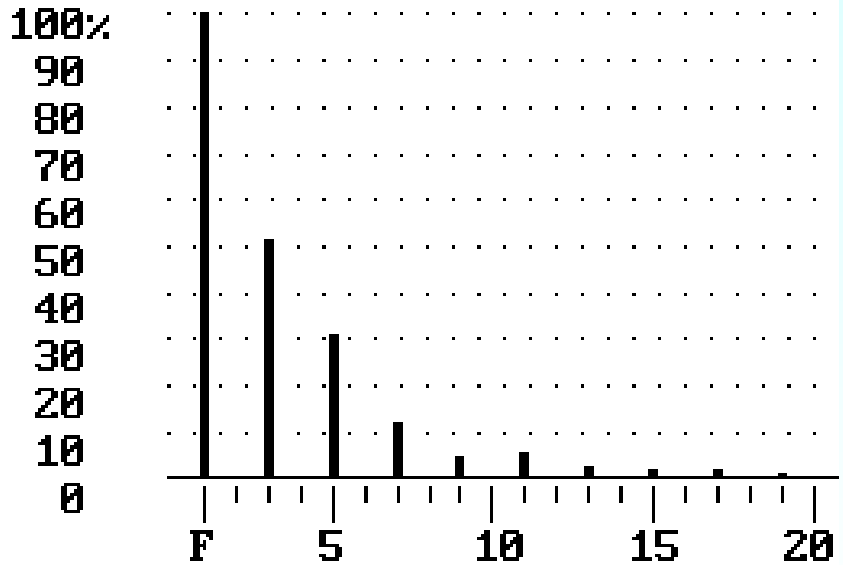
Delta - Y transformer







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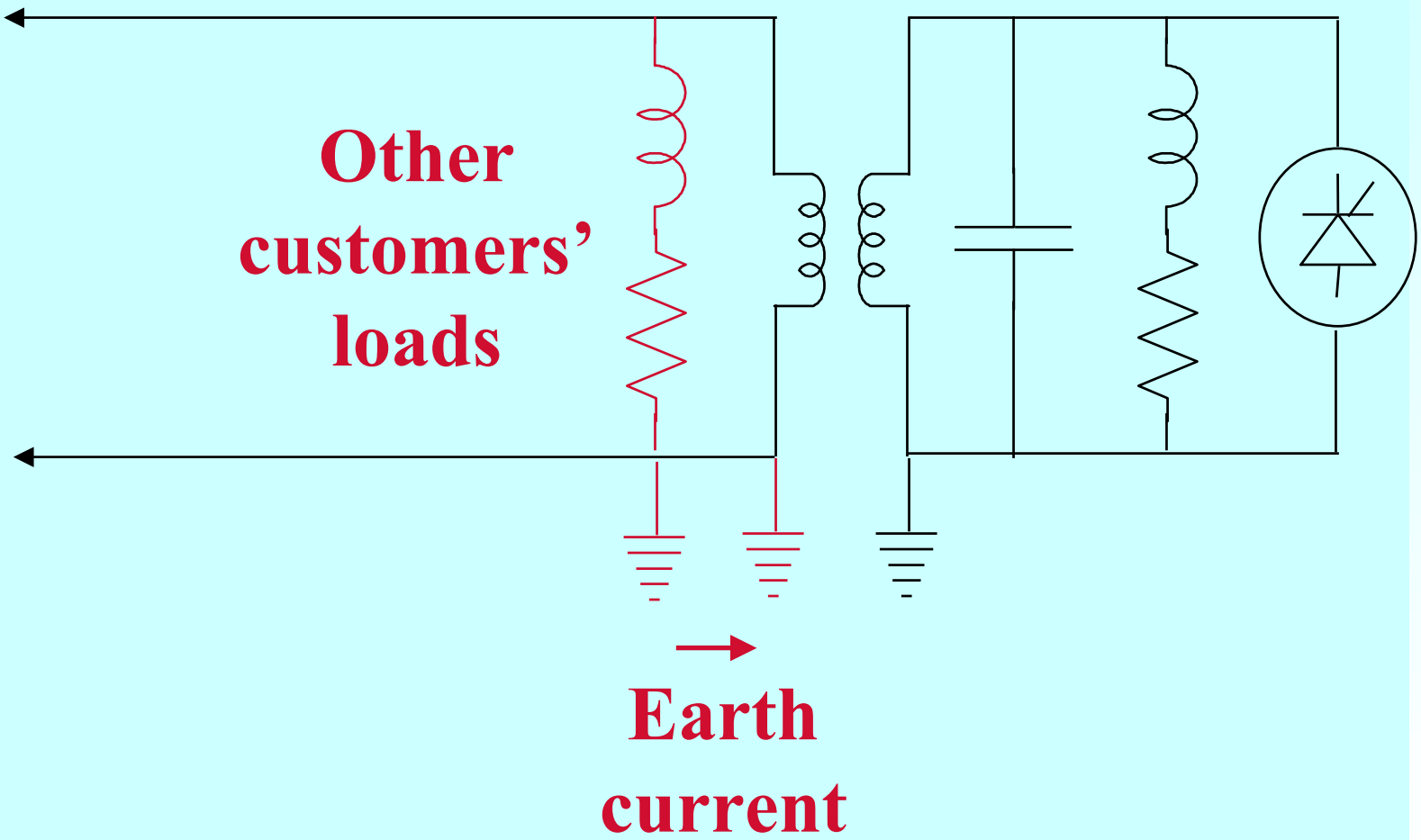
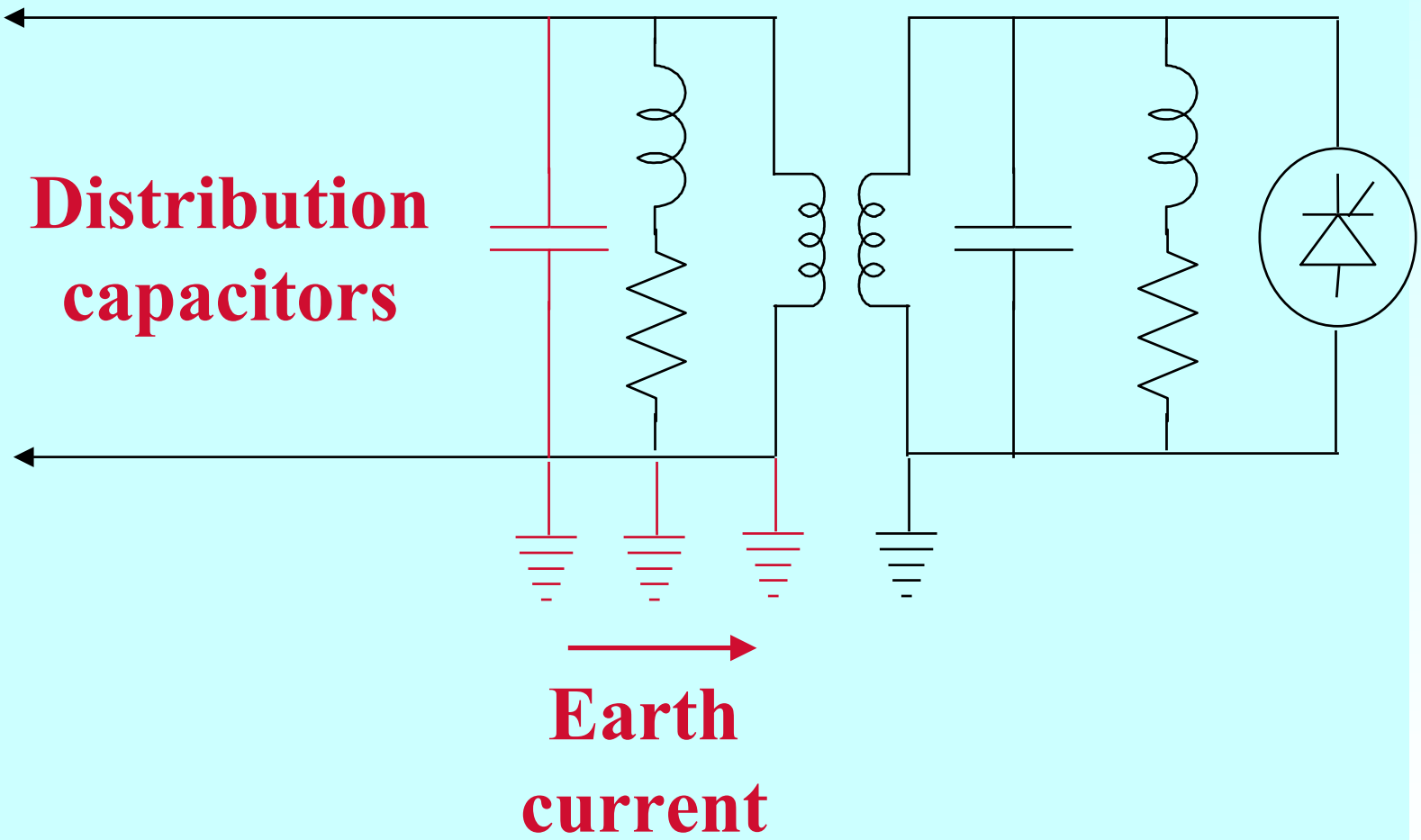
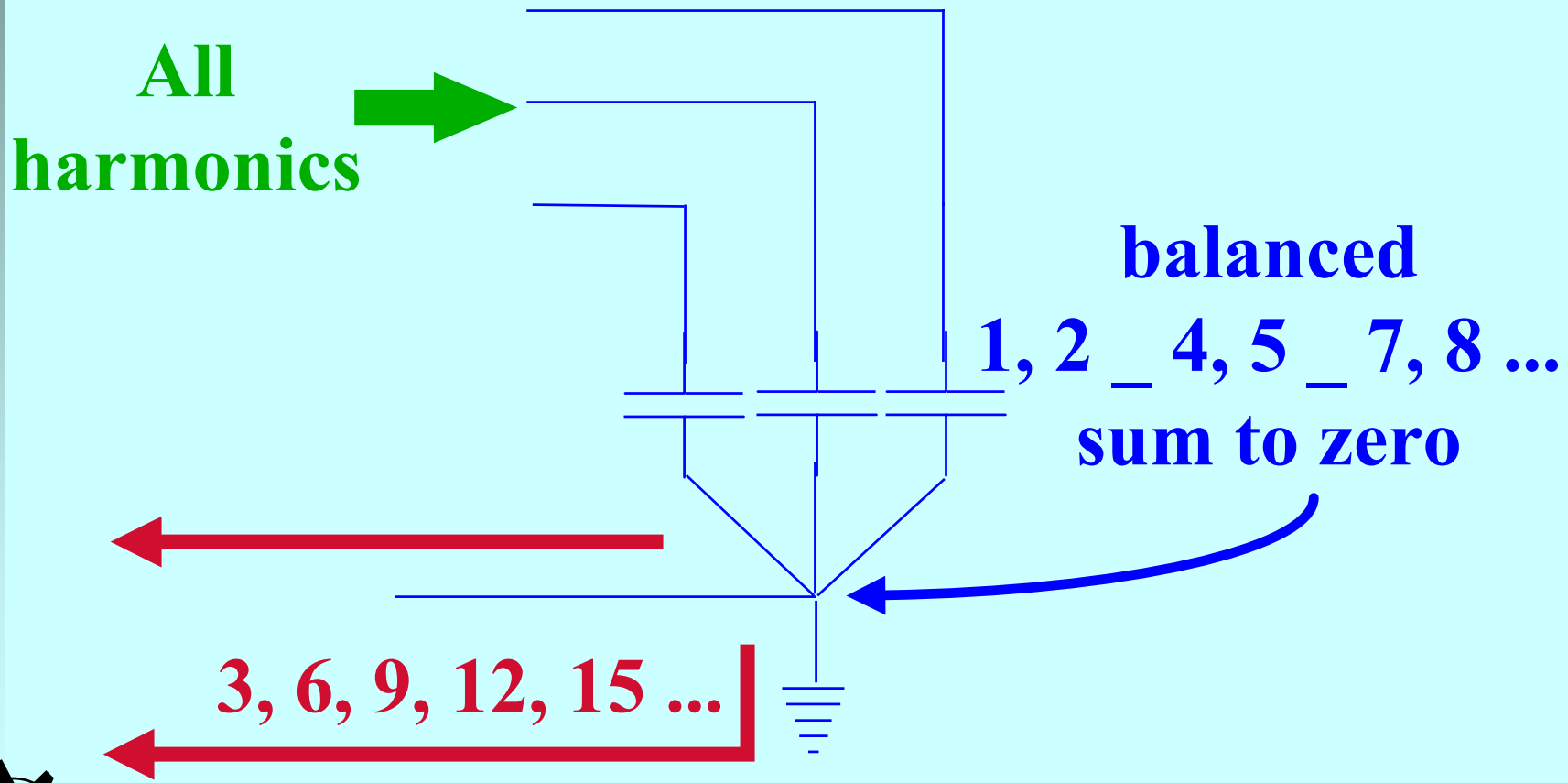
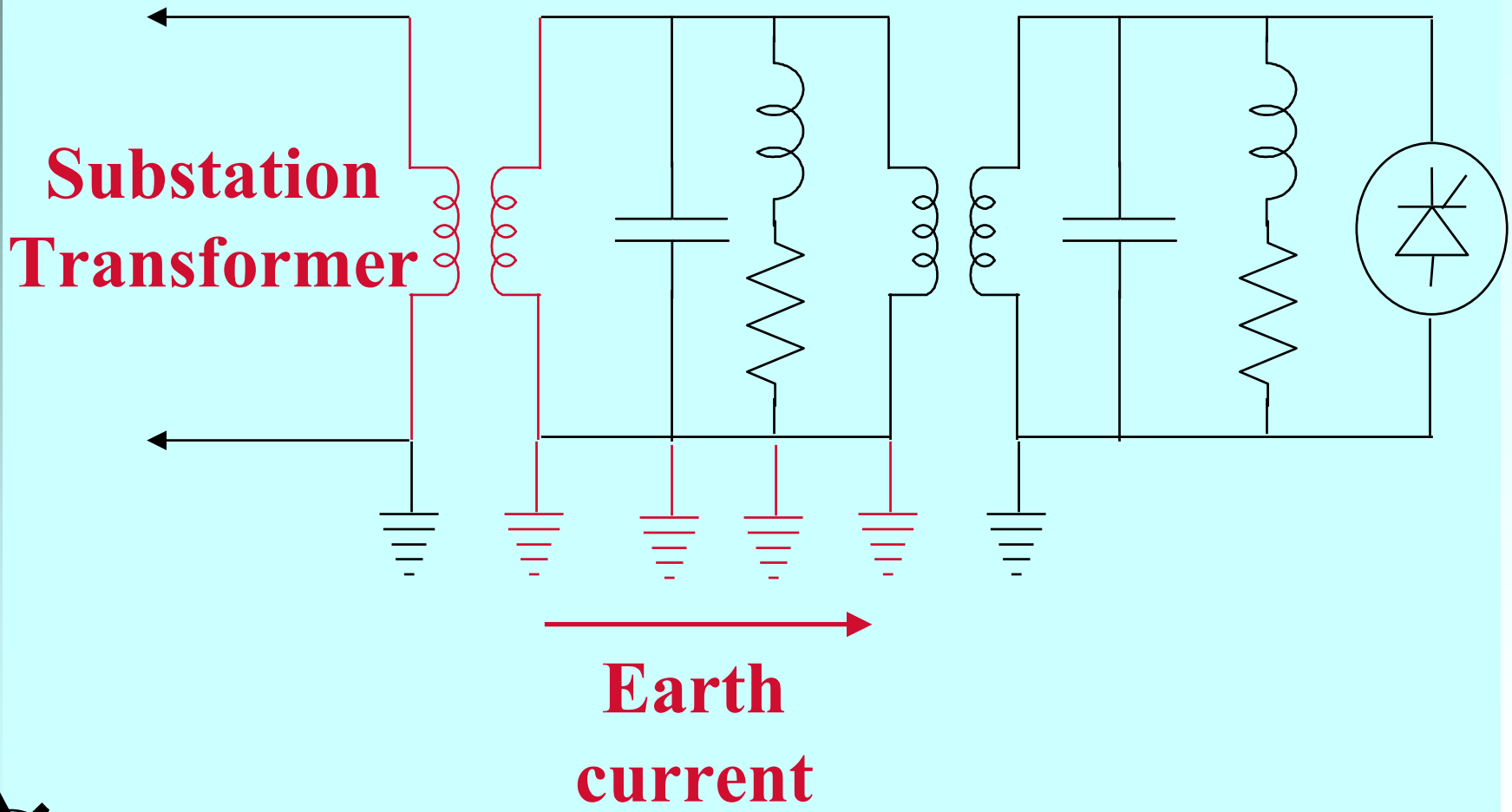

Other customers' loads
Earth current


Distribution capacitors
Earth current

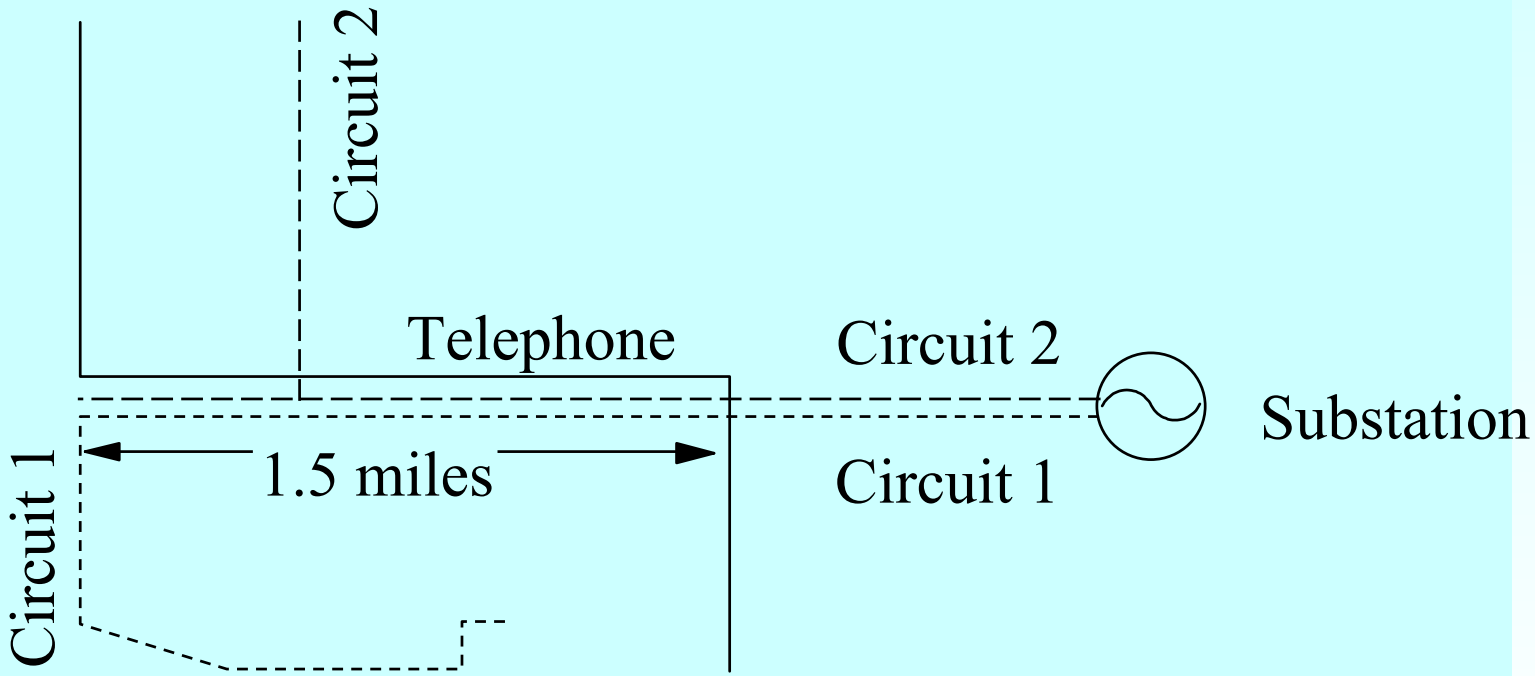
Triplen harmonics (3, 6, 9, 12 ...) flow in neutral and earth



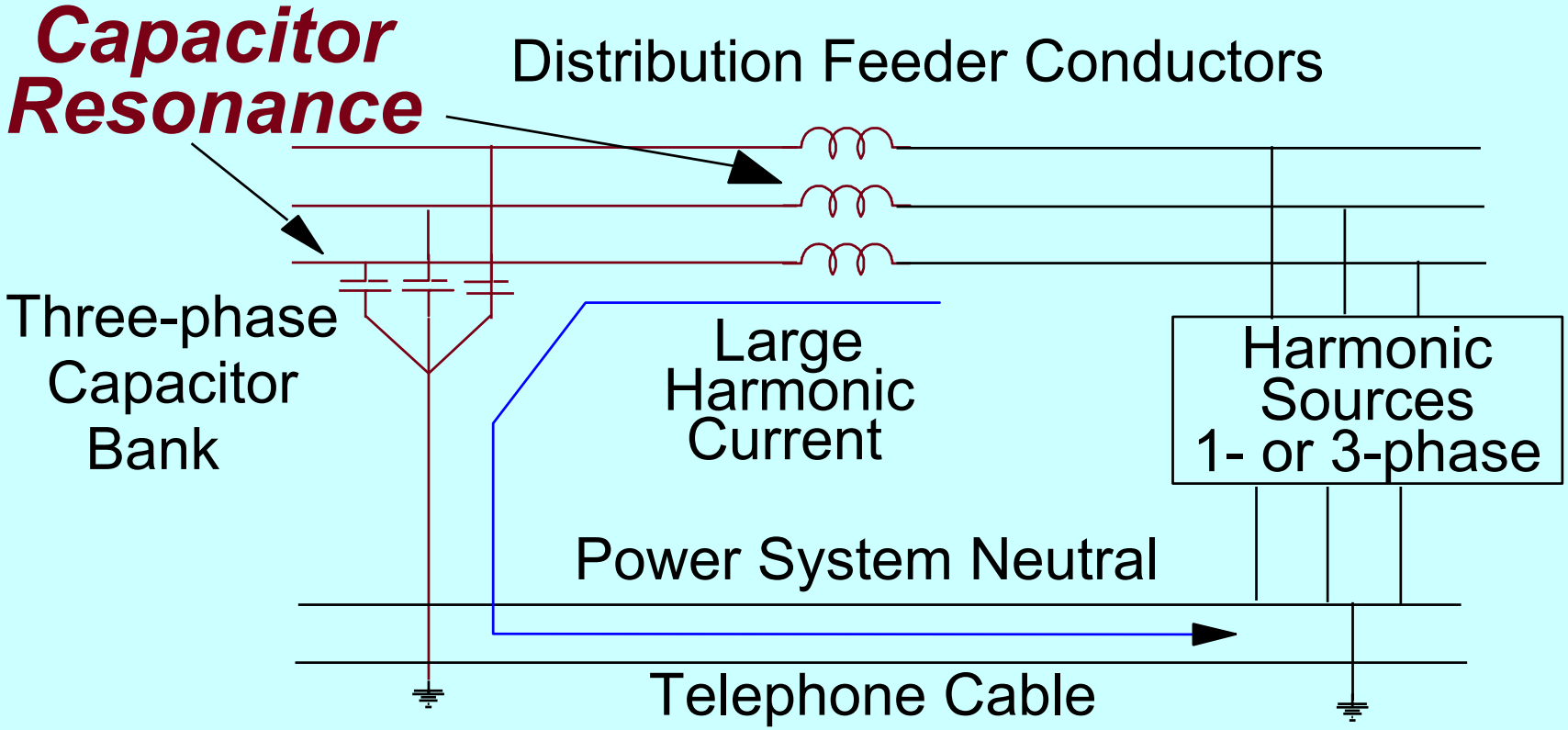

Substation
Transformer
Earth
current

Case Study

Exposure to power distribution



Capacitor Resonance

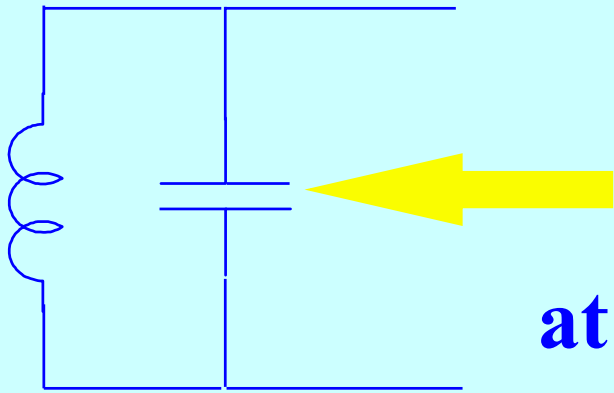


Characteristics:

- Higher harmonic current at one frequency
- Change in harmonic current at capacitor bank
- Significant change in harmonic current when bank switches off

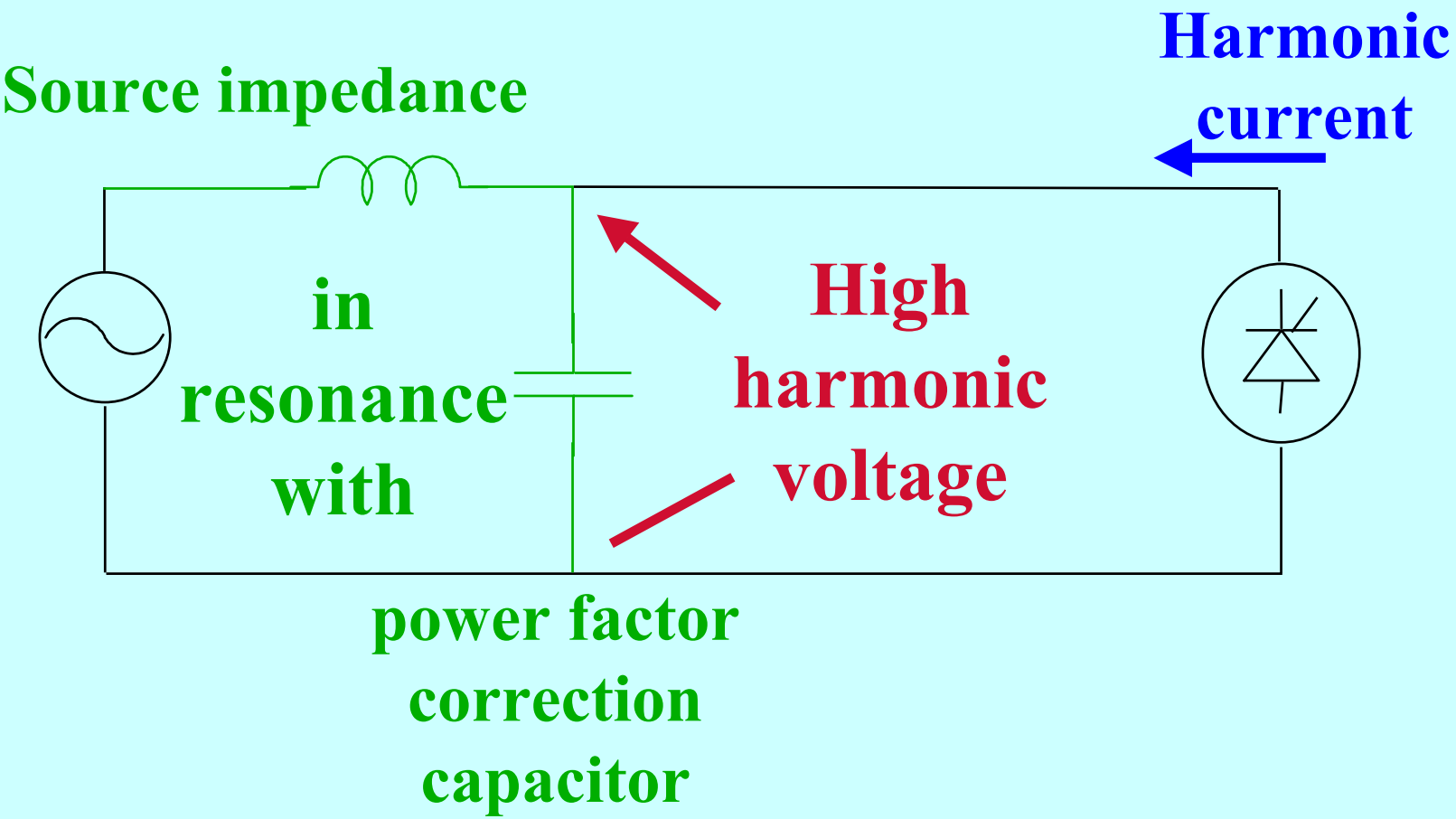
Capacitors: parallel resonance

$$LC = \frac{1}{2\pi f}$$

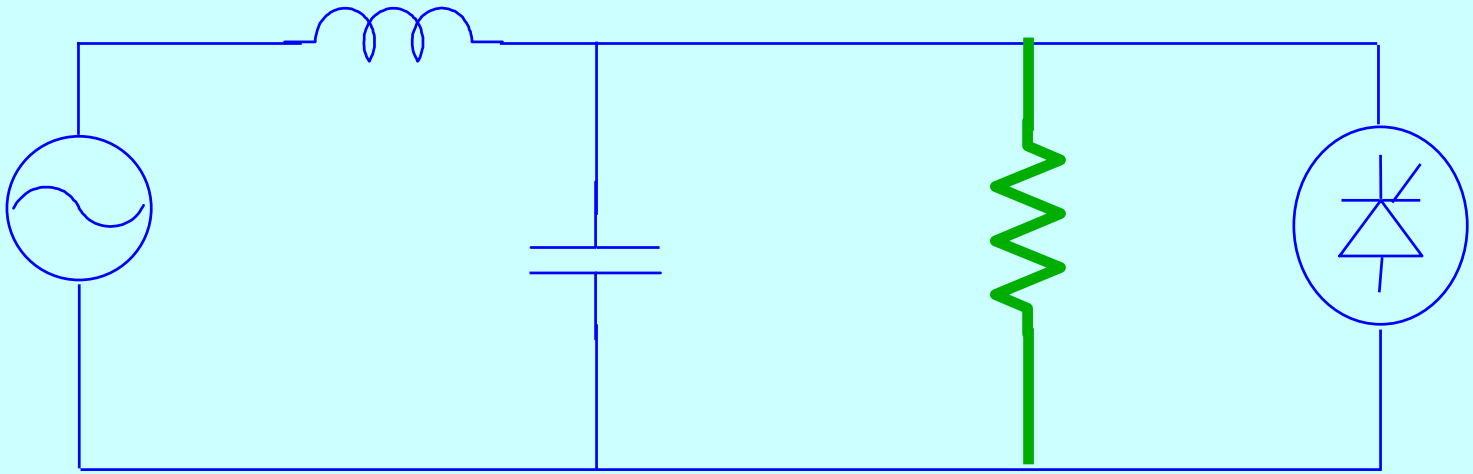


Very *high* impedance at frequency "f"

Capacitors: parallel resonance



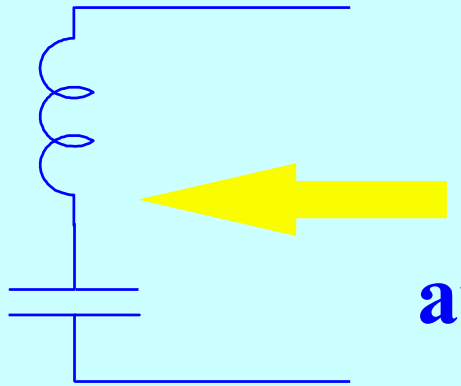
Parallel resonance worse with light loads



Load damps resonance

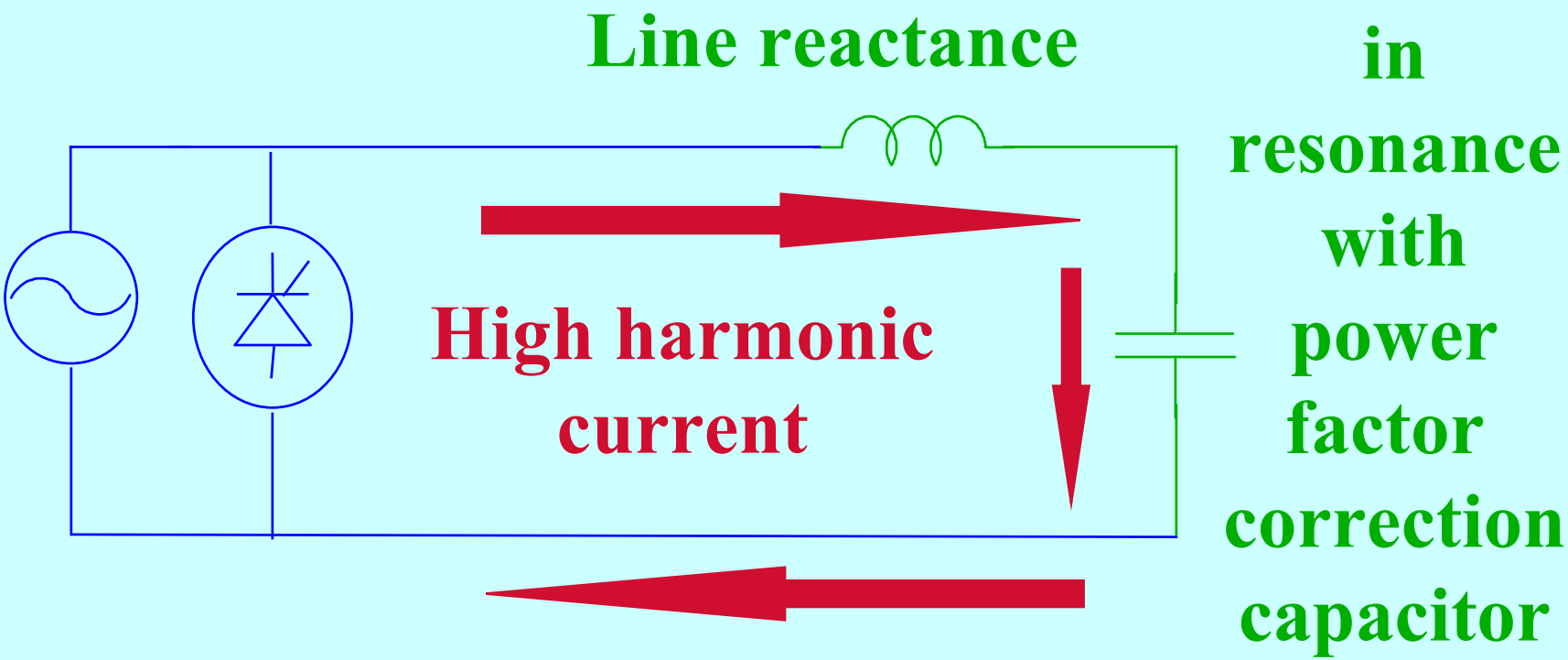
Capacitors: series resonance

$$LC = \frac{1}{2\pi f}$$

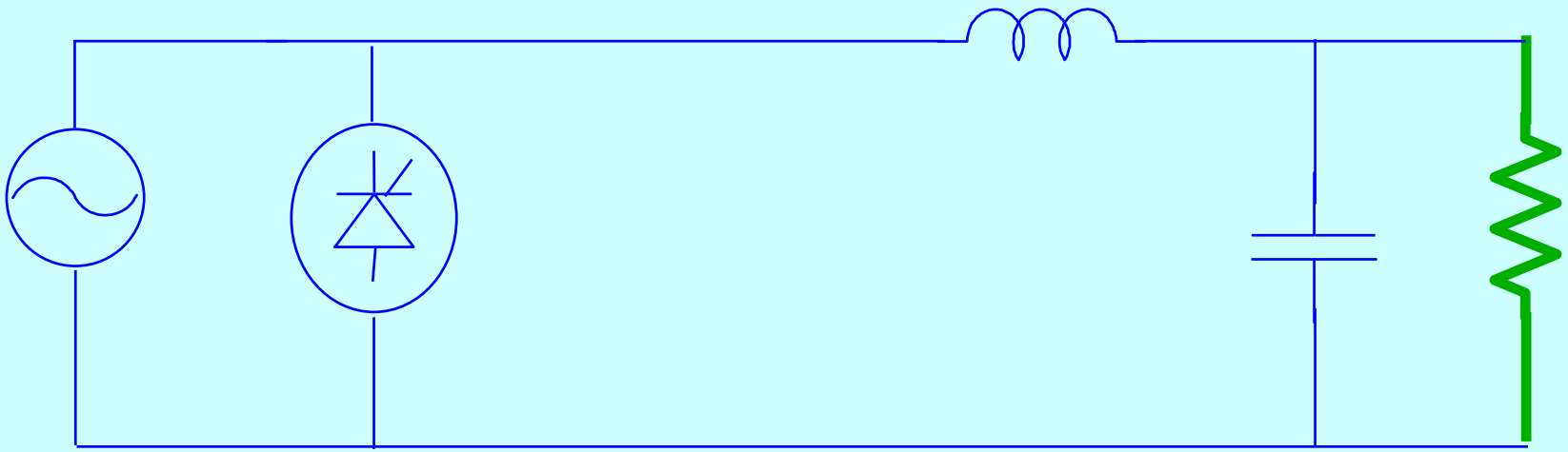


Very *low* impedance at frequency "f"

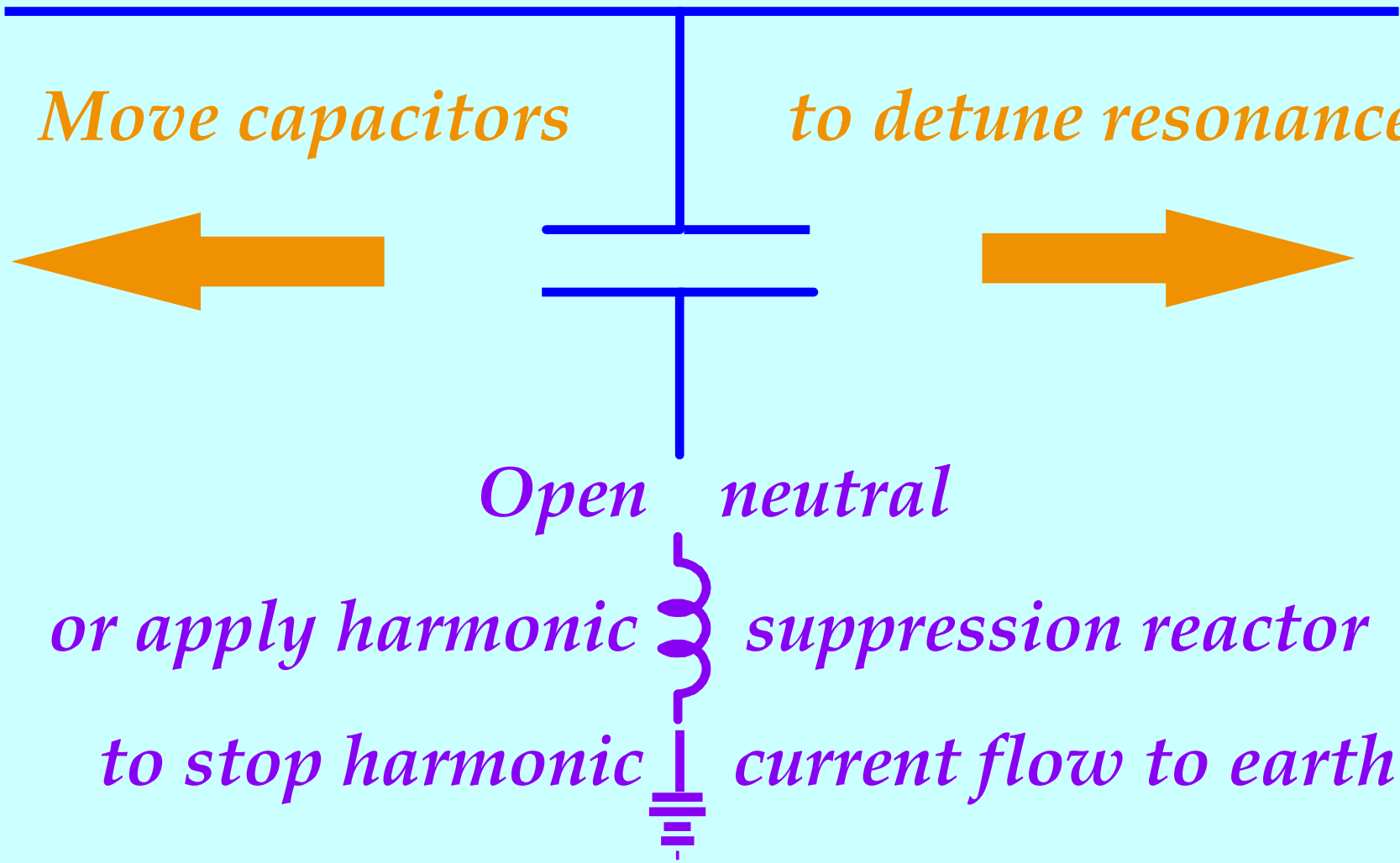
Capacitors: series resonance



Series resonance worse with light loads

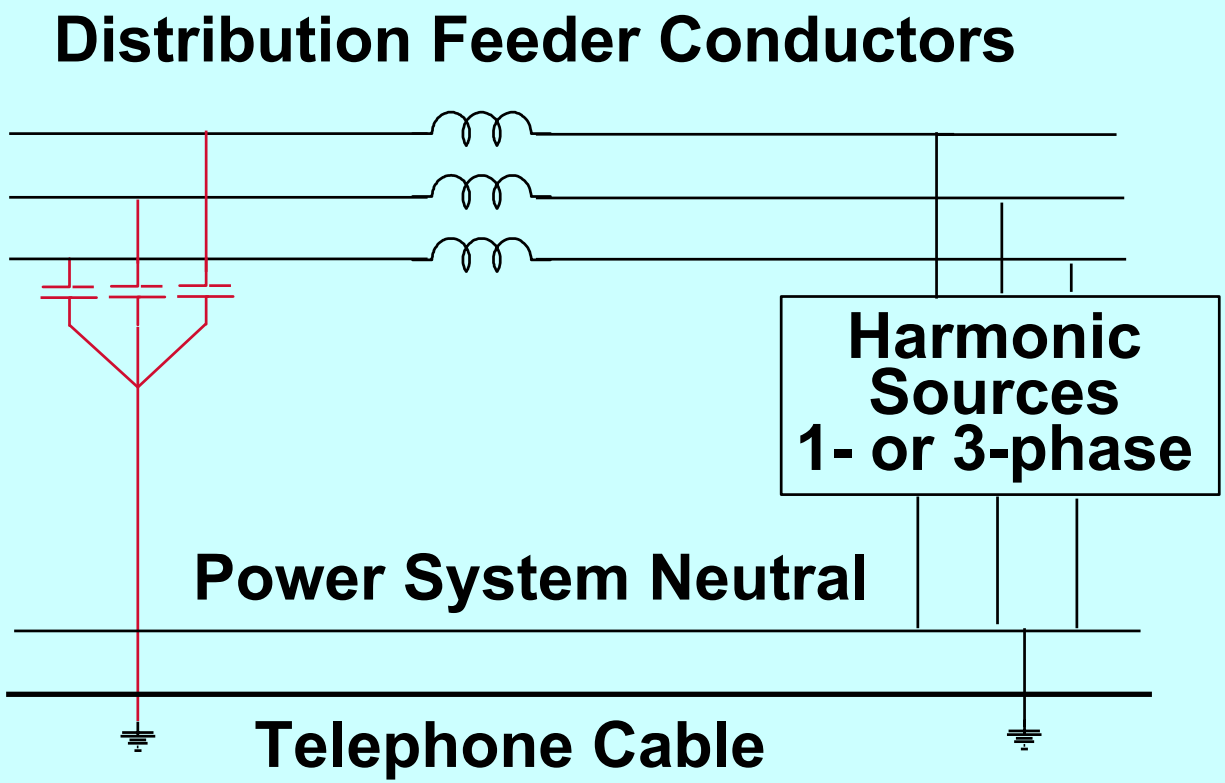


Load damps resonance

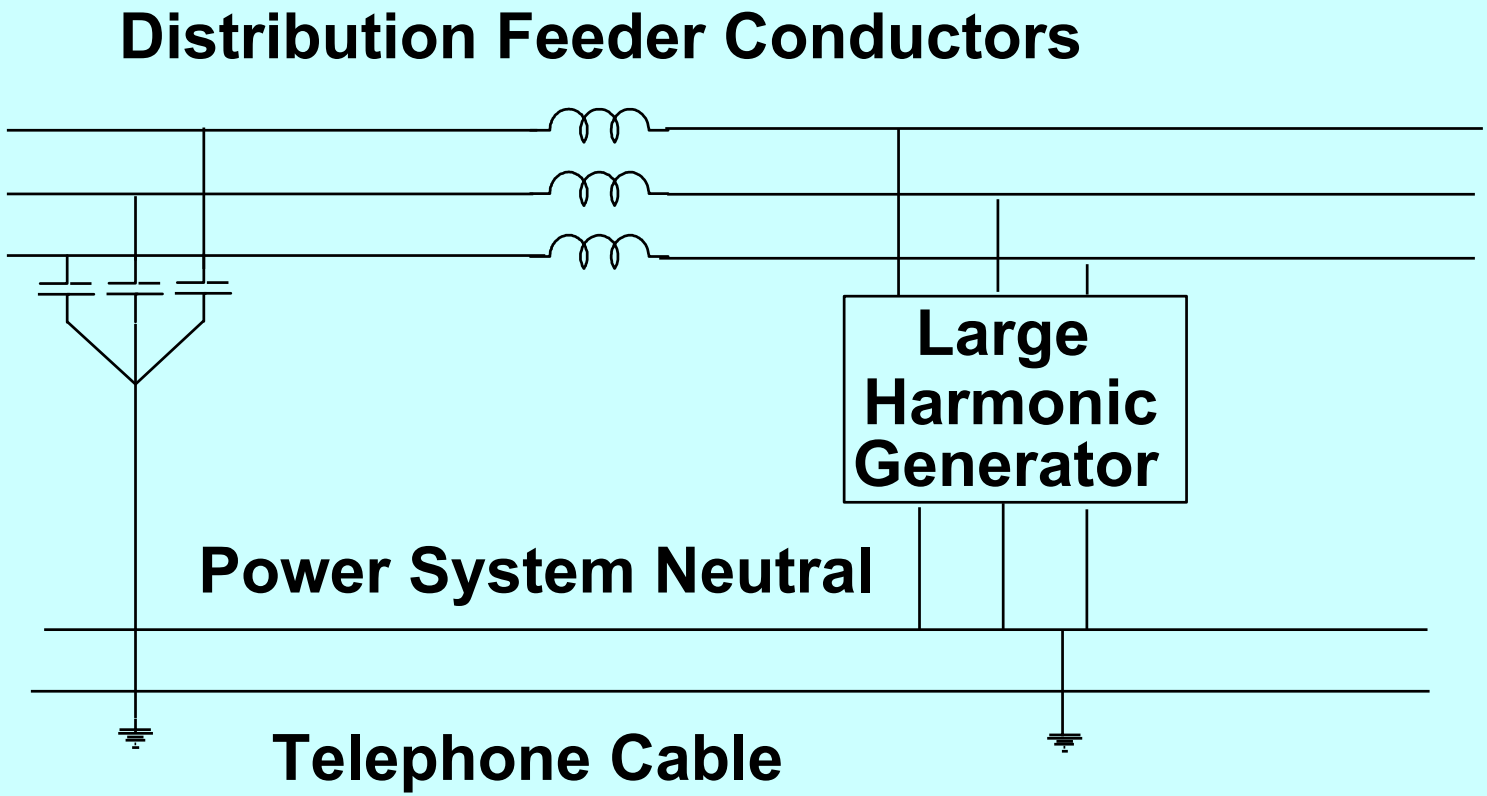

Move capacitors
to detune resonance
Open neutral
or apply harmonic
suppression reactor
to stop harmonic
current flow to earth

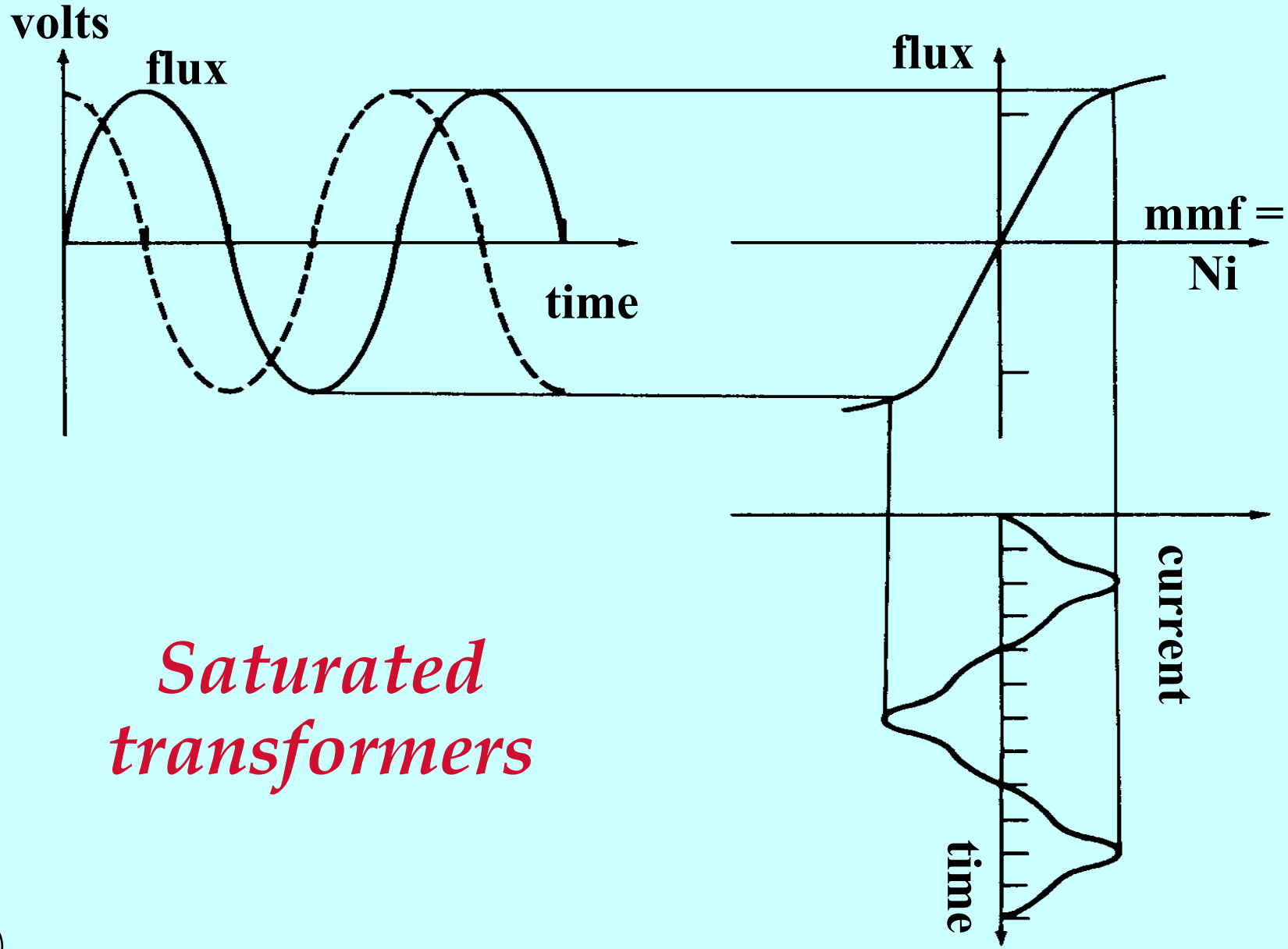
OPEN CAPACITOR FUSES

Open fuses on one or two capacitors causes large neutral/earth current

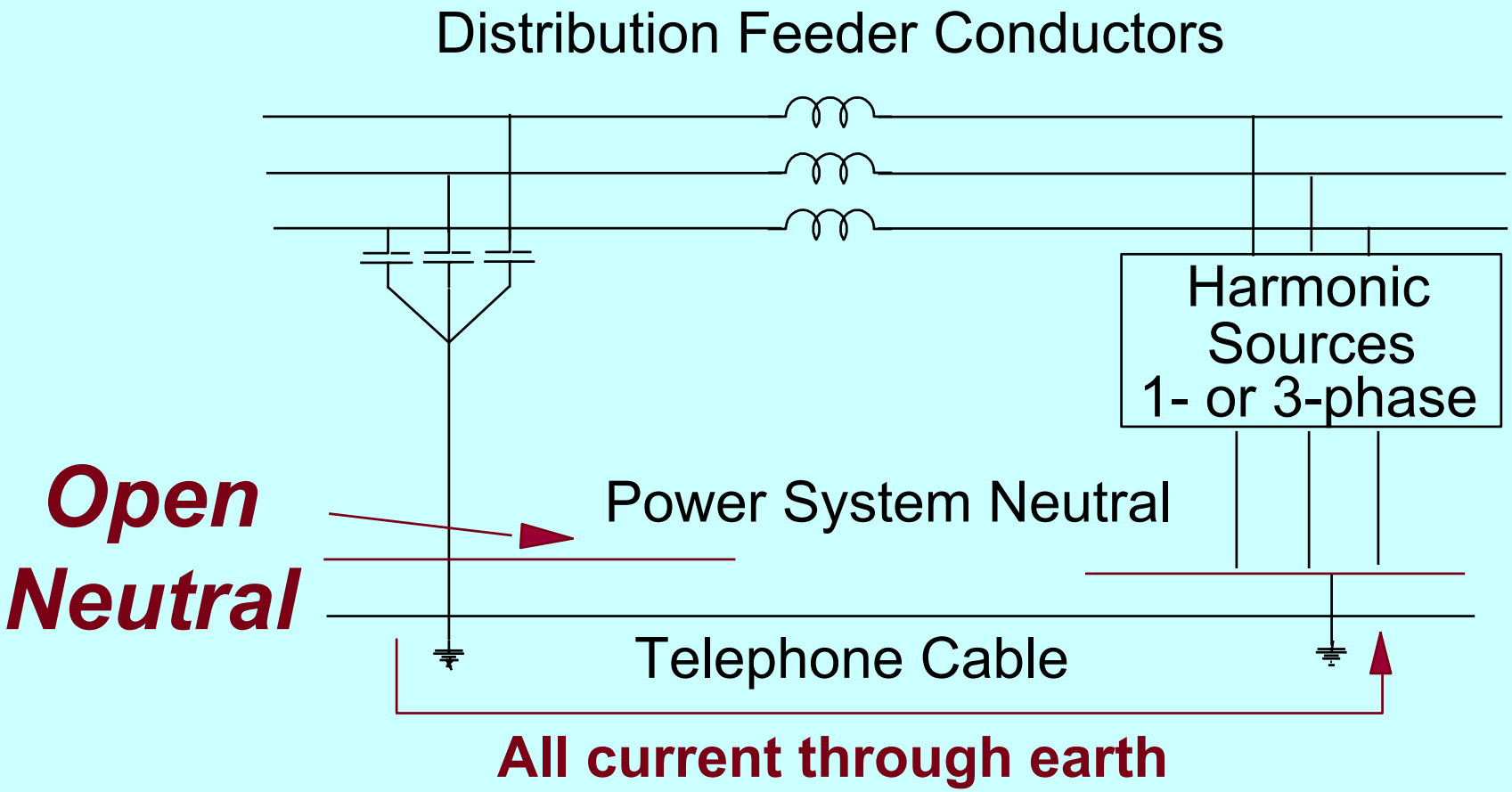


LARGE HARMONIC SOURCE





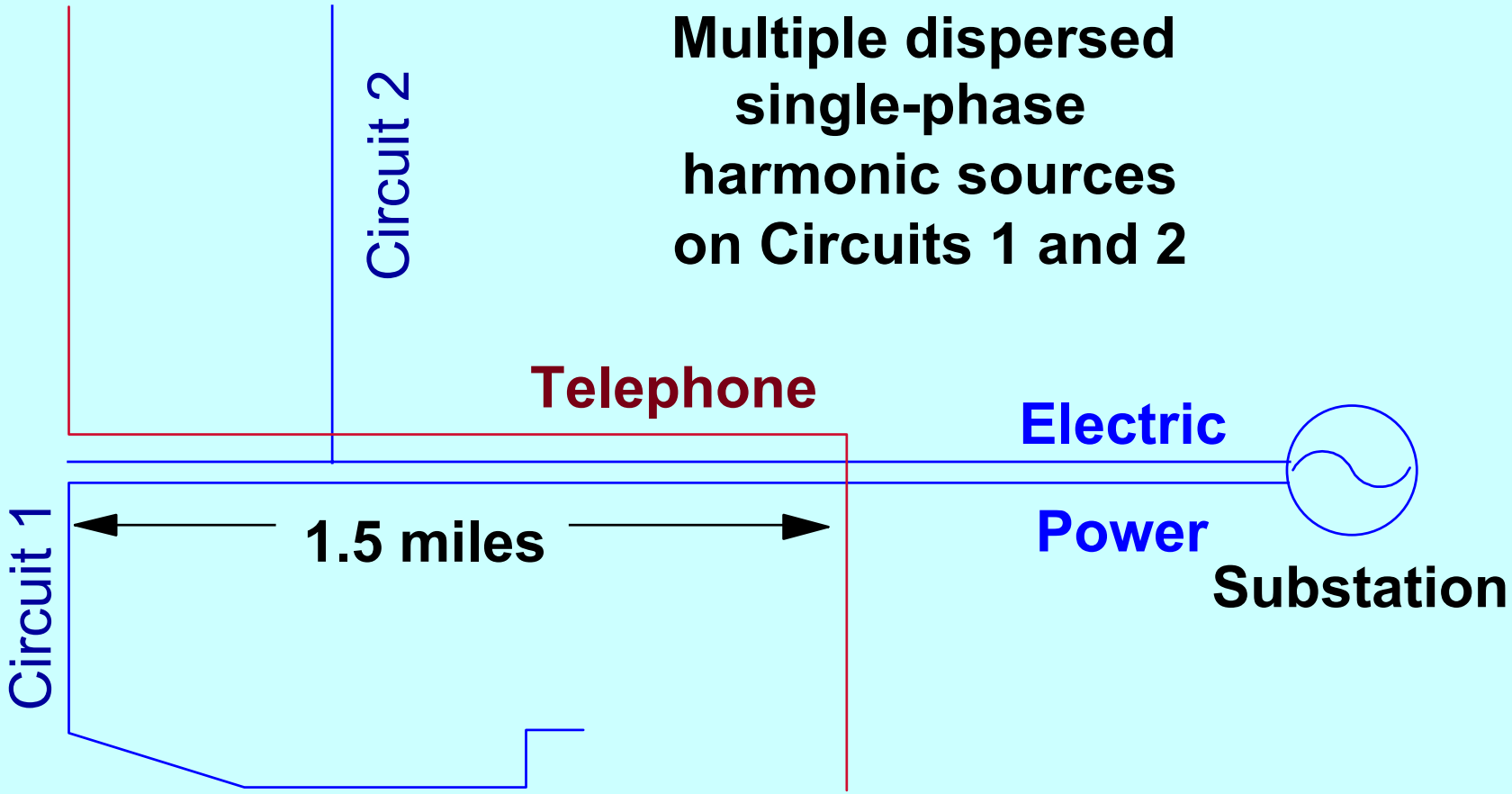
Saturated transformers



Characteristics:

Significant increase in noise between two earth connections

Small harmonic sources



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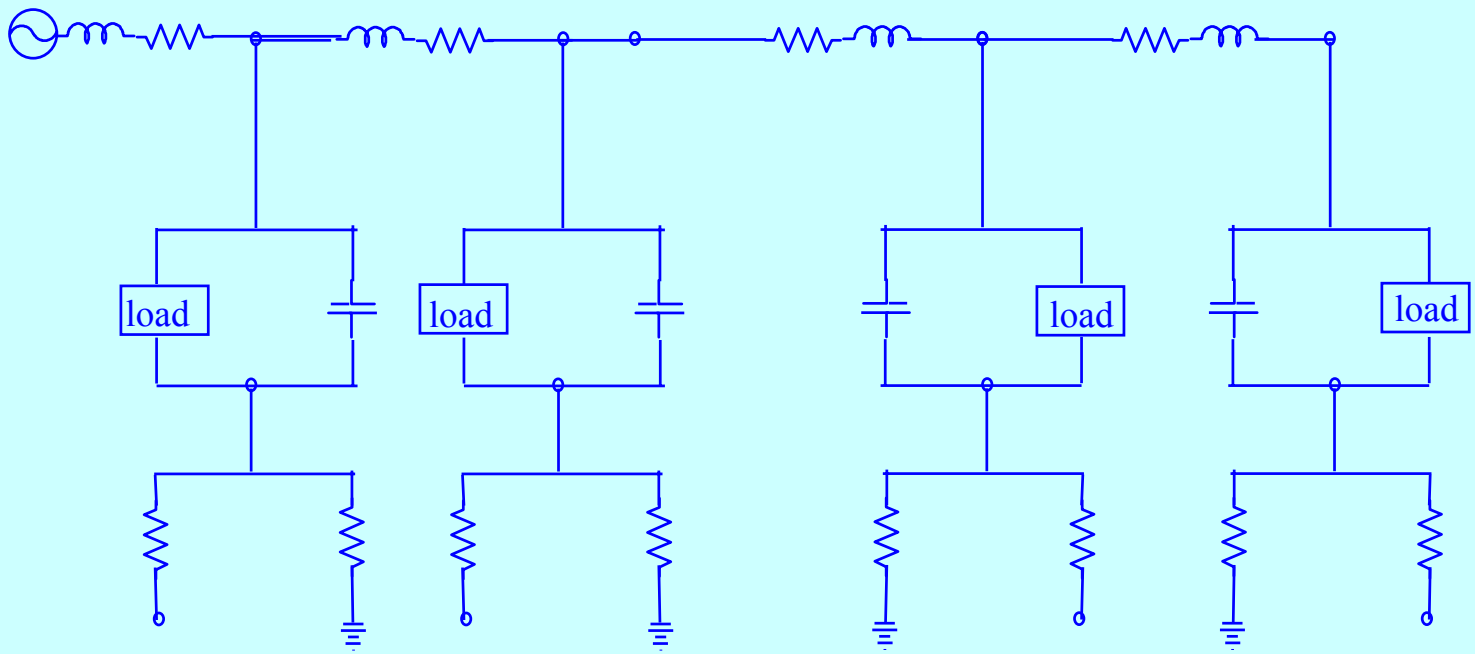
Model the system



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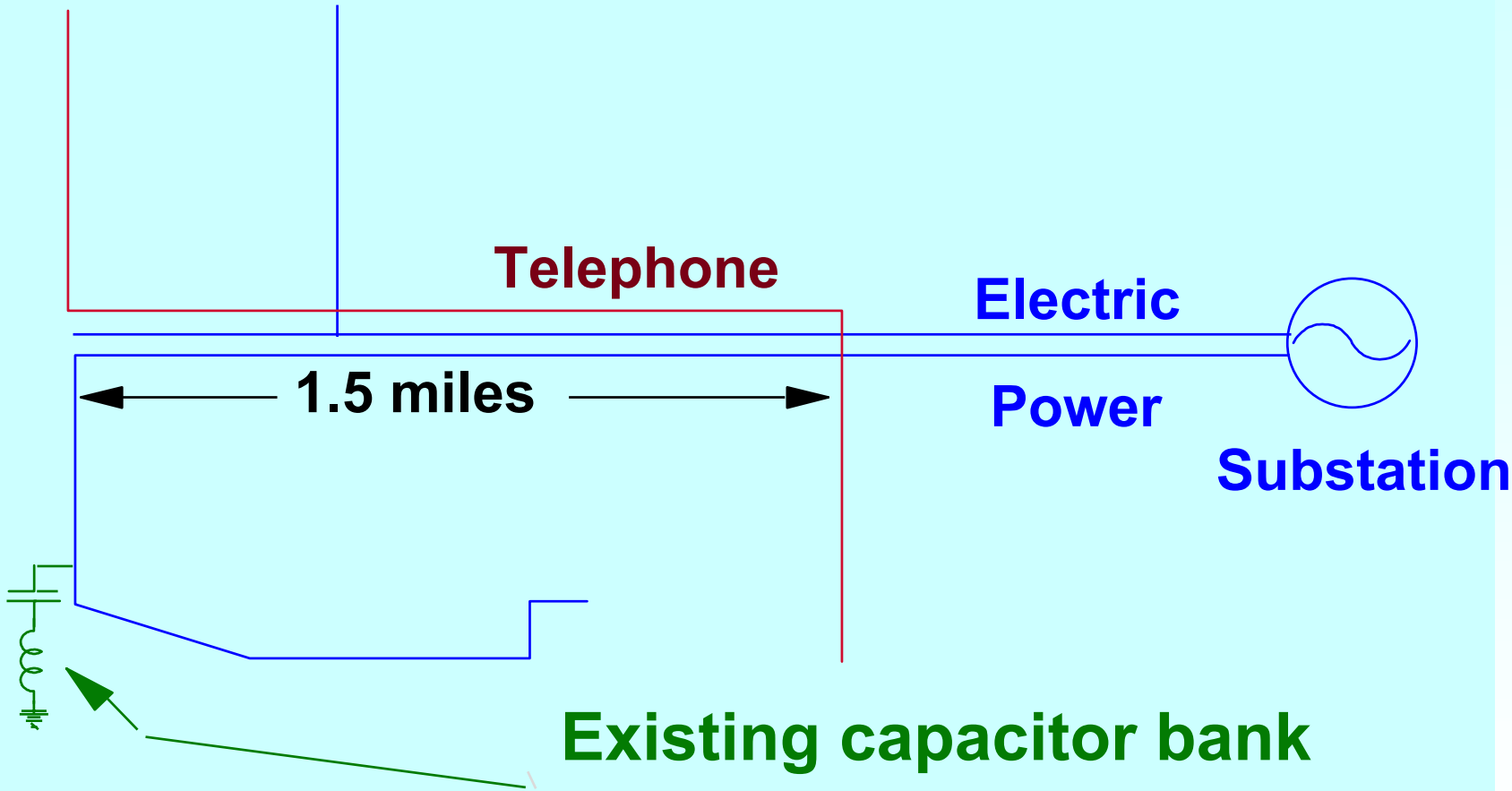
SMALL HARMONIC SOURCES: SOLUTION



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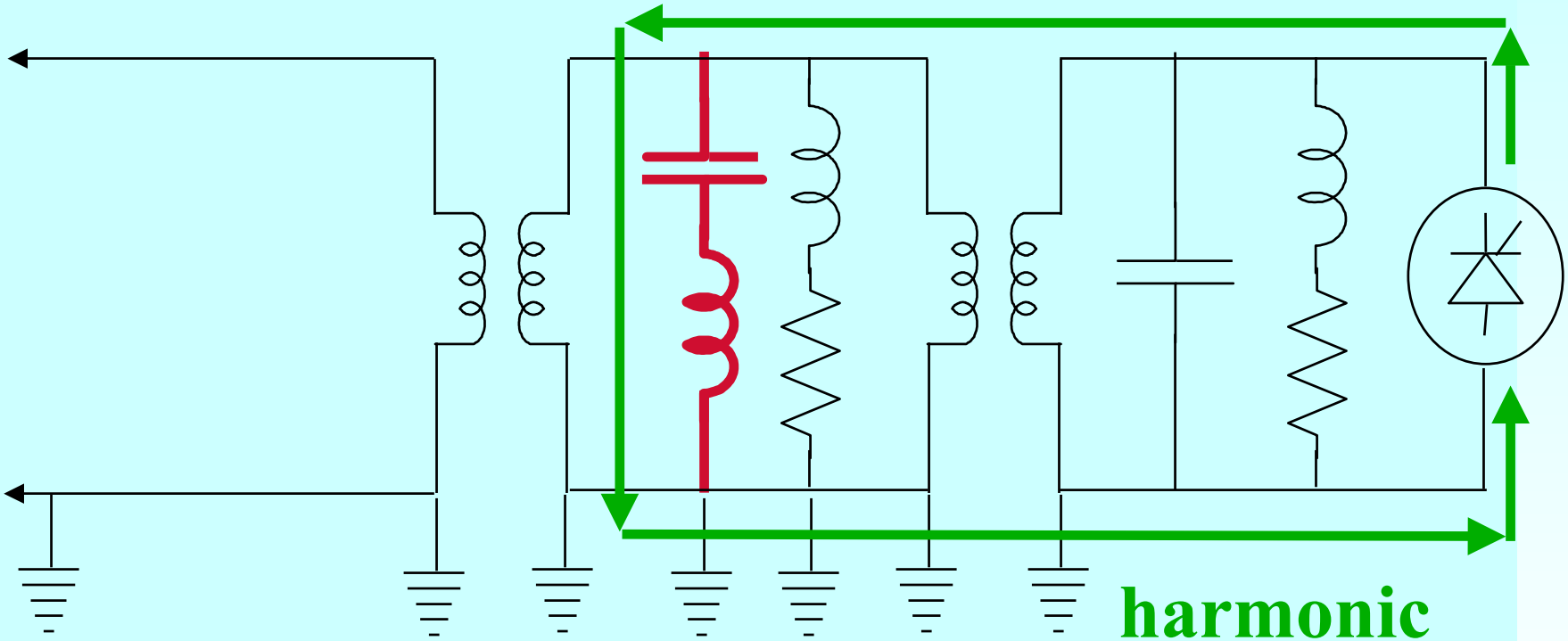
Convert capacitor to shunt filter



harmonic current returns

earth current is reduced

Shunt harmonic filter

Filter frequency: $2 \cdot \pi \cdot f := \frac{1}{\sqrt{L \cdot C}}$

Example:

f = 540 Hz (9th harmonic of 60 Hz)

C is 7200 V, 600 kVAR bank: C = 10.2 μF

L = 8.5 mH

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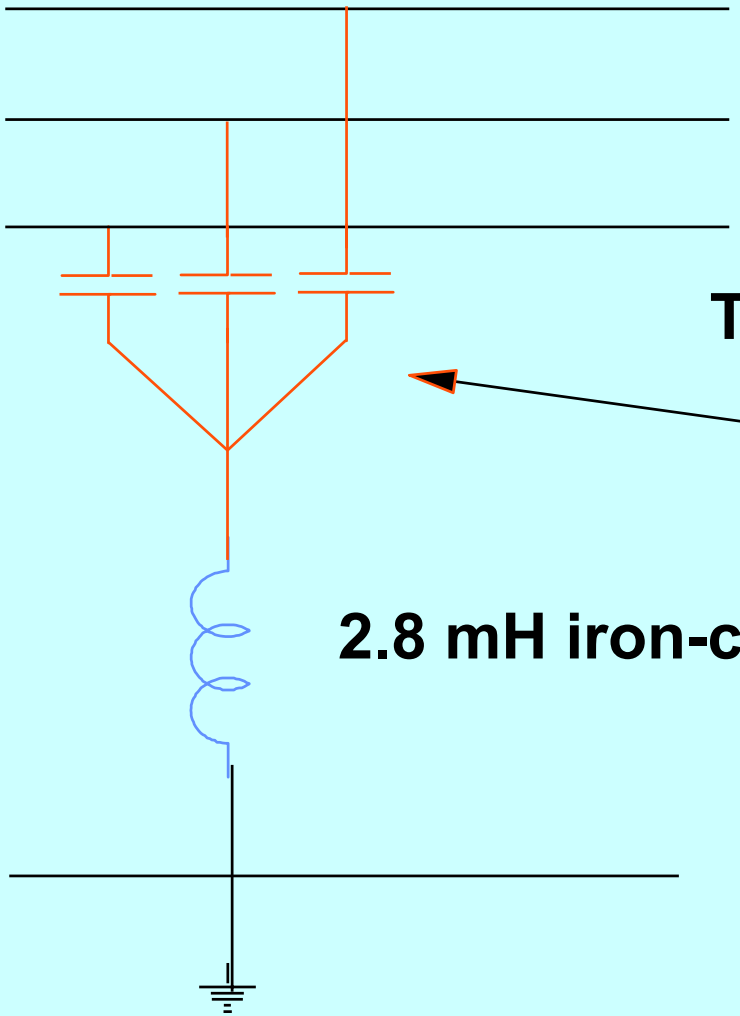
Harmonic filter



Three-phase capacitor bank

2.8 mH iron-core inductor

Telephone noise causes/solutions

- Capacitor resonance
  - Move capacitor
  - Open capacitor neutral
  - Harmonic suppression reactor
- Open capacitor fuse
  - Replace fuse
- Large harmonic source
  - Mitigate at source
- Saturated transformer
  - Repair or replace transformer
  - Reduce feeder voltage
- Small distributed harmonic sources
  - Reconfigure feeder
  - Upgrade phone to fiber
  - Filter

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Questions or Comments?

Contact Ward Jewell at (316) 978-6340 or
ward.jewell@wichita.edu

Further reading:

Ward Jewell, Bill Miller, Tom Casey, “Filtering Dispersed Harmonic Sources on Distribution,” *IEEE Transactions on Power Delivery*, Vol. 15, No. 3, July 2000, pp. 1045-1051.

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