Arrange circuits, control and protection for general electrical installations

Week 2: Fault Loop Impedance

A QUALITY VOCATIONAL ELECTRICAL TRAINING COURSE
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All writing in BLUE is examinable

All writing in RED
is
NOT examinable.

The cable selection process

Glossary:

MD = Maximum Demand

CB = Circuit Breaker

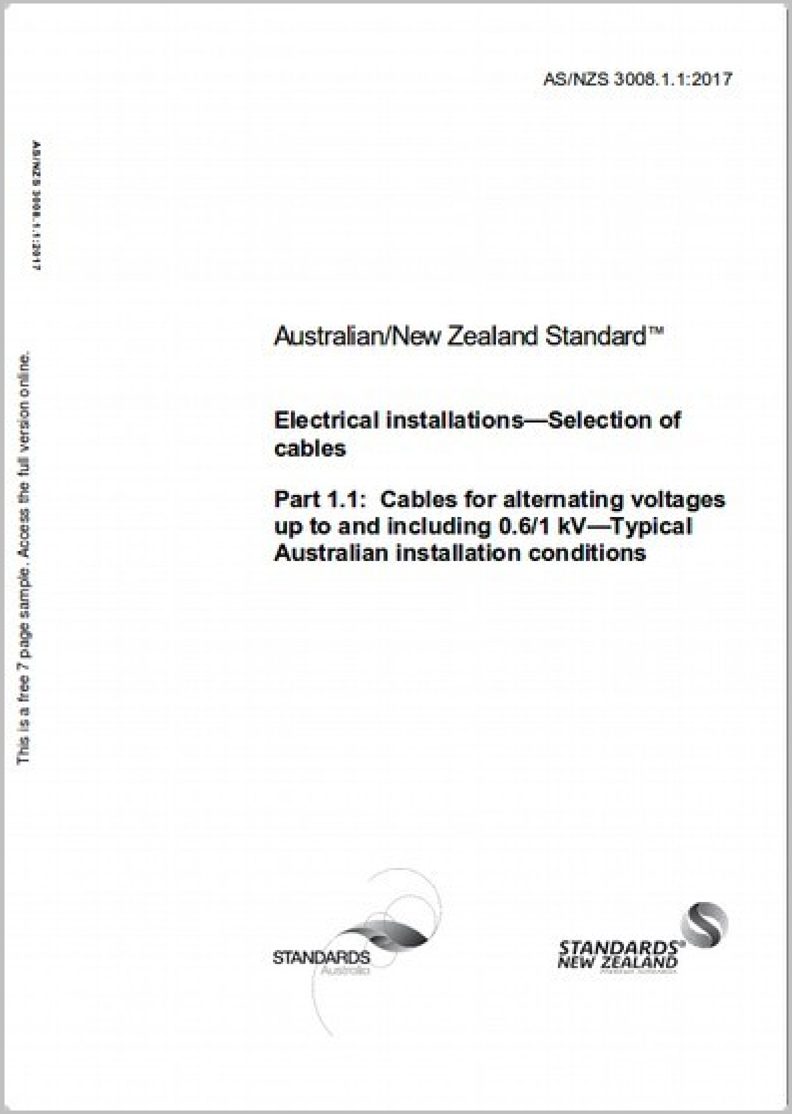
CCC = Current Carrying Capacity

VD = Voltage Drop

FLI = Fault Loop Impedance

PFC = Prospective Fault Current

SCTR = Short Circuit Temperature Rise



AS/NZS 3008.1.1:2017

AS/NZS 3008.1.1:2017

This is a free 7 page sample. Access the full version online.

Australian/New Zealand Standard™

Electrical installations—Selection of cables

Part 1.1: Cables for alternating voltages up to and including 0.6/1 kV—Typical Australian installation conditions

STANDARDS Australia

STANDARDS NEW ZEALAND

1) Calculate MD (AS/NZS 3000) →
- Consumer mains (Table C1, C2, C3)
- Sub mains (Table C1, C2, C3)
- Final sub circuits (Table C4, C8)

2) Select Circuit Breaker
(Standard sizes Table 8.1 AS/NZS 3000)

$$I_B \leq I_N \leq I_Z$$

MD ≤ CB ≤ CCC

2.5.3.1 AS/NZS 3000

3) Select cable based on Current Carrying Capacity
(Table C5 and C6 AS/NZS 3000, Section 3 AS/NZS 3008)

4) Check Voltage Drop
(3.6, Table C7 AS/NZS 3000, Section 5 AS/NZS 3008)

5) Check Fault-Loop Impedance
(5.7, Appendix B AS/NZS 3000)

6) Calculate Prospective Fault Current (2.5.4 AS/NZS 3000) **However no guidance is offered in AS/NZS 3000**

7) Check Short Circuit Temperature Rise (2.5.4 and Section 5 AS/NZS 3008)

This course covers FLI, SCTR and PFC, however these are only topics inside the much greater cable selection process.

Fault-Loop Impedance

What you need to know about Fault-Loop Impedance

1) What is it? → **Describe the loop**
→ **Why it is an issue**

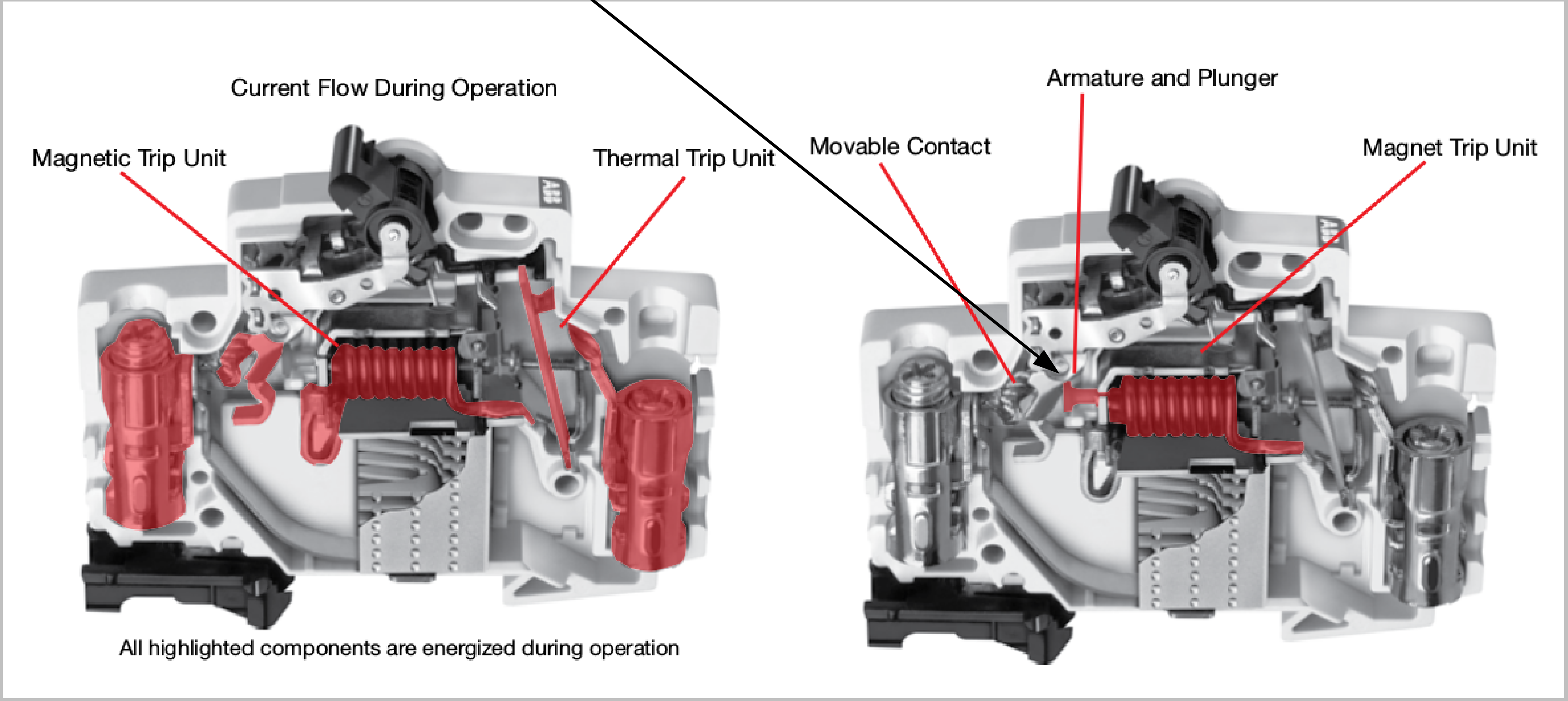
2) How to select cables so that maximum lengths are not exceeded: → **Lmax**
→ **Table B1**

3) How to test it: (Zmax) → **Table 8.1 (live)**
→ **Table 8.2 (dead)**

Circuit breakers

If not enough current flows this Solenoid wont trip during a short.

We calculate this using another application of Ohms law.

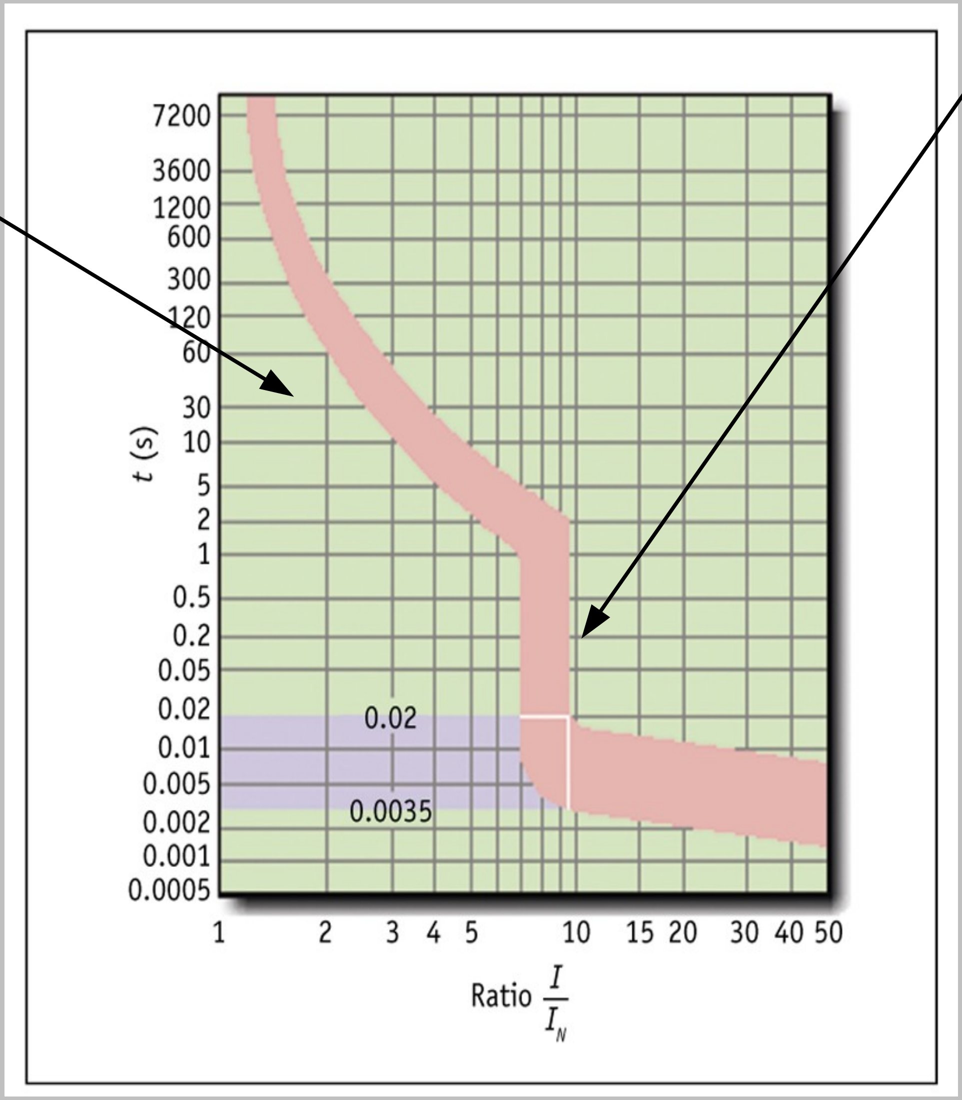


Thermal trip

(Bi-metal Strip)

(Conventional trip Time)

($I_B \leq I_N \leq I_Z$)



Magnetic trip

(Solenoid)

(Instantaneous Trip)

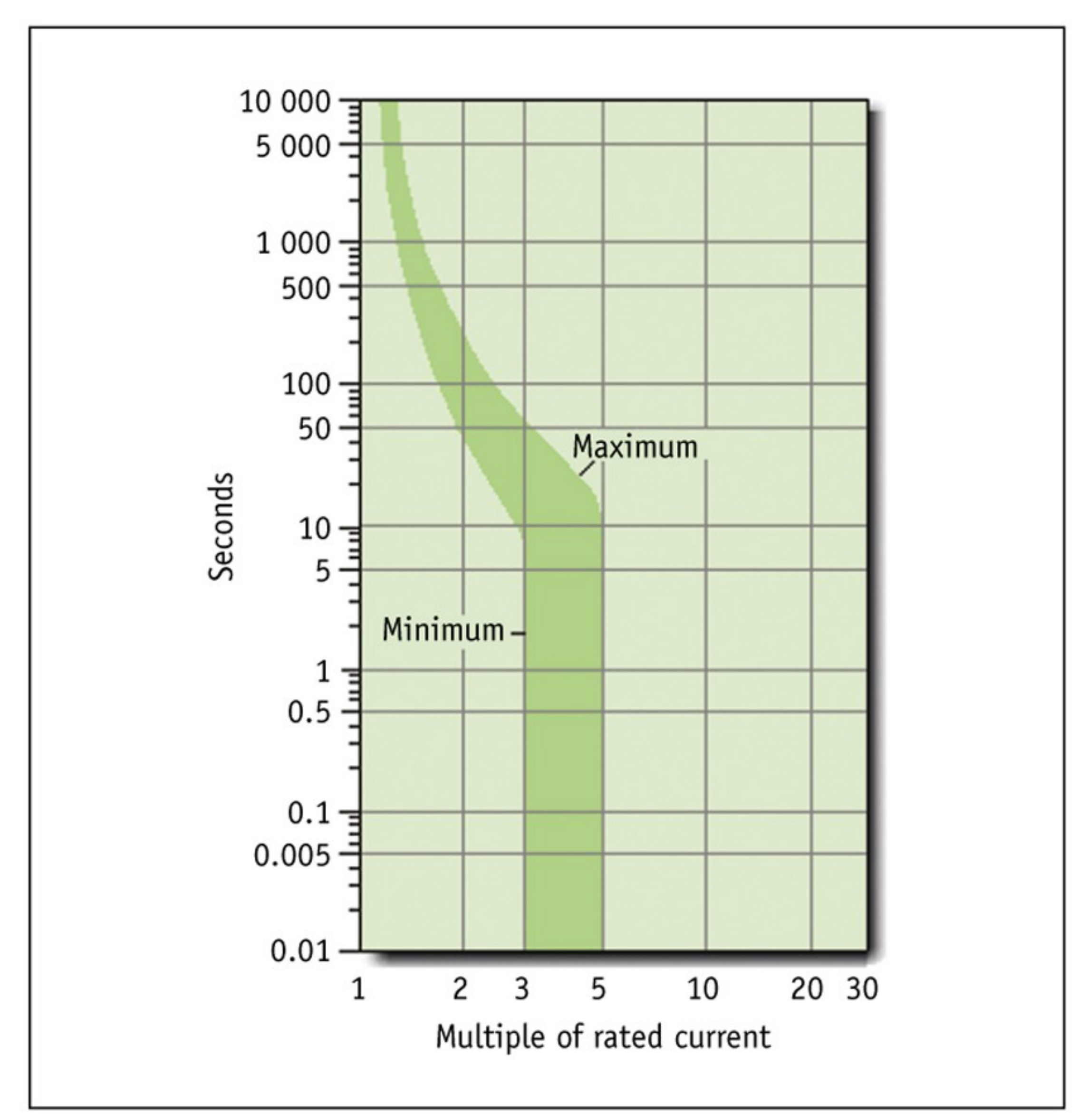
(Fault-Loop Impedance)

Not all circuit breakers trip the same

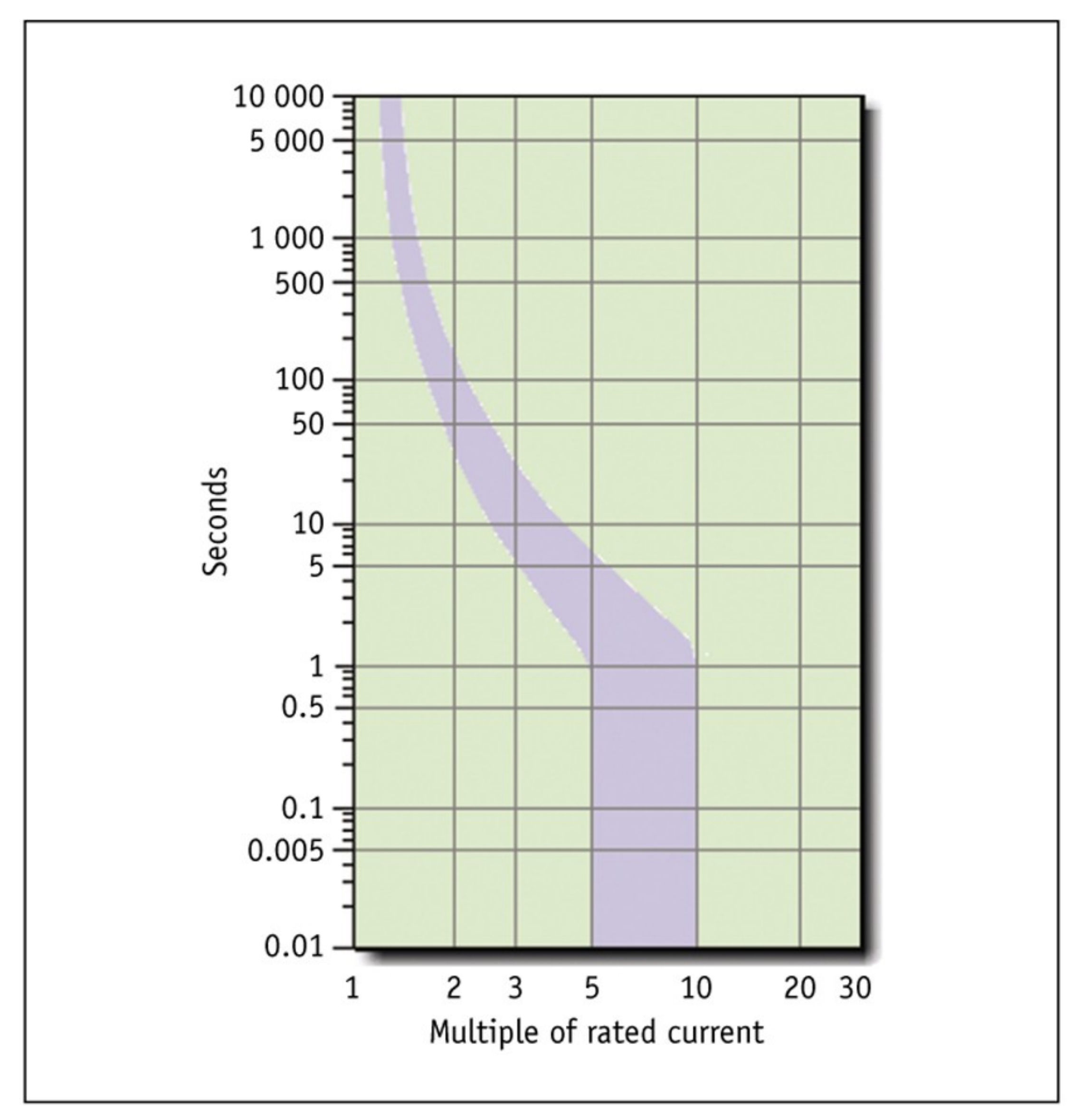
Type B – 4 x overload 20A x 4 = 80A to trip instantly
Type C – 7.5 x overload 20A x 7.5 = 150A to trip instantly
Type D – 12.5 x overload 20A x 12.5 = 250A to trip instantly
(B4.5 AS/NZS 3000)

Type B – Where a fast trip time is required or to protect a sensitive load
Type C – All common CB's
Type D – Used for high start up current applications such as Direct On Line (DOL) motors

The letter is idicated on CB's C20 = Type C 20A CB


10 000
5 000
1 000
500
100
50
10
5
1
0.5
0.1
0.005
0.01
Seconds
Maximum
Minimum
1
2
3
5
10
20
30
Multiple of rated current

Type B: 4 x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Seconds
1
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5
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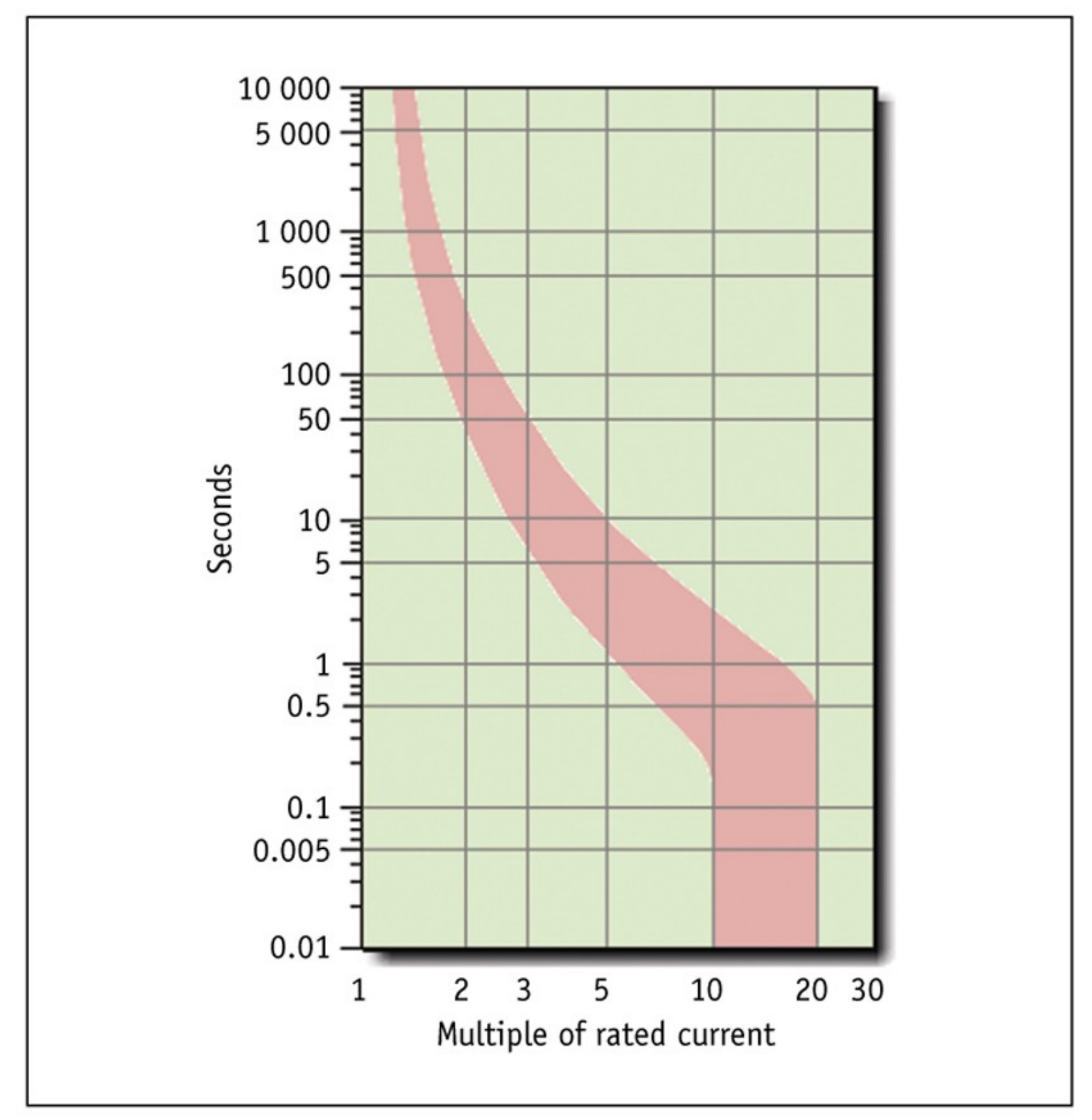
20
30
Multiple of rated current

Type C: 7.5 x


10 000
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0.005
0.01
Seconds
1
2
3
5
10
20
30
Multiple of rated current

Type D: 12.5 x

Glossary:

FLI = Fault-Loop Impedance

TX = Transformer

CM = Consumer Main

MSB = Main Switch Board

SM = Sub-Main

DB = Distribution Board

FSC = Final Sub-Circuit

Load = Load

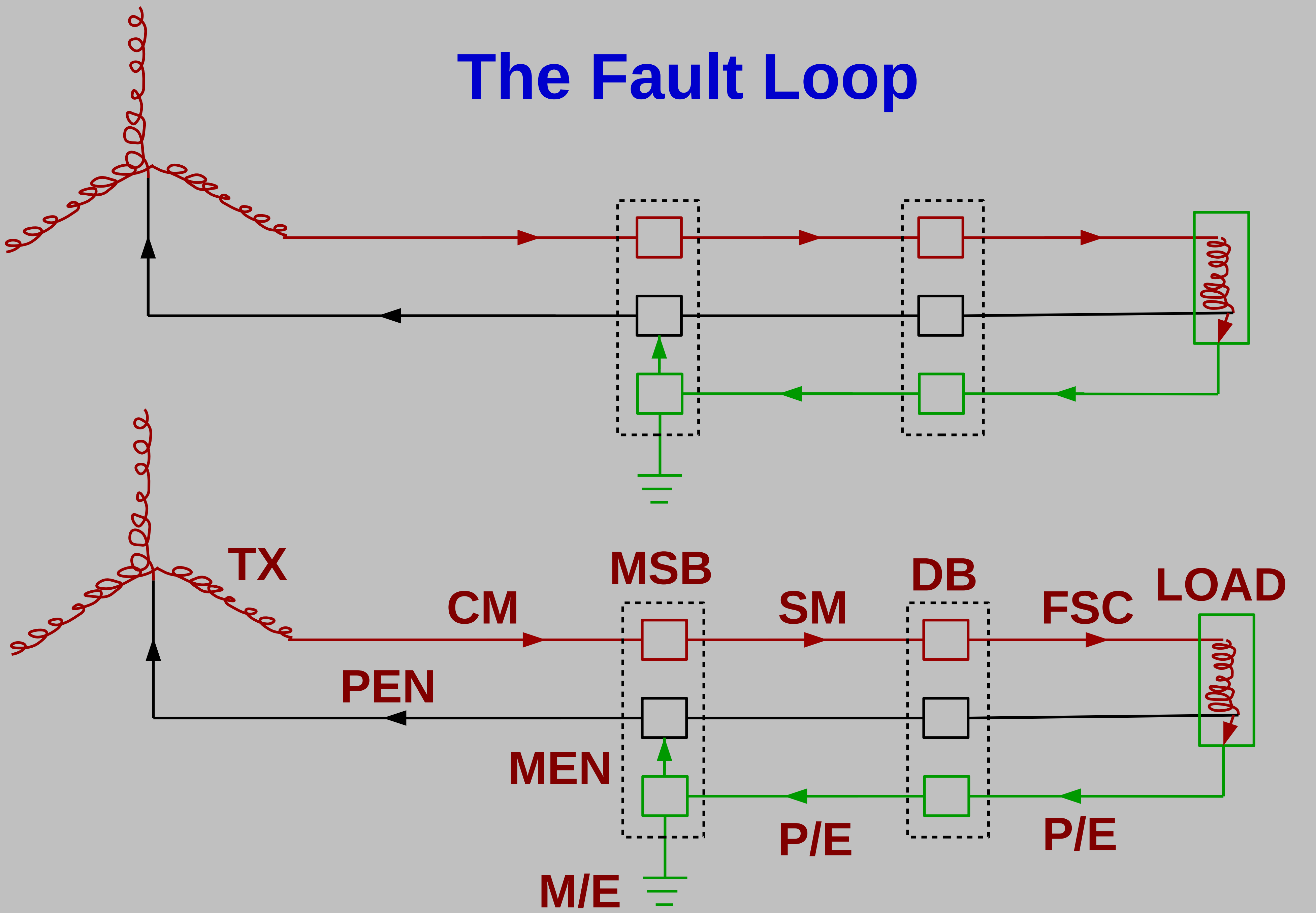
P/E = Protective Earth

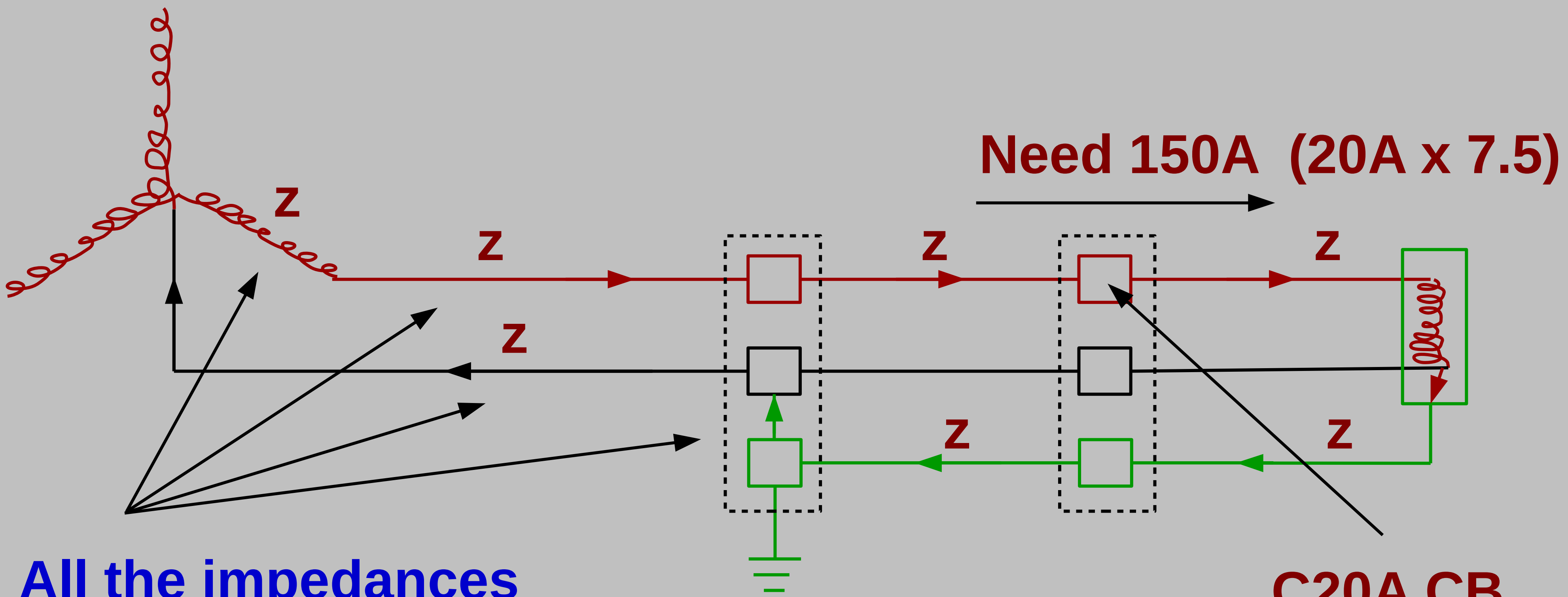
M/E = Main Earth

MEN = Main Earth Neutral

PEN = Protective Earth Neutral

The Fault Loop



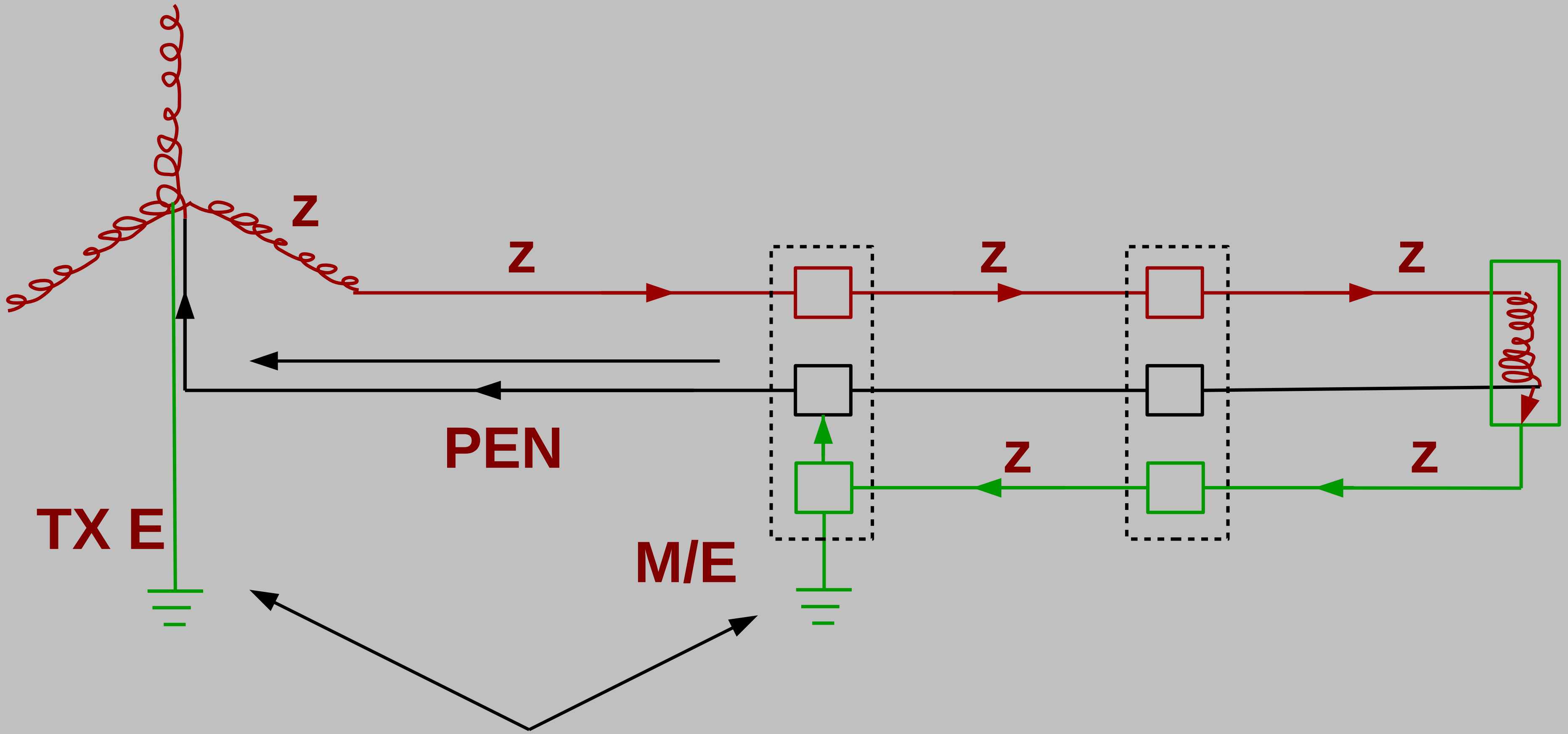


All the impedances added together makes the Fault-Loop Impedance

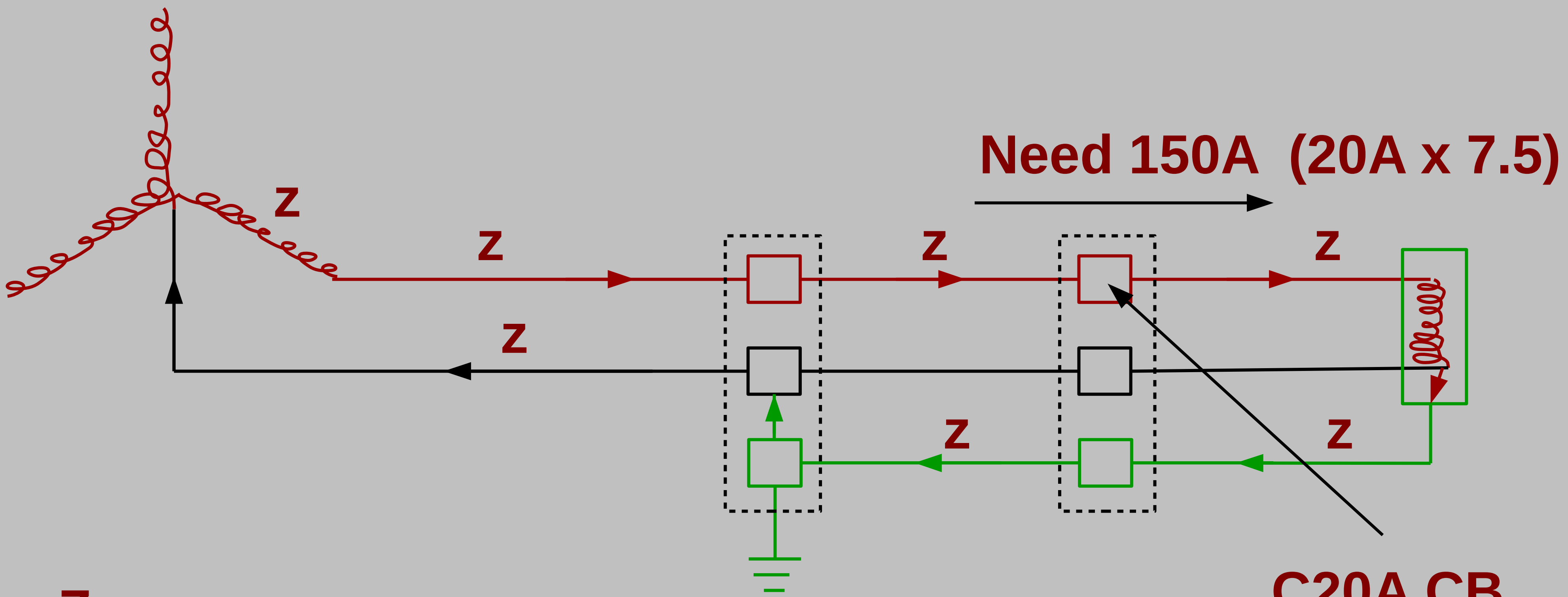
5.7.4 AS/NZS 3000 gives the formula:

$$Z_s \times I_a \leqslant U_o \quad = \quad Z_S = \frac{U_o}{I_a} \text{ or } \left(Zmax = \frac{V}{I_a} \right)$$

I_a – Is the current required to trip the circuit breaker. (I_a is Amps rated on the circuit breaker times the class)



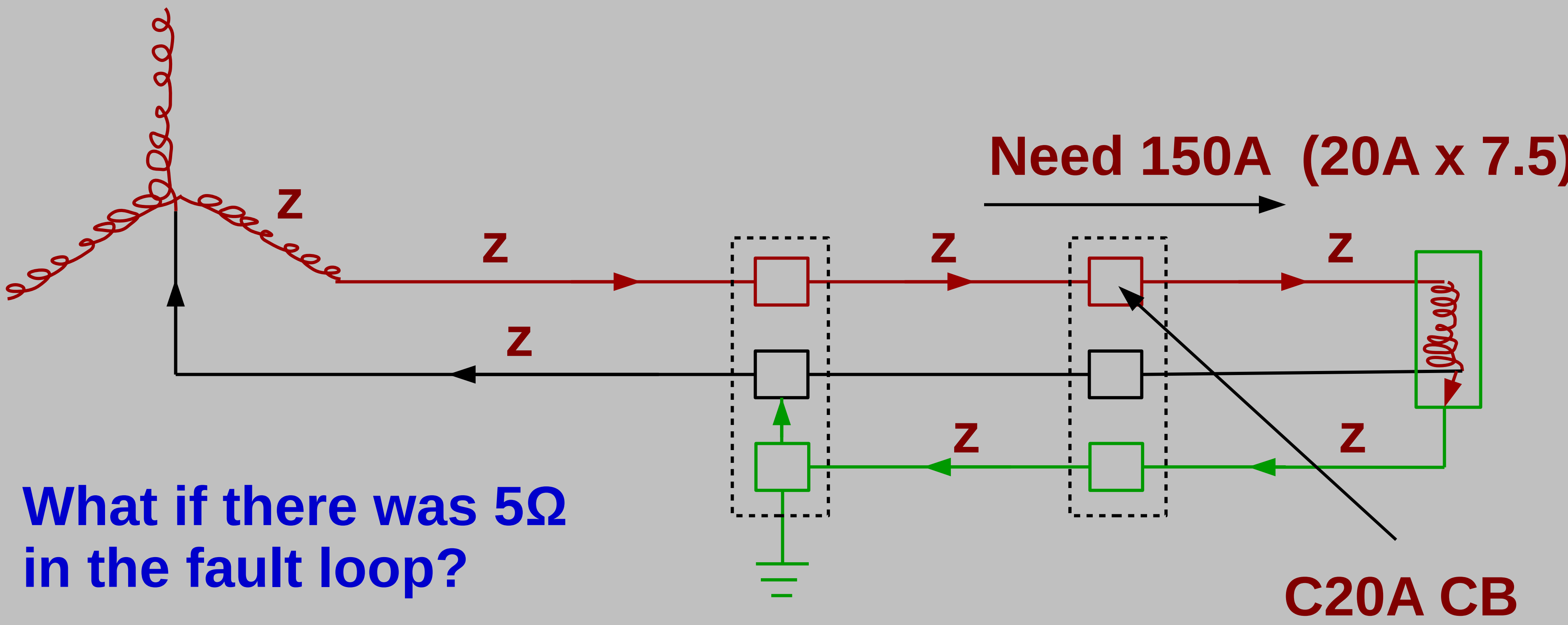
Barely any current runs through the ground as the impedance is much higher than the PEN conductor



Zmax

$$Zmax = \frac{V}{I_a} = \frac{230}{(7.5 \times 20)} = 1.533\,\Omega$$

Now check this against Table 8.1



What if there was 5Ω in the fault loop?

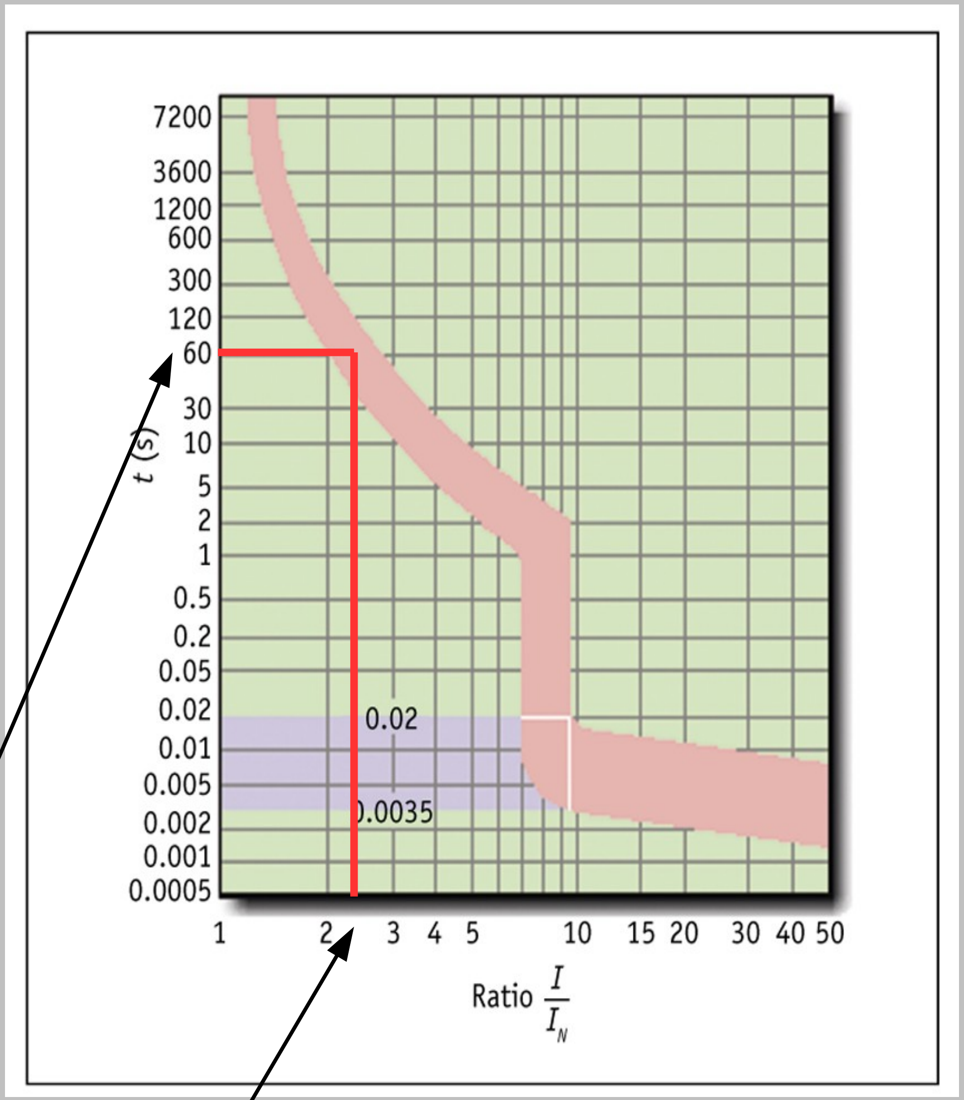
Transposed =

$$I_a = \frac{V}{Z} = \frac{230\ \text{V}}{5\ \Omega} = 46\ \text{A}$$

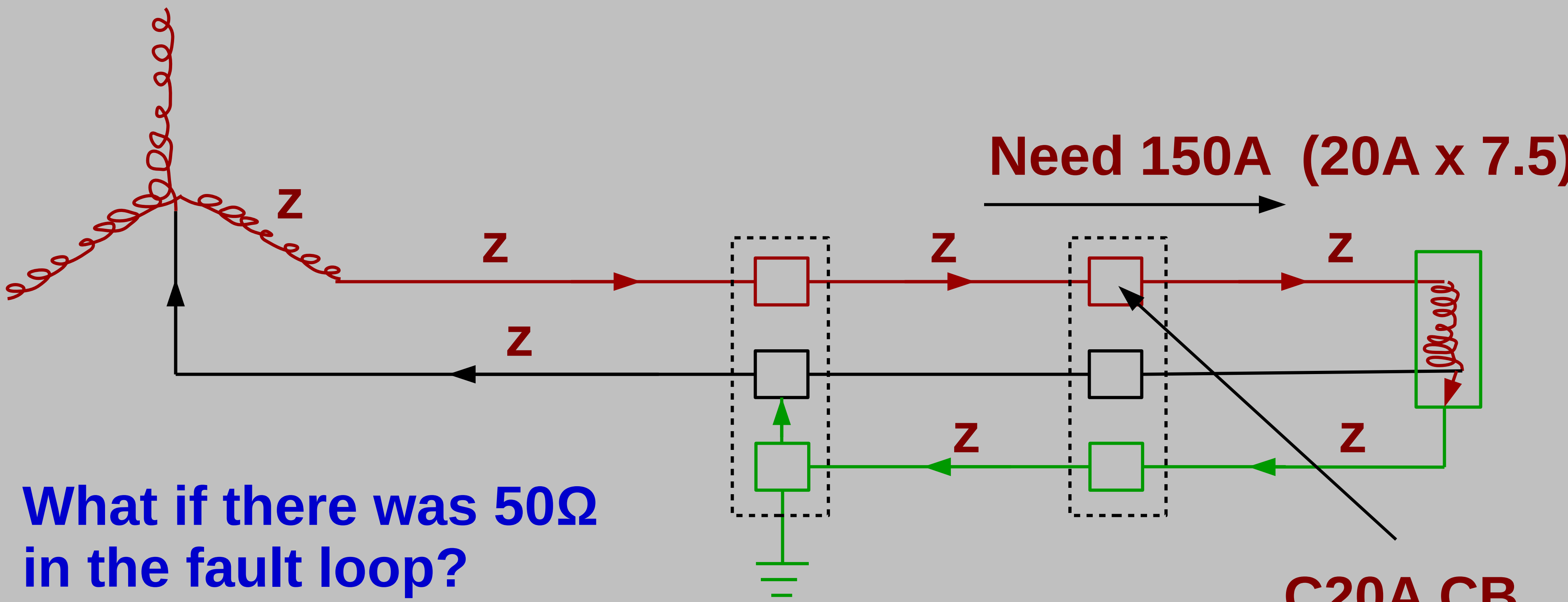
$$\frac{46\ \text{A}}{20\ \text{A}} = 2.3 \times \text{Overload}$$

How long will it take to trip the CB

Not fast enough (60 seconds) we need 7.5 x overload to turn the power off in 0.4 seconds max.
5.7.2 AS/NZS 3000



2.3 x Overload



What if there was 50Ω in the fault loop?

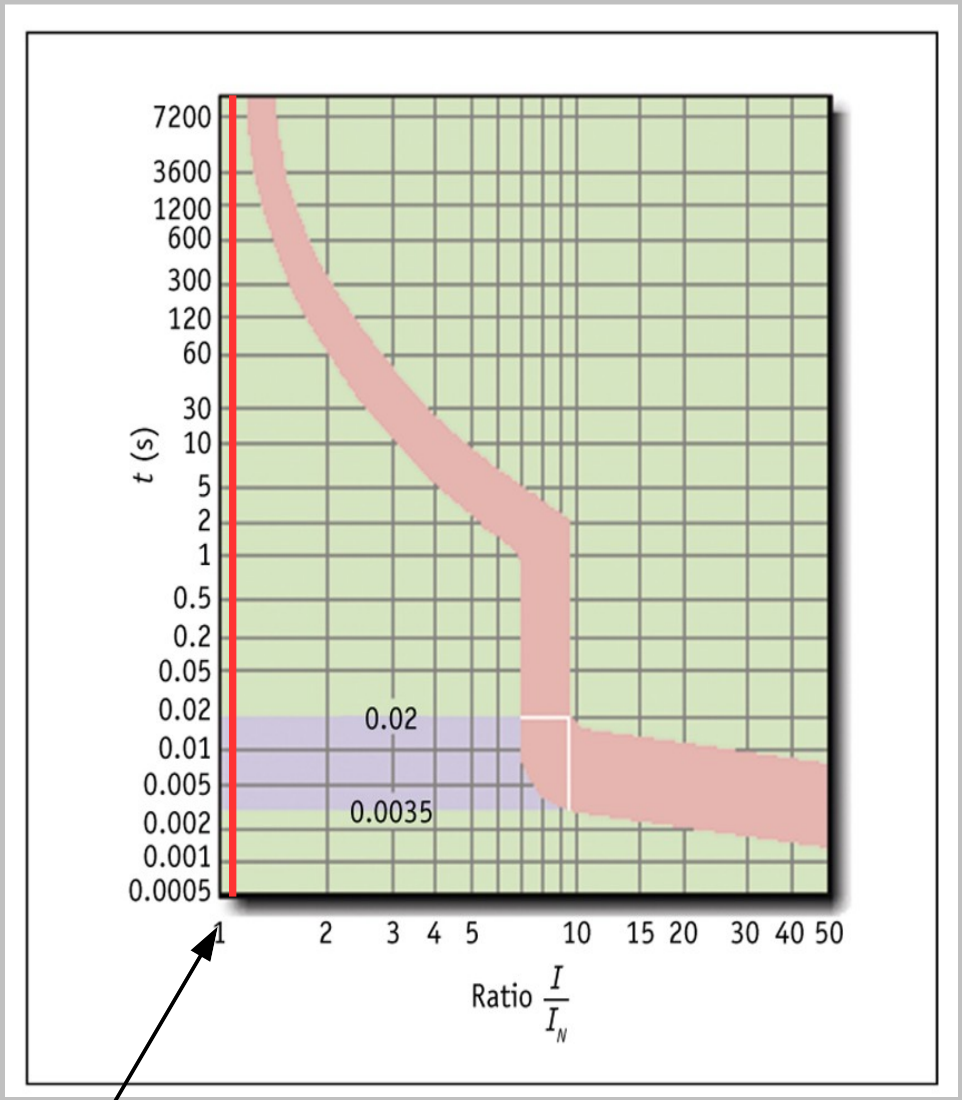
$$I_a = \frac{V}{Z} = \frac{230\,V}{50\,\Omega} = 4.6\,A$$

$$4.6\,A = 0 \times \text{Overload}$$

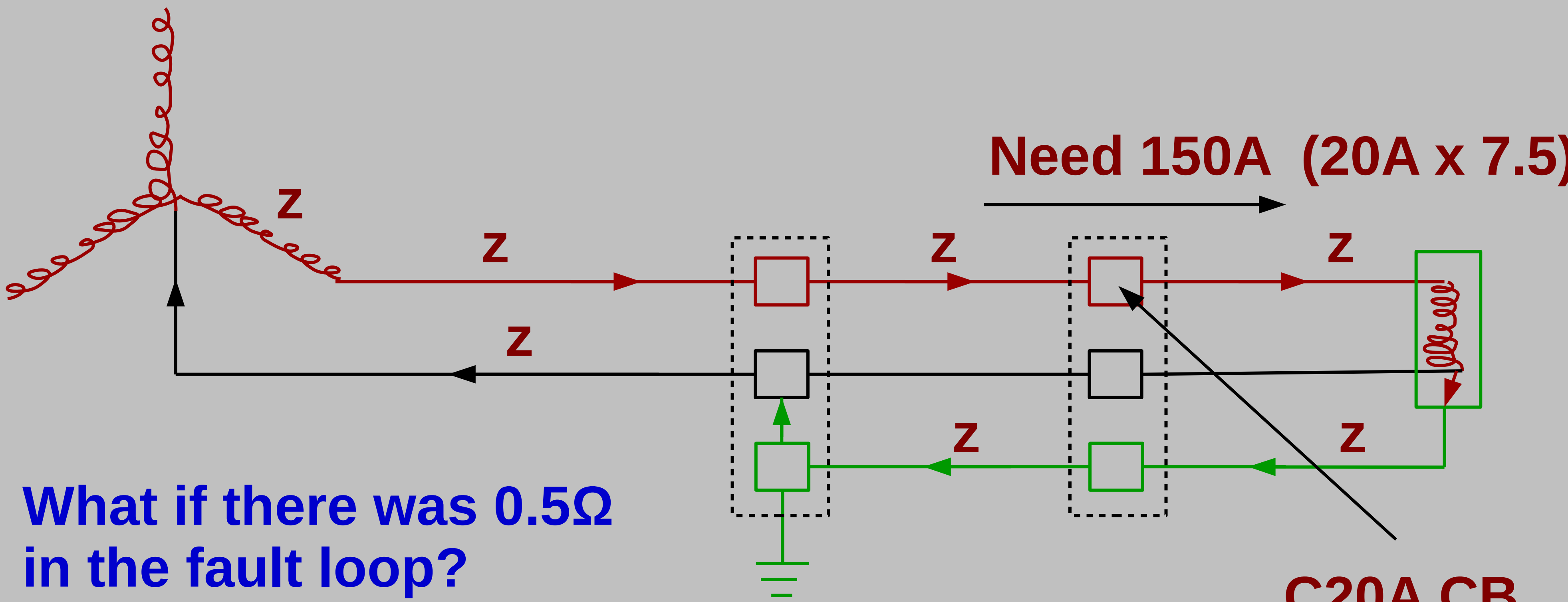
How long will it take to trip the CB

A circuit breaker may never trip with a 50Ω Fault-Loop

Don't leave the MEN out or you will render your circuit breakers useless!



0 x Overload



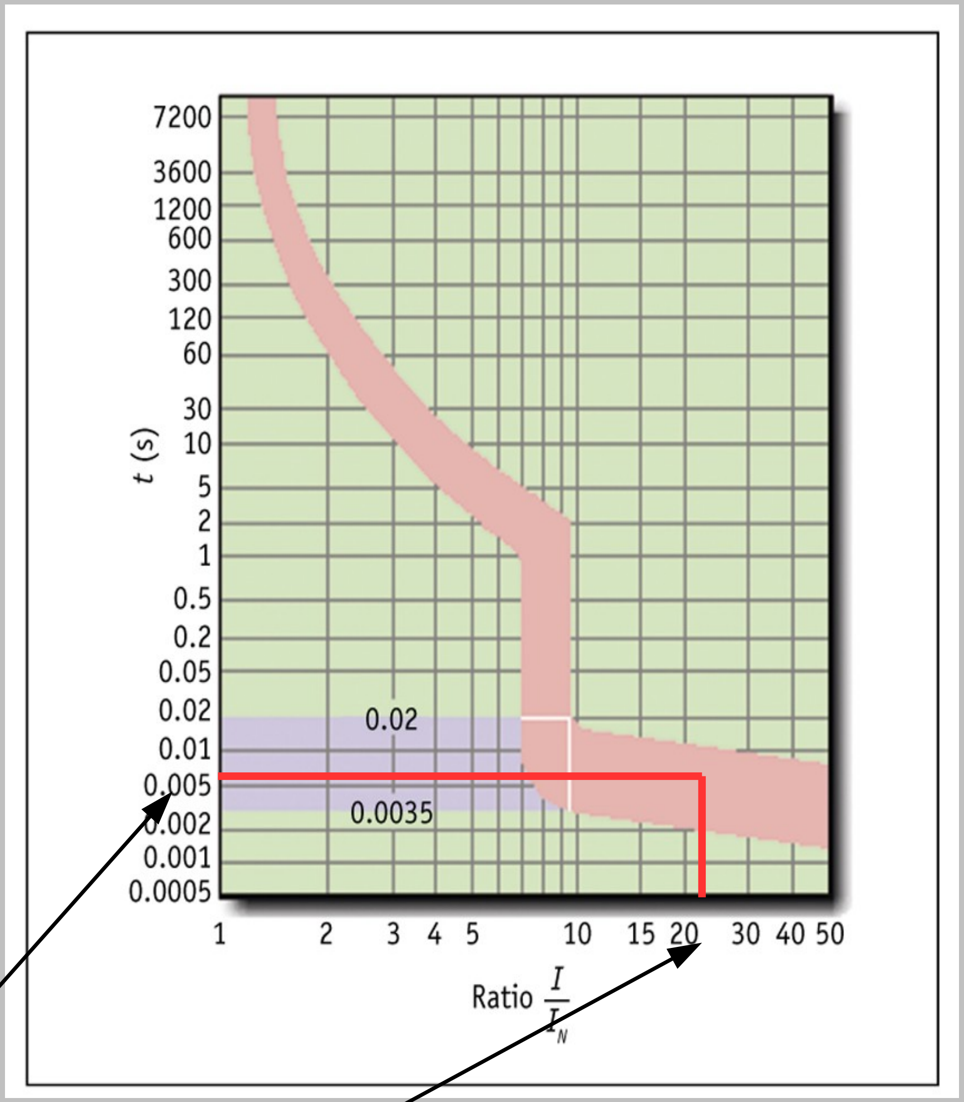
What if there was 0.5Ω in the fault loop?

$$I_a = \frac{V}{Z} = \frac{230\ V}{0.5\ \Omega} = 460\ A$$

$$\frac{460\ A}{20\ A} = 23 \times \text{Overload}$$

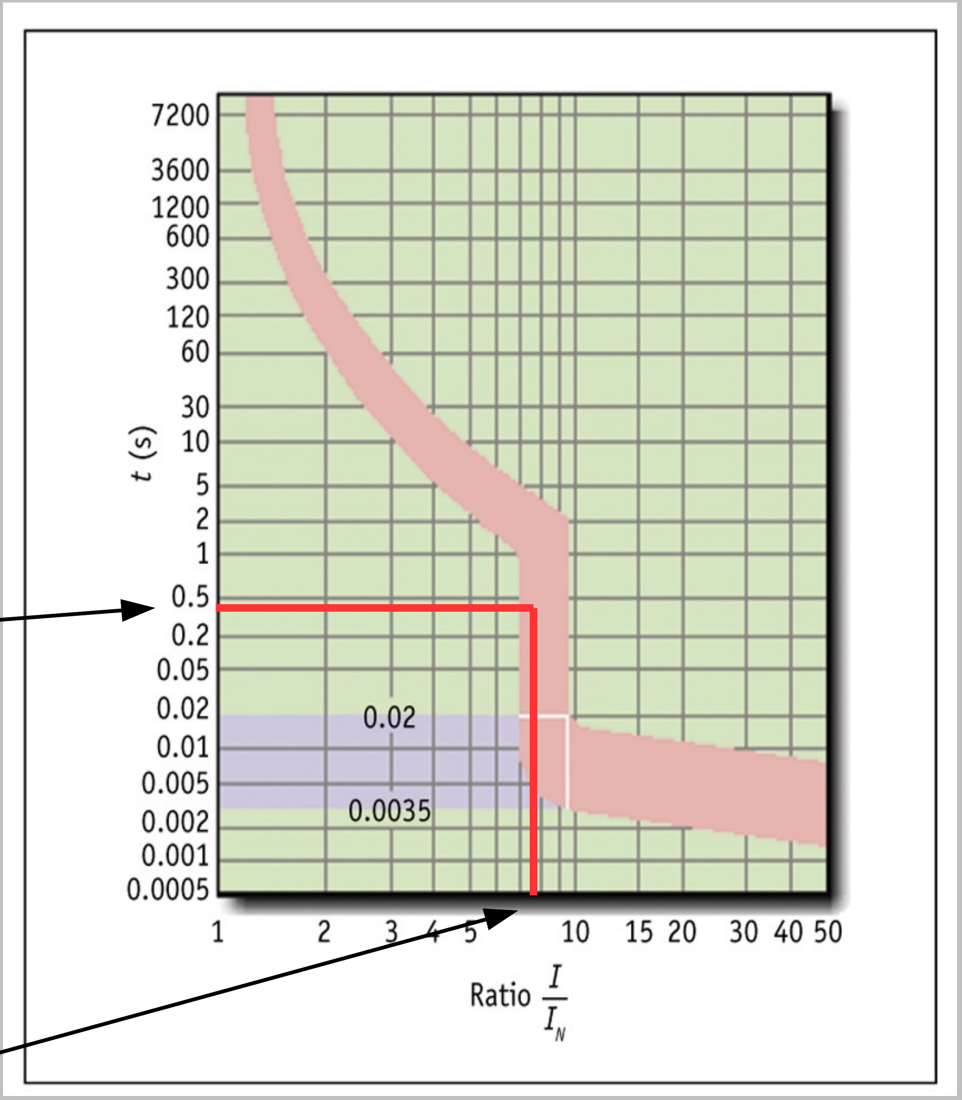
How long will it take to trip the CB

Easily faster than the minimum disconnection time or 0.4 seconds

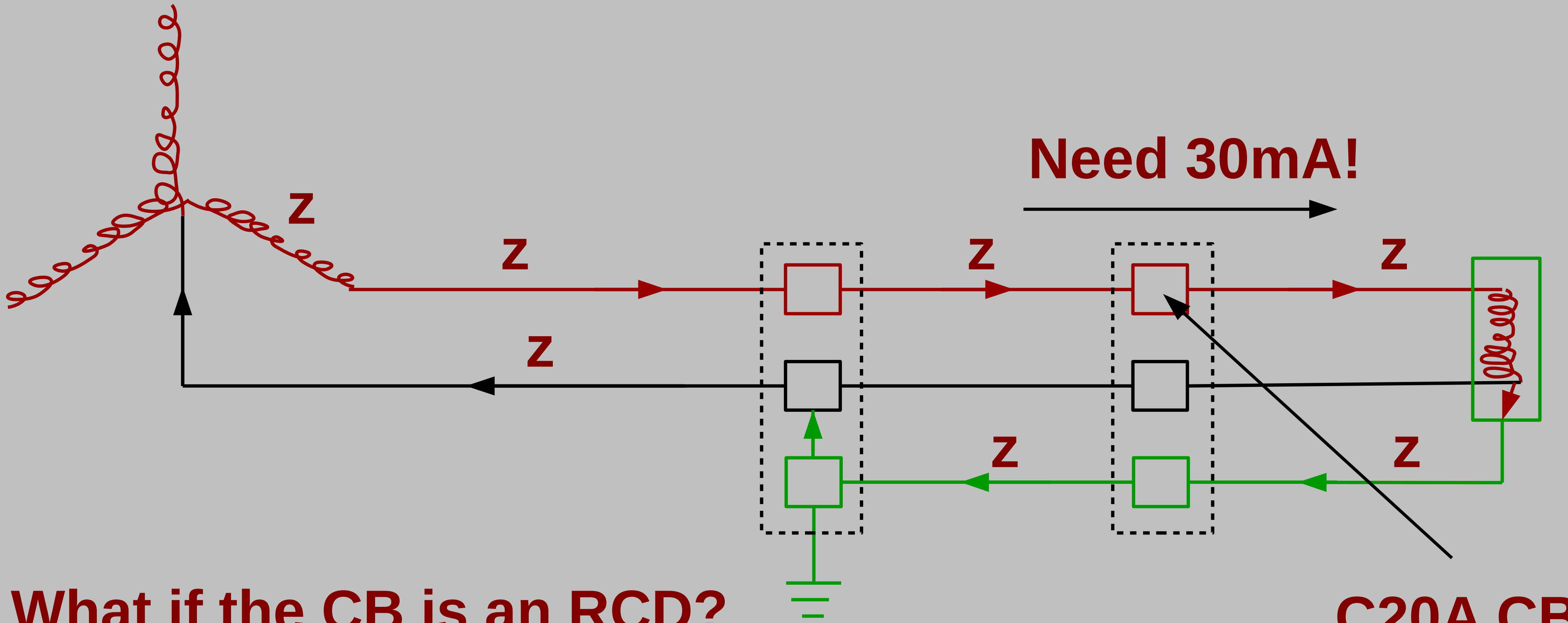


23 x Overload

7.5 x overload is the minimum current required to cause automatic disconnection of supply, (in 0.4 s) therefore 1.53Ω is the maximum fault-loop impedance for a C20A CB



$$Zmax = \frac{V}{I_a} = \frac{230}{(7.5 \times 20)} = 1.533\,\Omega$$

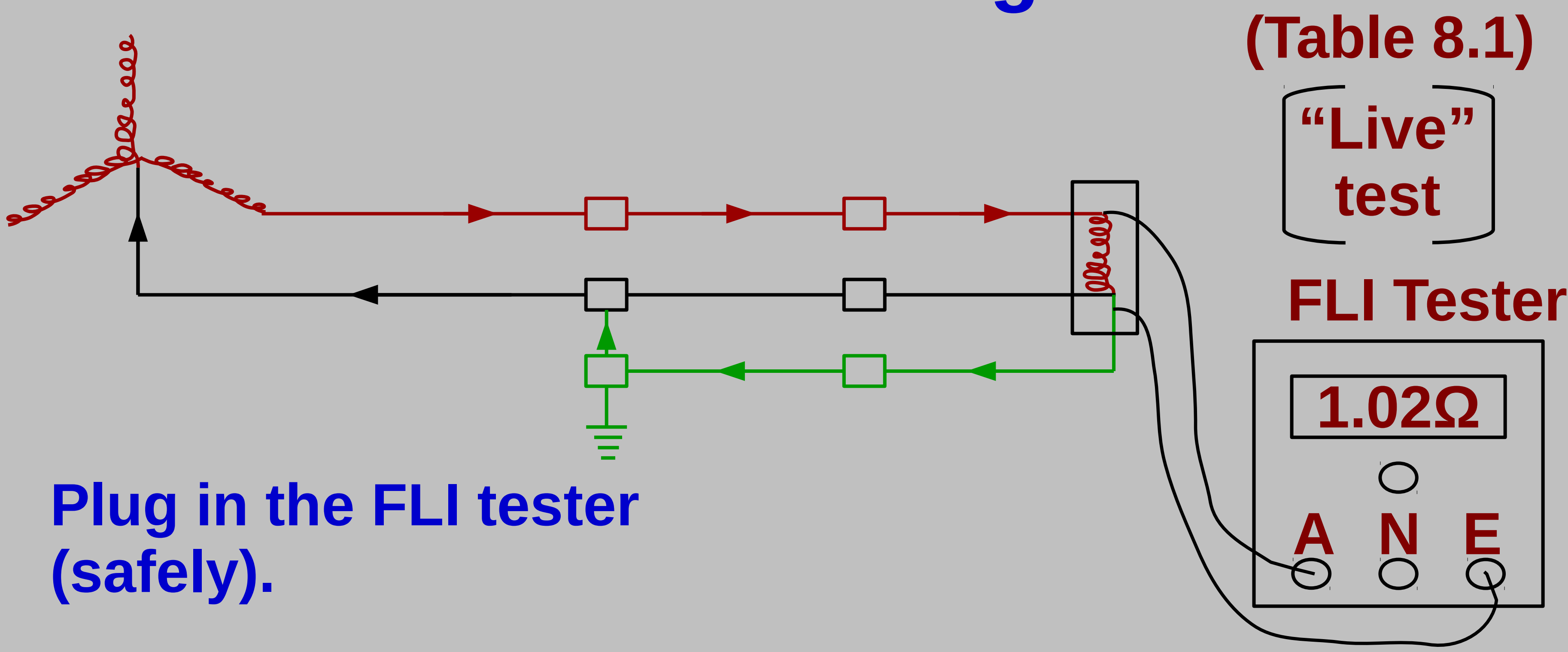


What if the CB is an RCD?

$$RCD = \frac{230\,V}{30\,mA} = 7667\,\Omega$$

You can have almost 8kΩ in the fault loop and it will still trip (if the RCD is faulty, we are back to needing 150A)

Live testing

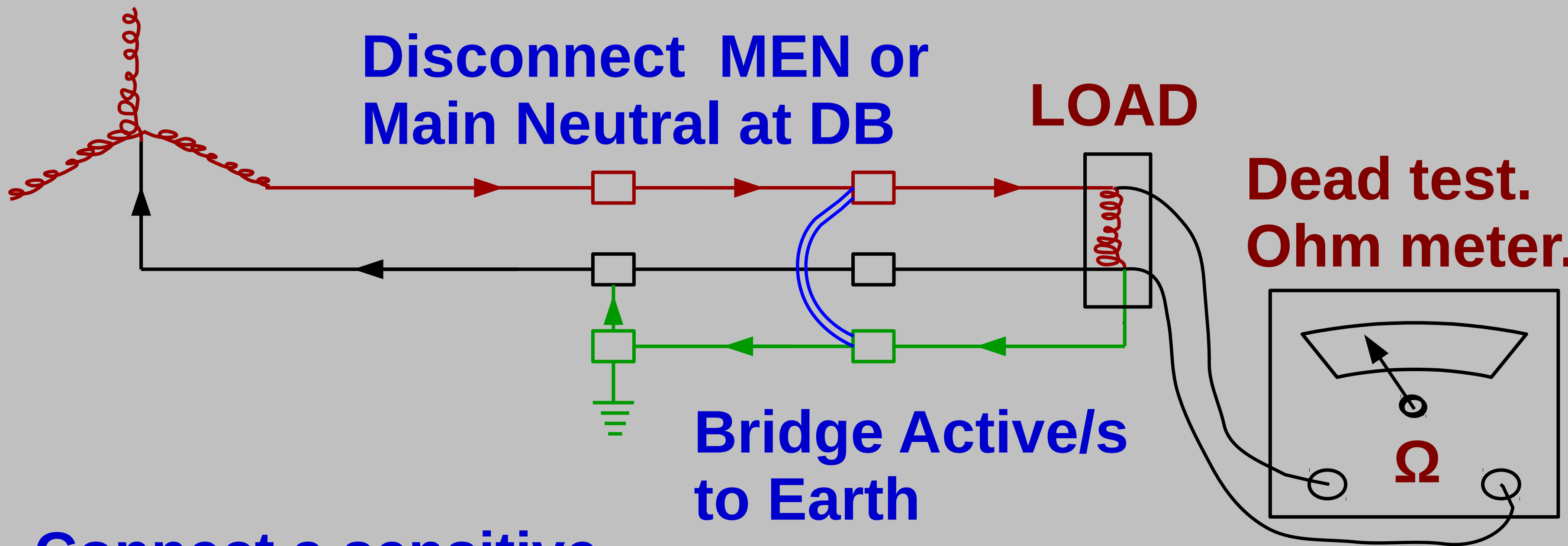


Plug in the FLI tester (safely).

Press the test button.

The value must be less than those in table 8.1 (Zmax for live test)

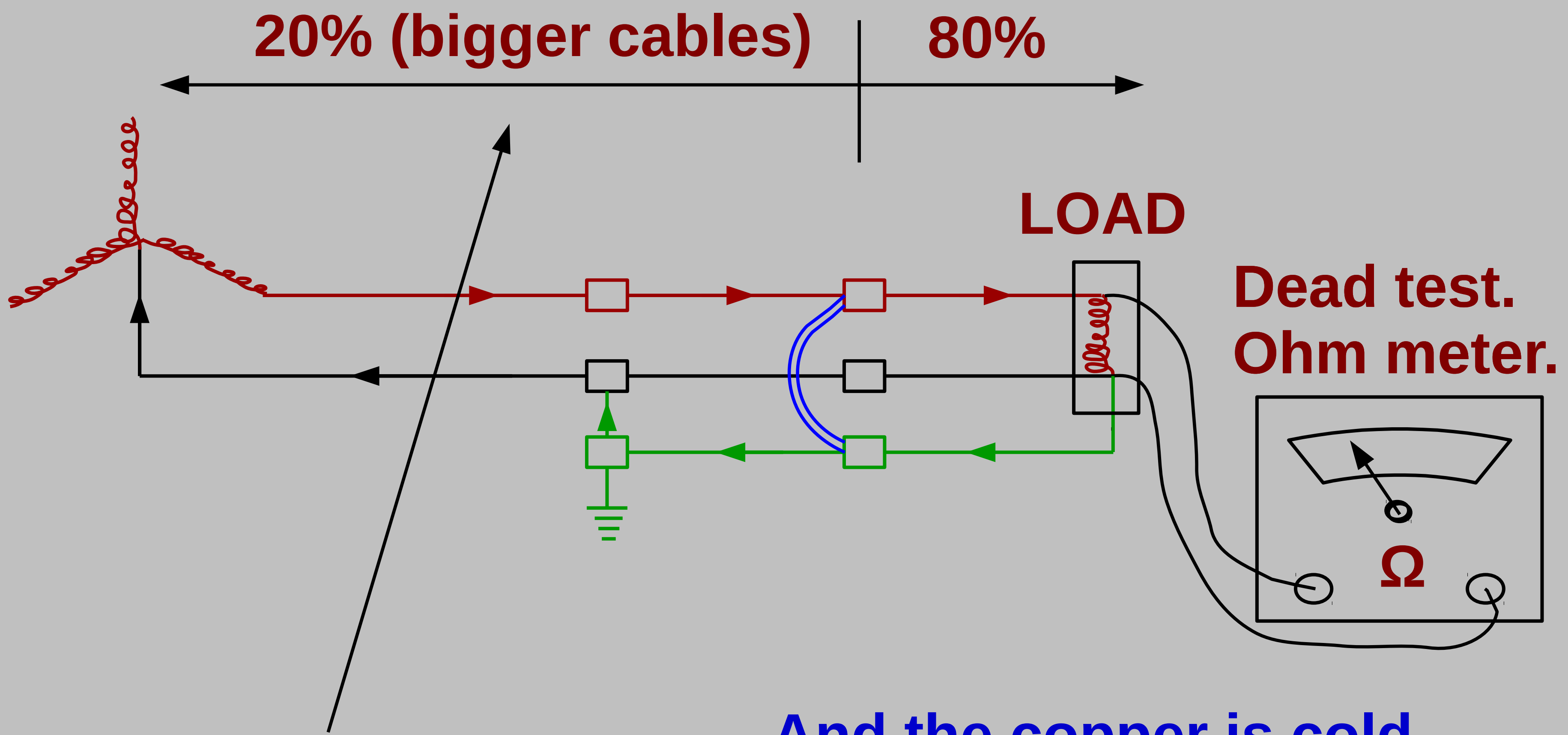
Dead testing



Connect a sensitive
Ohm meter

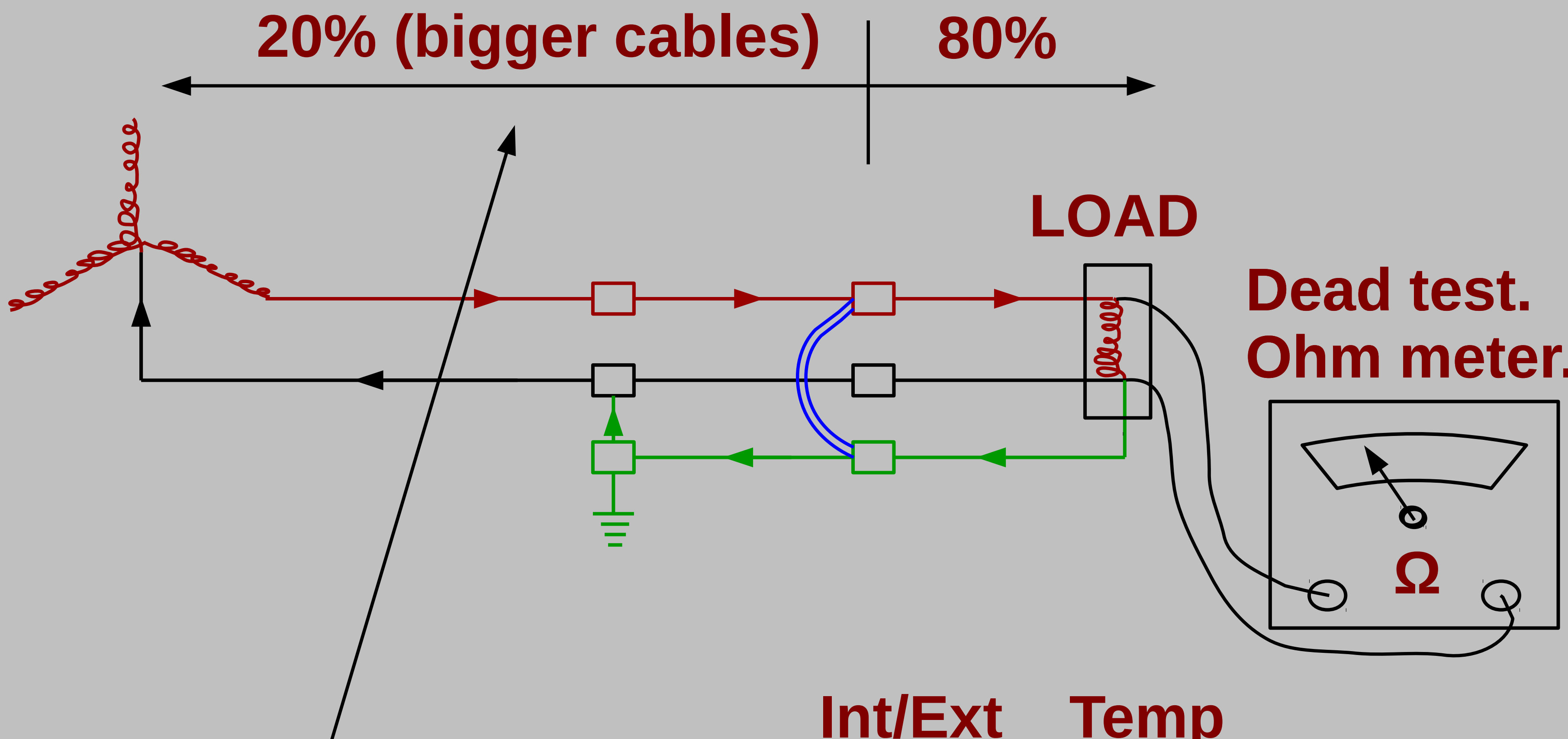
The value must be less
than those in table 8.2
(Zmax for dead test)

A method accepted by
AS/NZS 3000 that does
not require an
expensive meter



However this method does not test 20% of the circuit

And the copper is cold when tested and could have a higher resistance when operating at 75^{o}



Therefore we use the following modified formula:

$$Zmax = \frac{V}{I_a} \times 0.8 \times 0.8$$

$$0.8 \times 0.8 = 0.64$$

$$Zmax = \frac{V}{I_a} \times 0.64 = \frac{230}{(20 \times 7.5)} = 0.98\,\Omega$$

Now check this against Table 8.2 (R_{phe})
(Resistance Phase to Earth)

Max Circuit length

(So as not to have FLI issues)
Lmax – Maximum length
B5.2.2 AS/NZS 3000

$$Lmax = \frac{0.8 \times U_o \times S_{ph} \times S_{pe}}{I_a \times \rho \times (S_{ph} + S_{pe})}$$

Use Table B1 for most cases

U_o – Nominal phase volts (230V)
S_{ph} – Cross section area of the active conductor in mm^2
S_{pe} – Cross section area of the protective Earthing in mm^2
I_a – Trip setting x Rating of Circuit Breaker (e.g. 20 x 7.5)
ρ – Resistivity at normal working temperature in Ω-mm^2/m
Cu – 0.0225Ω
Al – 0.036Ω

What is the max length of cable protected by a C20A CB with a 2.5mm Active and a 2.5mm Earth

$$\mathbf{Lmax = \frac{0.8 \times U_o \times S_{ph} \times S_{pe}}{I_a \times \rho \times (S_{ph} + S_{pe})}}$$

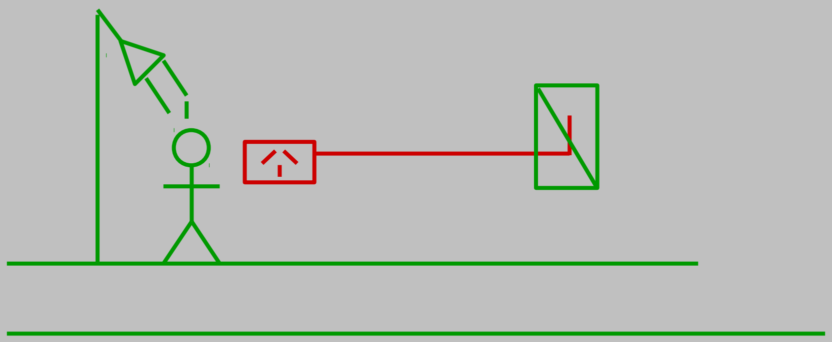
$$\mathbf{Lmax = \frac{0.8 \times 230 \times 2.5 \times 2.5}{7.5 \times 20 \times 0.0225\ x\ 5}}$$

$$\mathbf{= \frac{1150}{16.875}}$$

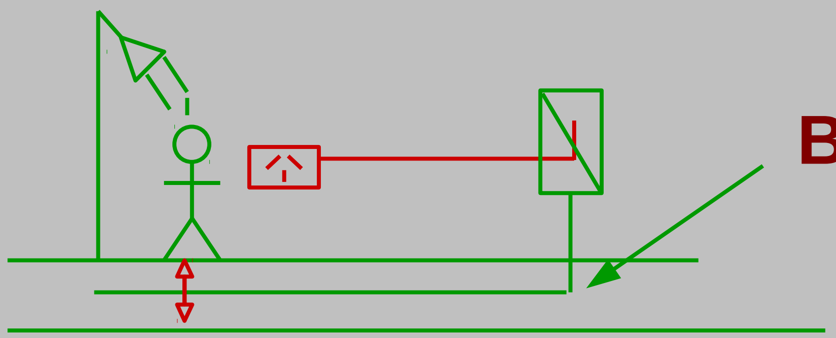
$$\mathbf{= 68.15\ metres}$$

Now check against table B1

Why are slabs bonded under wet areas?



No Earth? Ω?



Bonded Slab

FLI < much lower