Fast Communication-Based Protection and Isolation Schemes

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S&C Electric Company

Presented by

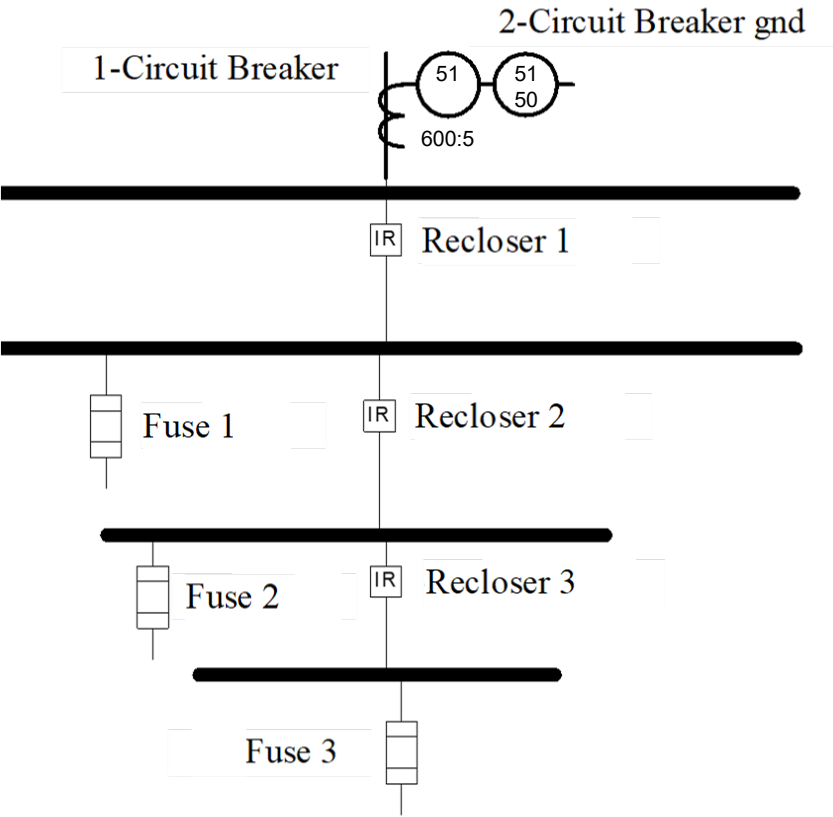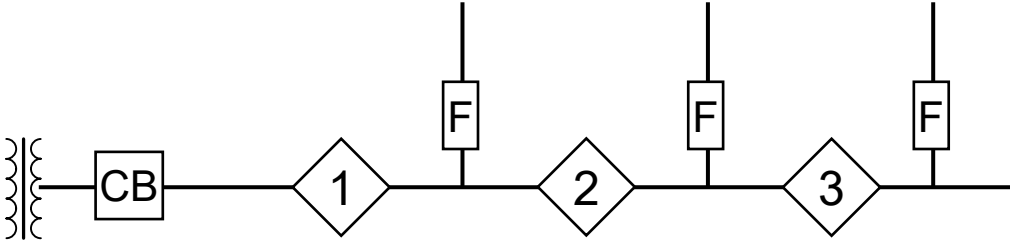**Qing Guo**

03/29/2023

Outline

- Existing solutions

- Fast coordination between reclosers

- Fast coordination between reclosers and fuses

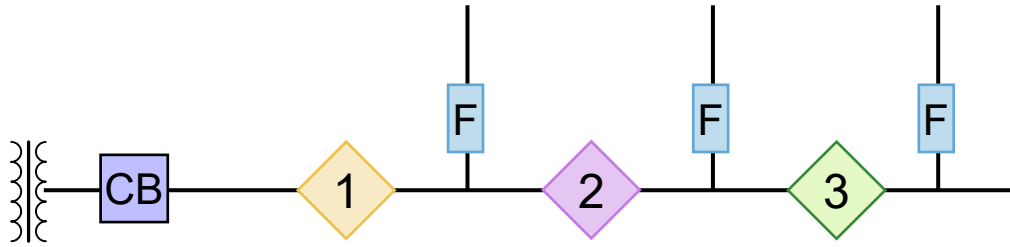- Fast downstream isolation scheme

Outline

- Existing solutions

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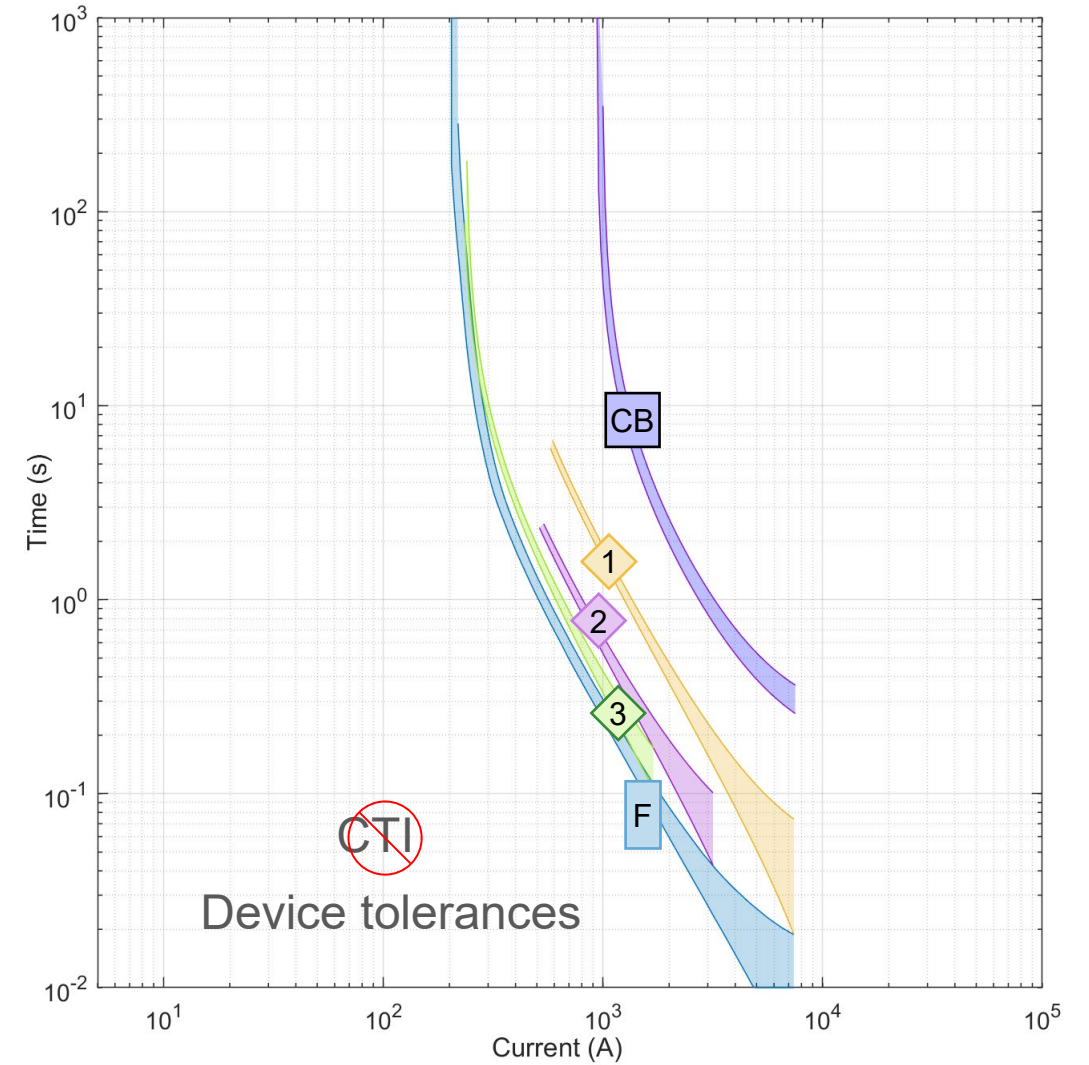- Fast downstream isolation scheme

Example Feeder Model

Time-Based TCC Coordination

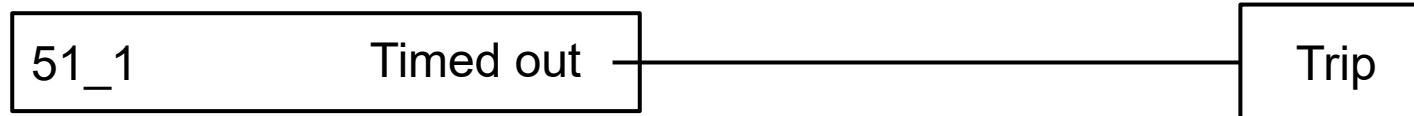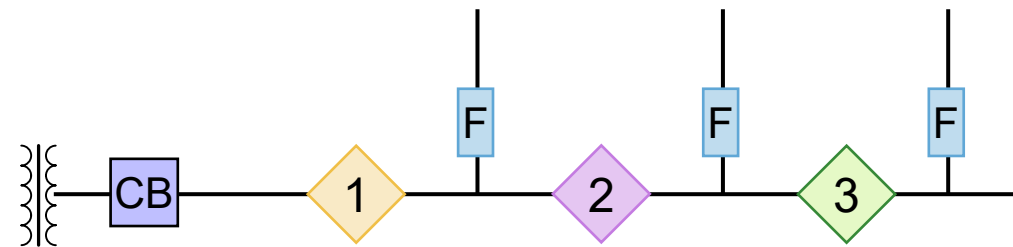■ TCC (Time Current Characteristic)

• Limited # devices
• Slow with more devices
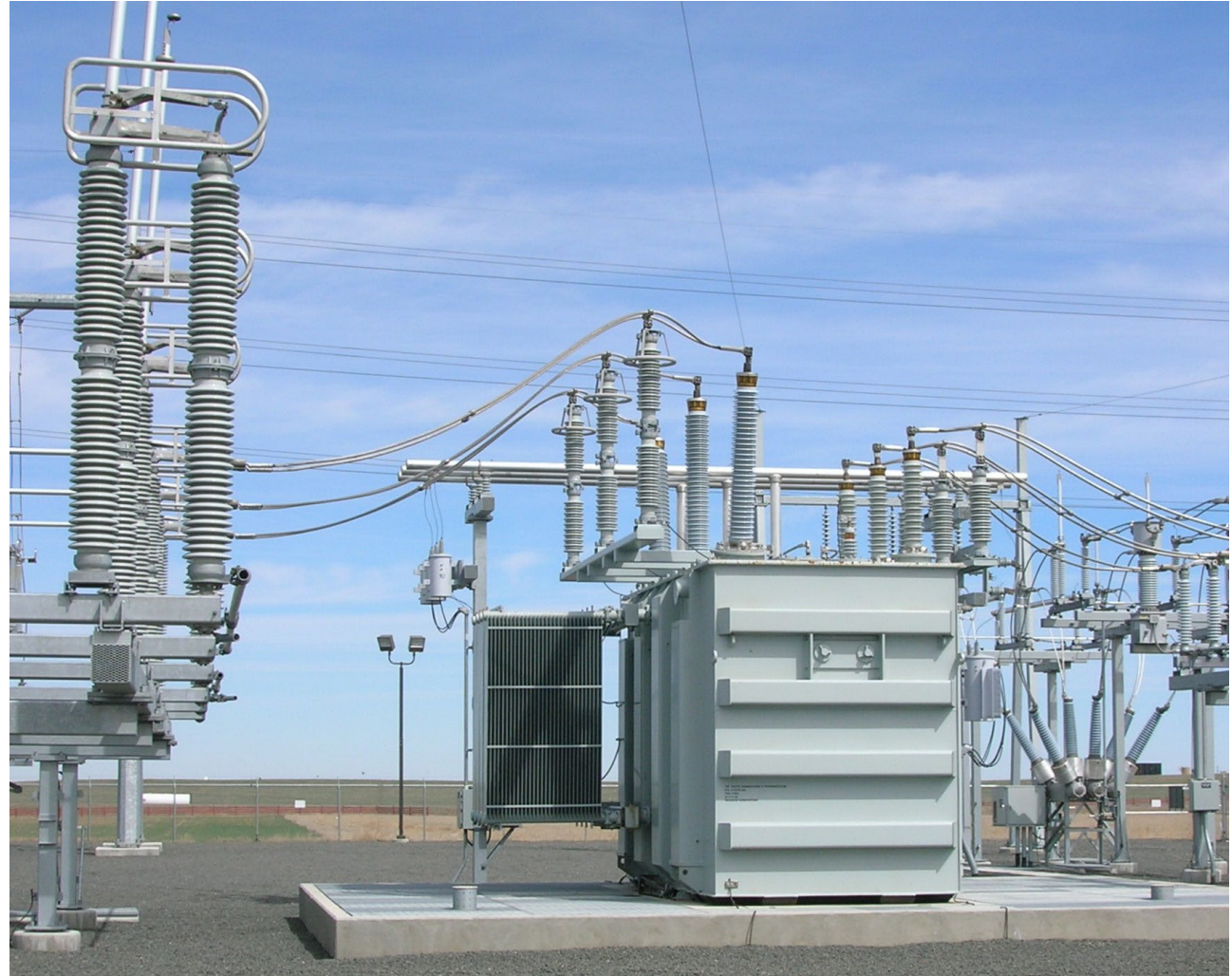• Engineering effort

Time-Based TCC Coordination

- TCC (Time Current Characteristic)

Why Faster Is Better?
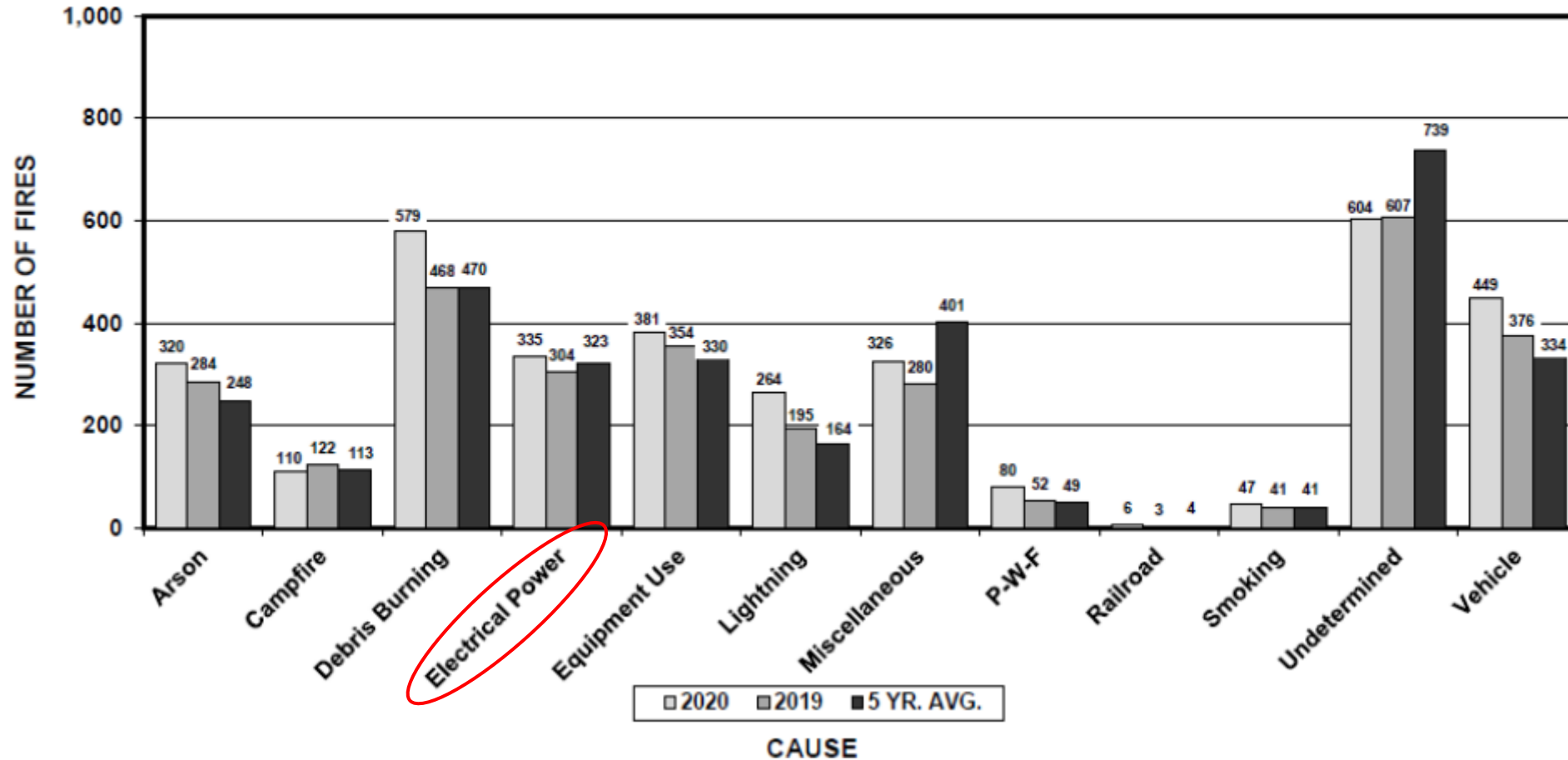
- Prolonged equipment life

- Reduced arc flash

Credit: Greg Goebel from Loveland CO, USA

Why Faster Is Better?

■ Reduced wildfire risk

FIRES BY CAUSE
2020, 2019 and 5 Year Average

* California Department of Forestry & Fire Protection, "2020 Wildfire Activity Statistics"

Why Faster Is Better?

- Ride through capabilities for voltage sags below 70%

|	Cycles	Milliseconds
Consumer electronics (ITIC guidance)	1	20
Personal computers (actual tests)	15	120
Adjustable speed drives (single phase fault)		160

Other considerations:

- FIDVR

- Motor stalling

- Loss of synchronism (synchronous motors)

* M. H. J. Bollen, Understanding Power Quality Problems – Voltage Sags and Interruptions, IEEE Press, 1999
* S. Ž. Djokic et al, "Sensitivity of AC Adjustable Speed Drives to Voltage Sags and Short Interruptions" (IEEE Trans. Power Delivery, Vol. 20, No. 1, 2005, pages 494-505)
* K. G. Ravikumar et al, "Analysis of fault-Induced delayed voltage recovery using EMTP simulations" (2016 IEEE/PES Transmission and Distribution Conference and Exposition)

Block

Wait more
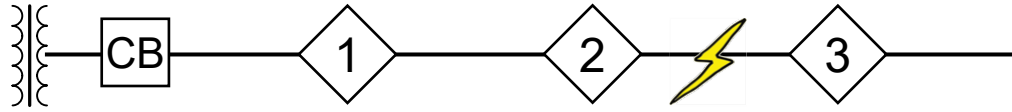
Wait more

Max possible latency
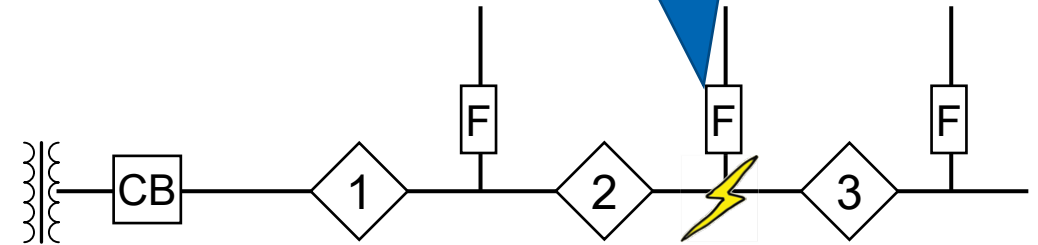
Permit

Open

Open
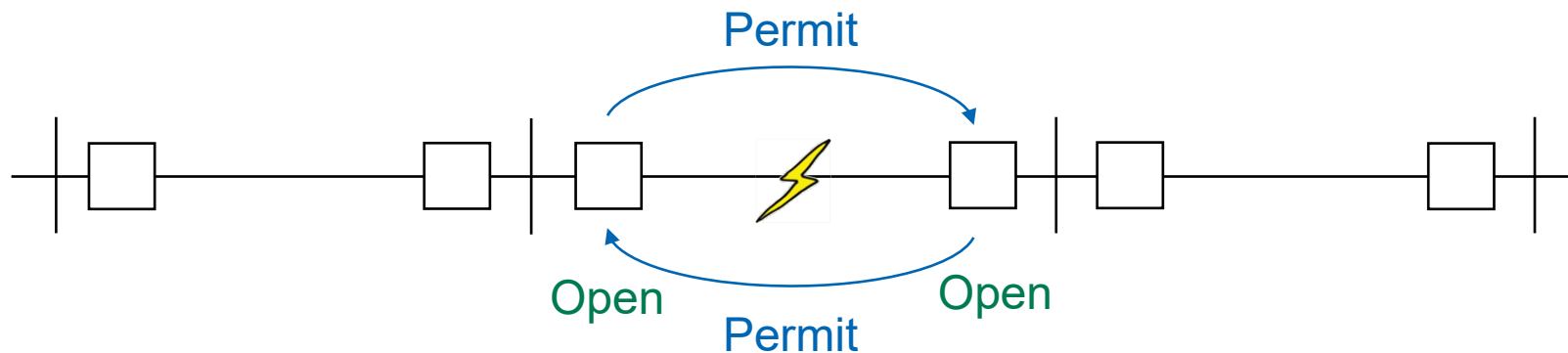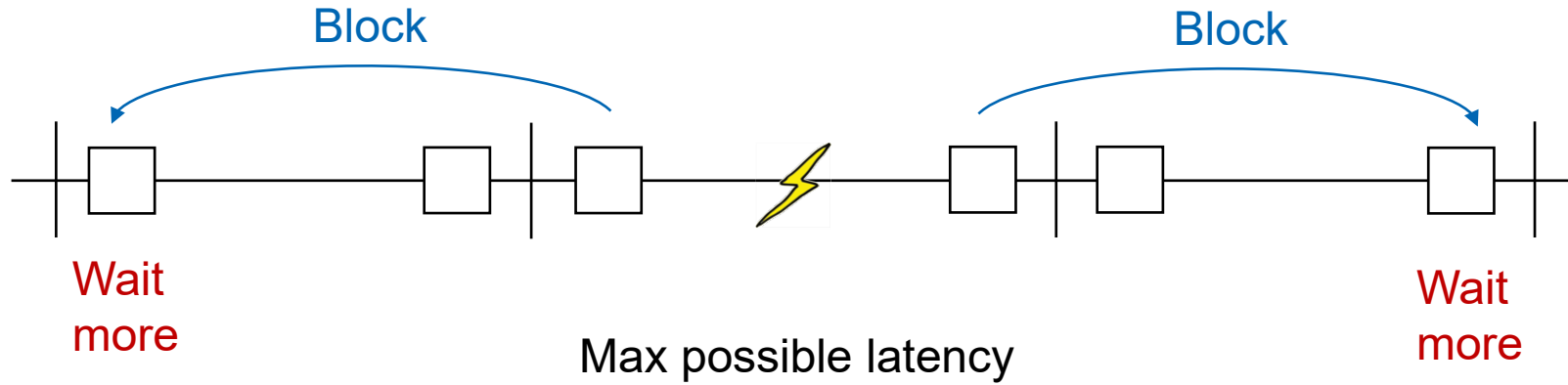
Permit

Typical latency

Faster

* B. Kasztenny et al, "Permissive or blocking pilot protection schemes? How to have it both ways" (74th Annual Conference for Protective Relay Engineers, 2021)

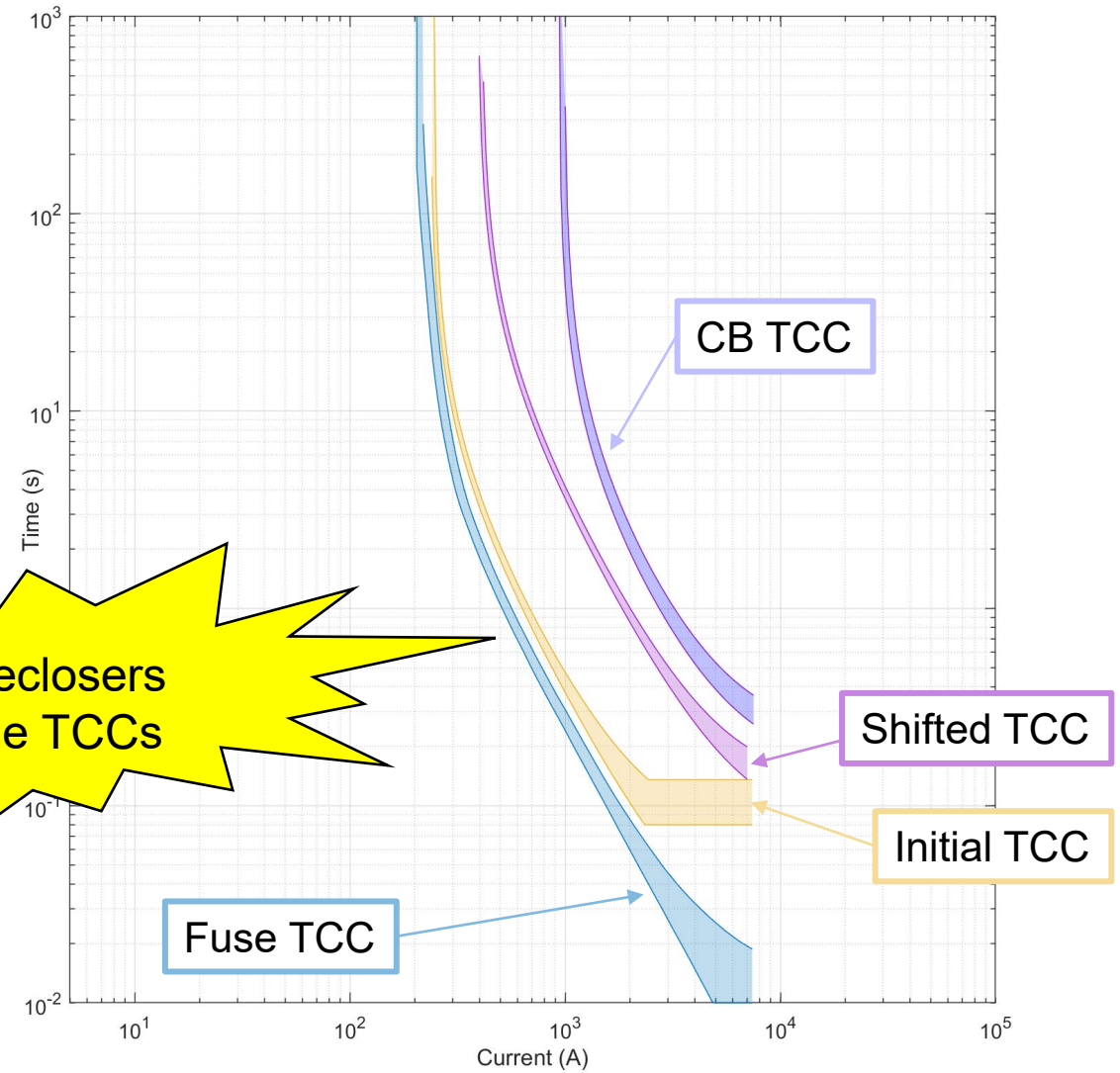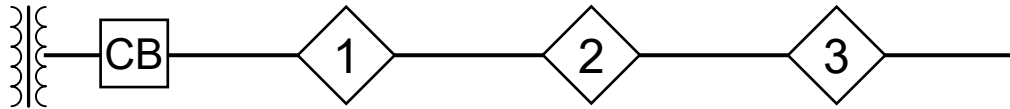# Challenges for Permissive Scheme in Distribution

No fault current
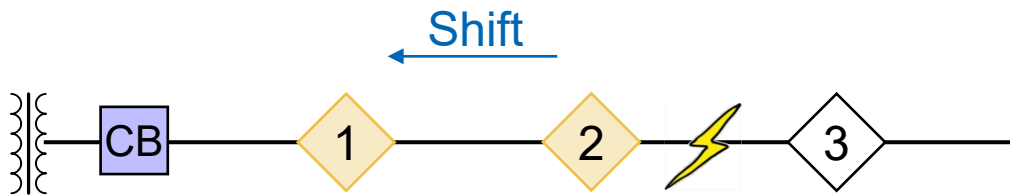
Coordination with fuses

Distribution: relies on relatively slow radios
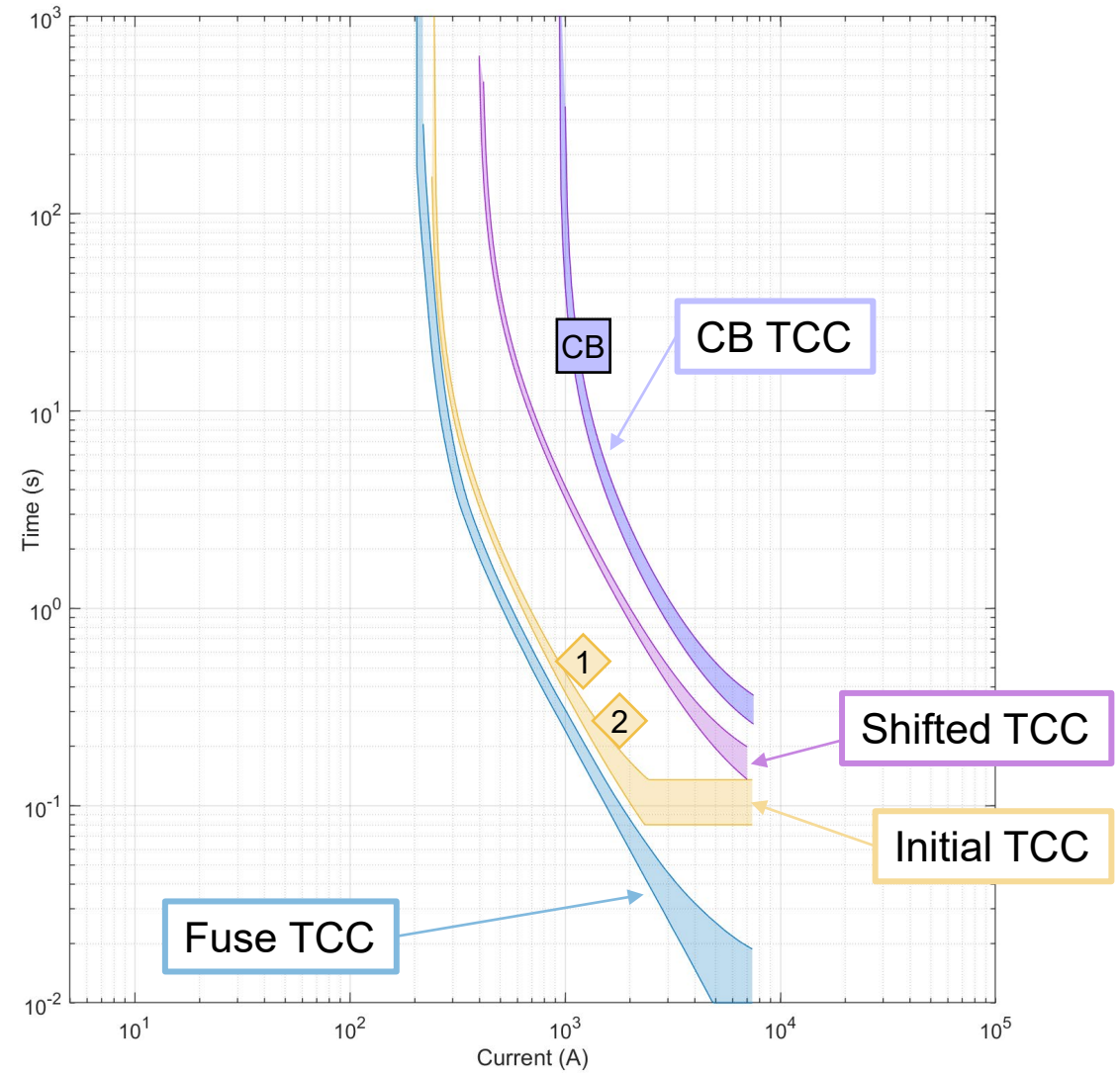(typical latency 40 ms, max latency 80 ms)

Blocking Scheme

All reclosers same TCCs

CB TCC

Shifted TCC

Initial TCC

Fuse TCC

* D. M. Staszesky, R. P. O'Leary, T. J. Tobin, "Fault protection system and method for an electrical power distribution system" (US 2009/0290275 A1, 2009)

Blocking Scheme

Shift

Shift = Overcurrent detected

Blocking Scheme

Shift

Shift = Overcurrent detected

Blocking Scheme

CB — 1 — 2 — 3

| 51_1 (Initial) | Picked up | Send "Shift" message |
| | Timed out | |

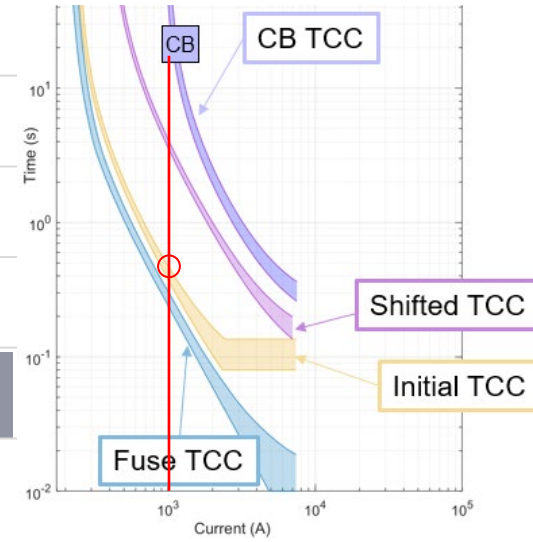"Shift" message received

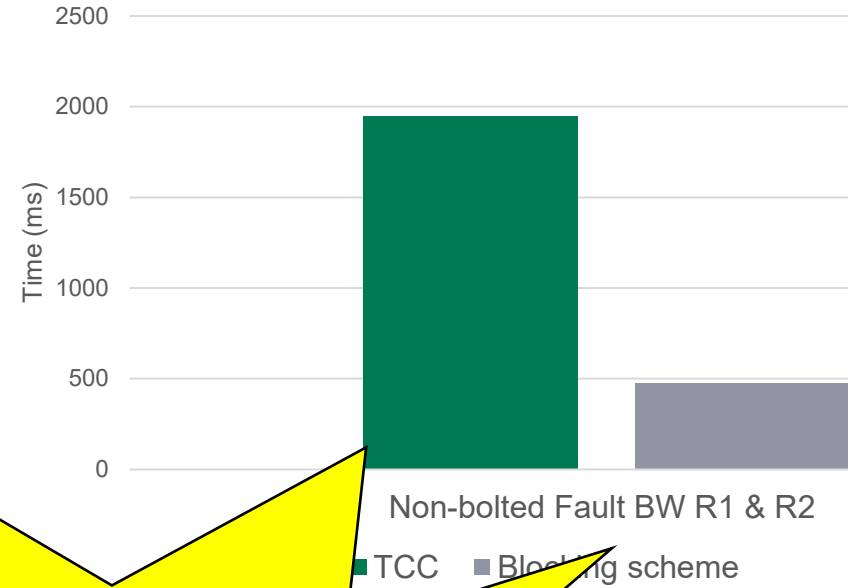51_2 (Shifted)   Timed out

Trip
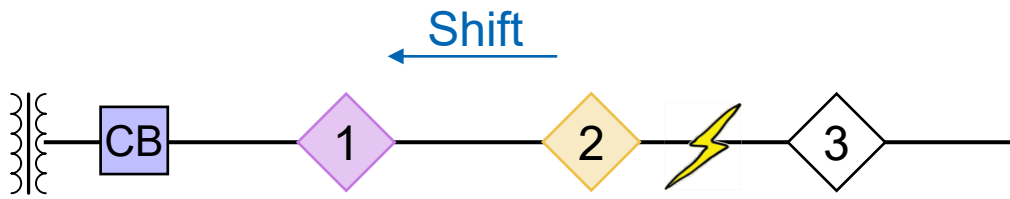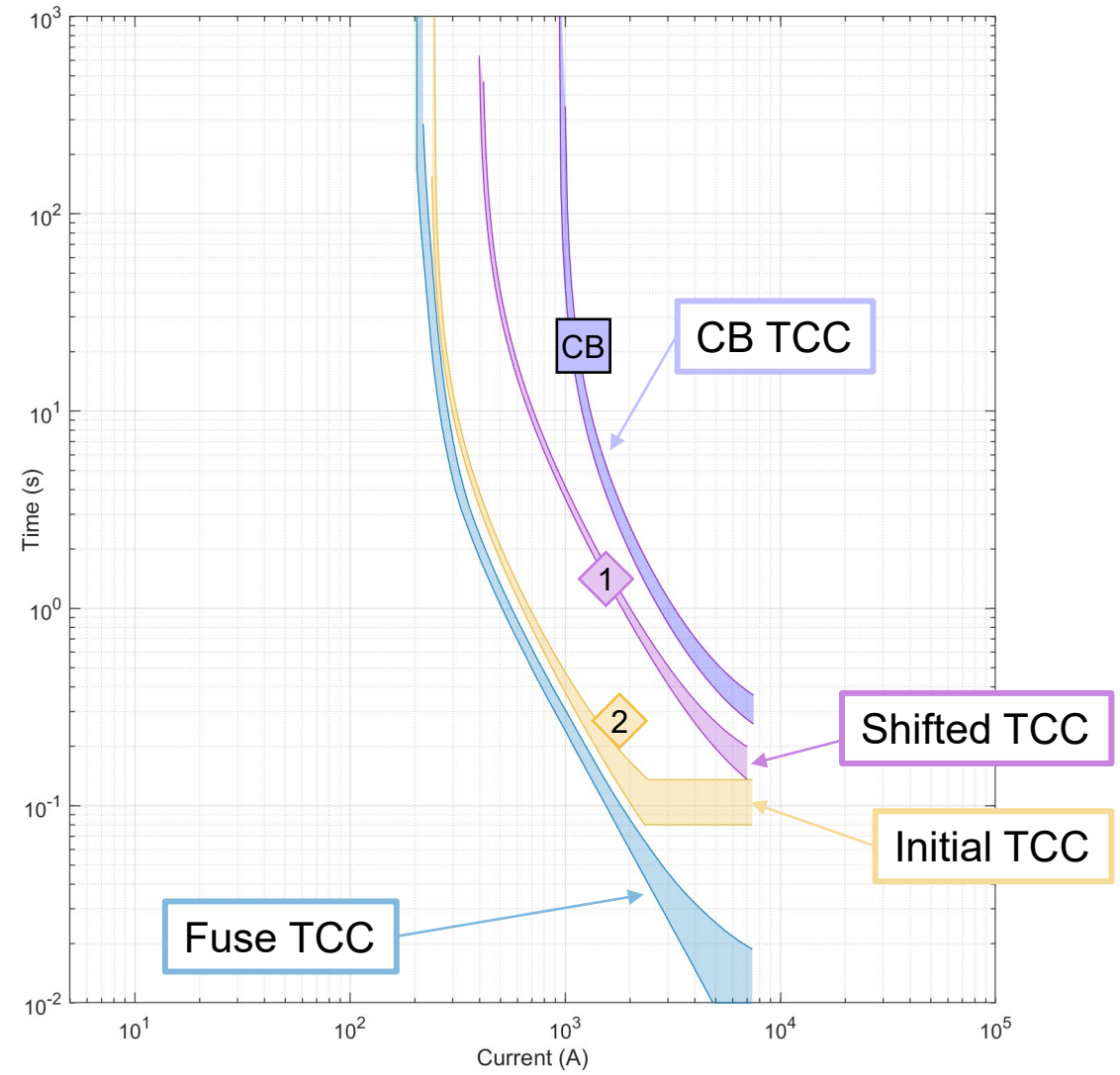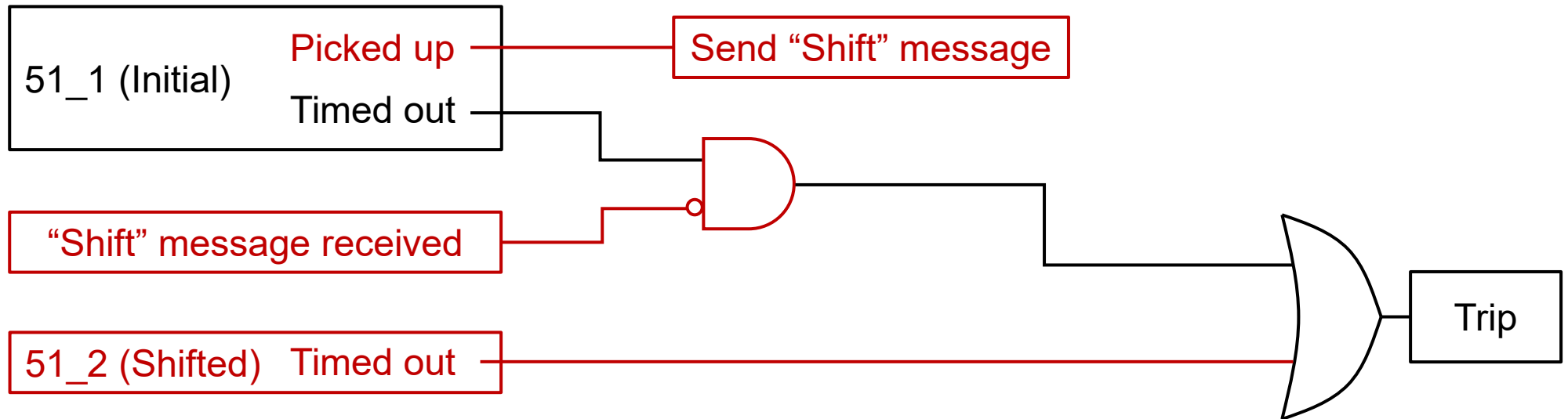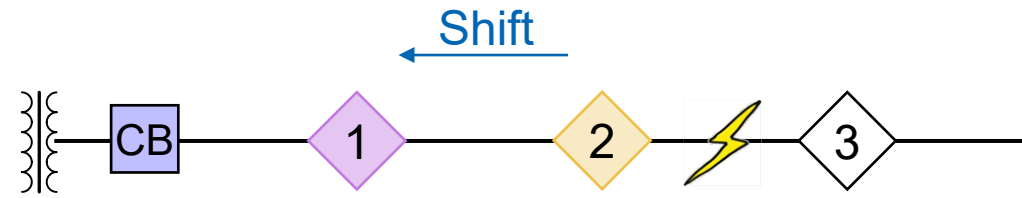
Red: additions

Blocking Scheme
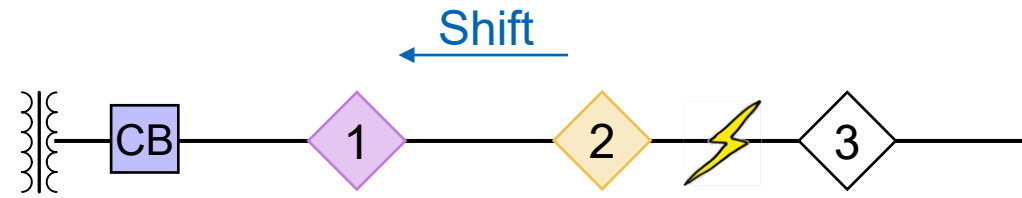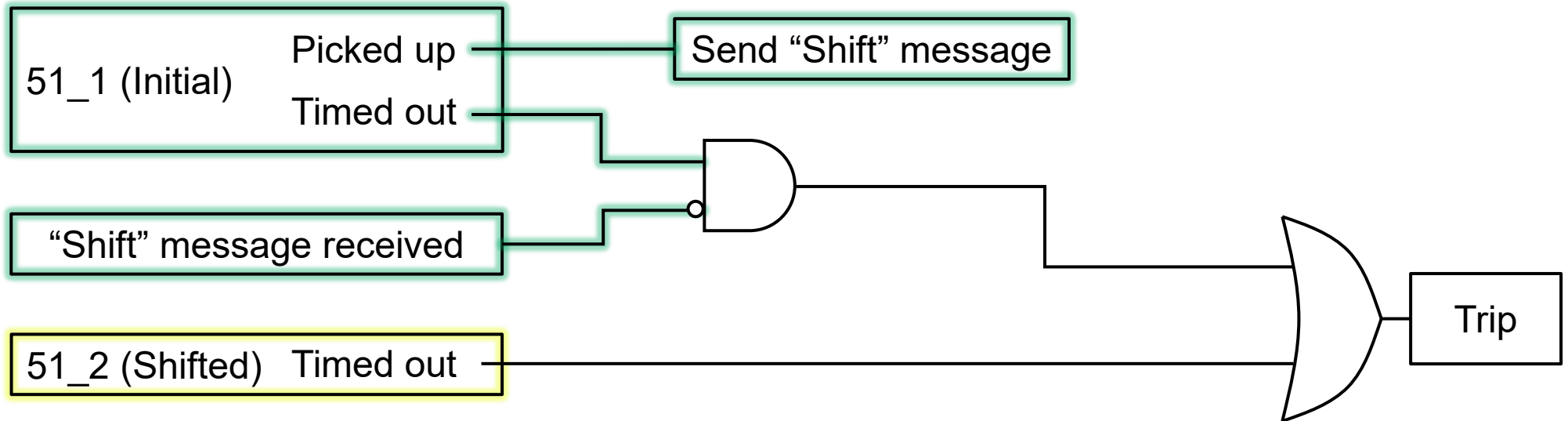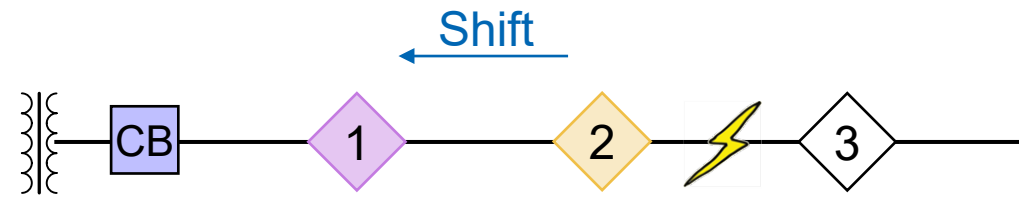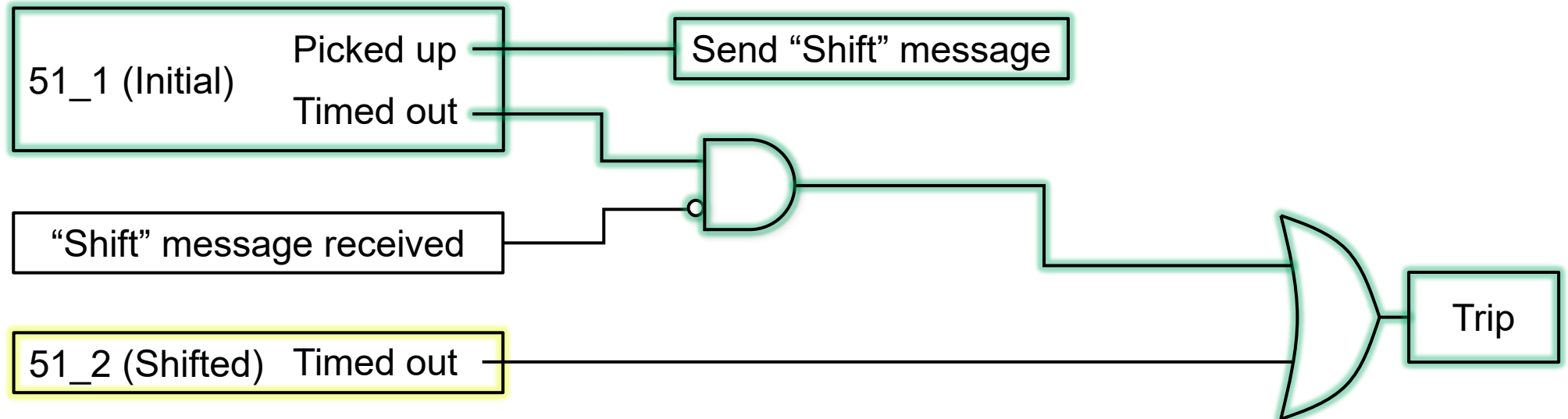
Blocking Scheme

Comparison
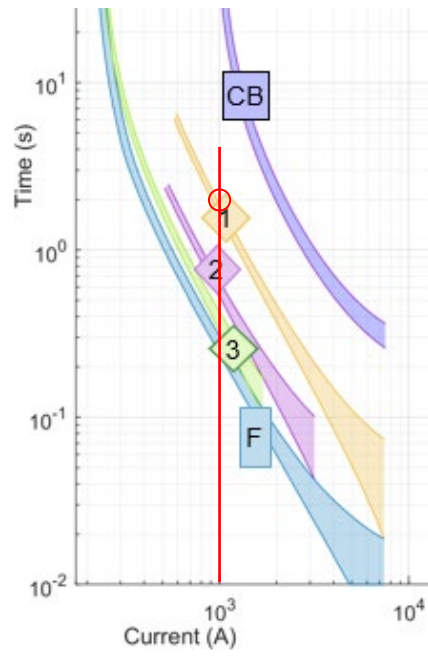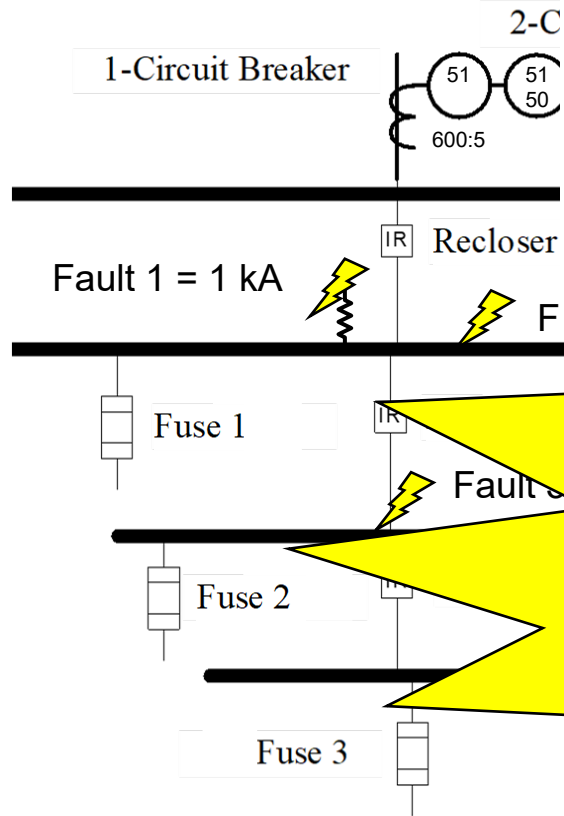
Speed of Operation

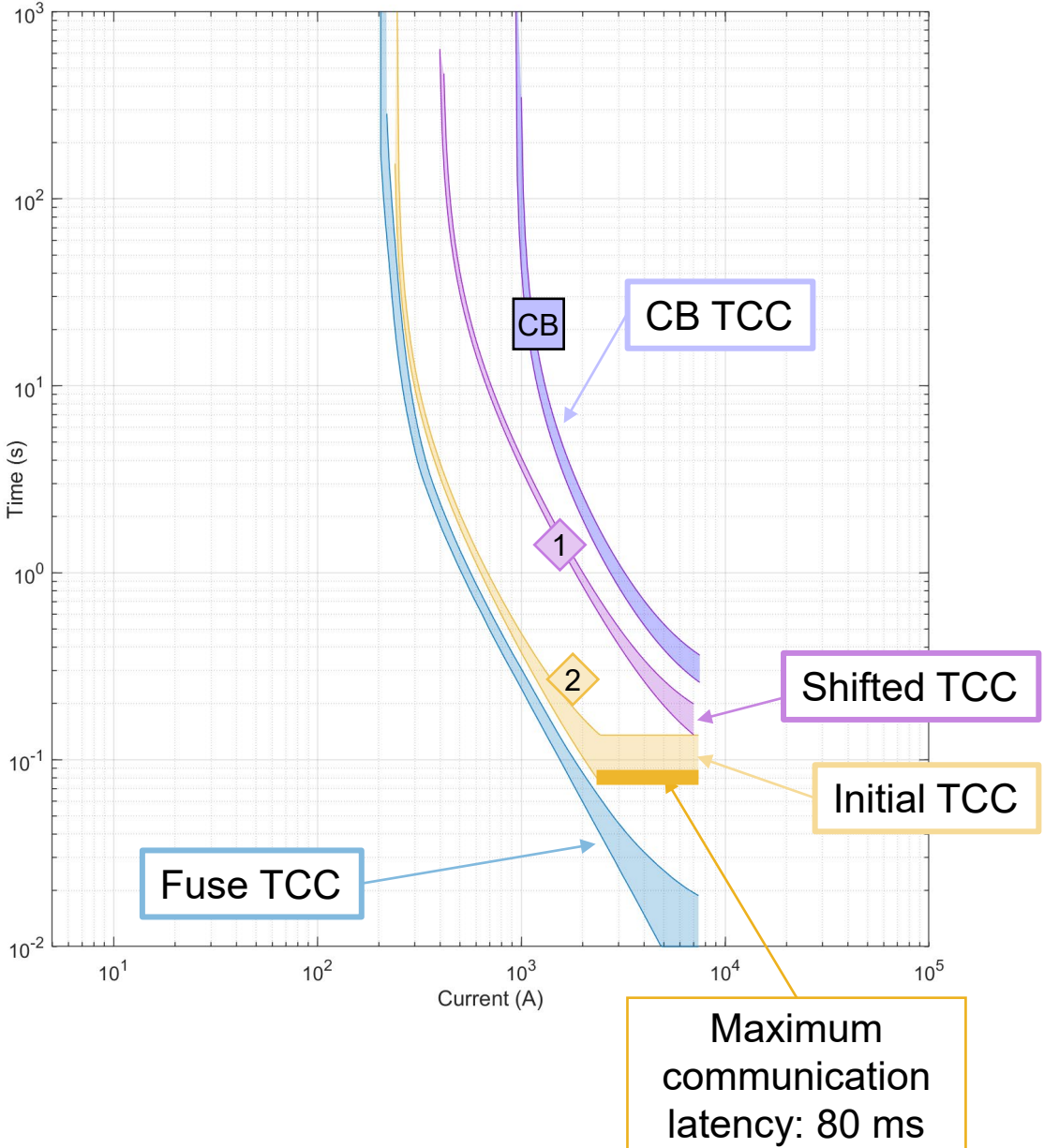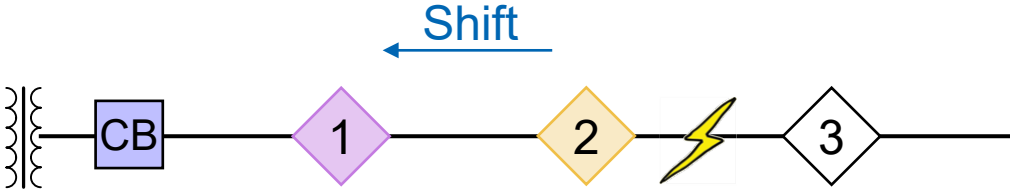Benefits of blocking scheme:
- Faster operation
- Improved segmentation
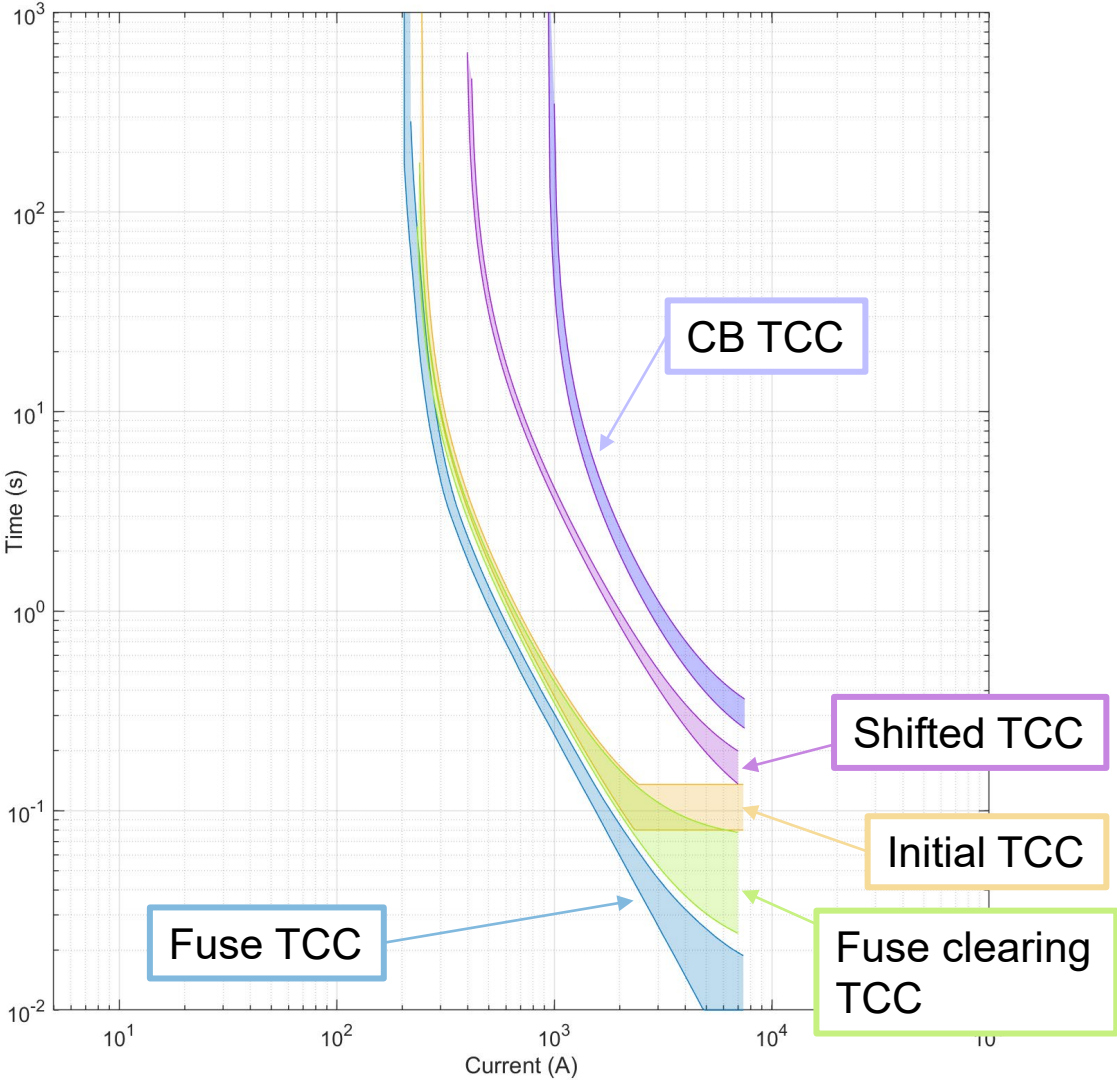- Reduced engineering effort
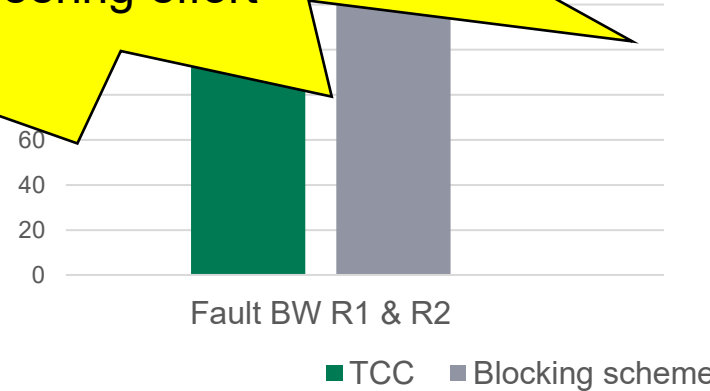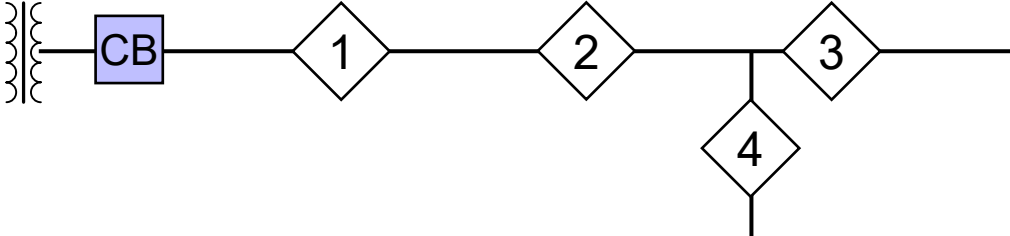
Can We Interrupt Faster?
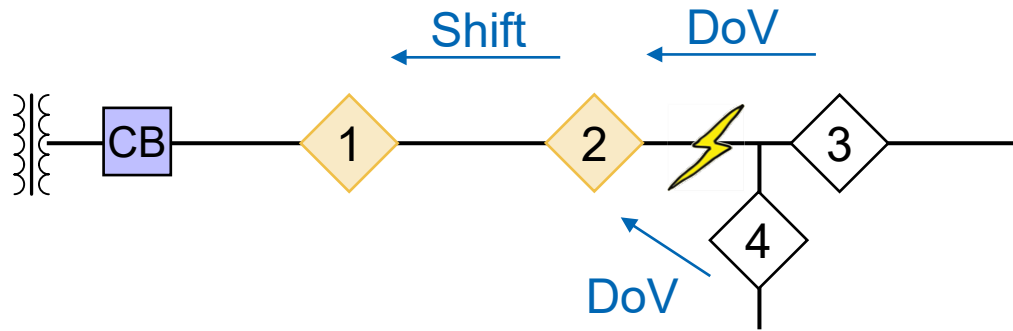
Outline

- Existing solutions

☞ - Fast coordination between reclosers

- Fast coordination between reclosers and fuses

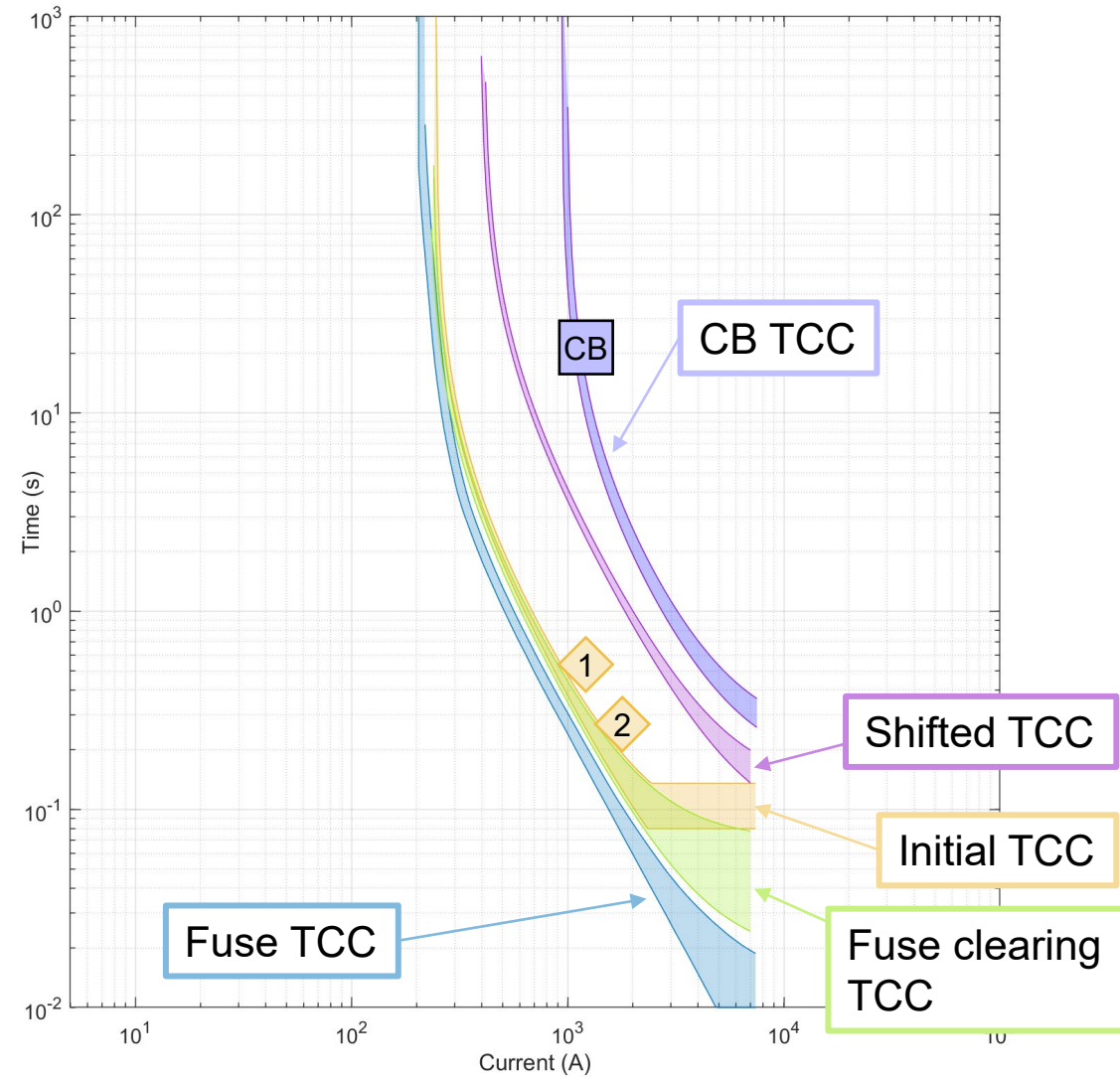- Fast downstream isolation scheme
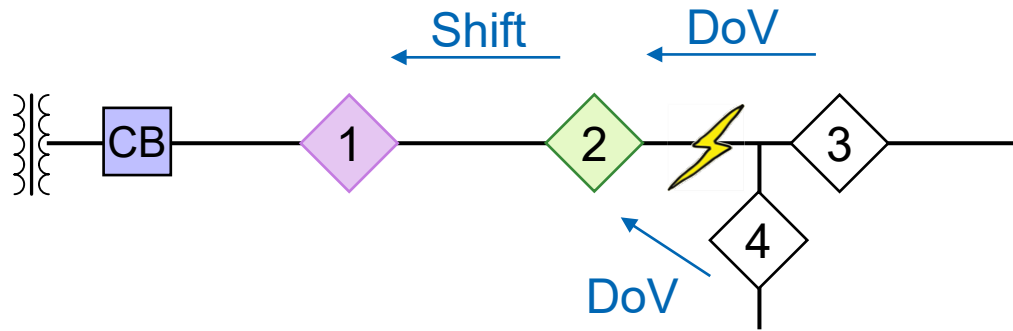
Communication-Based Permissive Scheme

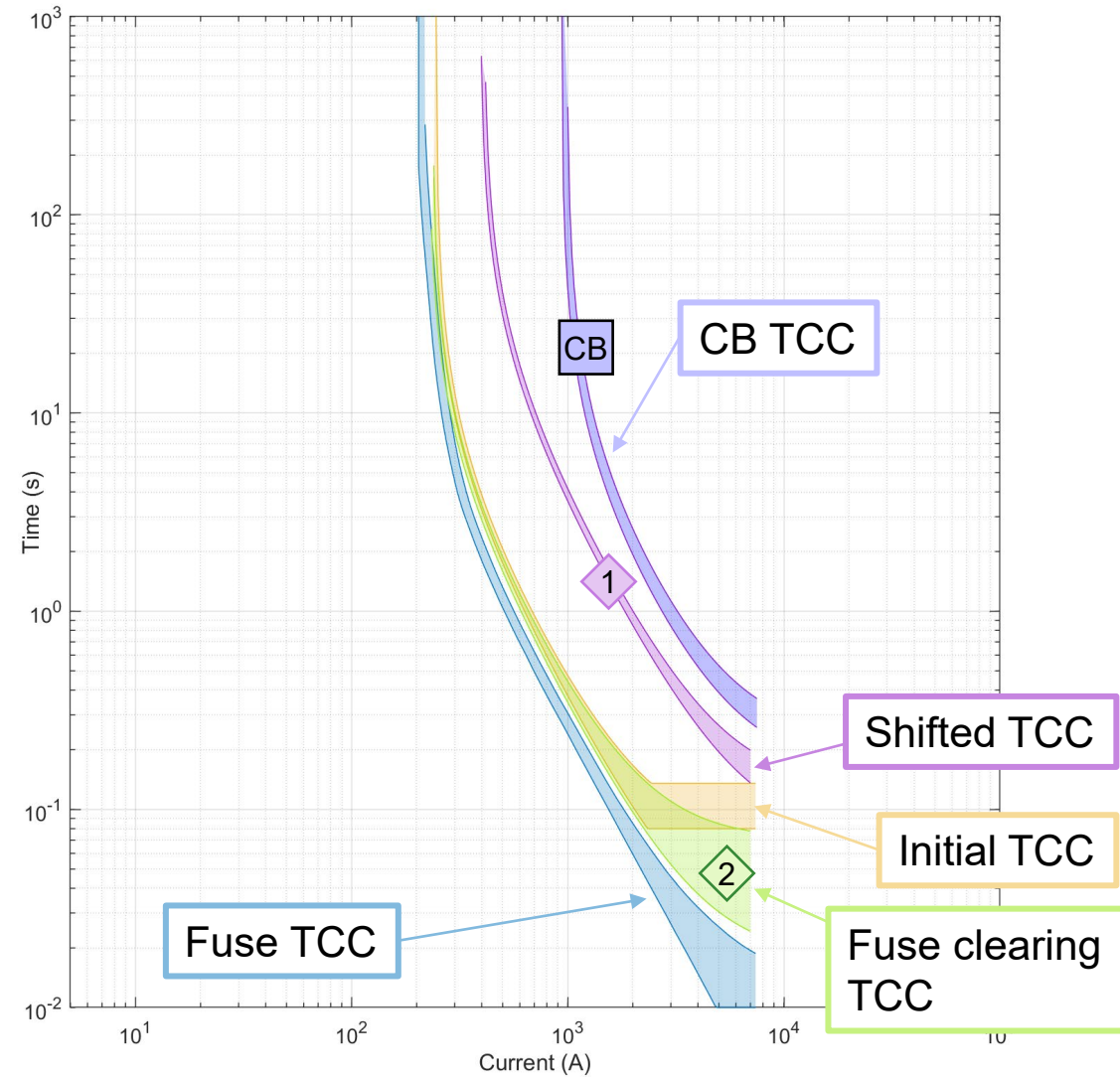# Communication-Based Permissive Scheme

DoV = Voltage dropped, no overcurrent

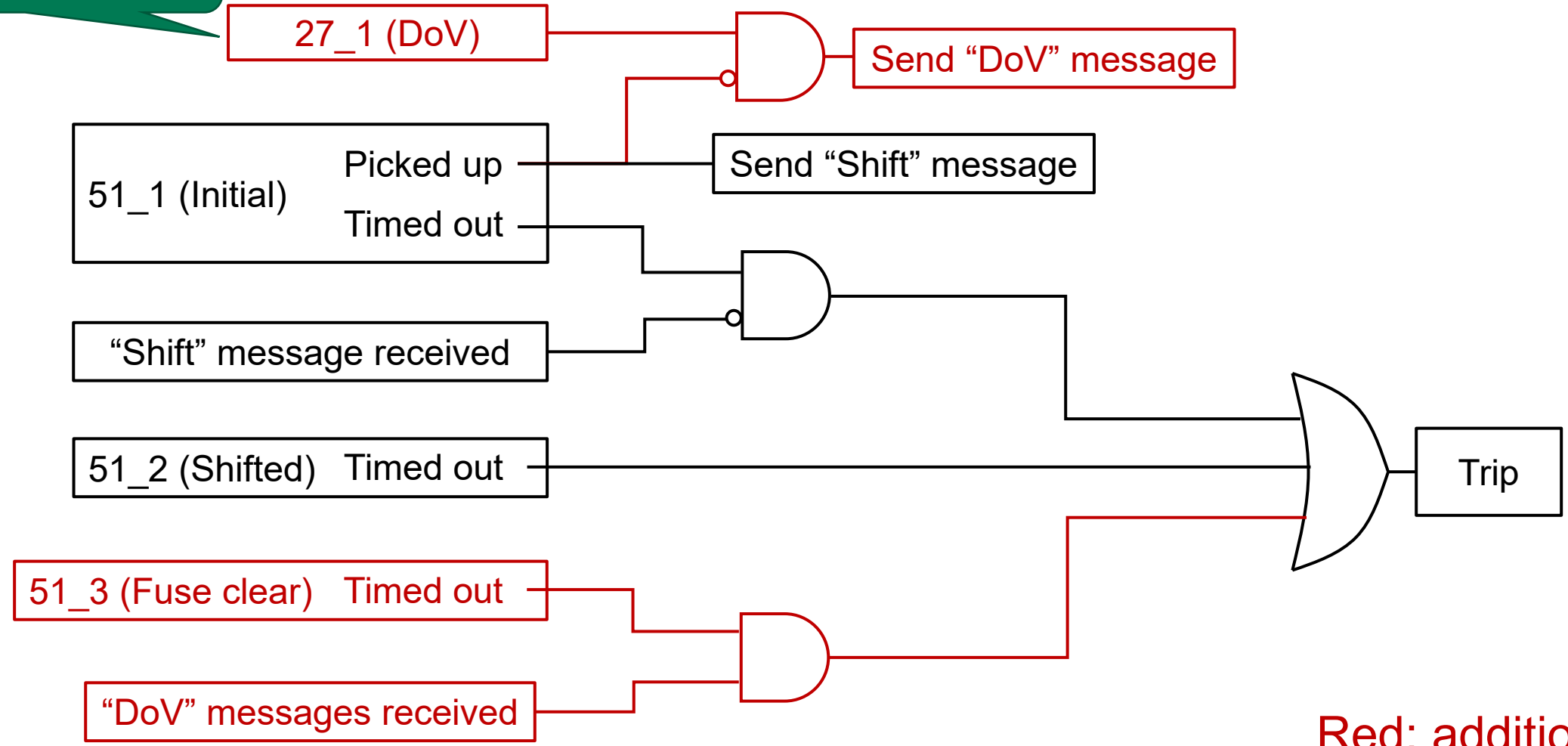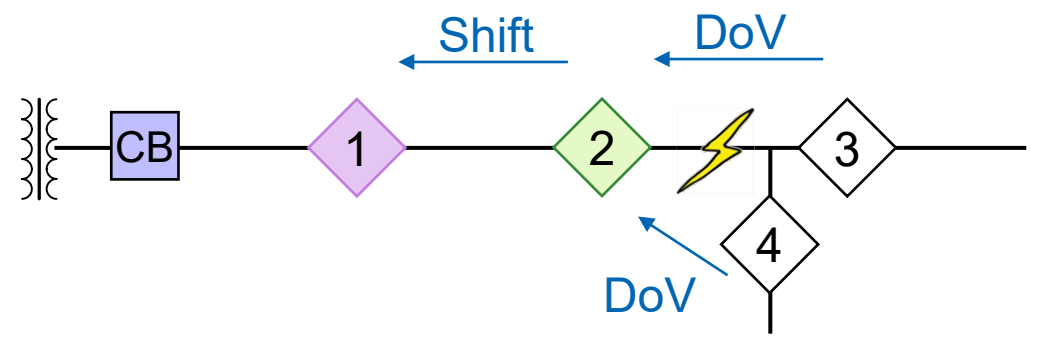# Communication-Based Permissive Scheme

Shift

DoV

DoV

DoV = Voltage dropped, no overcurrent

Improvement is significant for slower communications such as radio
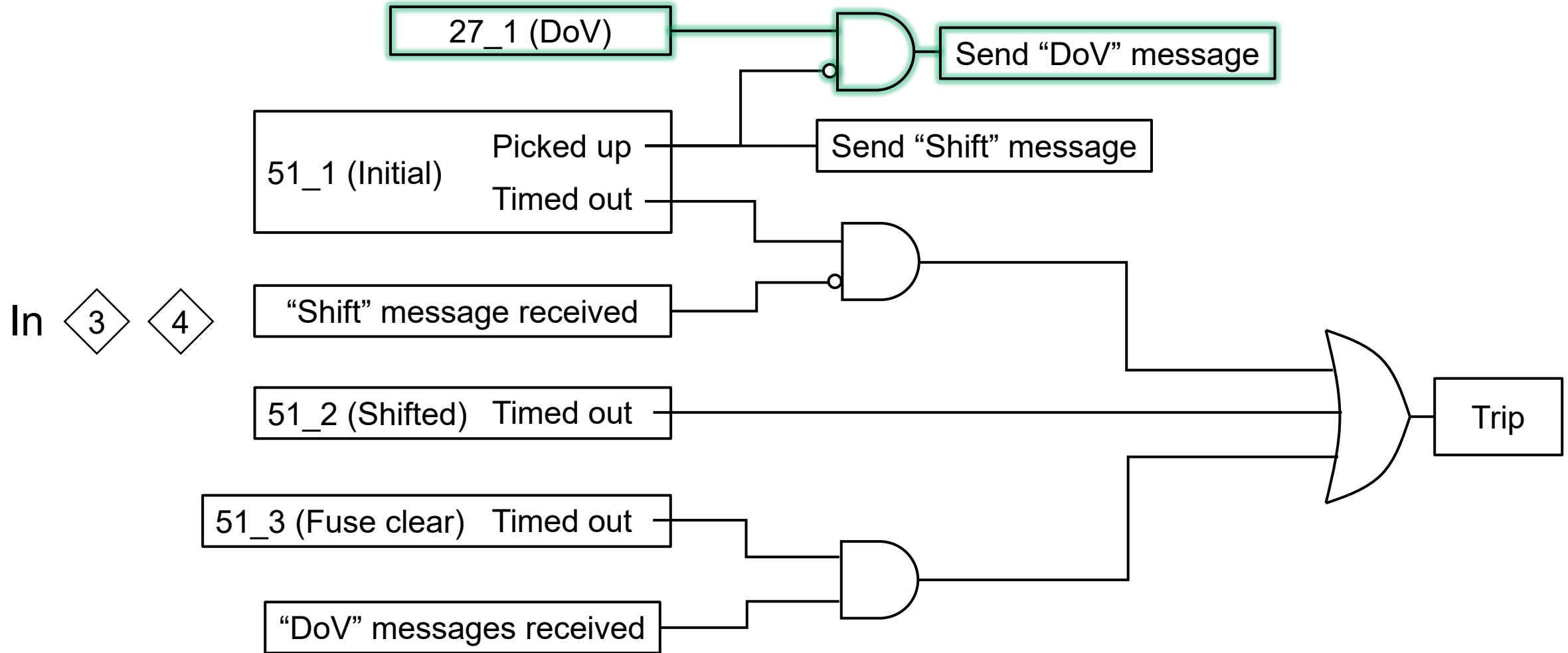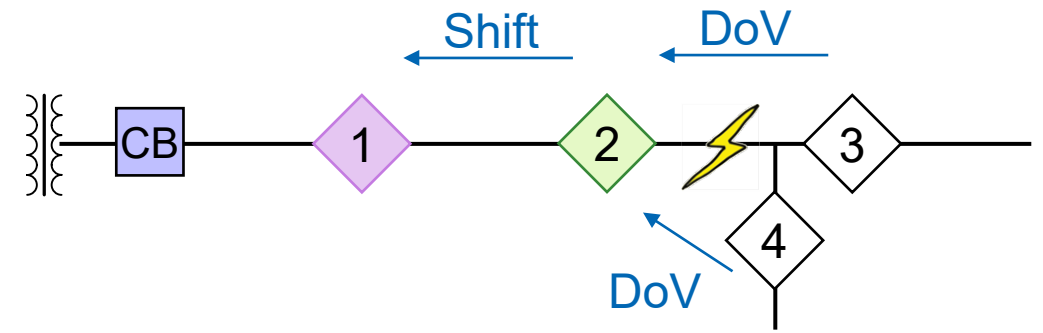
Communication-Based Permissive Scheme
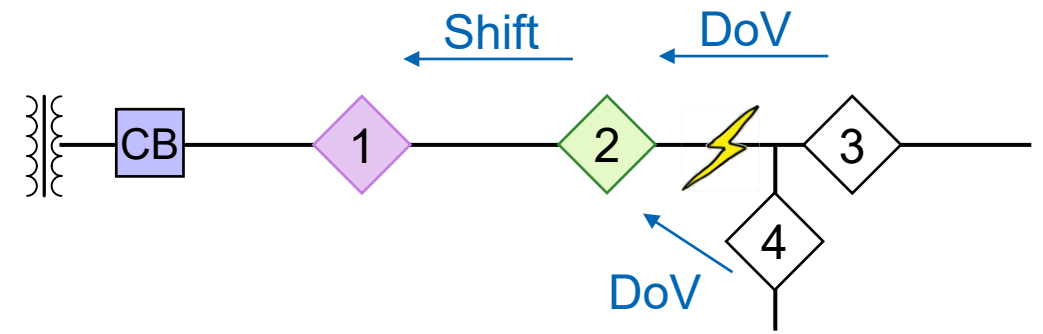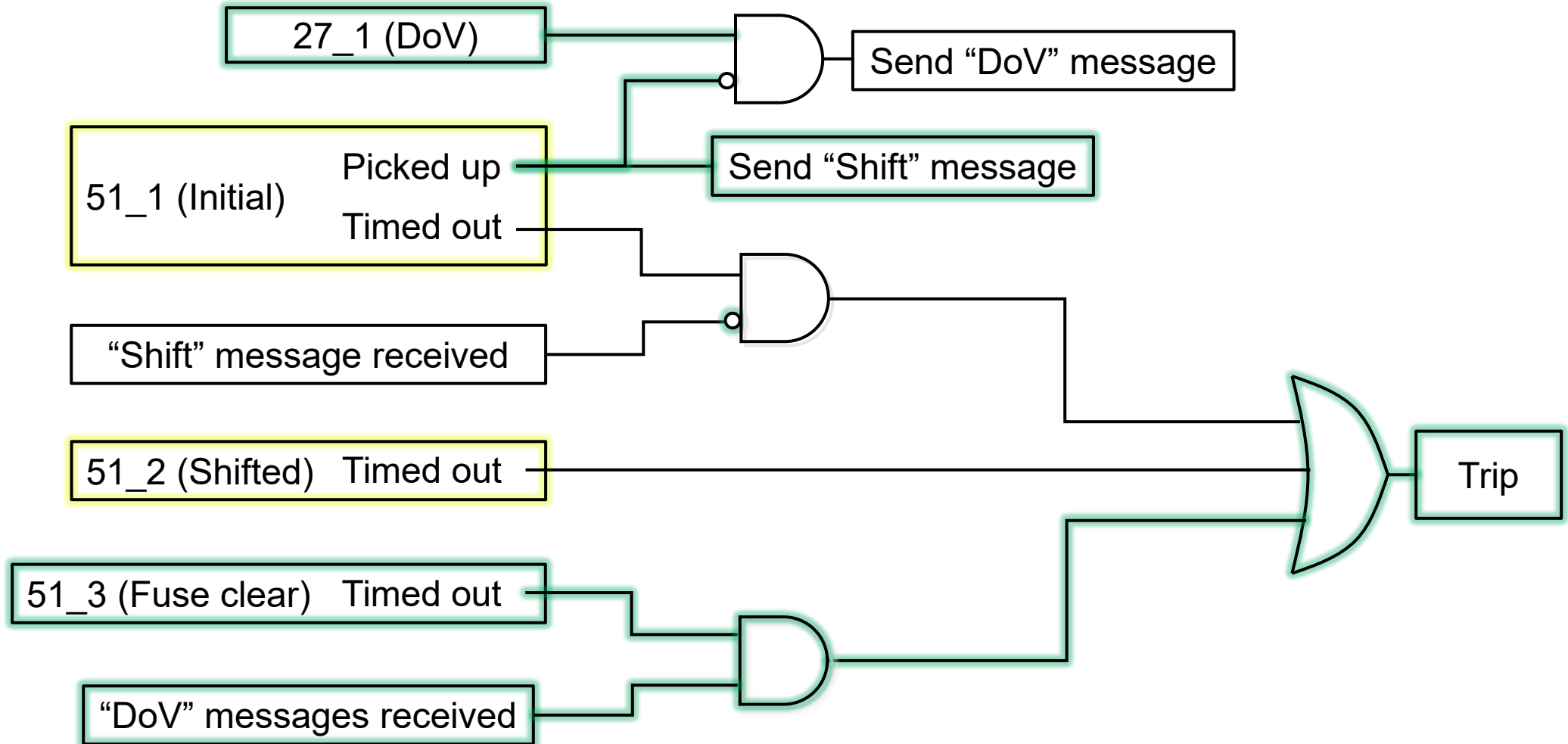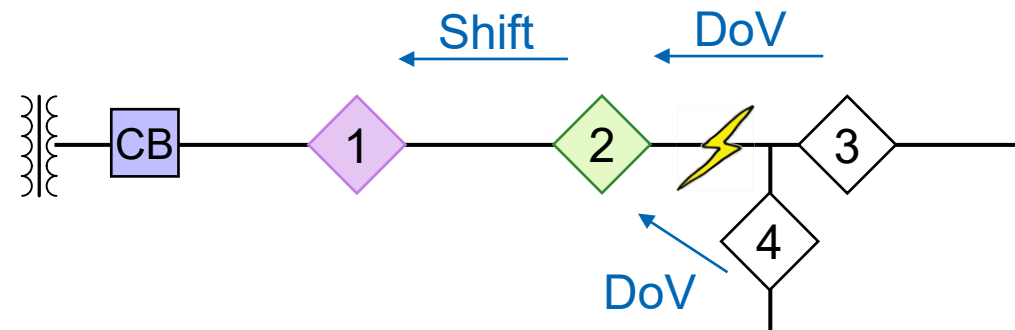

Drop of Voltage:
Voltage drops below ~70%

27_1 (DoV)

Send "DoV" message

51_1 (Initial)

Picked up — Send "Shift" message

Timed out

"Shift" message received

51_2 (Shifted)   Timed out
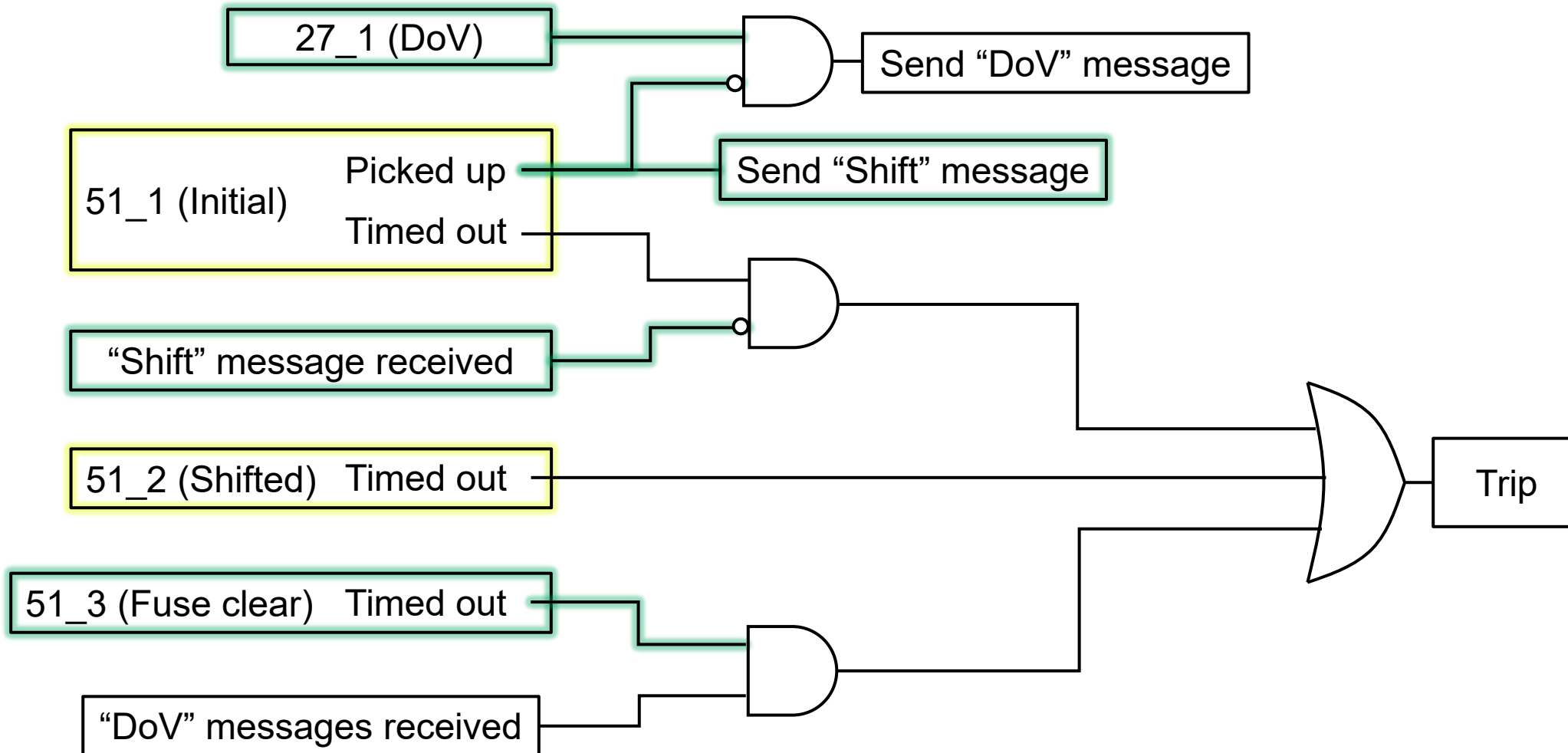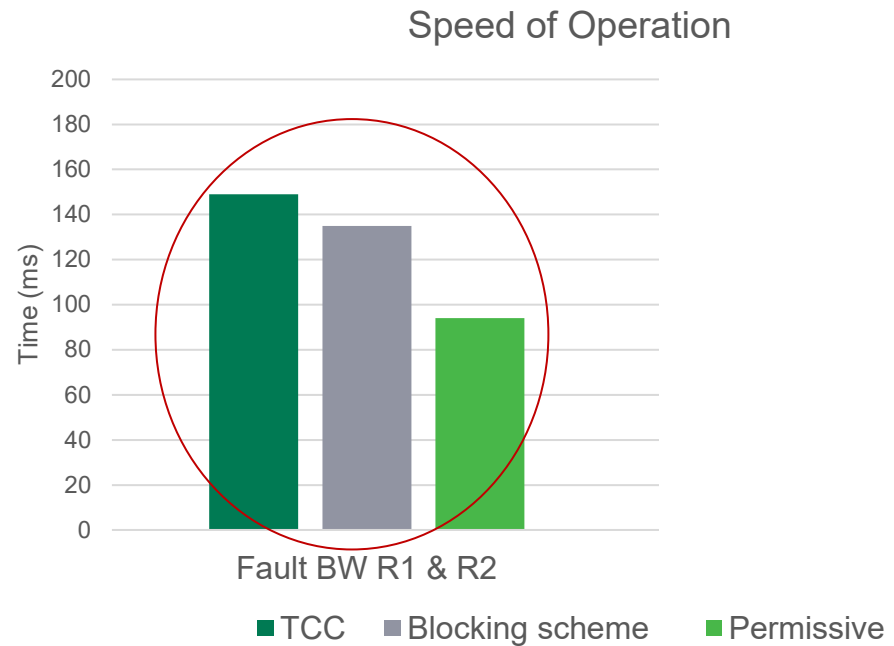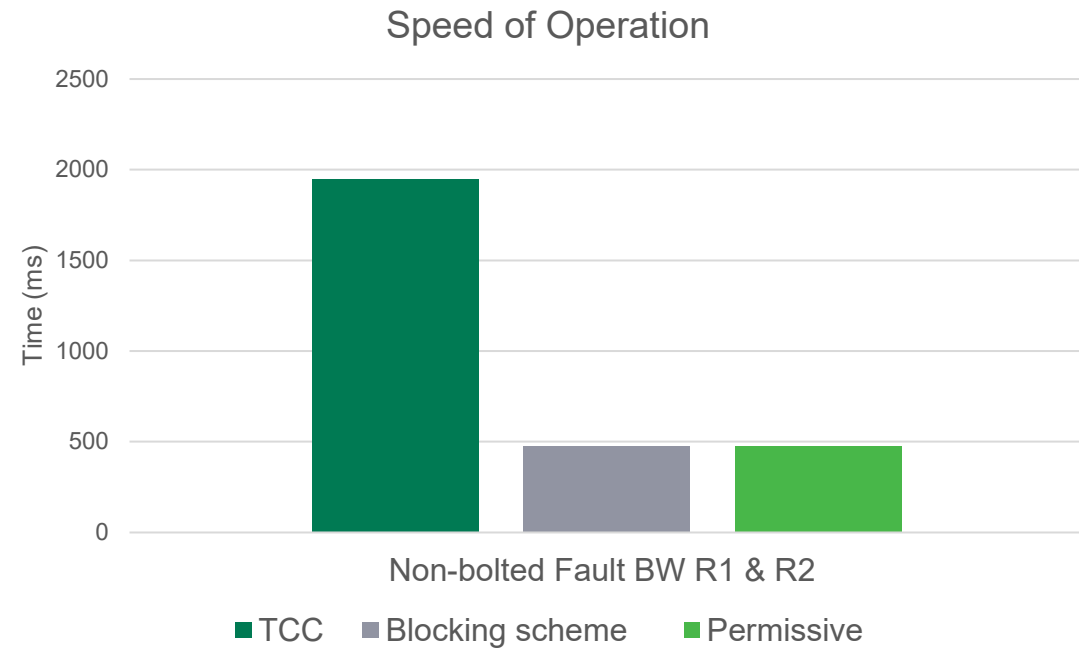
51_3 (Fuse clear)   Timed out

"DoV" messages received

Trip

Red: additions

Communication-Based Permissive Scheme

Shift

DoV

CB 1 2 3 4

DoV

27_1 (DoV)

Send "DoV" message

51_1 (Initial)
Picked up
Timed out

Send "Shift" message

In ⟨3⟩ ⟨4⟩

"Shift" message received

51_2 (Shifted)   Timed out

Trip

51_3 (Fuse clear)   Timed out
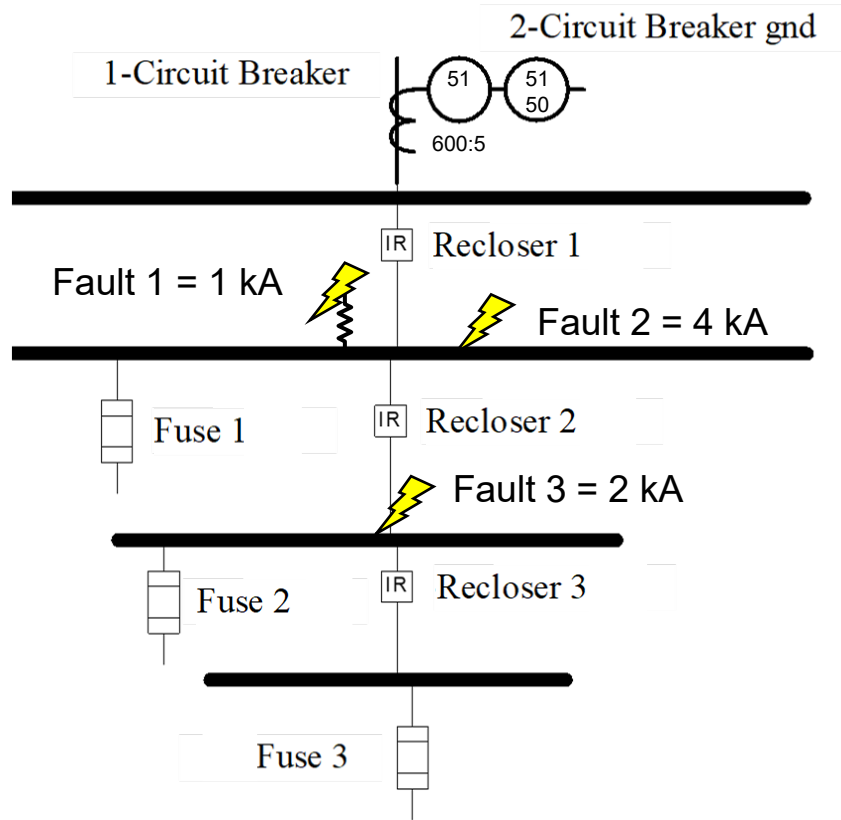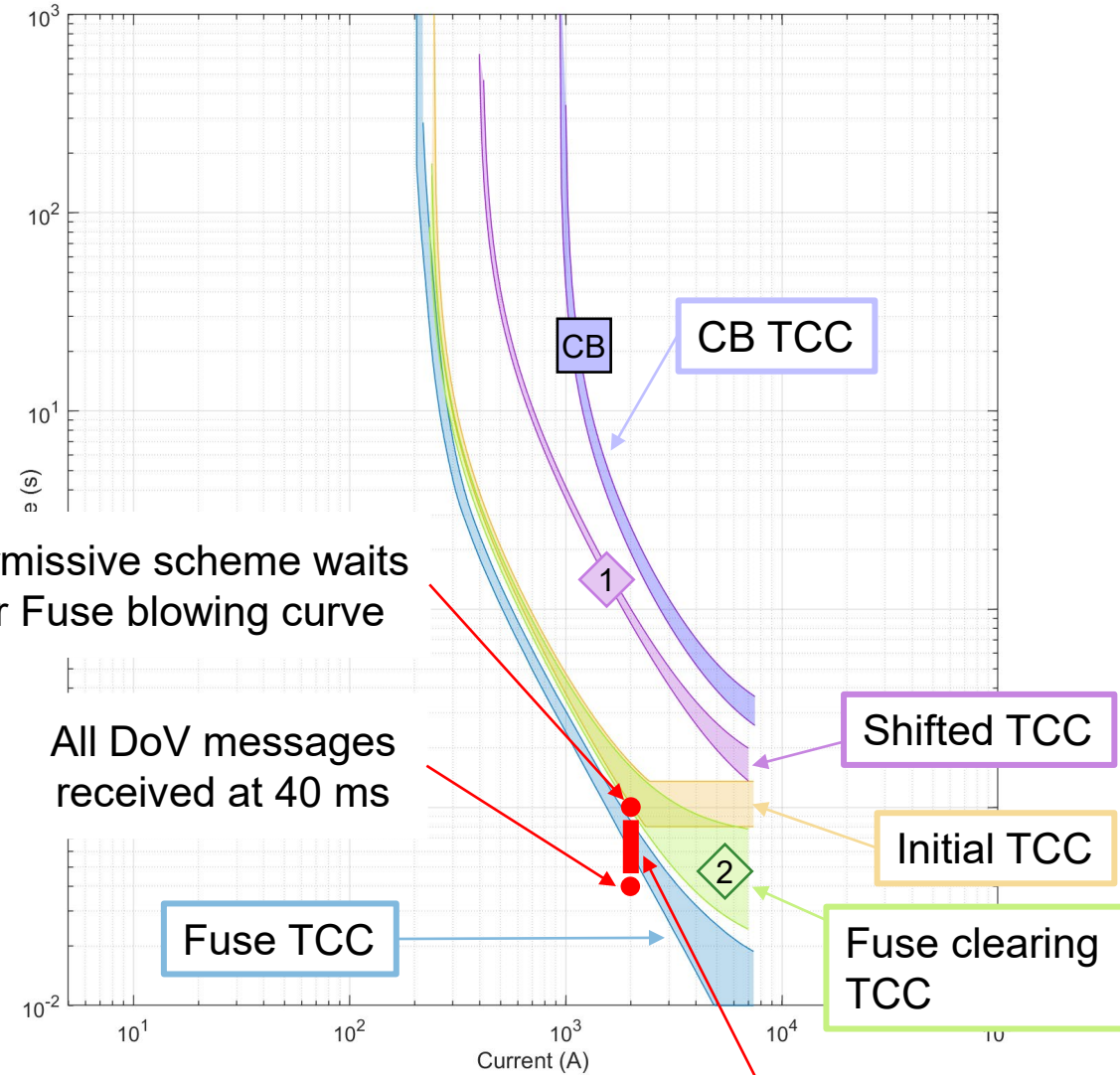
"DoV" messages received

Communication-Based Permissive Scheme

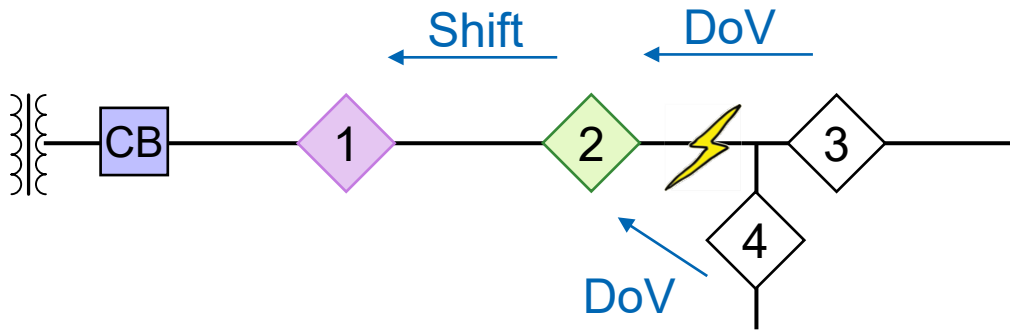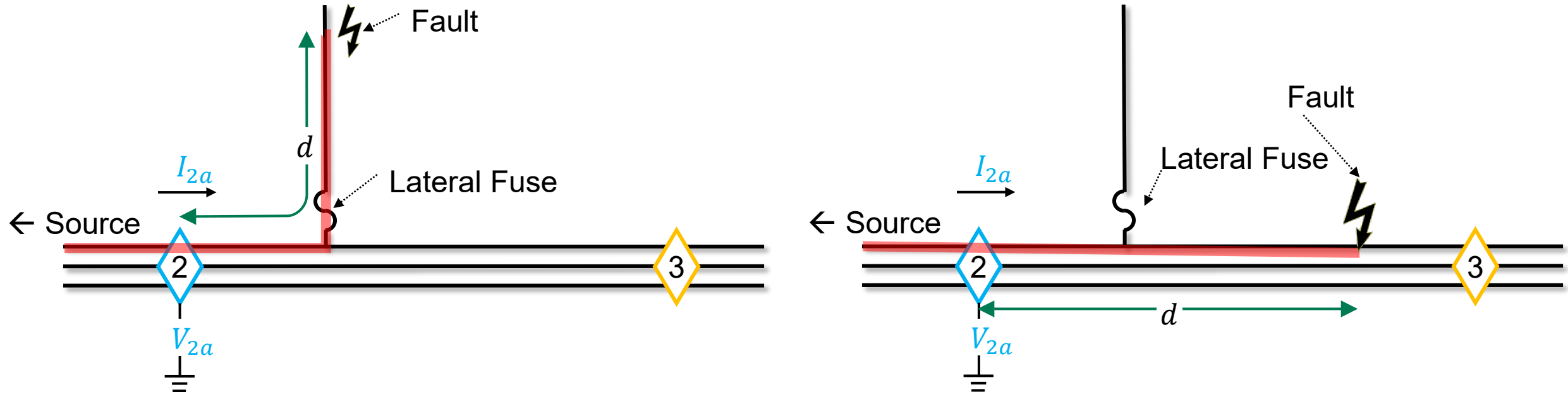# Communication-Based Permissive Scheme

Comparison

Can We Interrupt Even Faster?

Shift

DoV

CB   1   2   3

4

DoV

CB   CB TCC

1

Permissive scheme waits
for Fuse blowing curve

All DoV messages
received at 40 ms

Shifted TCC

Initial TCC

2

Fuse TCC

Fuse clearing
TCC

Bridge the gap?

Current (A)

Outline

- Existing solutions

- Fast coordination between reclosers

☞ • Fast coordination between reclosers and fuses

- Fast downstream isolation scheme

Impedance-Enhanced Protection Scheme

Fault

d

I_{2a}

Lateral Fuse

← Source

2

V_{2a}

3

Fault

Lateral Fuse

I_{2a}

← Source

2

V_{2a}

d

3

Phase A voltage

Phase A self-impedance per unit distance

$$V_{2a} = (Z_{aa}d + R_f)I_{2a}$$

Phase A current

d **is distance between upstream relay and fault**

Fault resistance

Impedance-Enhanced Protection Scheme

$$V'_a \approx V_{3a}$$
$$I_{3a} \approx 0$$

Fault

I_{2a}

← Source

Lateral Fuse

V'_a

I_{3a}

2

3

d_1

V_{2a}

V_{3a}

I_{2a}

← Source

Lateral Fuse

Fault

V'_a

I_{3a}

2

3

d_1

V_{2a}

V_{3a}
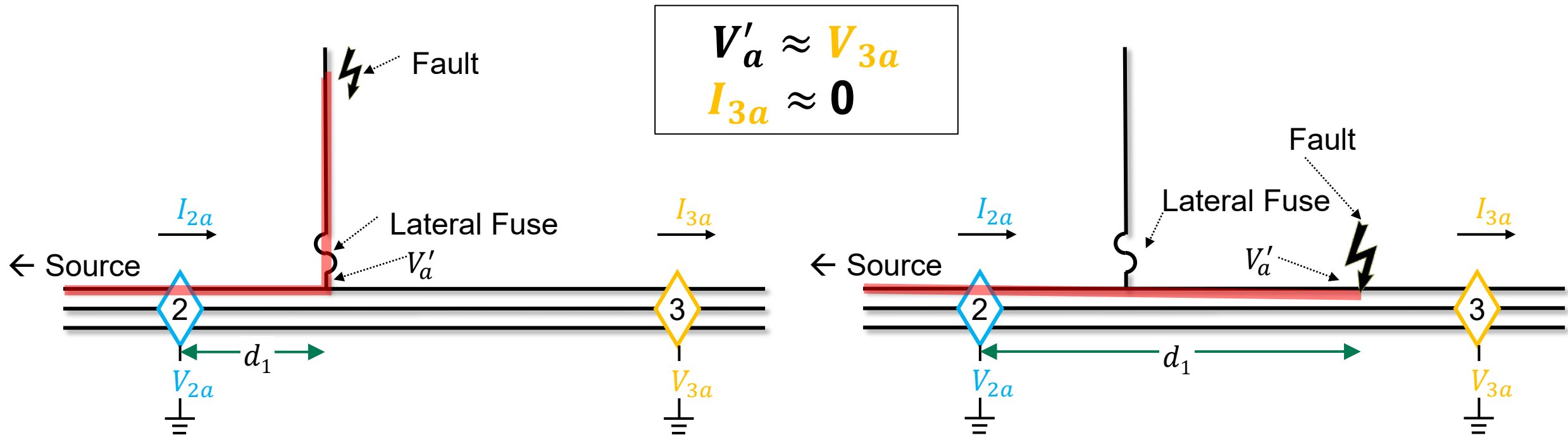
Phase A voltage of upstream relay

Phase A self-impedance per unit distance

Phase A current of upstream relay

Phase A voltage where fault
branches off main feeder

$$V'_a = V_{2a} - Z_{aa}d_1I_{2a}$$

d_1: **How far is the fault on the main feeder**

Impedance-Enhanced Protection Scheme
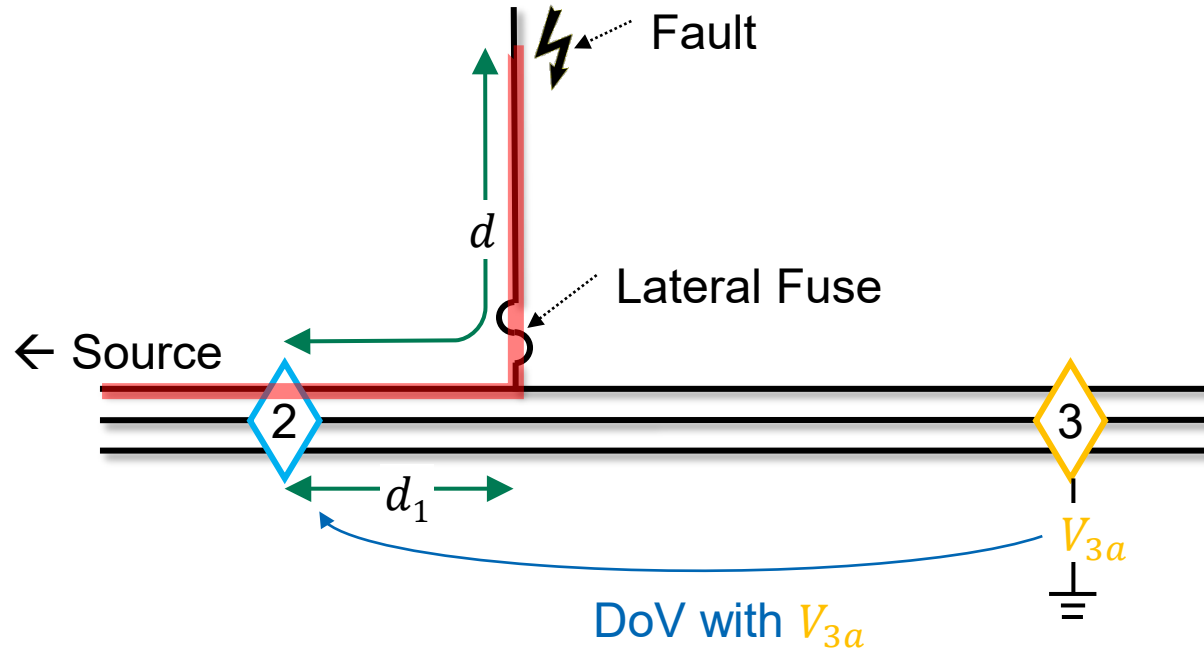
$d_1 < d$

Fault is on lateral

$d_1 \approx d$

Fault is on main feeder

Impedance-Enhanced Protection Scheme
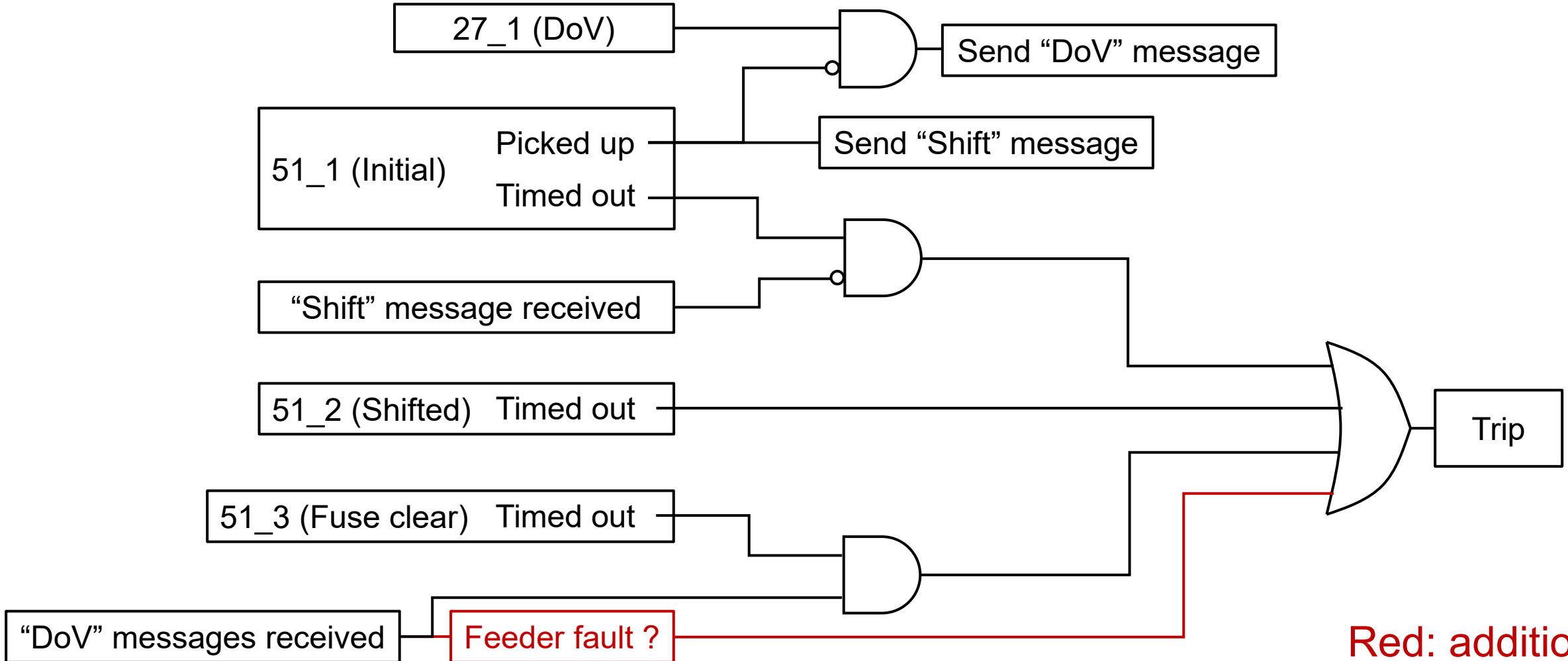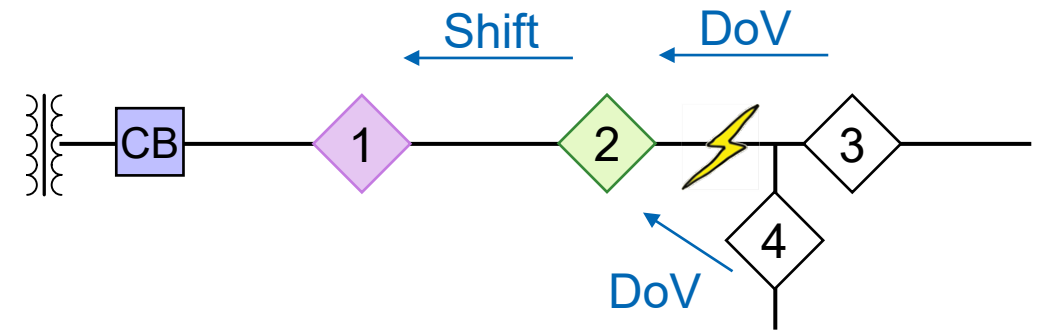
Impedance-Enhanced Protection Scheme

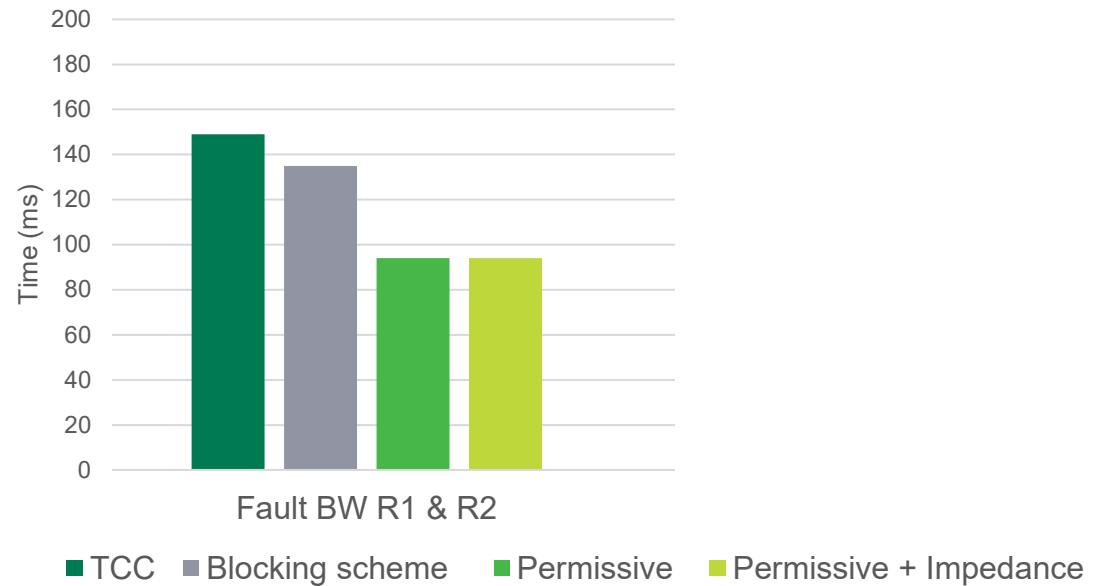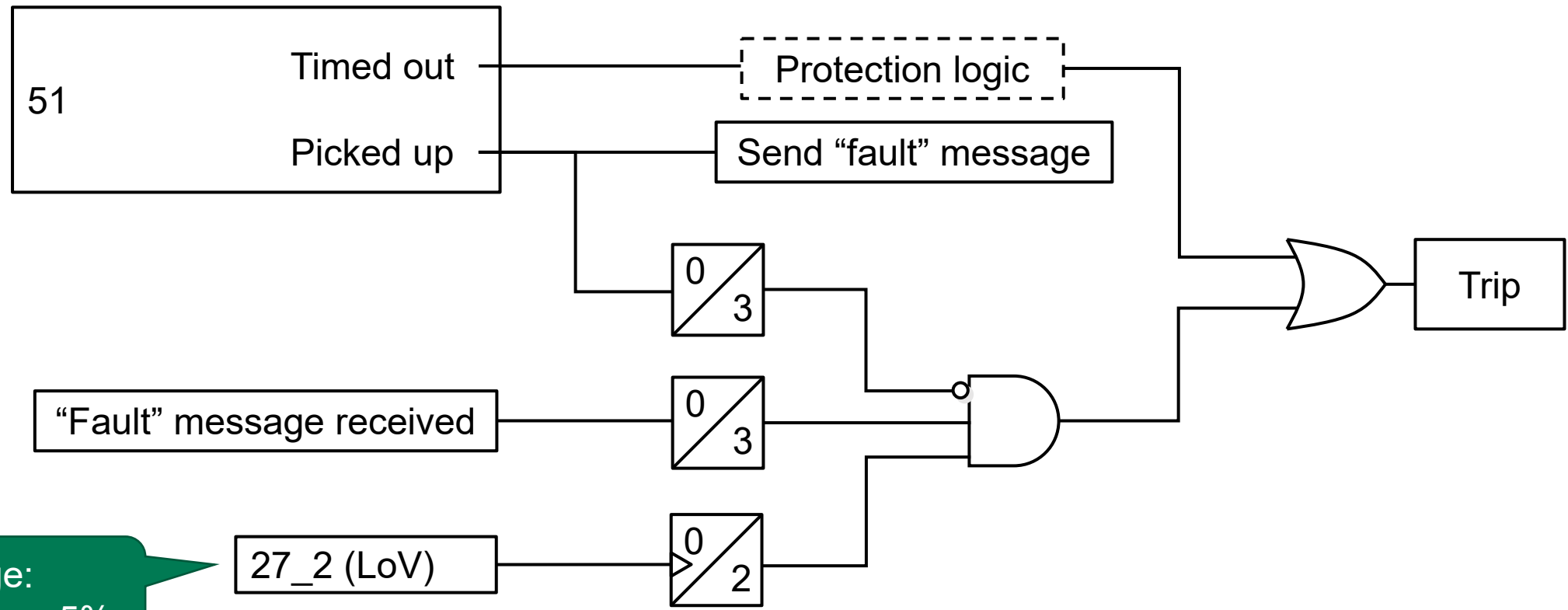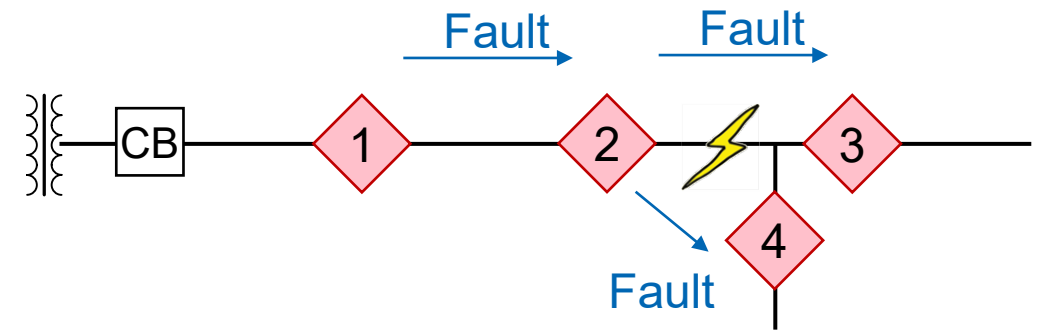# Impedance-Enhanced Protection Scheme
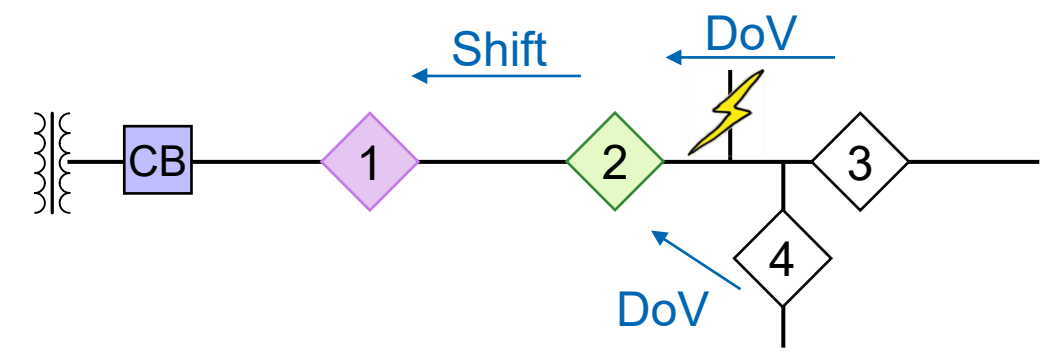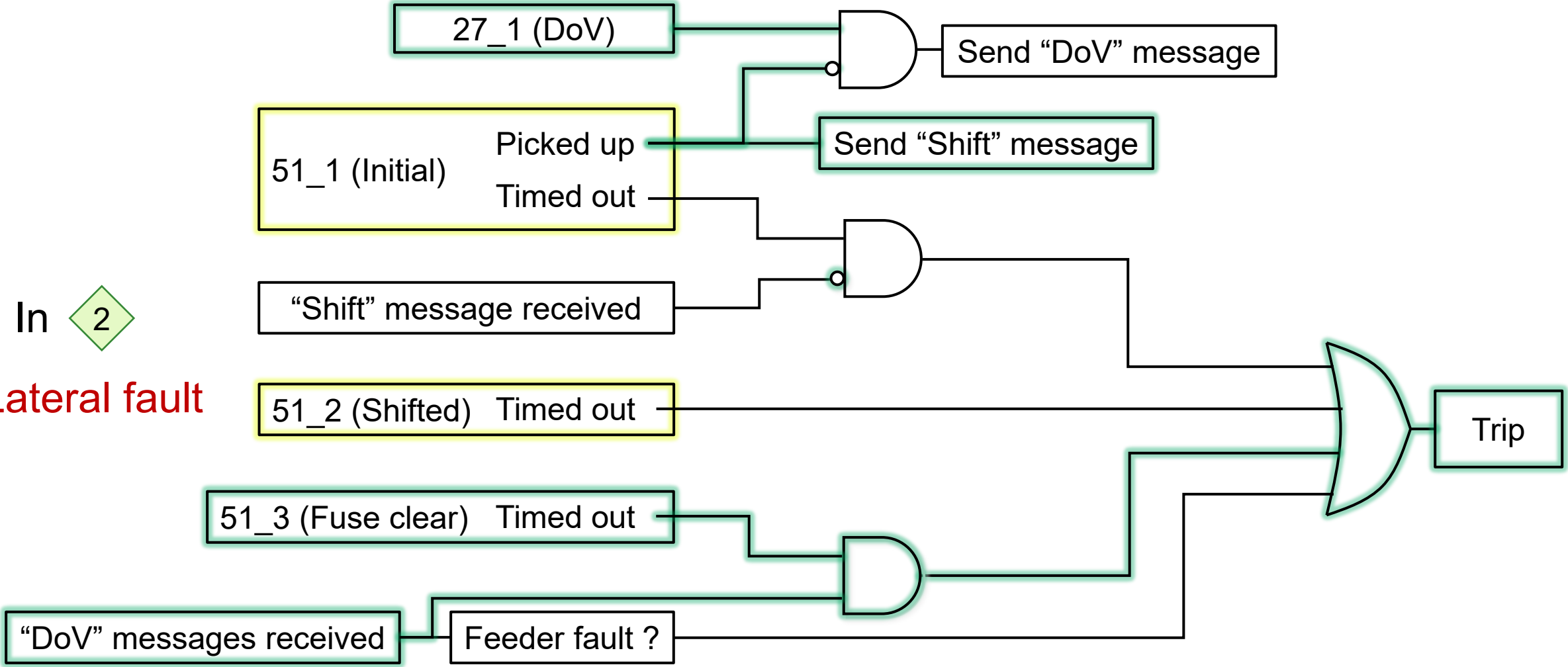
Comparison
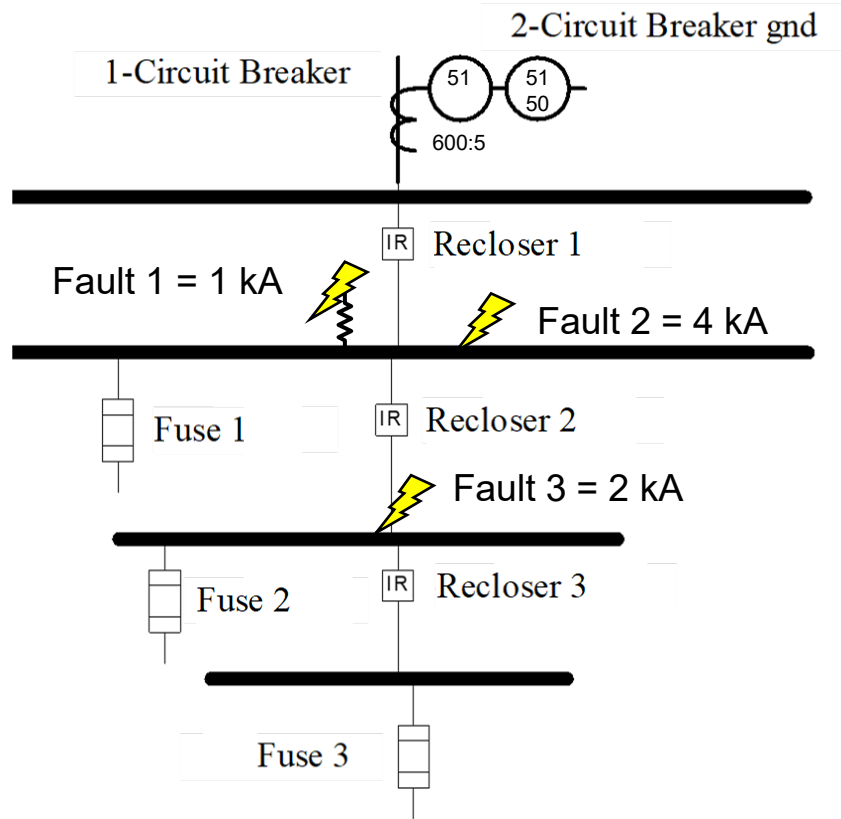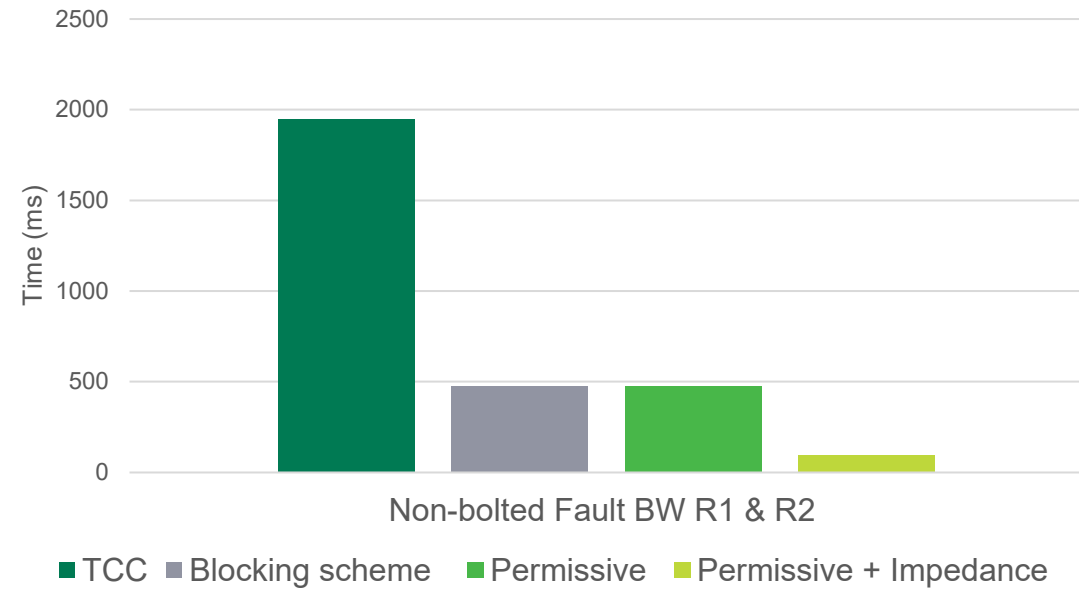
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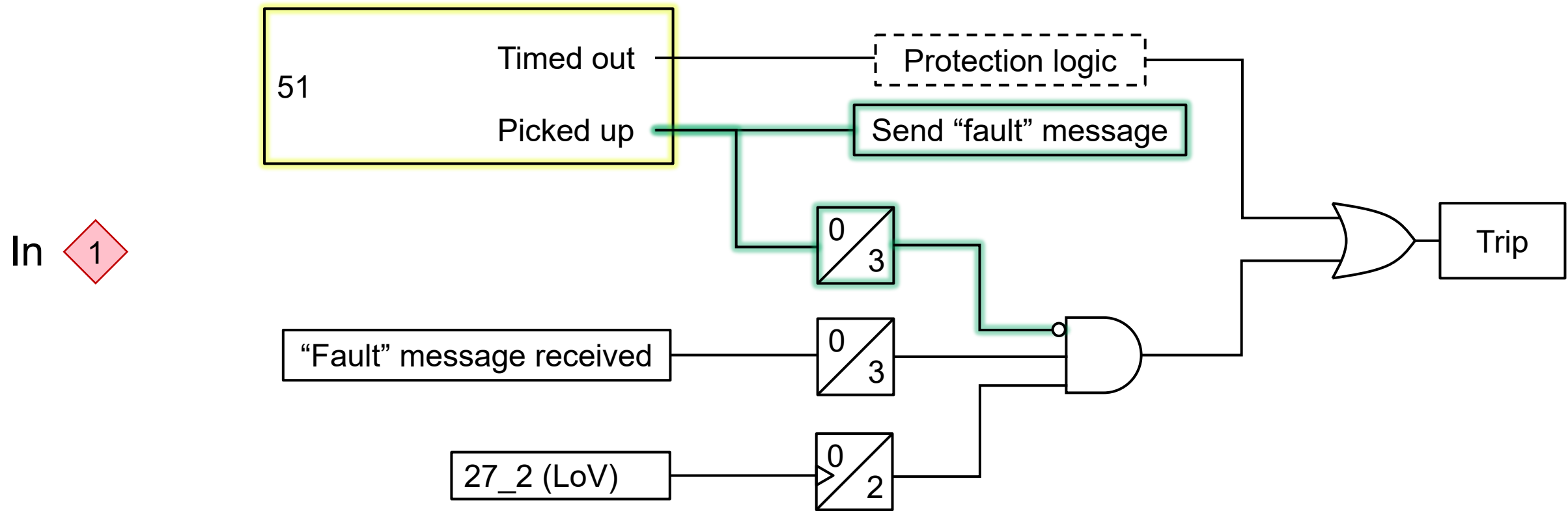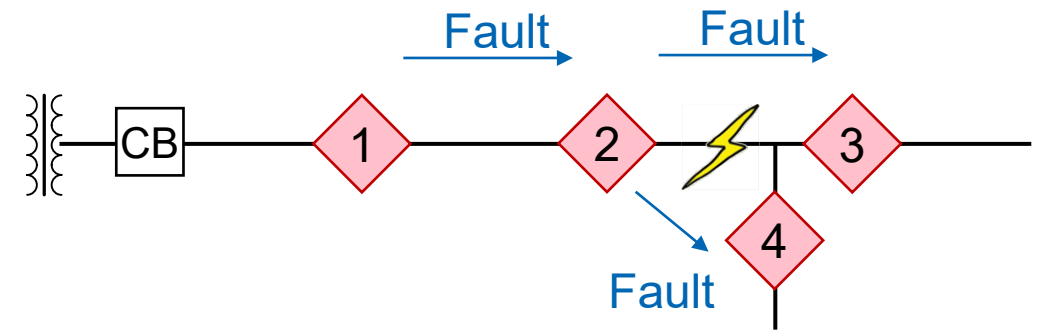
☞ • Fast downstream isolation scheme
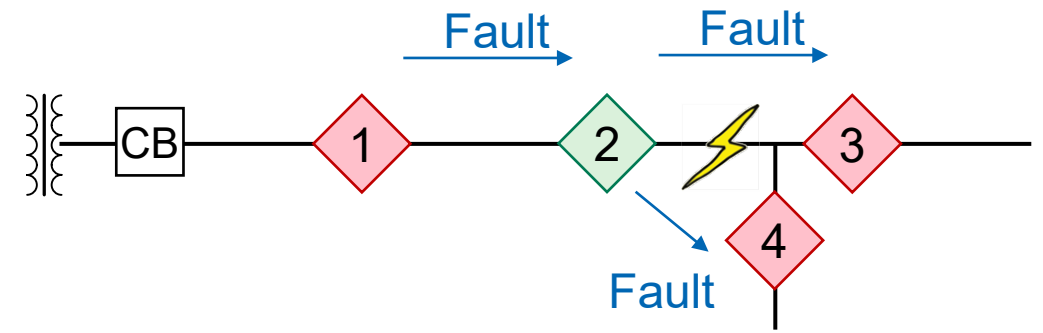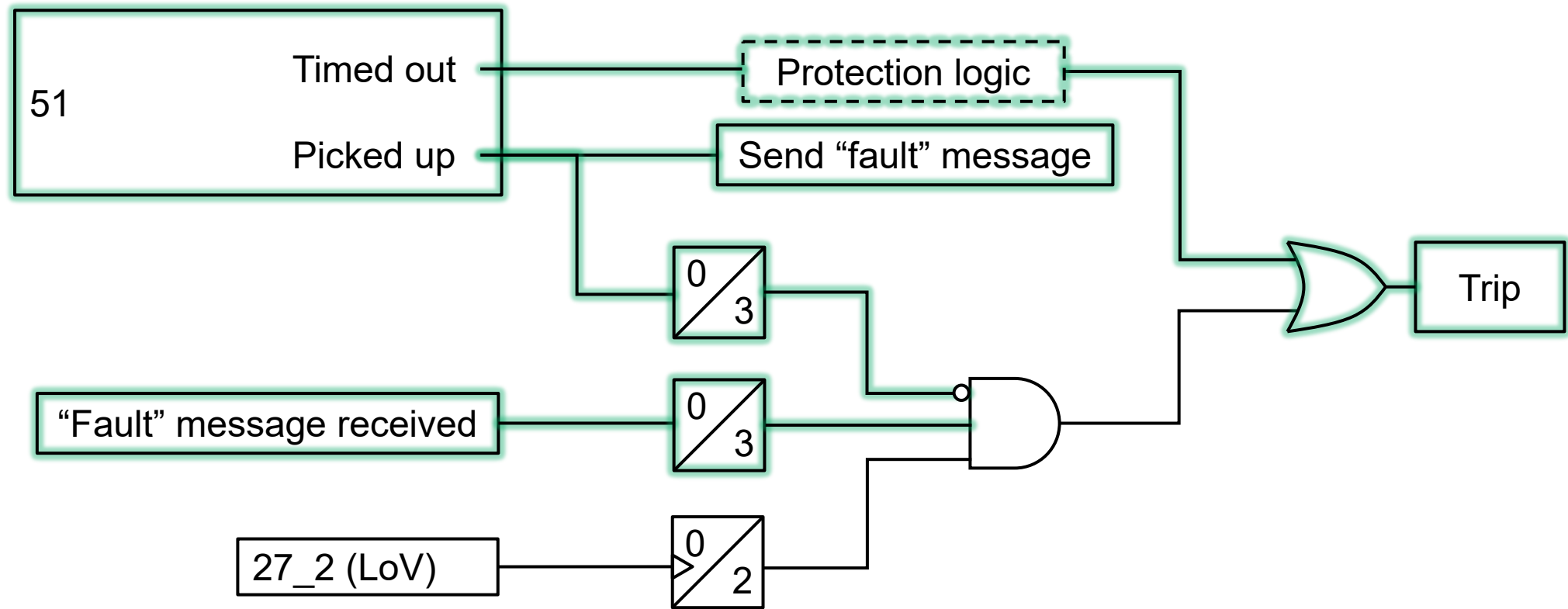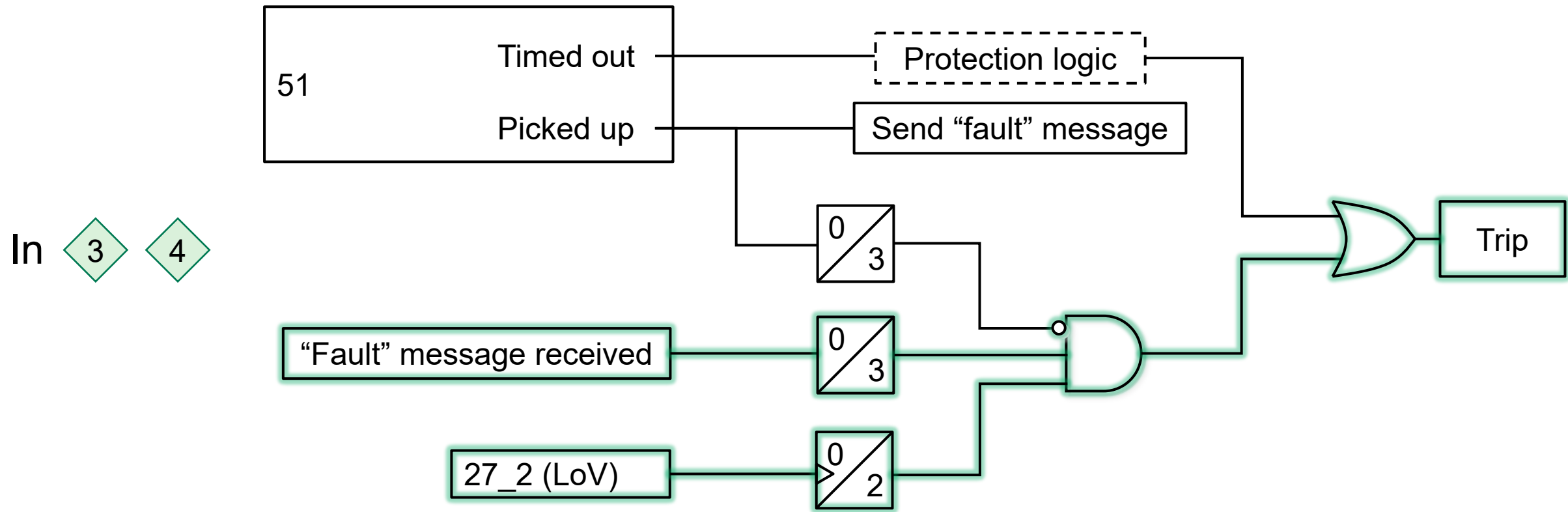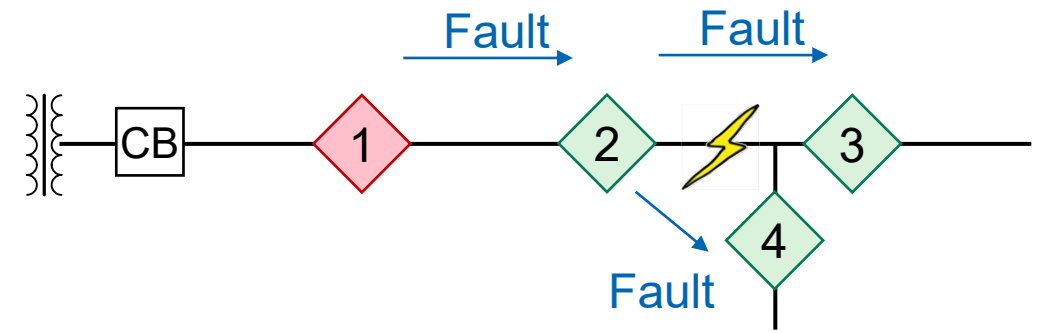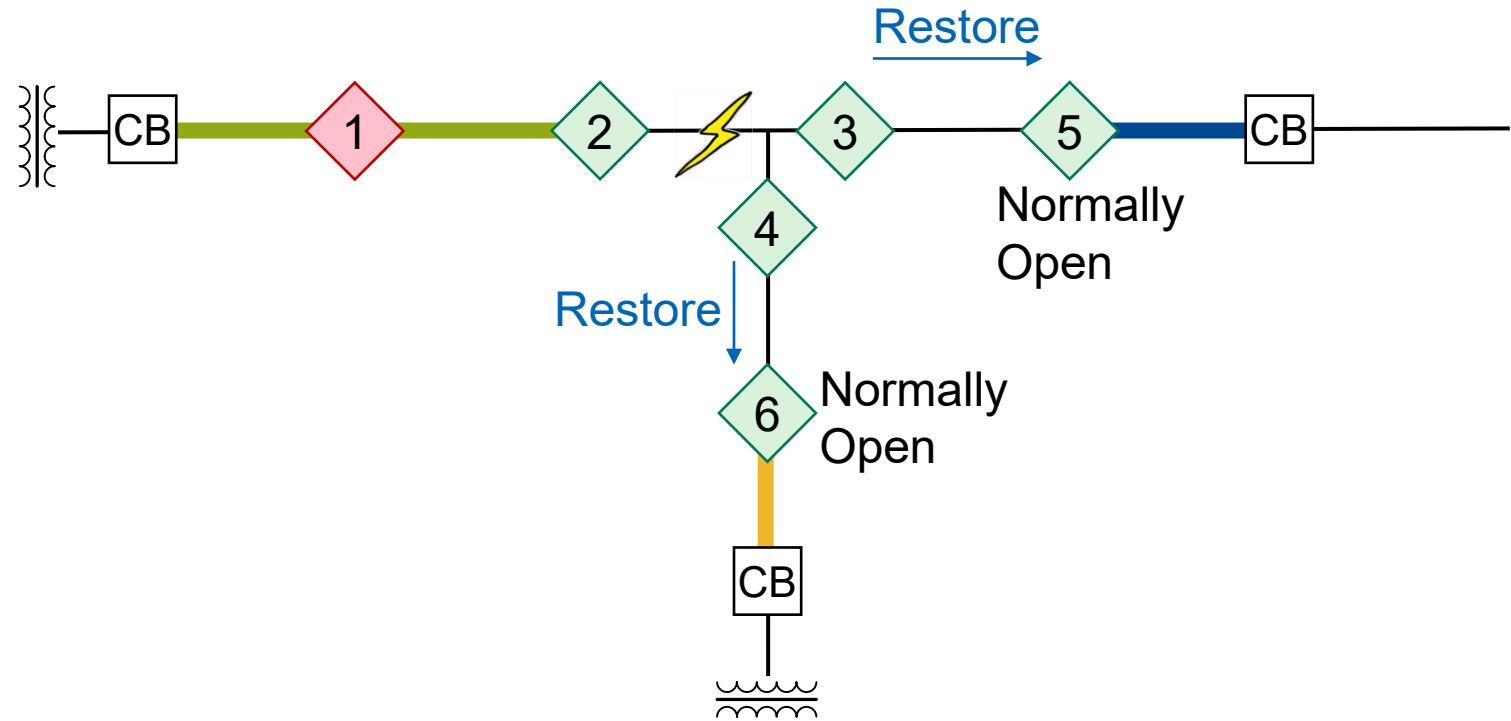
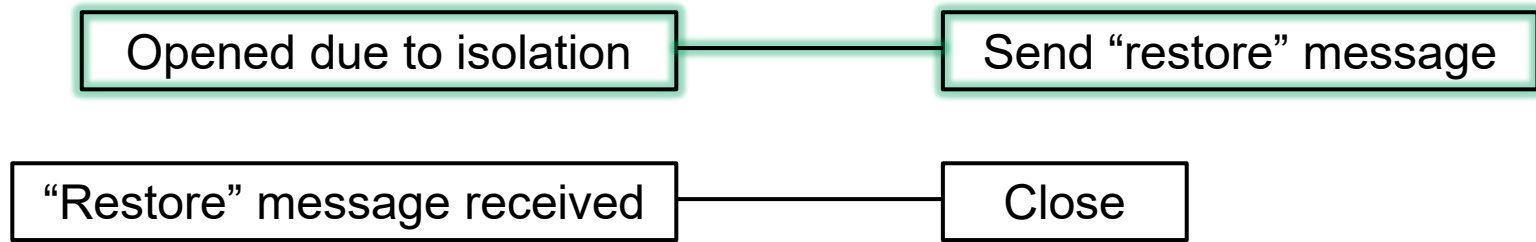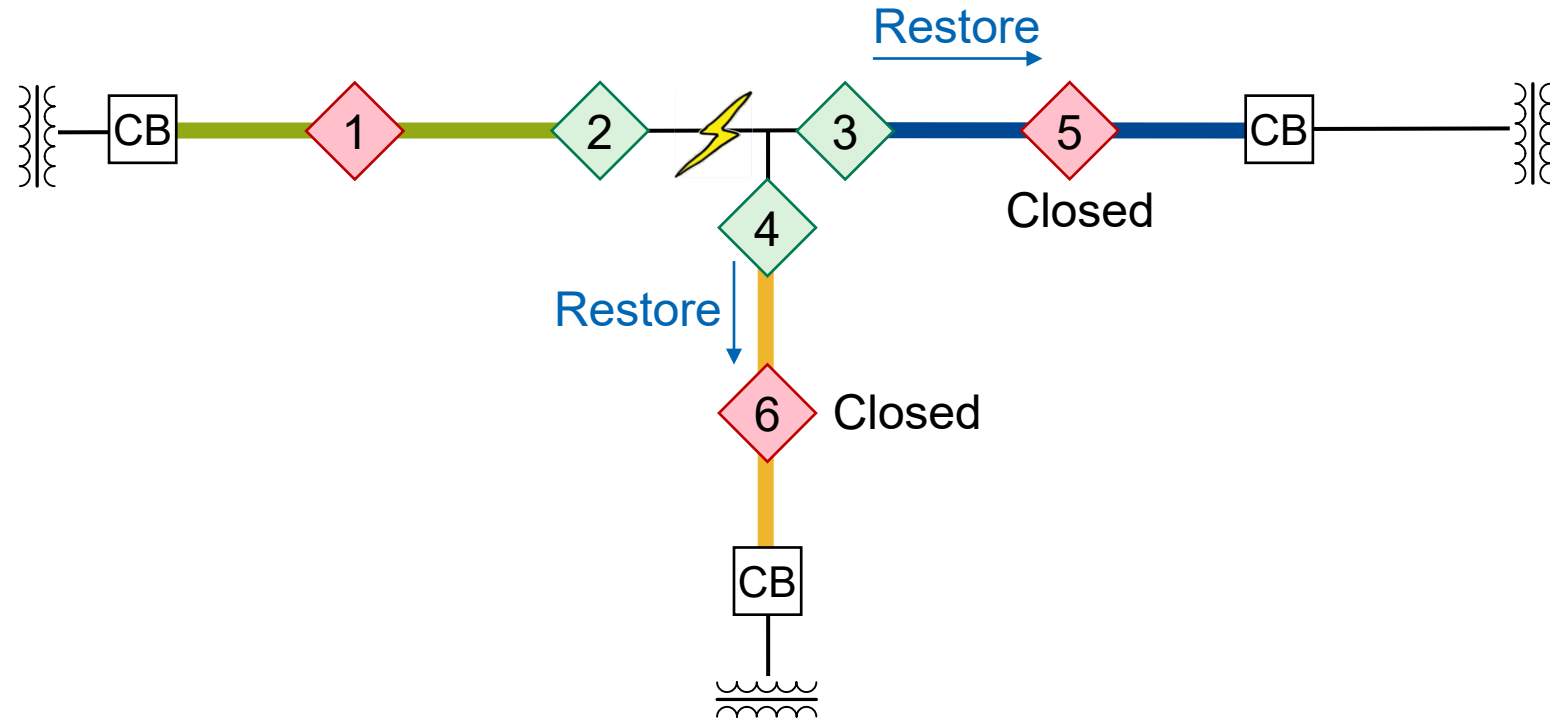# Downstream Isolation Scheme

Downstream Isolation Scheme
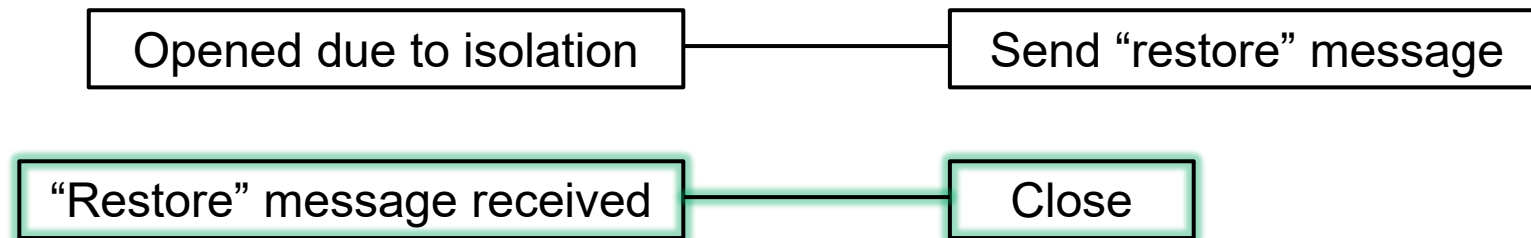
Downstream Isolation Scheme

Downstream Isolation Scheme
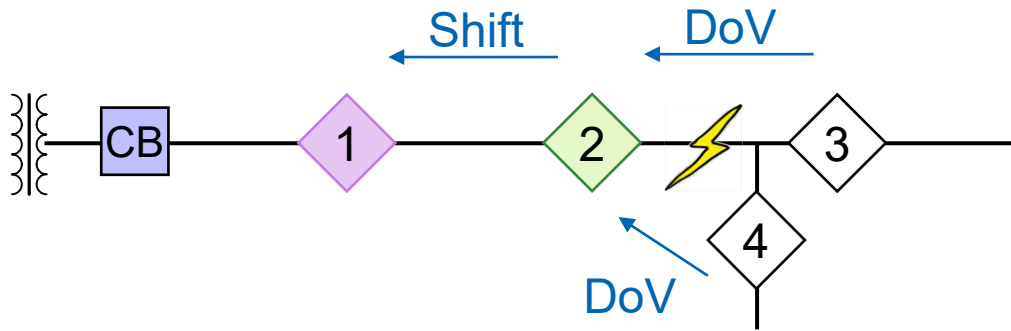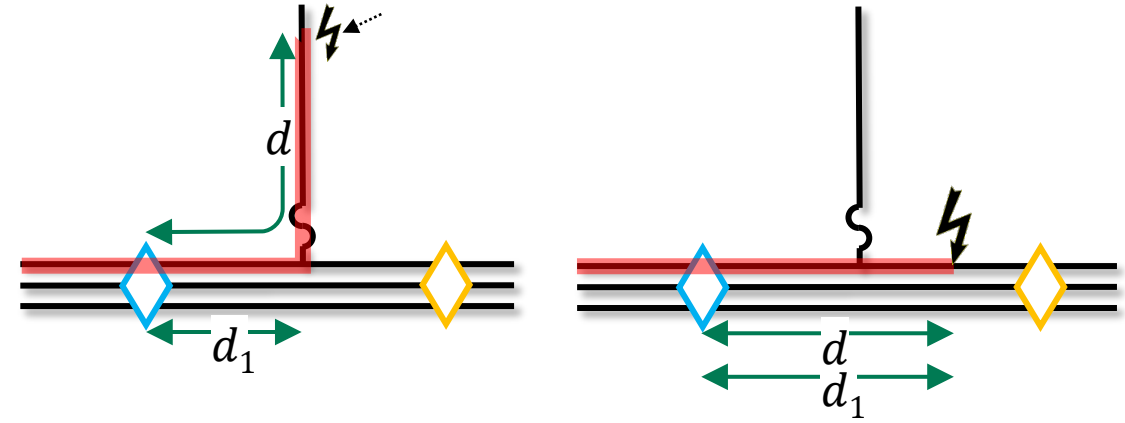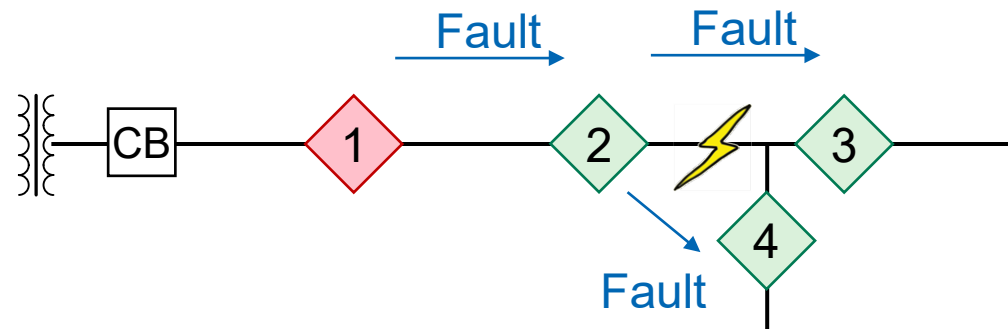
Restoration

Restoration

Summary

Permissive (resilient to packet drops)

Impedance-Enhanced

Downstream Isolation