# Self-Healing Distribution System in Smartgrid

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  - Automatic Fault Isolation and Service Restoration (FISR)
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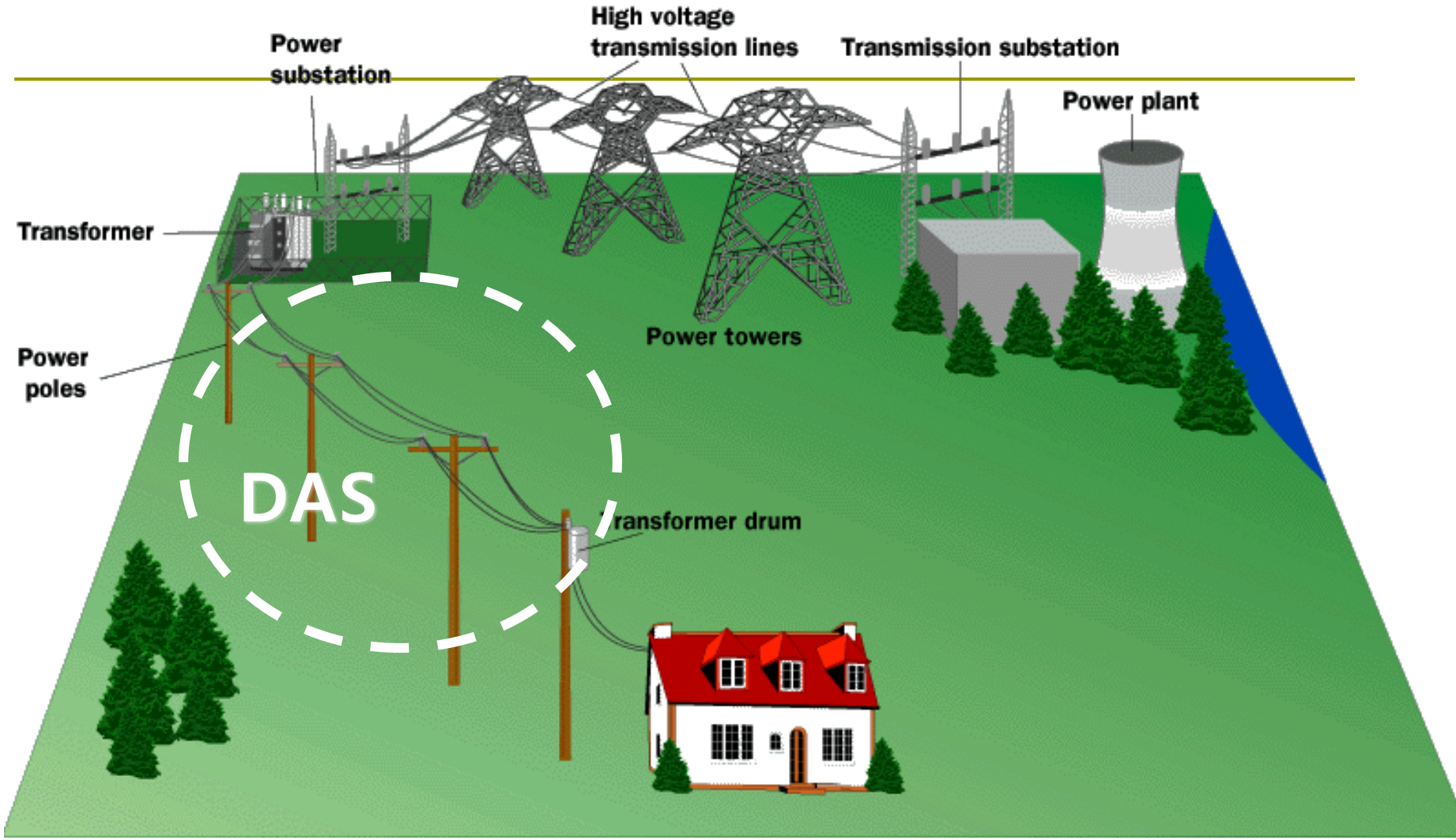
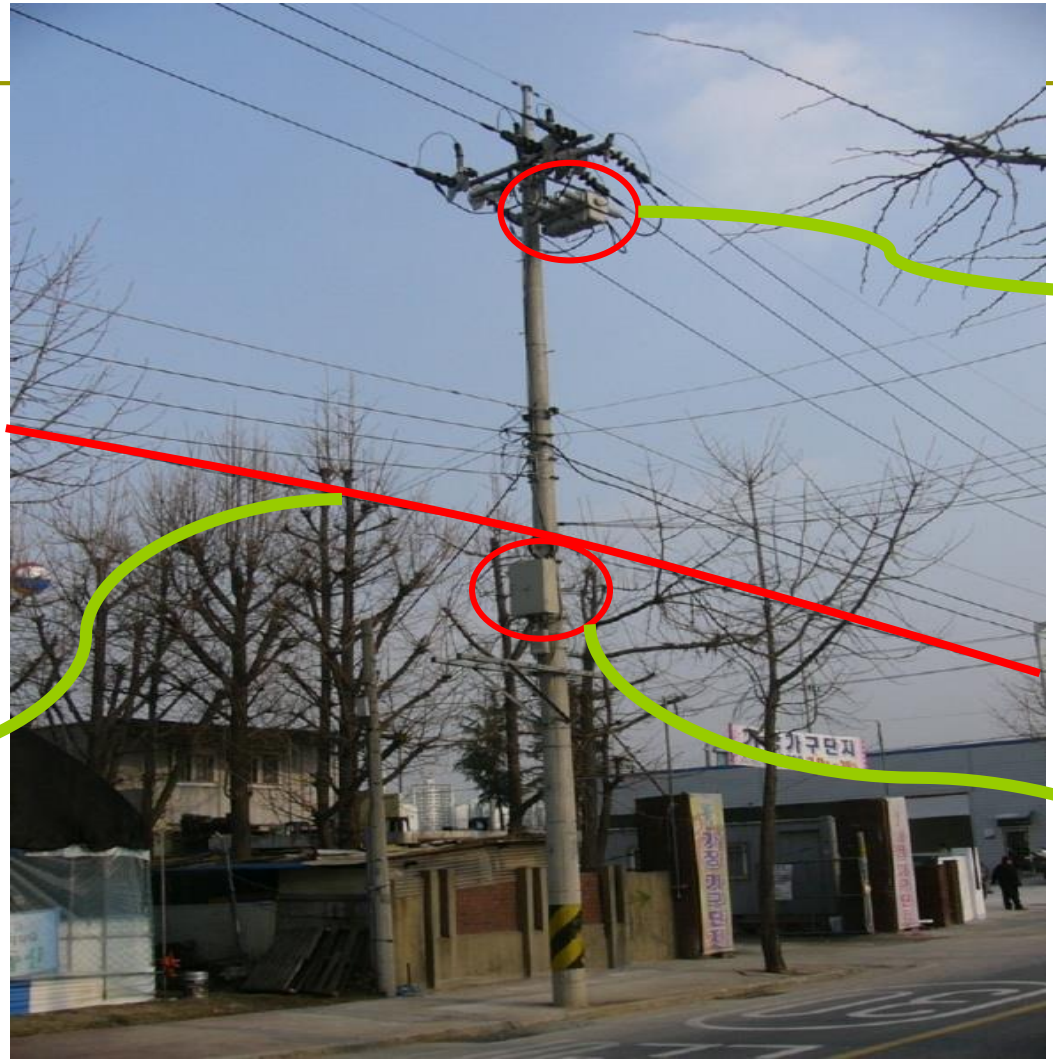
  - FISR in Ungrounded System
- Communication-based FISR
  - Self-healing Grounded System
  - Self-Healing Ungrounded System

# DAS

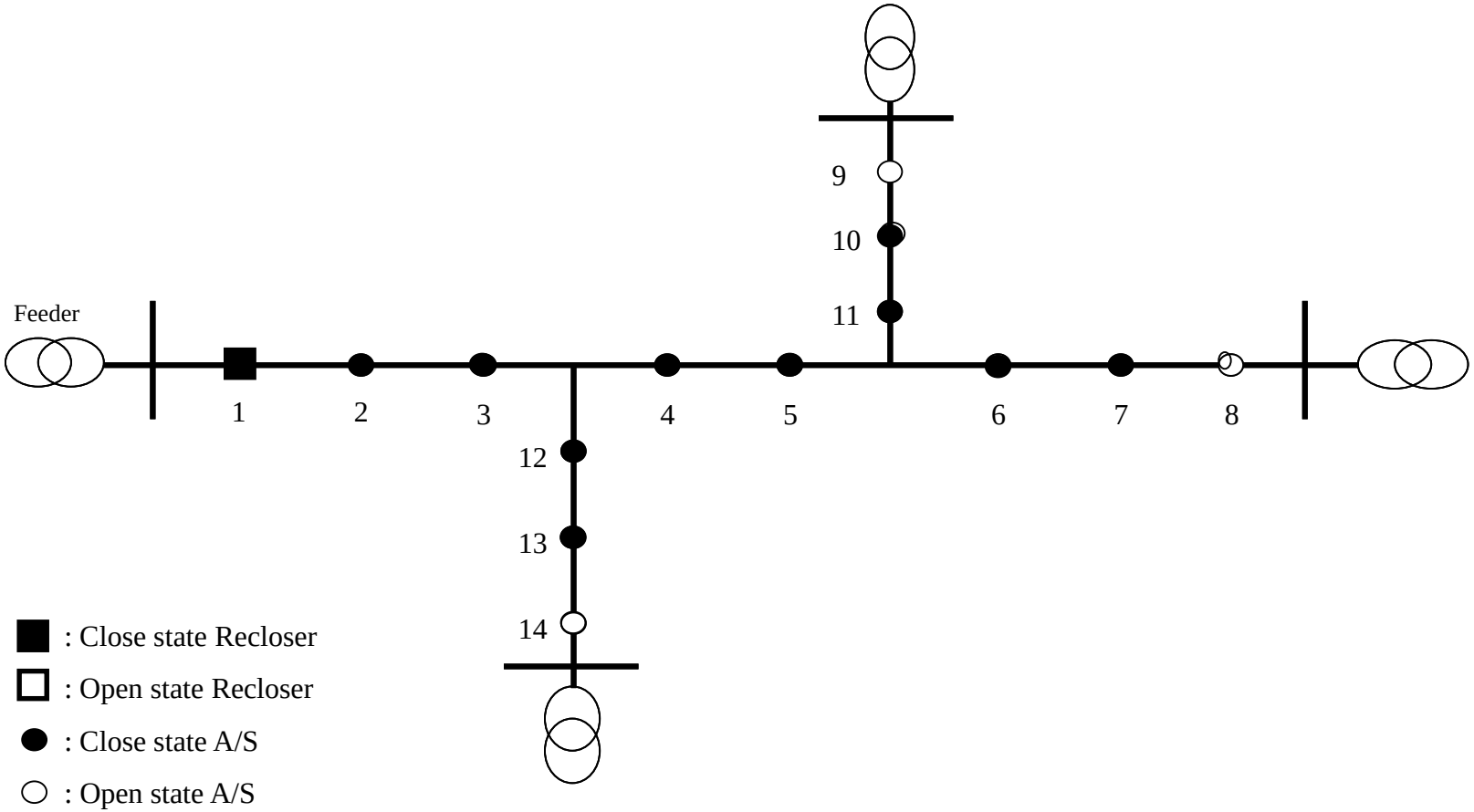
Distribution Automation System


High voltage
transmission lines
Power
substation
Transmission substation
Power plant
Transformer
Power towers
Power
poles
DAS
Transformer drum

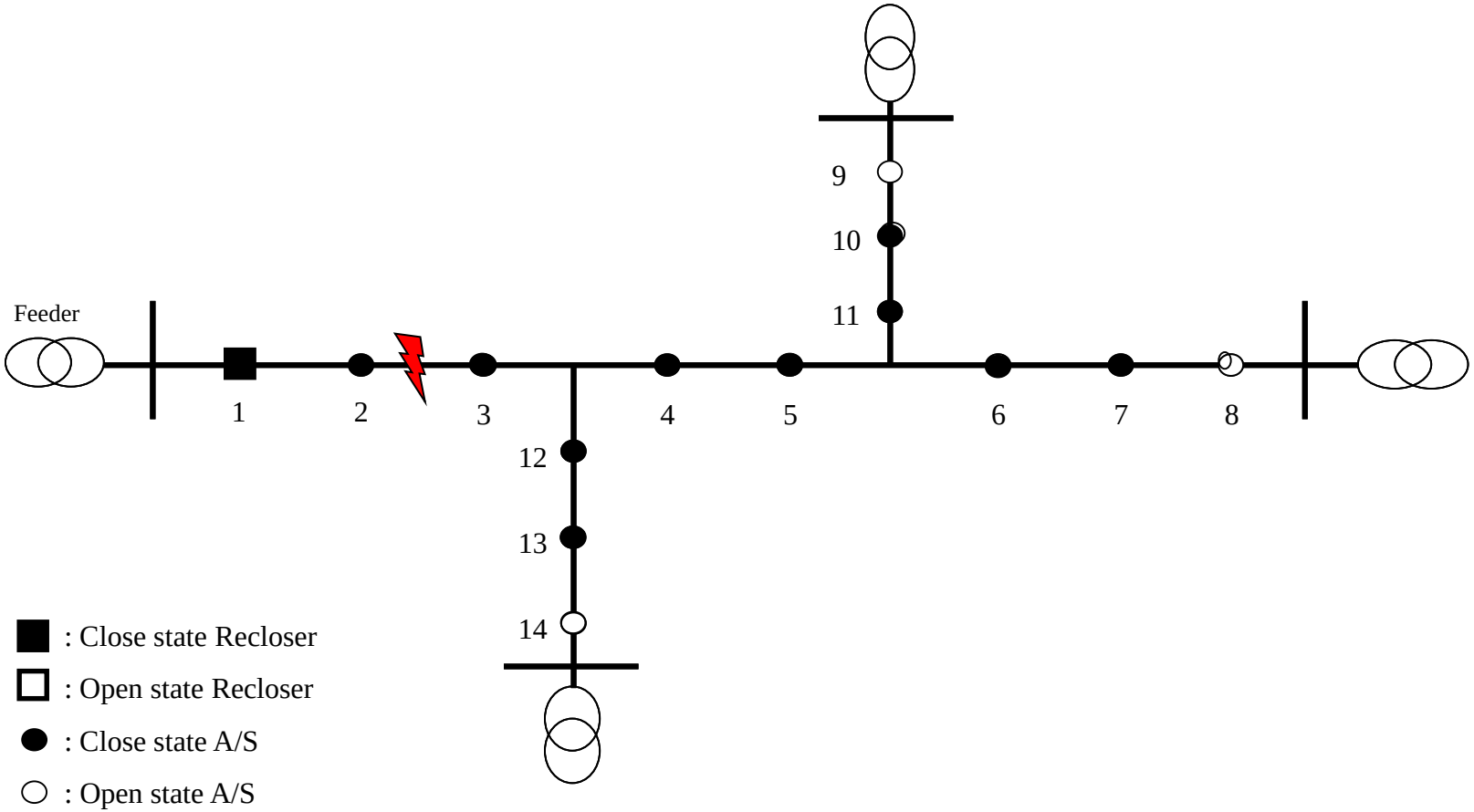
# DAS Control Center


Auto-
Sw
Comm.
RTU

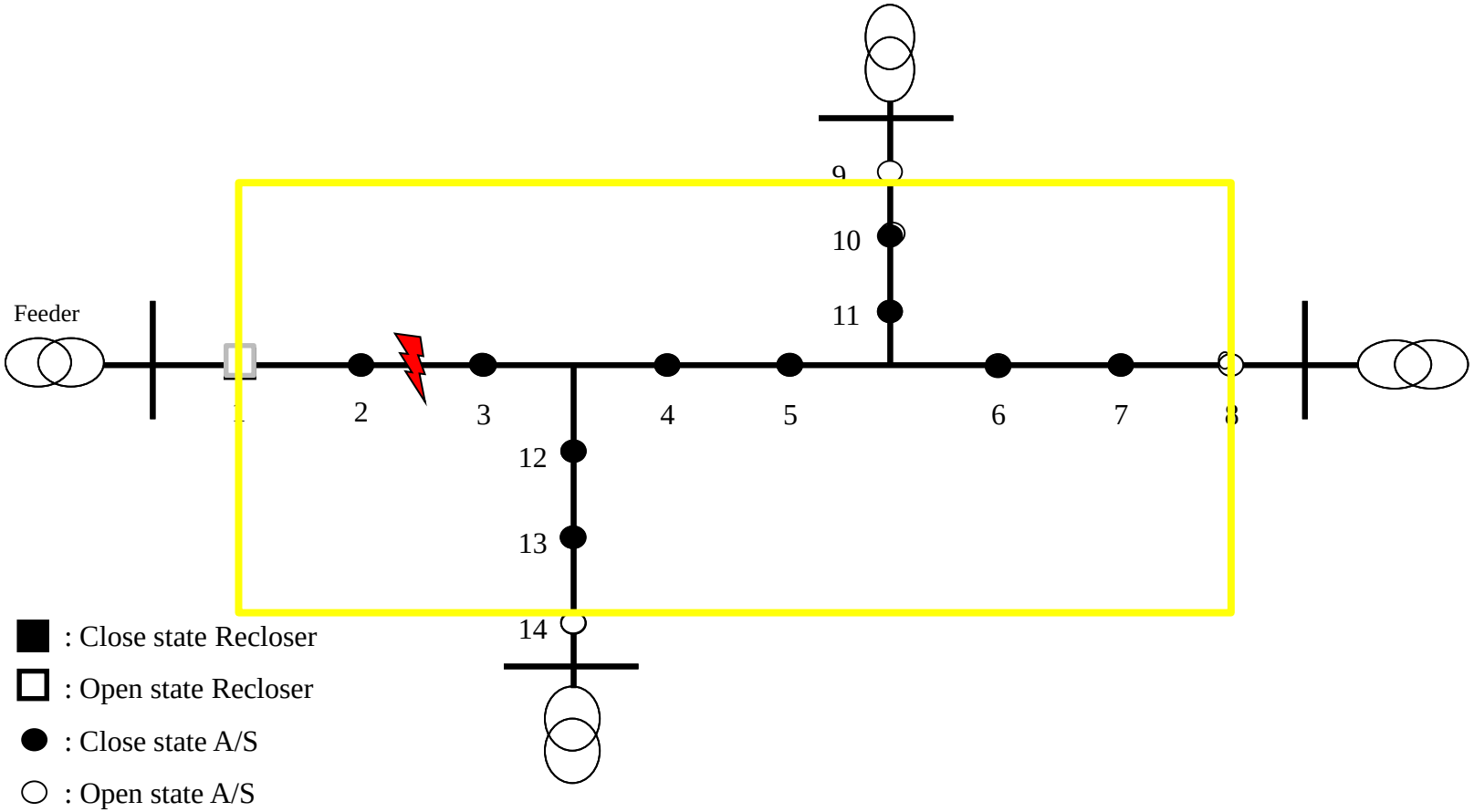
# Open-Loop Distribution Feeder System



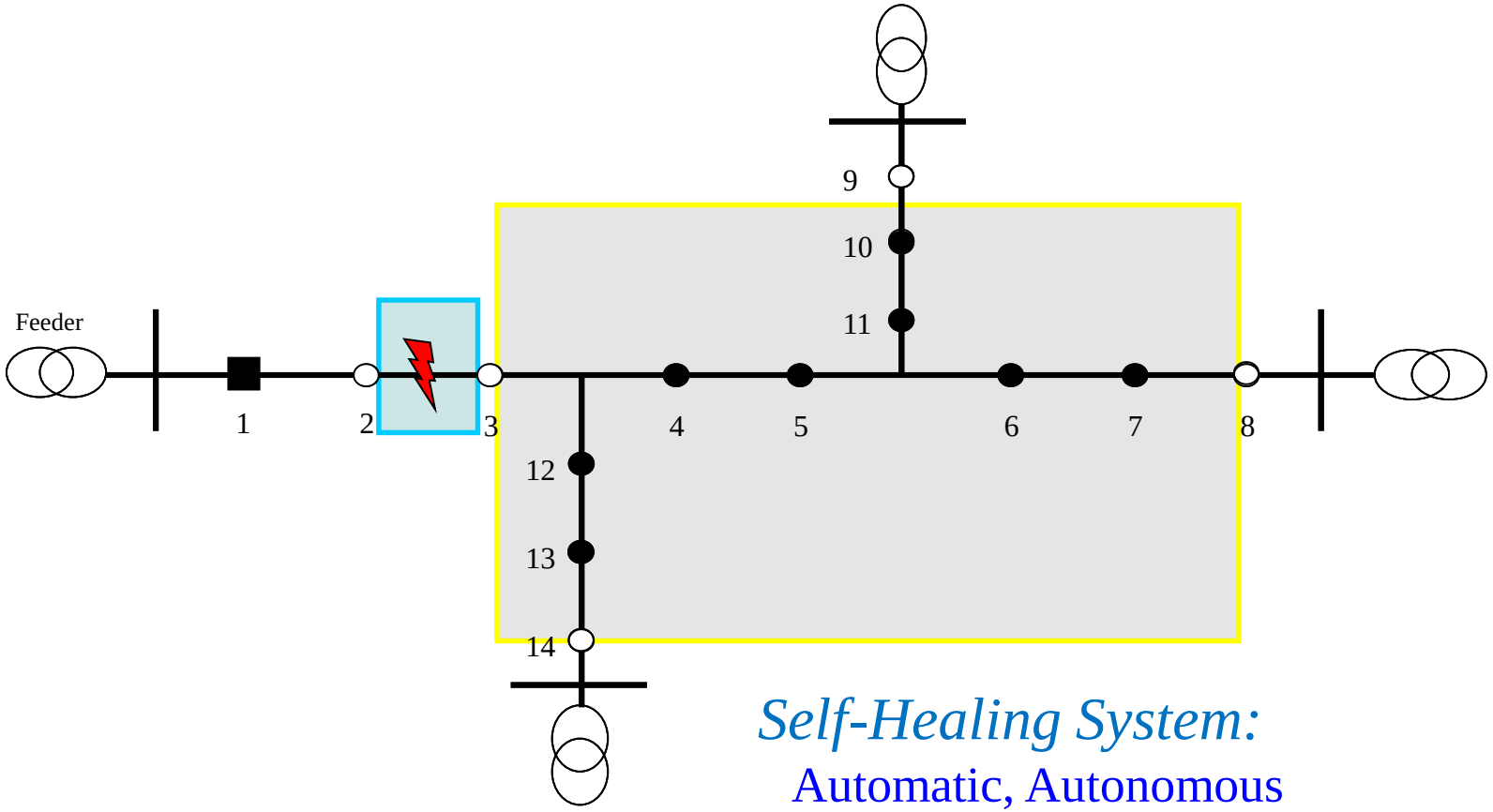
# Fault


Feeder
1
2
3
4
5
6
7
8
9
10
11
12
13
14
: Close state Recloser
: Open state Recloser
: Close state A/S
: Open state A/S

# Fault and Outage



# Fault Isolation and Service Restoration




*Self-Healing System:*

Automatic, Autonomous

Fault Isolation and Service Restoration

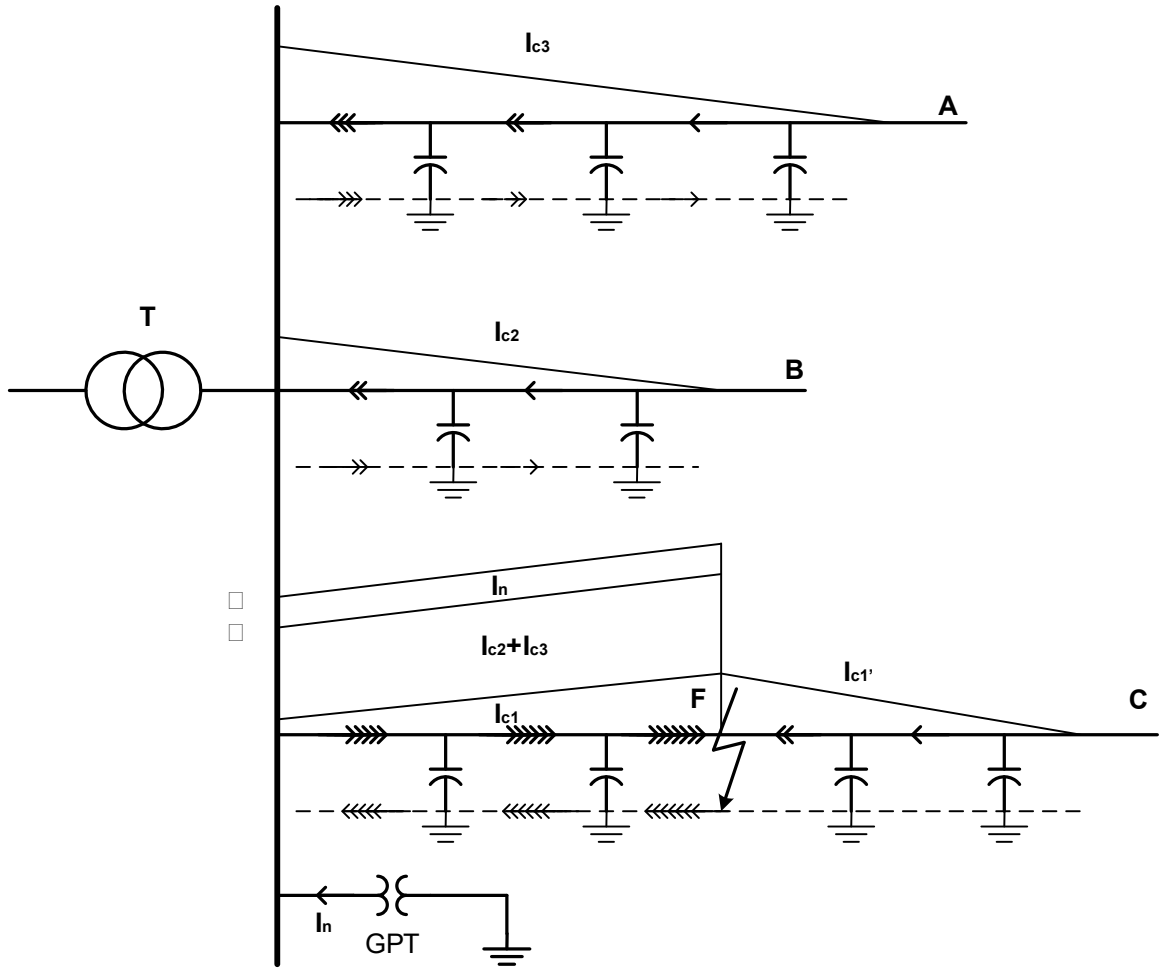
# Self-Healing Systems

- Ungrounded System
- Solidly grounded System

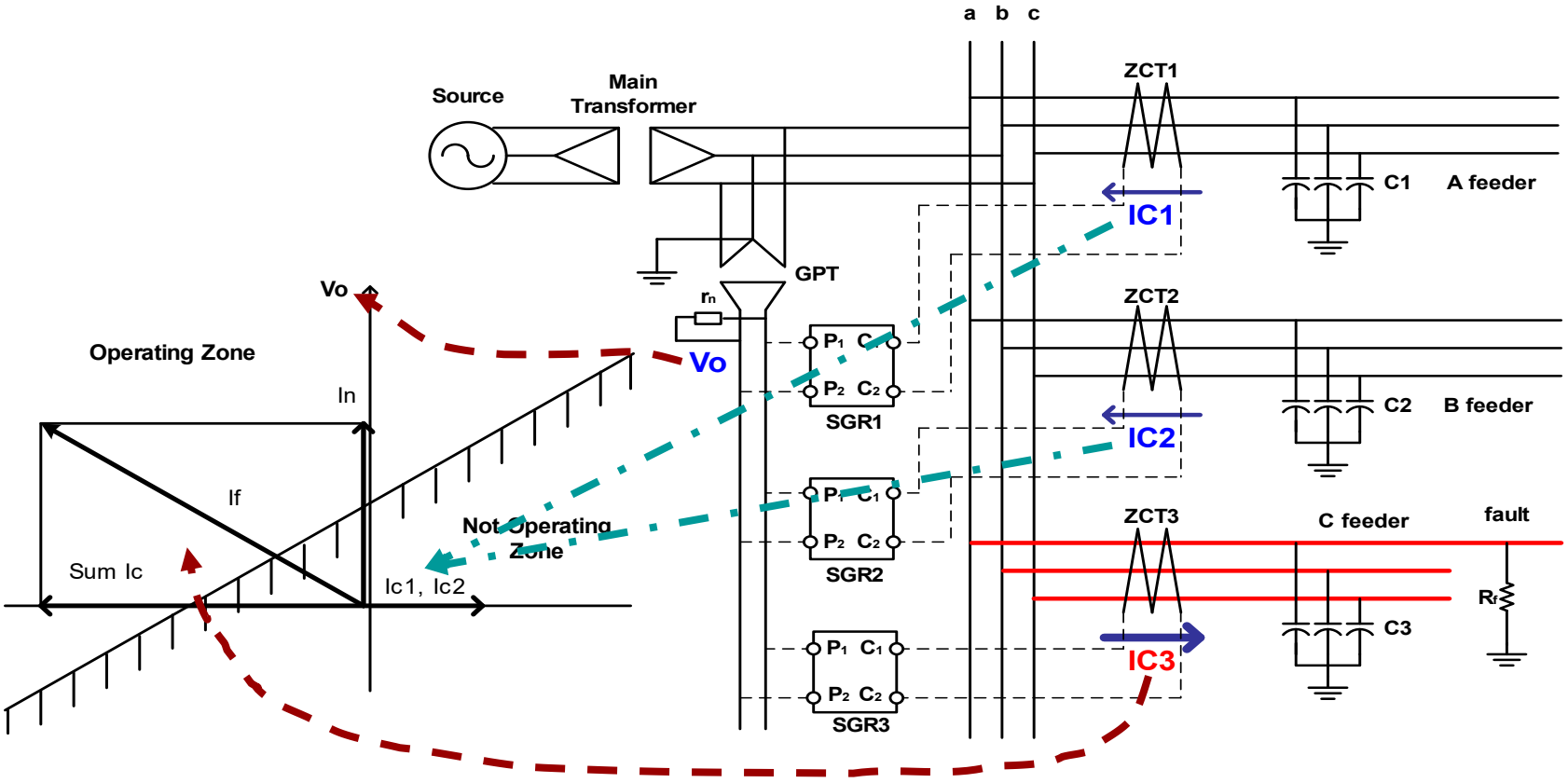
# Current FISR Scheme

A. Ungrounded Distribution System

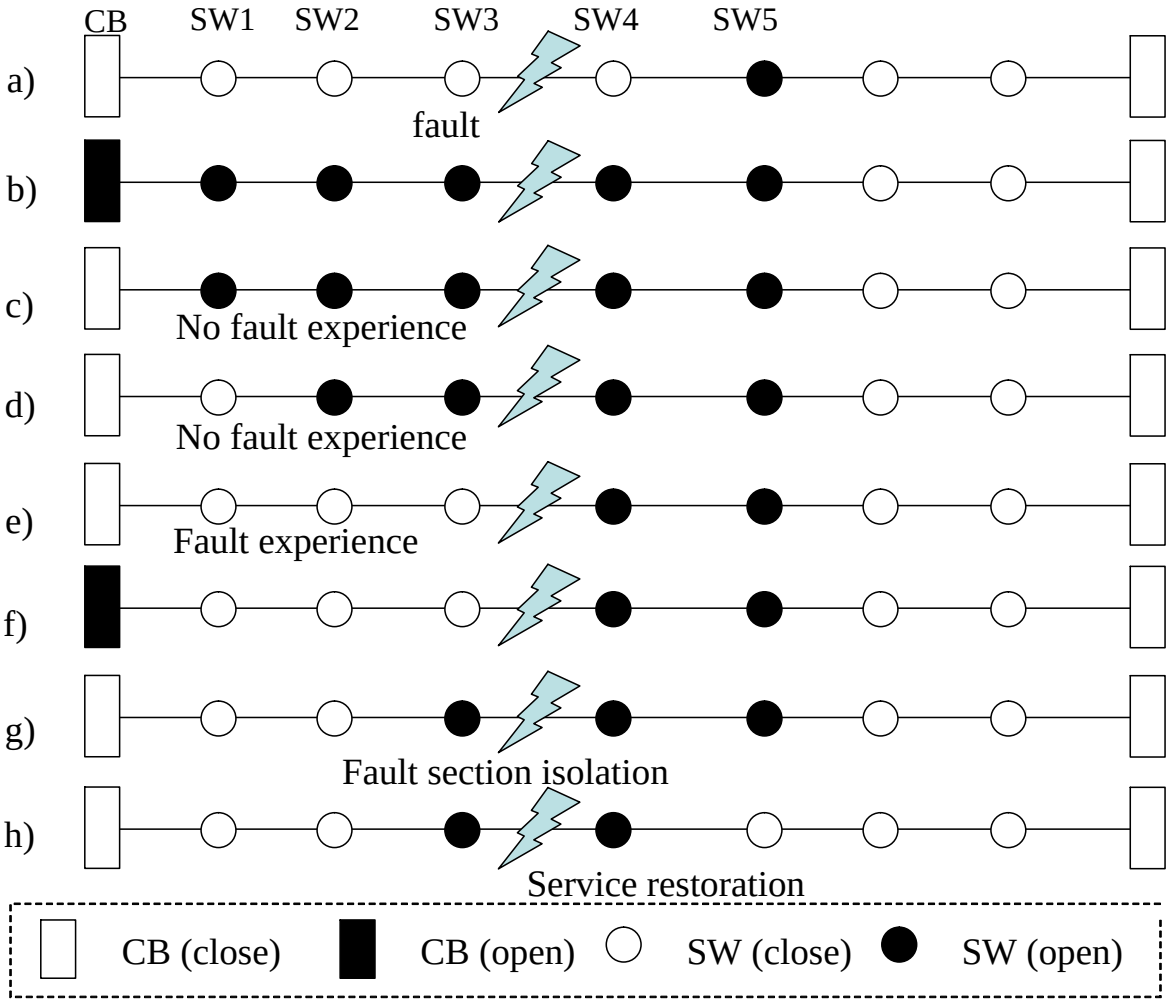
# Zero-sequence Current in SLG fault



# SGR-based Faulted Circuit Detection



# FISR in Ungrounded System

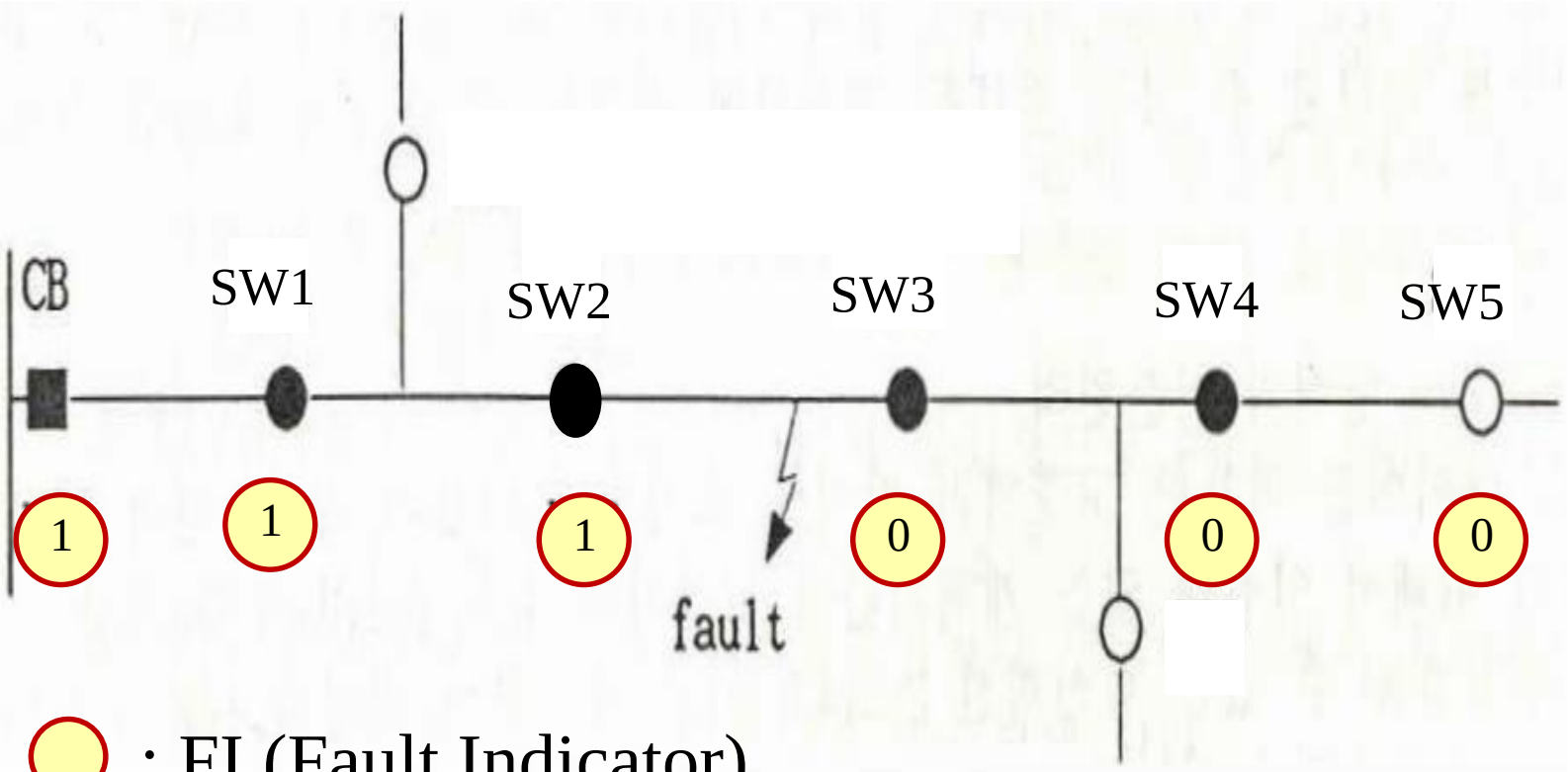



- many switchings
- customer interruption

# Current FISR Scheme

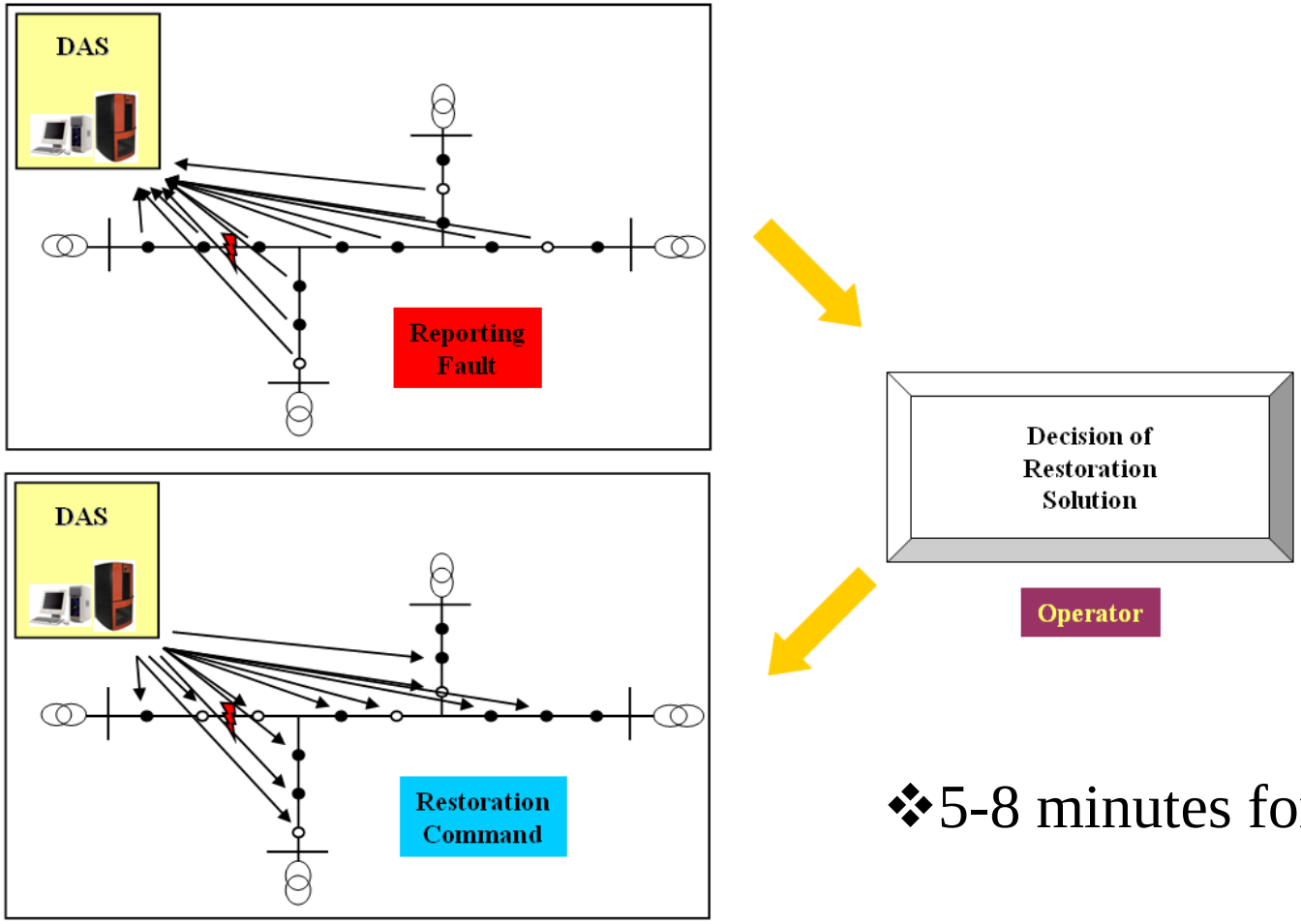
B. Solidly Grounded Distribution System

# Fault Section Identification



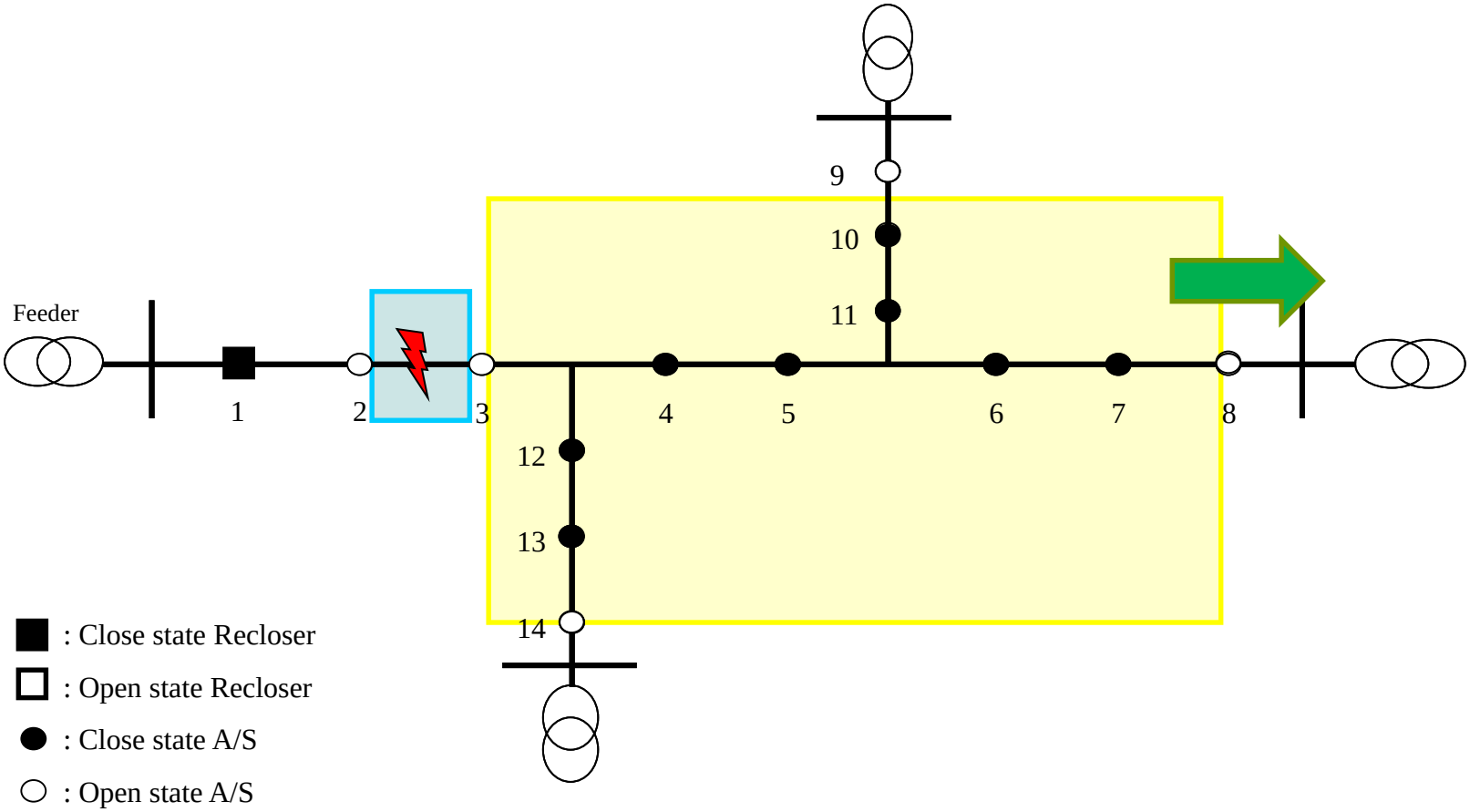

: FI (Fault Indicator)

# Centralized FISR




❖5-8 minutes for FISR

# Example

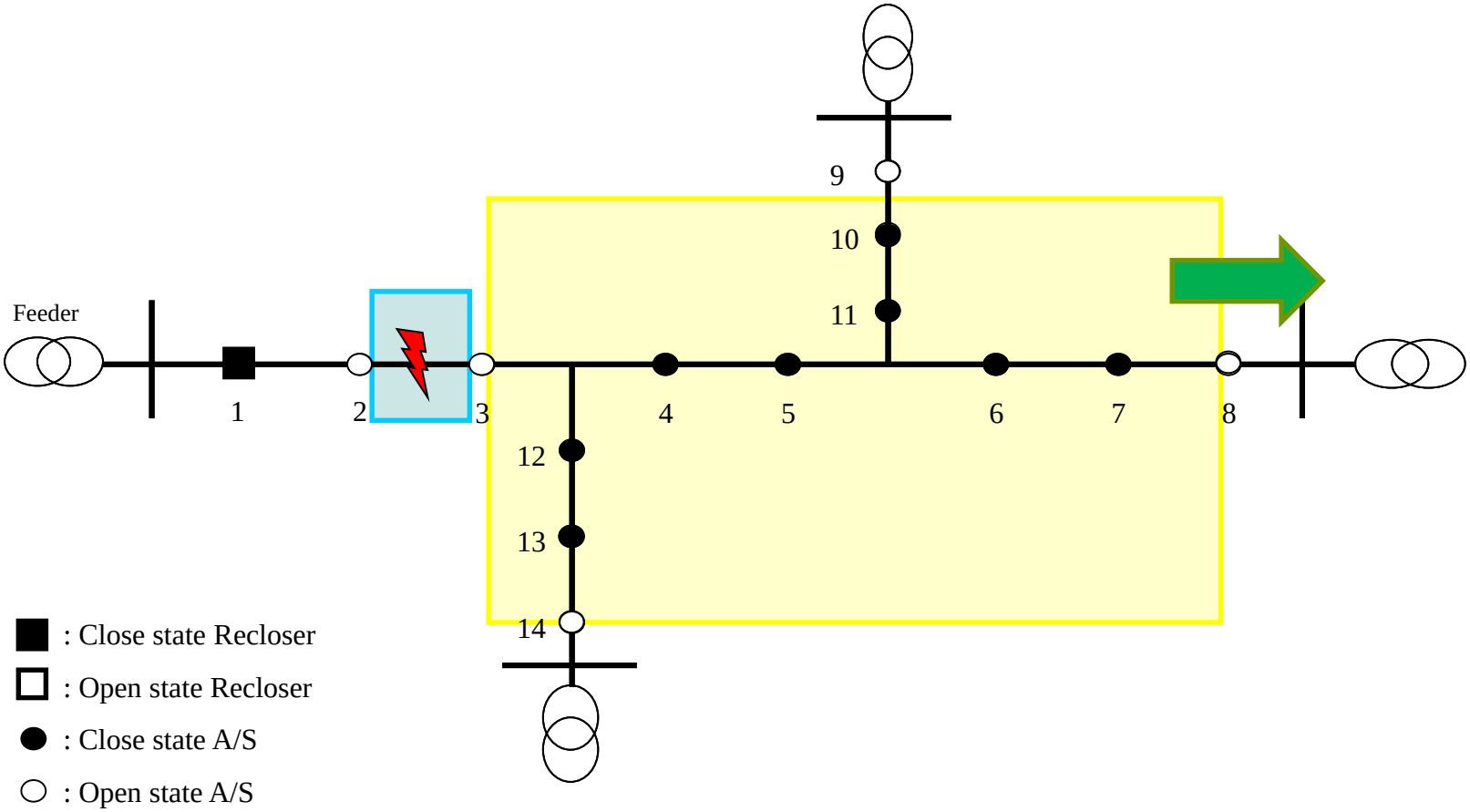

Feeder
1
2
3
4
5
6
7
8
9
10
11
12
13
14
: Close state Recloser
: Open state Recloser
: Close state A/S
: Open state A/S

# Restoration Planning

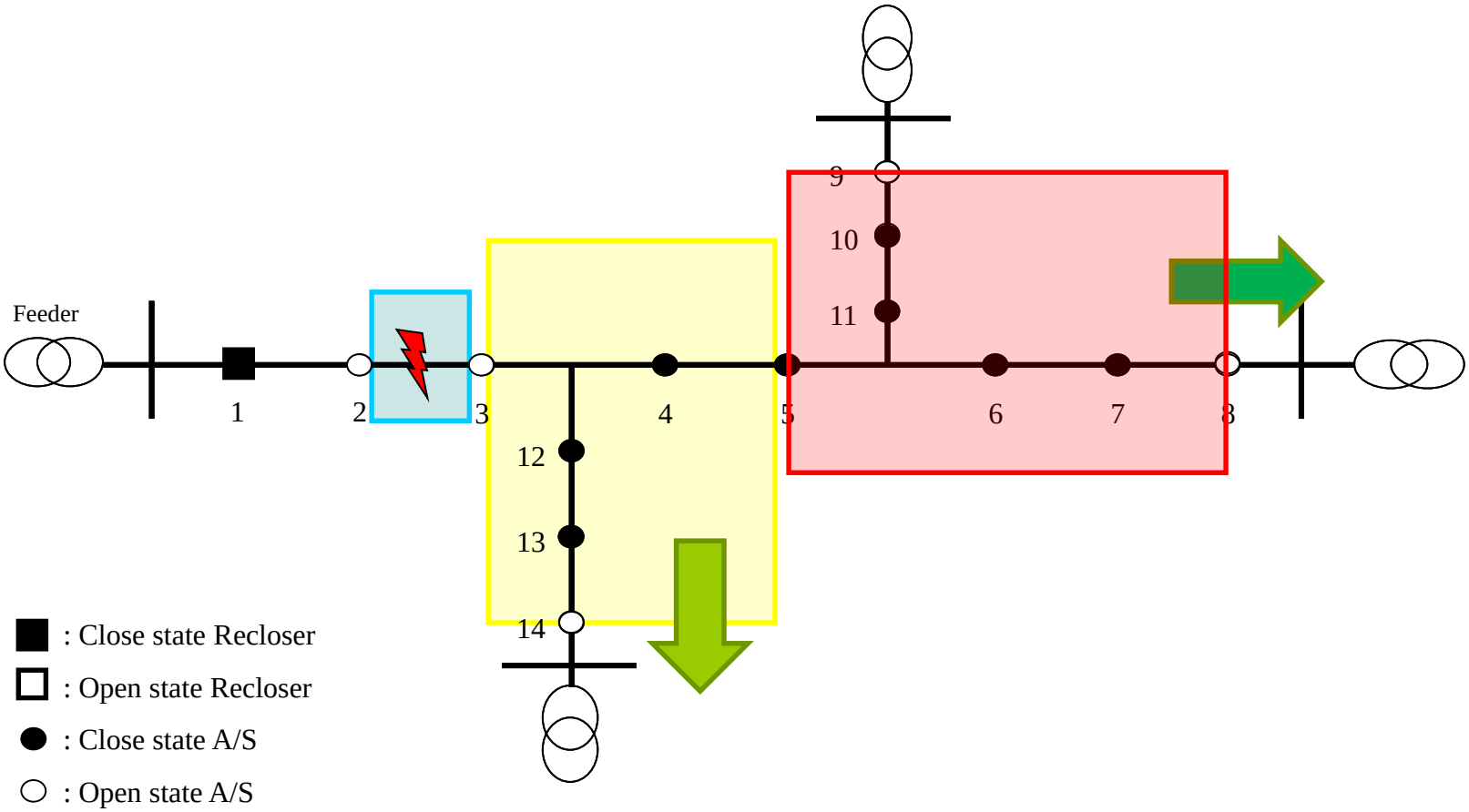
Five Basic Schemes:

① SGR
② DGR
③ TGR
④ SGRLT
⑤ DGRLT

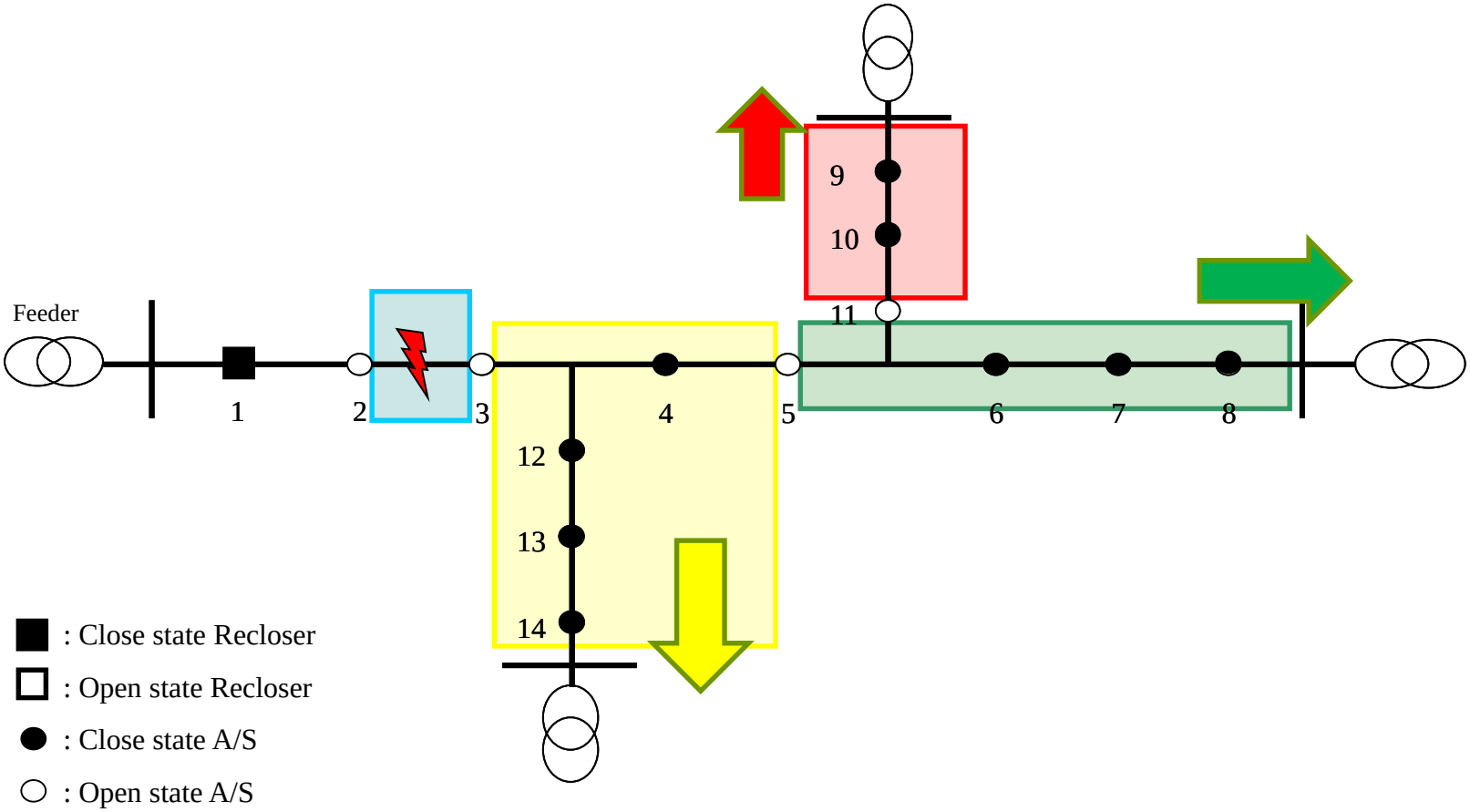
# Single Grouping Restoration (SGR)



# Double Grouping Restoration (DGR)



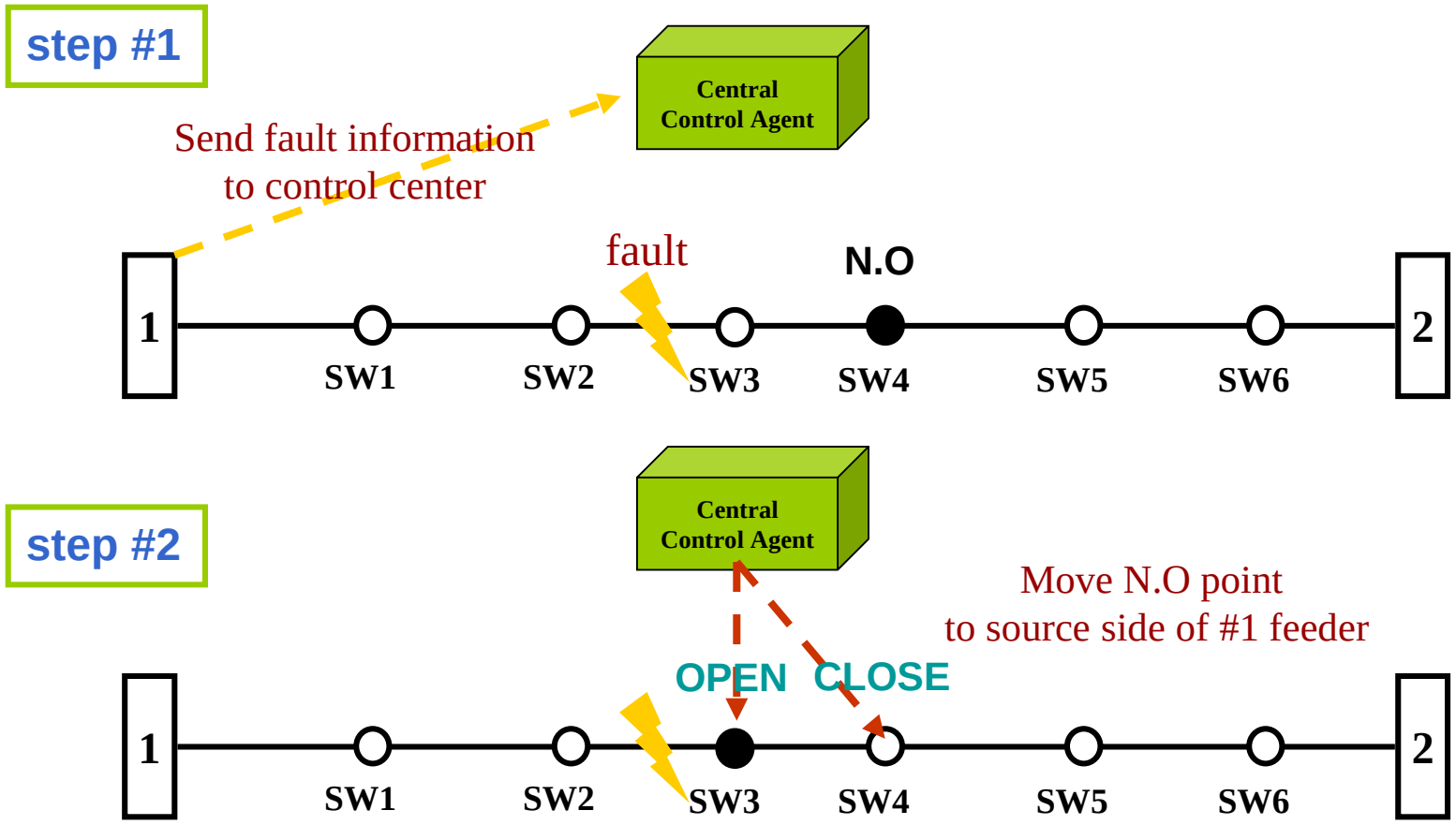
# Triple Grouping Restoration (TGR)



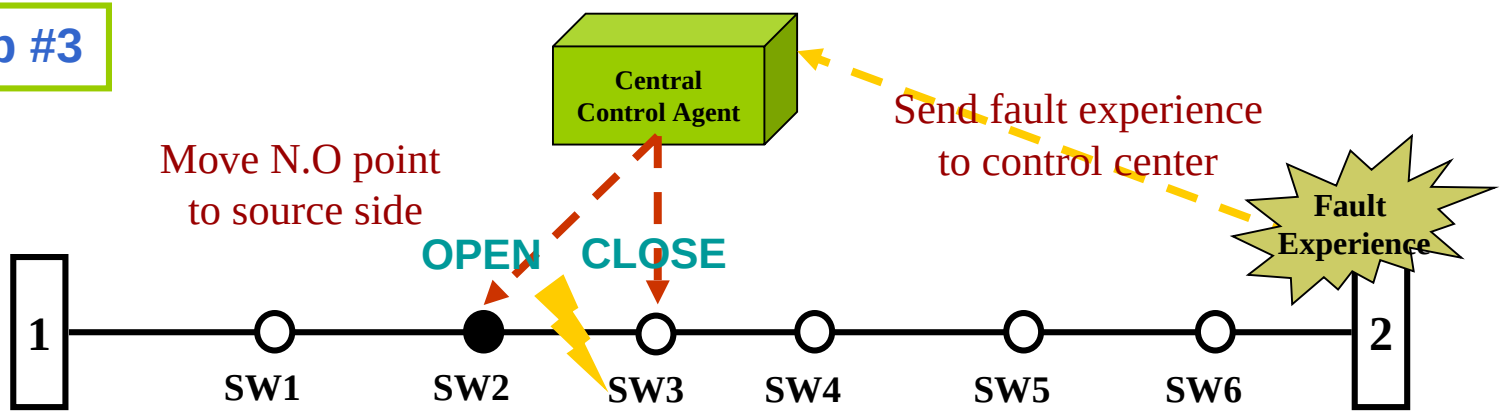
# Self-Healing Distribution System

# A. Self-Healing in Ungrounded System

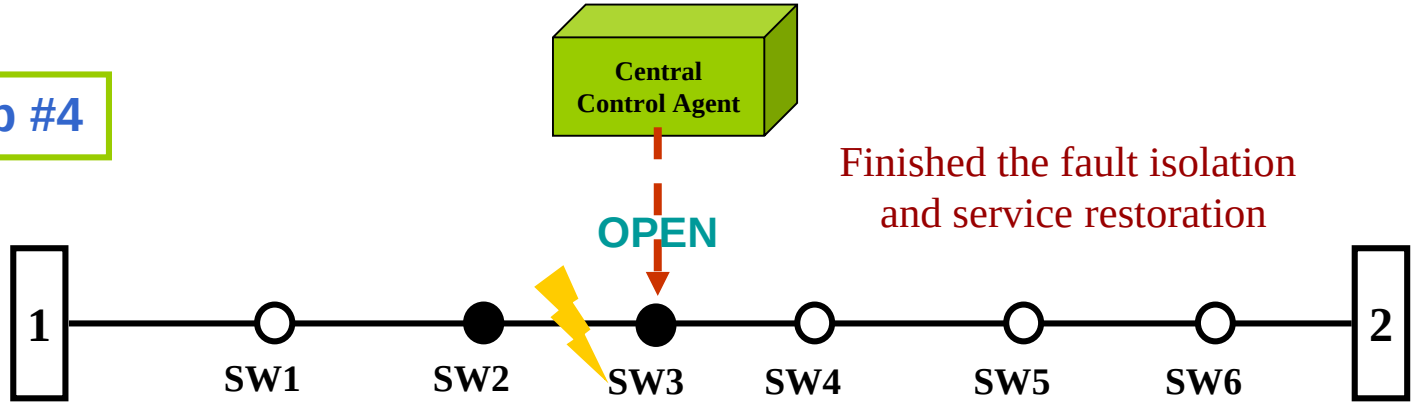
# A. Single-Tie Case



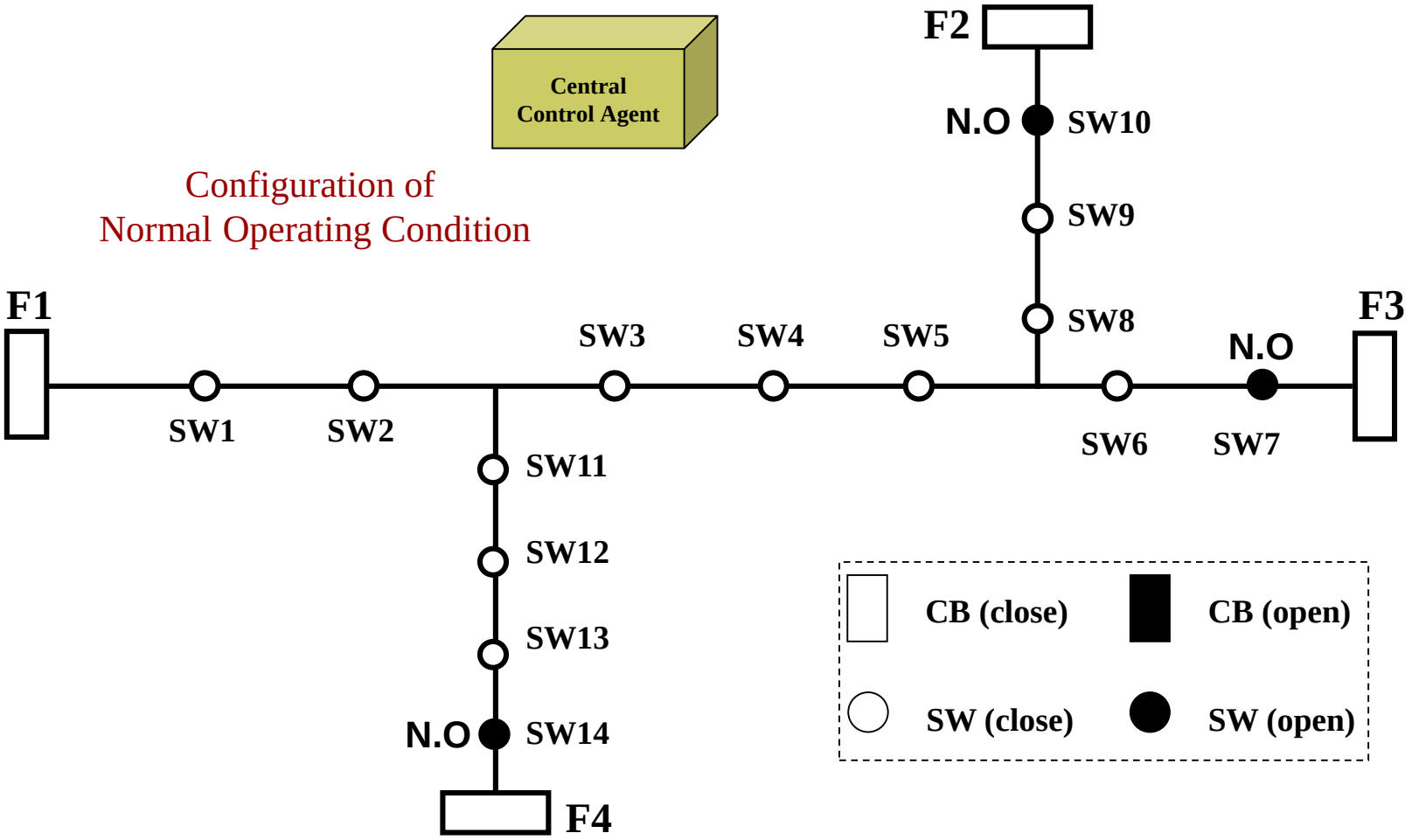
step #3

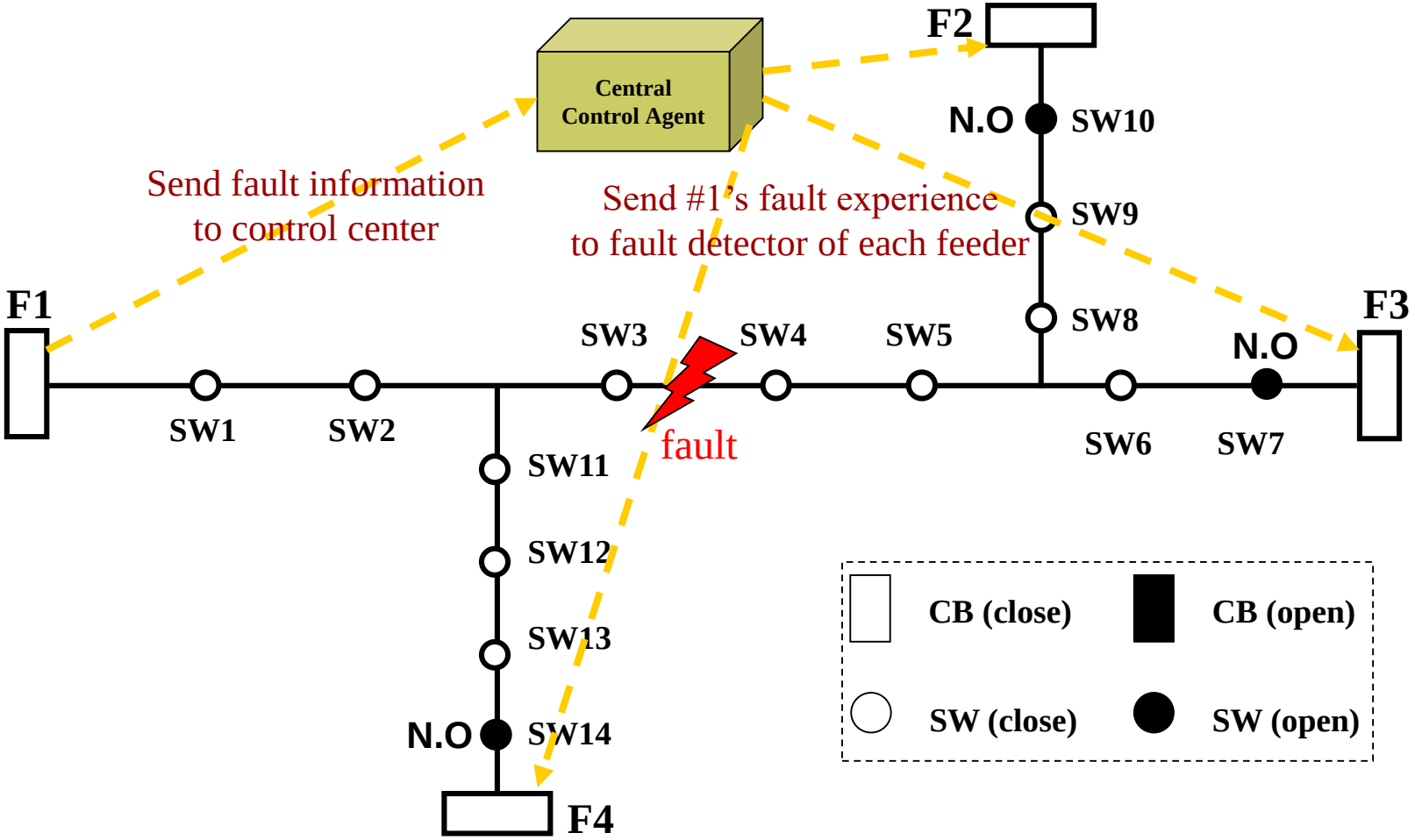

Central
Control Agent
Send fault experience
to control center
Move N.O point
to source side
Fault
Experience
OPEN
CLOSE
1
2
SW1
SW2
SW3
SW4
SW5
SW6

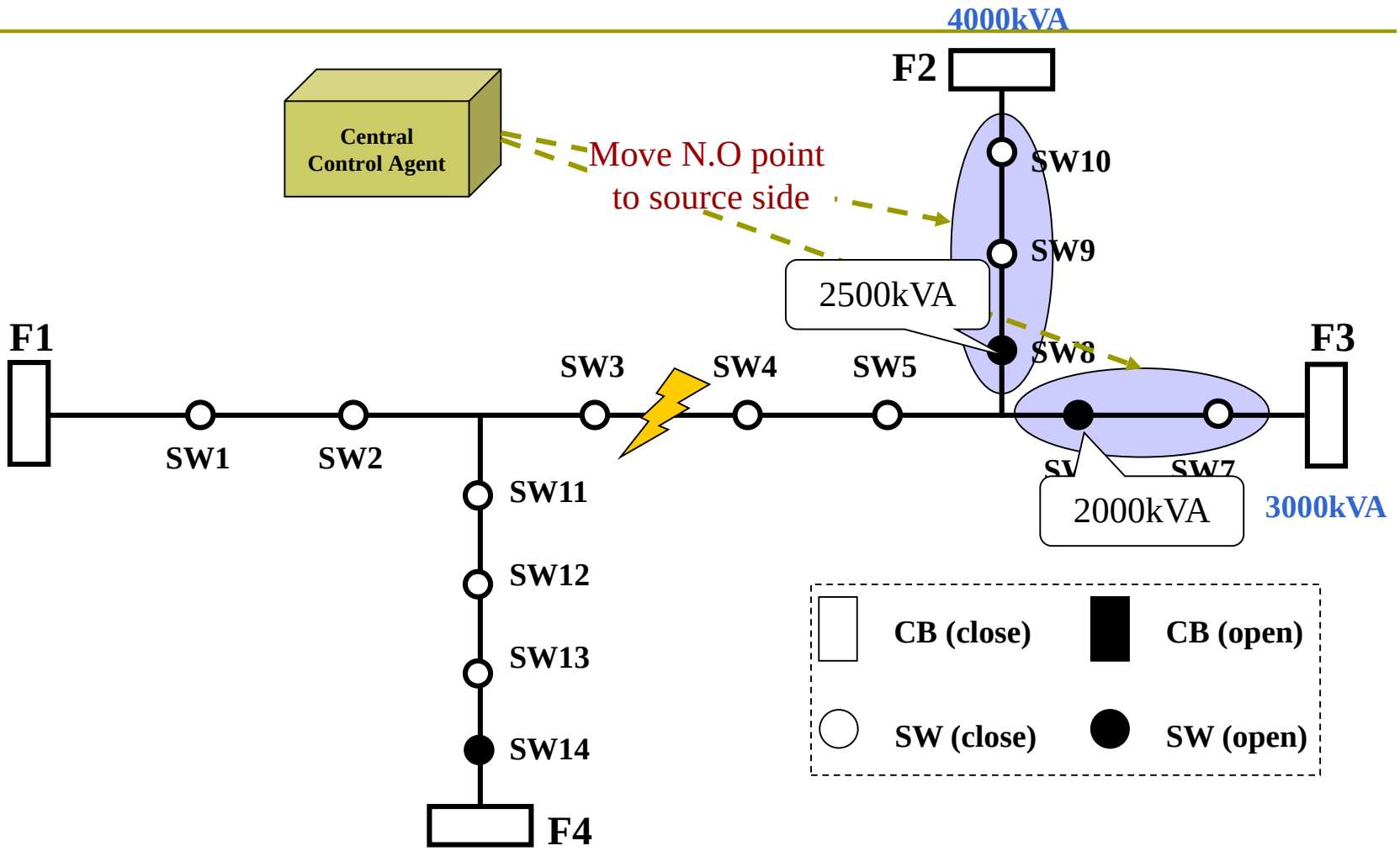
step #4

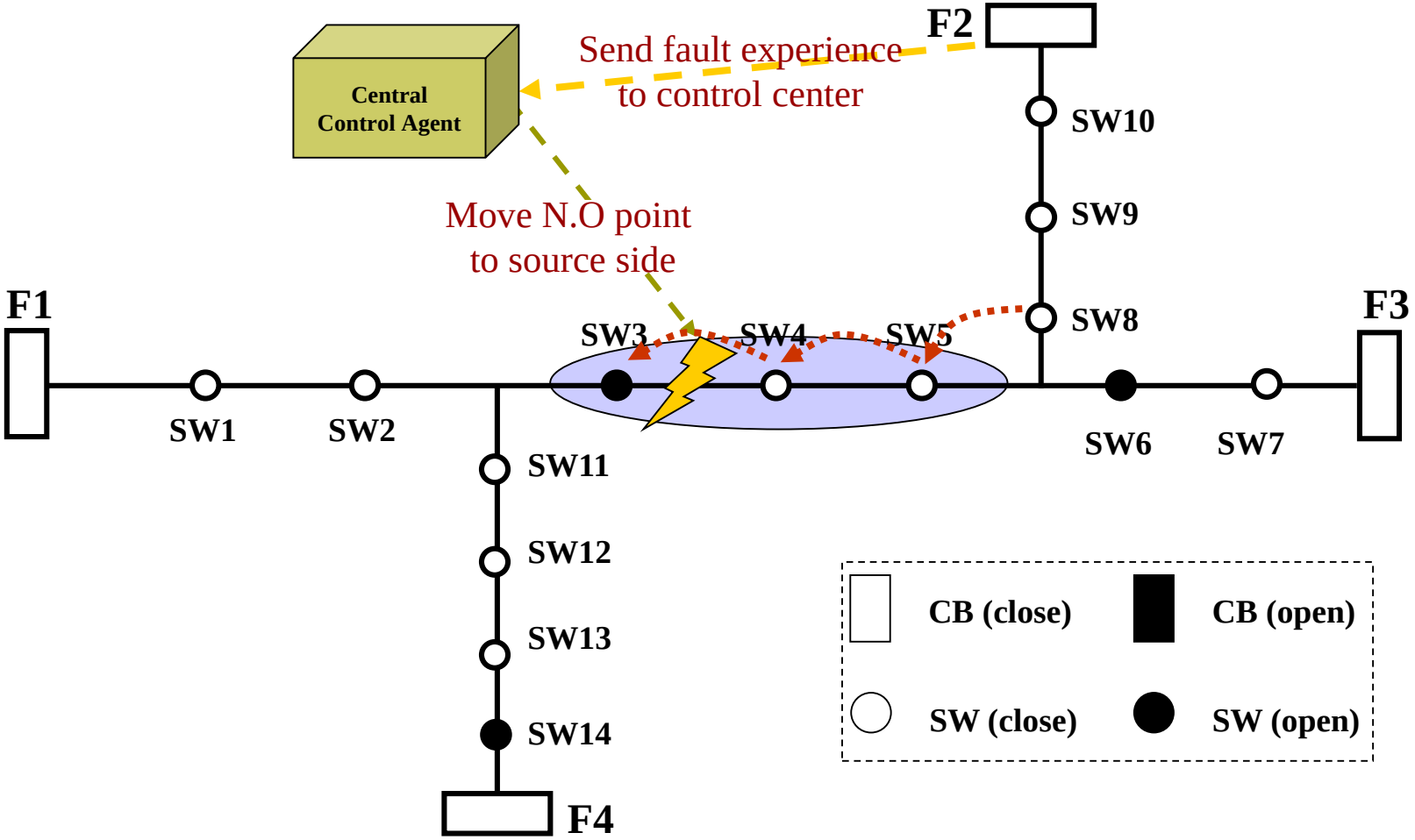

Central
Control Agent
Finished the fault isolation
and service restoration
OPEN
1
2
SW1
SW2
SW3
SW4
SW5
SW6

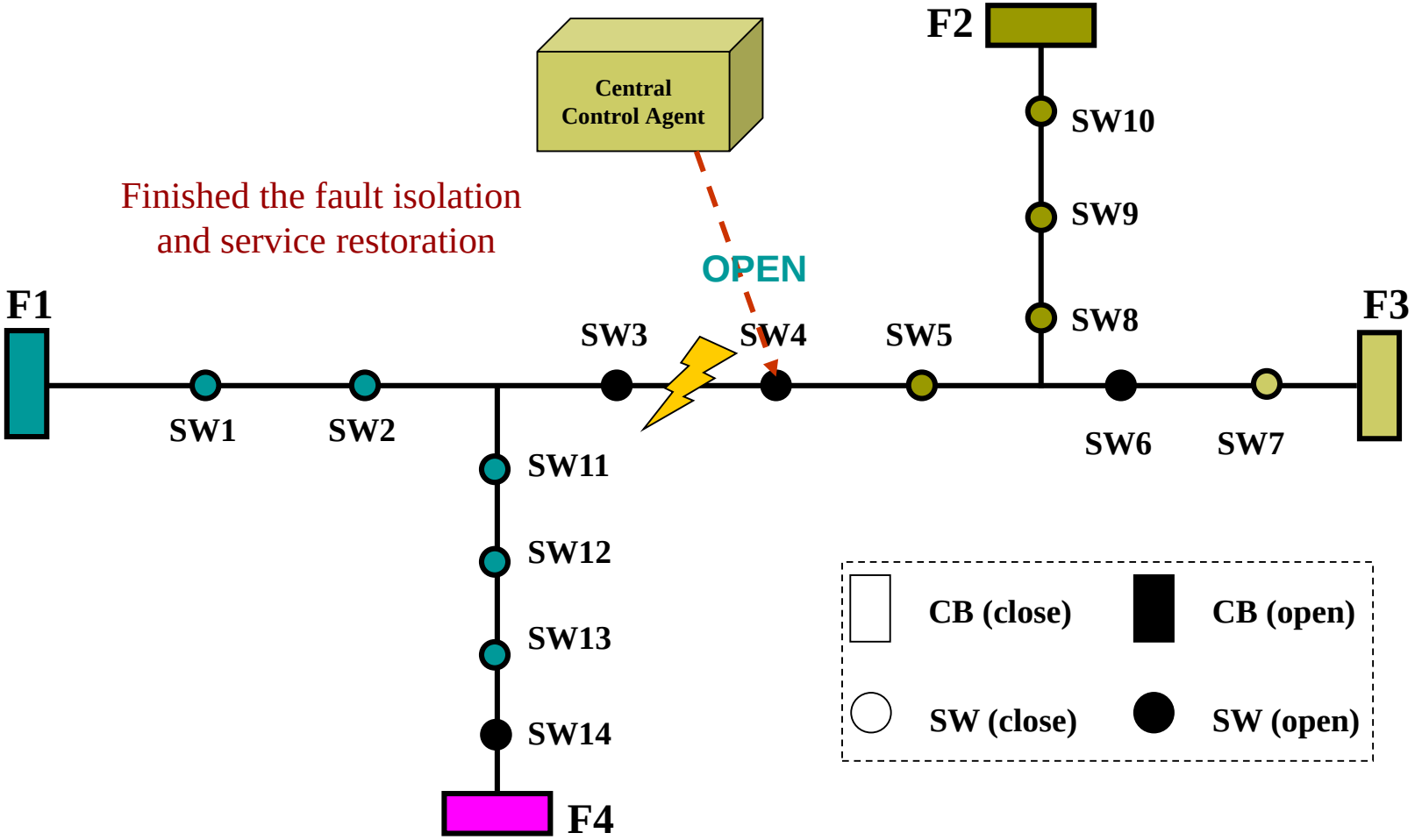
# B. Multi-Tie Case




Central
Control Agent
F2
N.O
SW10
SW9
SW8
F3
N.O
F1
SW3
SW4
SW5
SW1
SW2
fault
SW6
SW7
SW11
SW12
SW13
N.O
SW14
F4
Send fault information
to control center
Send #1's fault experience
to fault detector of each feeder
CB (close)
CB (open)
SW (close)
SW (open)


4000kVA
F2
Central
Control Agent
Move N.O point
to source side
SW10
SW9
2500kVA
SW8
F1
F3
SW3
SW4
SW5
SW1
SW2
SW11
SW12
SW13
SW14
F4
2000kVA
3000kVA
CB (close)
CB (open)
SW (close)
SW (open)


Central
Control Agent
Send fault experience
to control center
Move N.O point
to source side
F1
F2
F3
F4
SW1
SW2
SW3
SW4
SW5
SW6
SW7
SW8
SW9
SW10
SW11
SW12
SW13
SW14
CB (close)
CB (open)
SW (close)
SW (open)

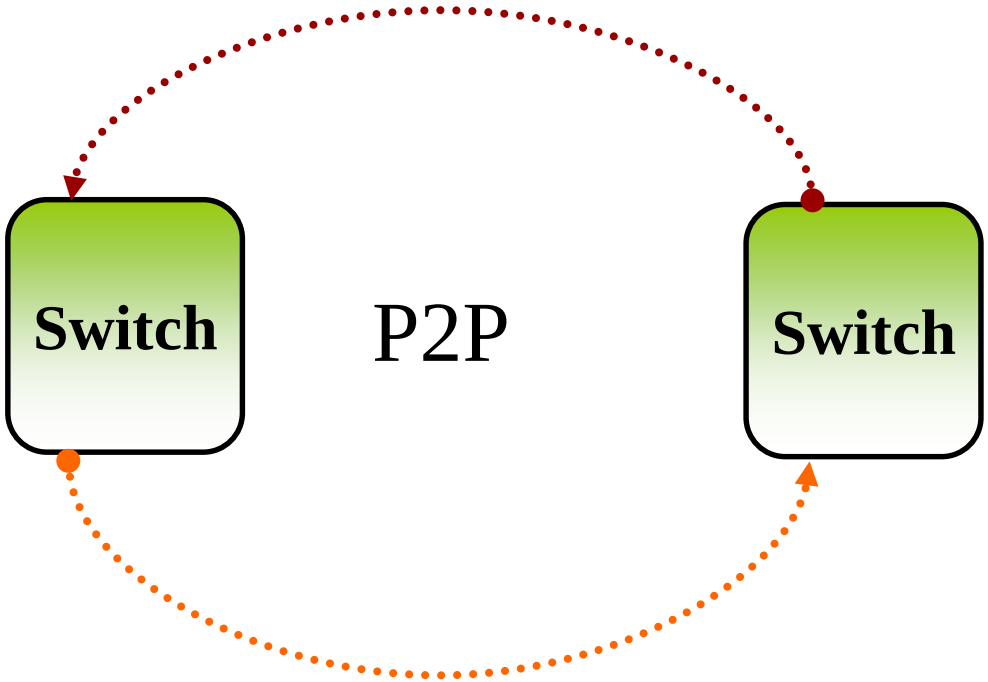

Central
Control Agent
Finished the fault isolation
and service restoration
OPEN
F1
F2
F3
F4
SW1
SW2
SW3
SW4
SW5
SW6
SW7
SW8
SW9
SW10
SW11
SW12
SW13
SW14
CB (close)
CB (open)
SW (close)
SW (open)

# Remarks

- Fault section can be isolated without outage
- This scheme can be expanded to multi-tie system
  - Progressive scheme is limited to a single tie system
- Decreased number of switching

# B. Self-Healing
# in Solidly-grounded System

# Peer-to-Peer Communication

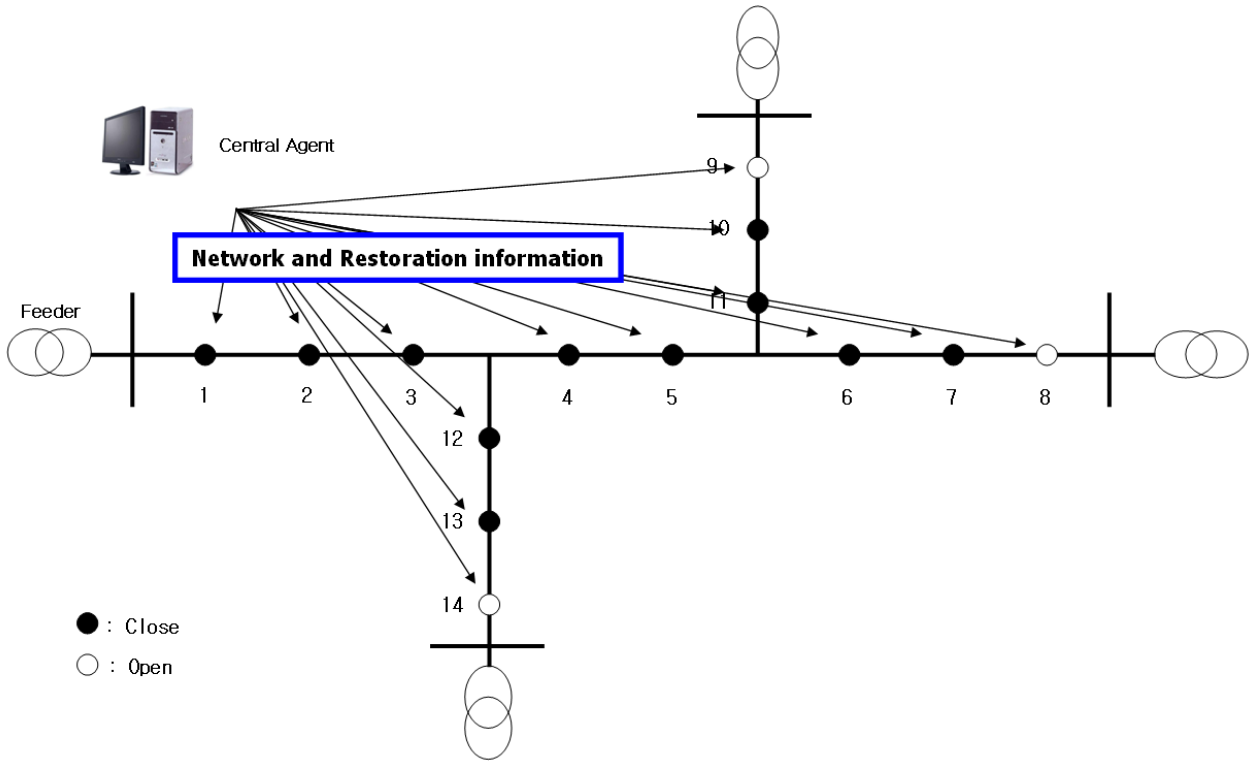


# New FISR has a three steps

1) Adaption of Agents (Information Transmission)
2) Fault Section Identification
3) Service Restoration

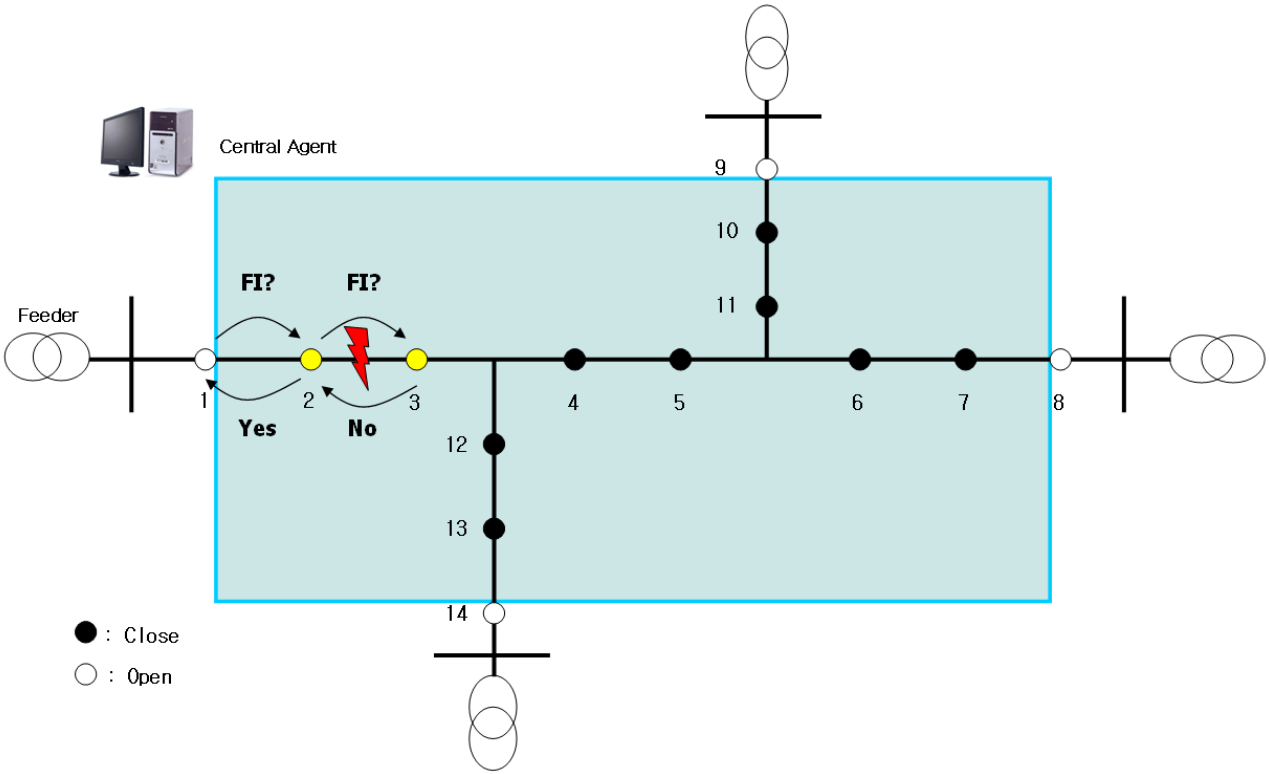
# Adaption of Agents Step (Information Transmission)

- Communication network information (IP address of other agents)
- Switching of pre-planned restoration solution



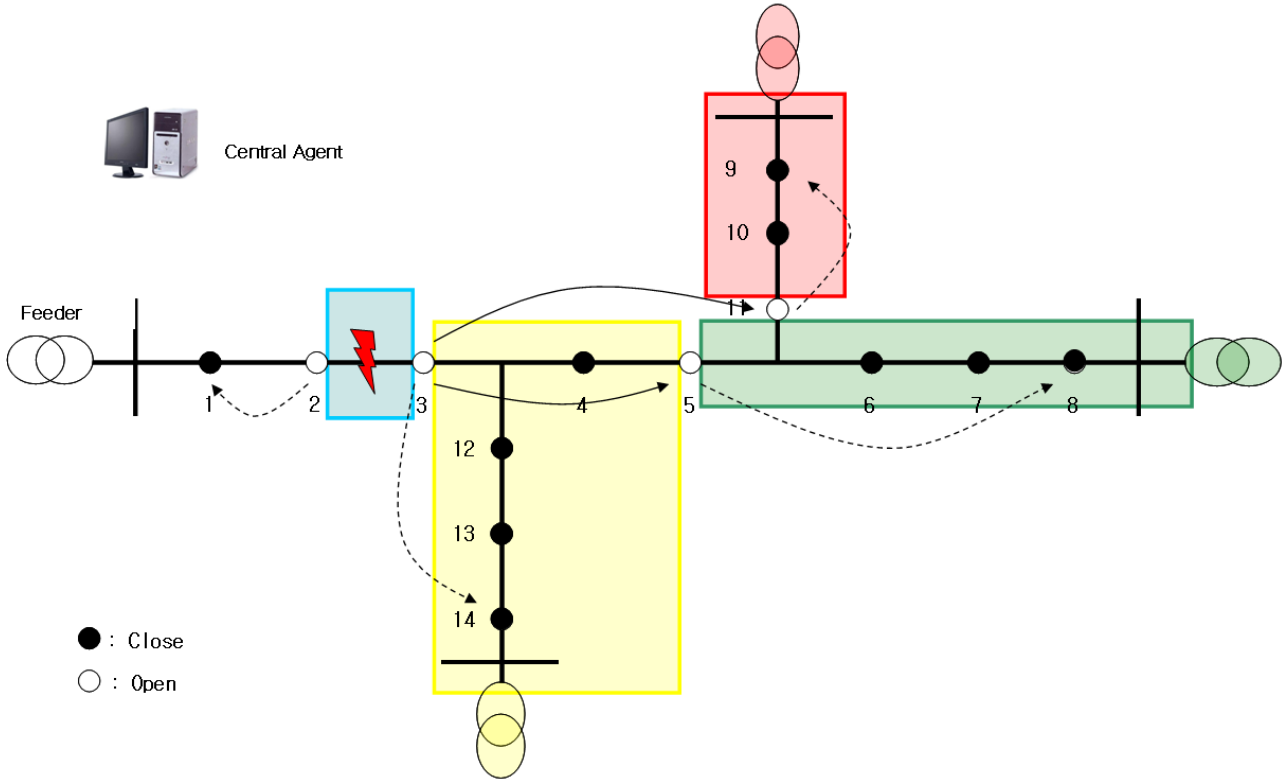
# Fault Section Identification Step

- Exchange of FI & autonomous decision of switching

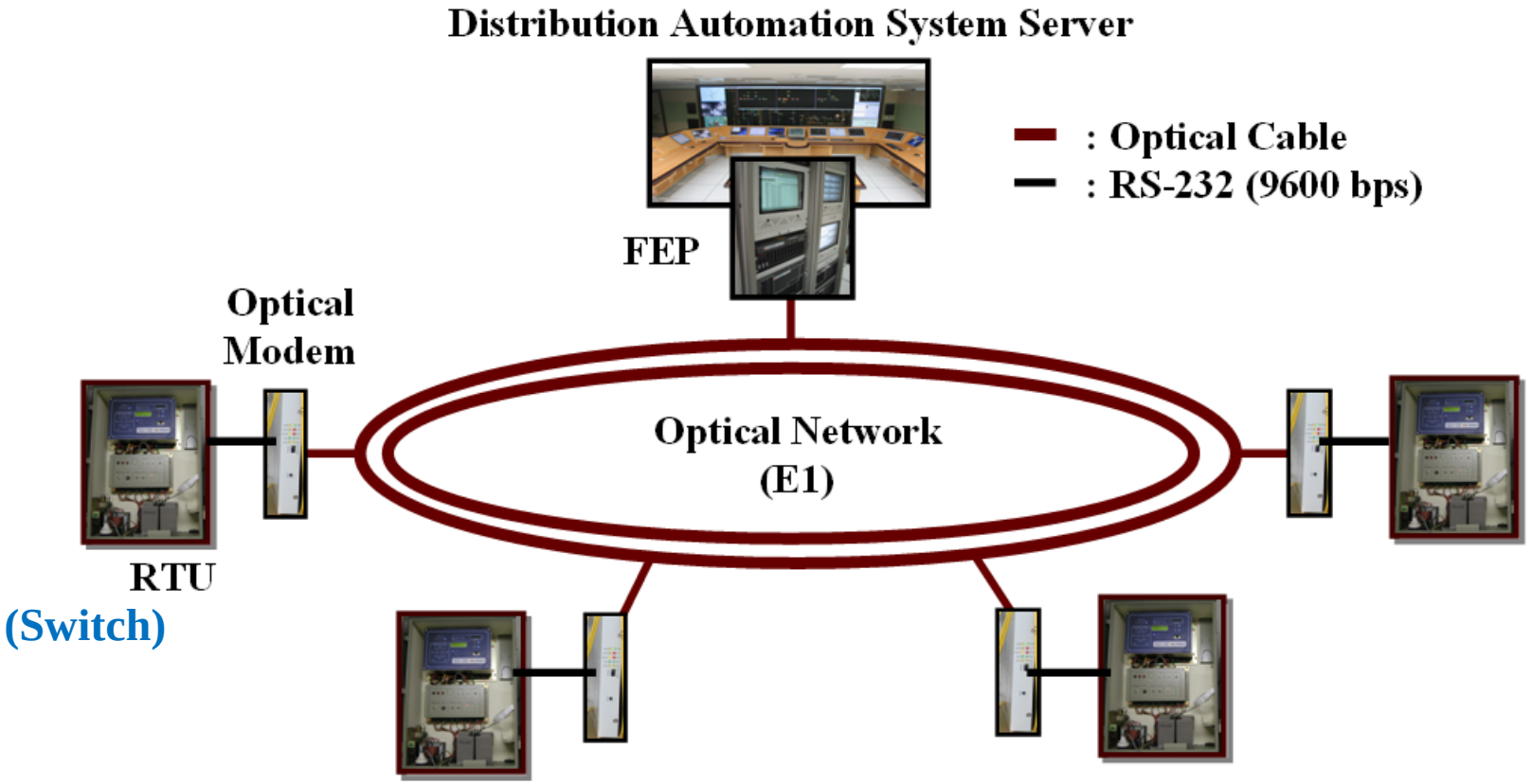


# Service Restoration Step

- Switching command sent to others

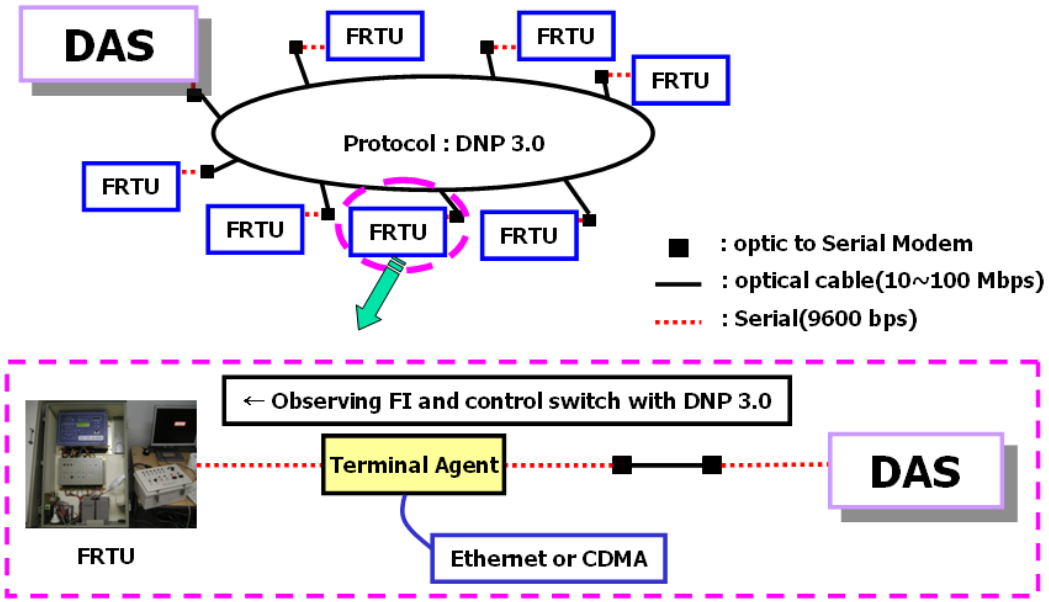


# DNP 3.0 : Master-Slave



# MASX : Agent Enabler

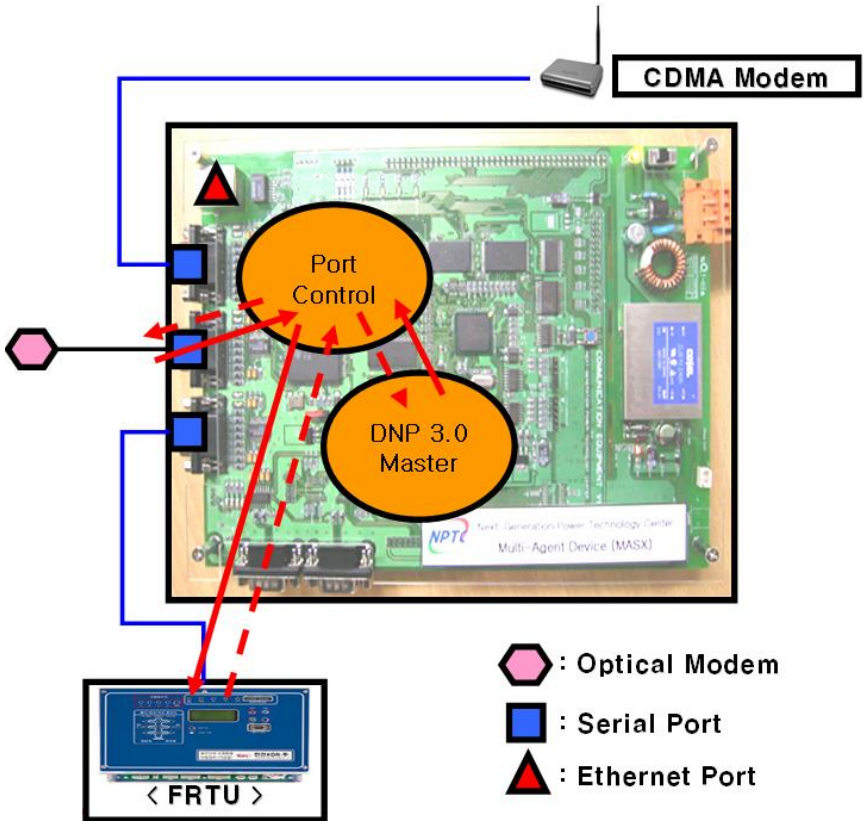

**Agent Device (MASX)**



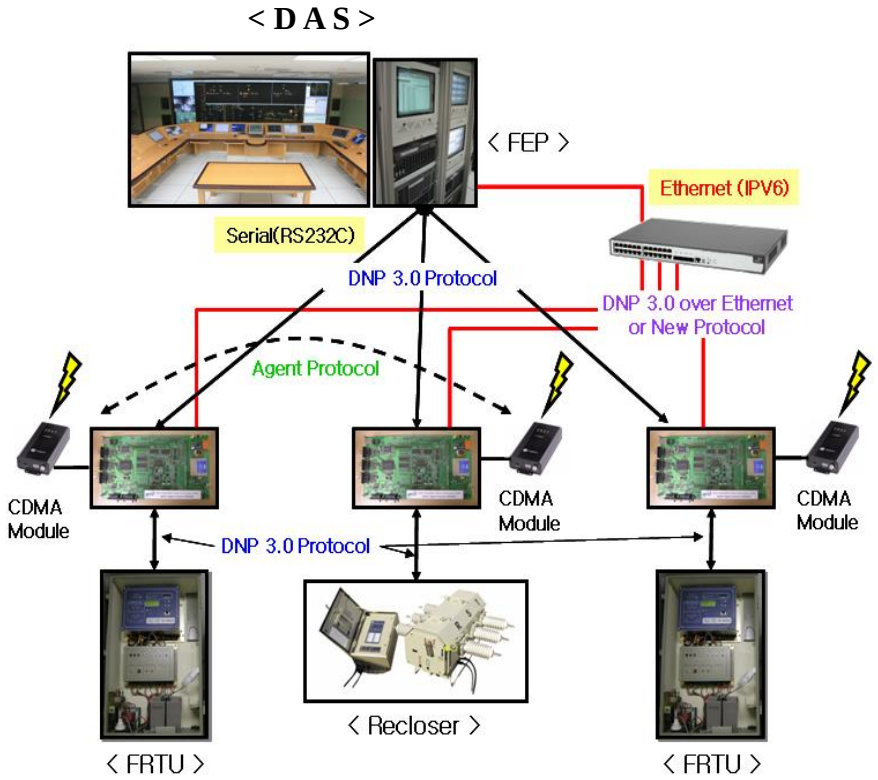

**Application structure of MASX**

# Protocol & Communication structure of MASX

## Protocol structure

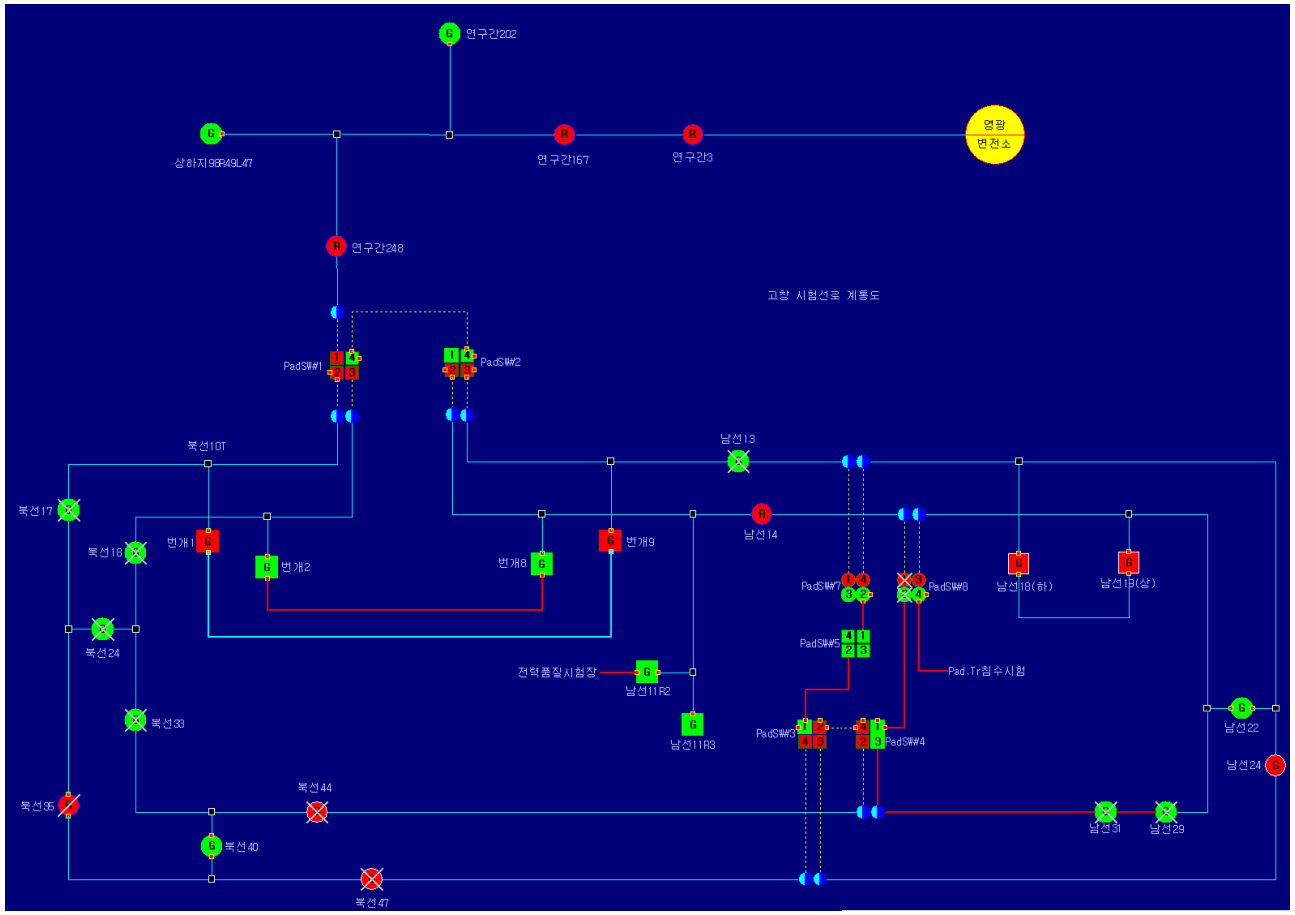



## Communication network structure

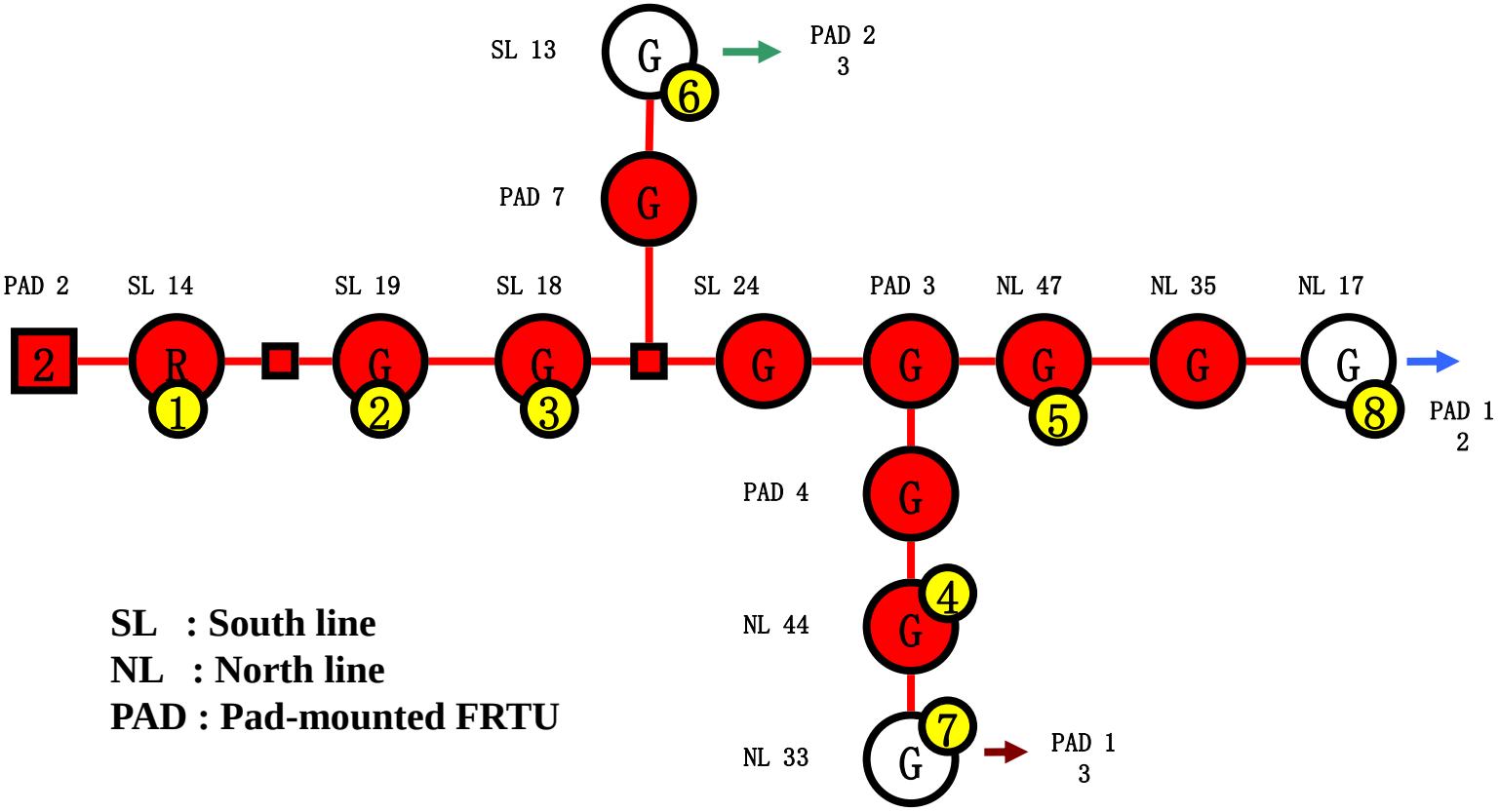


# Test in Gochang test center

- Network diagram



# Example network



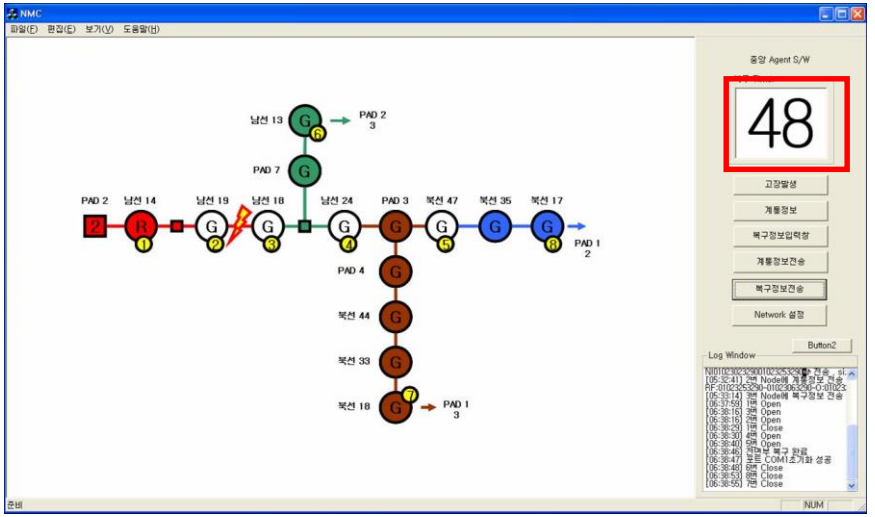
# Field-Test Scenario

- **Fault location**
  - **Between 18 and 19**
- **Fault type**
  - **A phase grounded fault**
- **Restoration solution**
  - **1 related : 03-06-C (from 3 to 6 , close)**
  - **2 related : 03-04-O, 03-06-C, 04-07-C**
  - **3 related : 03-04-O, 03-06-C, 04-05-O, 04-07-C, 05-08-C**

# Artificial Fault Generator

# Test Result

Gochang power test center in Korea
(Preparing field test)




Test result interface

| Index | Restoration solution | Necessary time(s) |
|---|---|---|
| 1 related | 03-06-C | 24 |
| 2 related | 03-04-O, 03-06-C, 04-07-C | 36 |
| 3 related | 03-04-O, 03-06-C, 04-05-O, 05-08-C, 04-07-C | 48 |

Test result measurement

# Conclusions

- Communication-based FISR introduced

A. Ungrounded system

- Outage free
- More efficient usage of power equipments

B. Solidly grounded system

- Faster fault handling time
  - from 5 ~ 8 min to less than 1 min (CDMA)
  - a few seconds (Ethernet)

# More information at APAP2017

www.apap2017.org

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