Distributed Restoration System for Improved Distribution Grid Reliability

Michael Quinlan, Yoav Sharon

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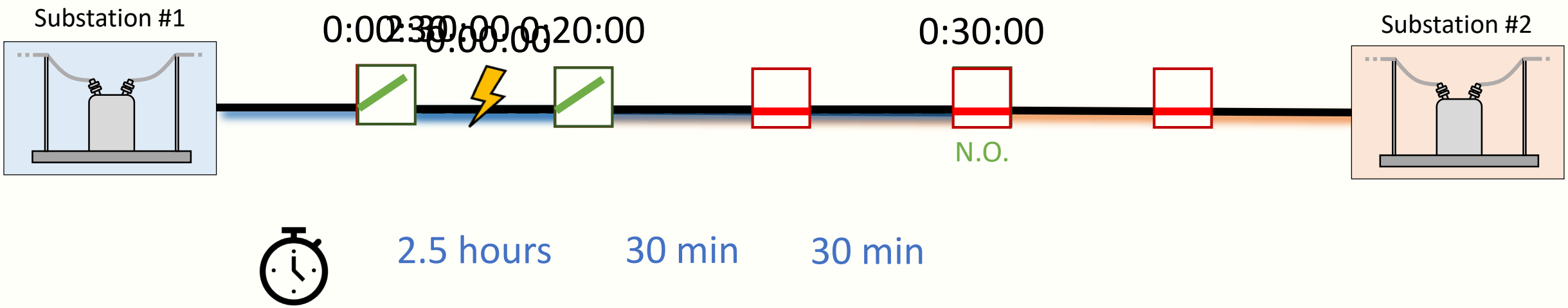
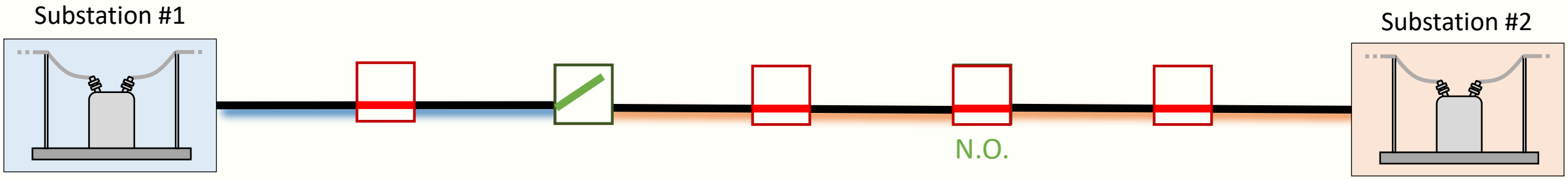
Fault Location Isolation & Service Restoration (FLISR)

Manual Process



Fault Location Isolation & Service Restoration (FLISR)

Manual Process → Automated Process



	2.5 hours	30 min	30 min	**89910 CMI**
	2 hours	20 sec	20 sec	**40071 CMI**
$	$42,850	$25,579	$25,579	**$94,008**
$	$36,879	$15,412	$15,412	**$67,703**

55% reduction in CMI

Customer Minutes of Interruption

$26,305 saved per event

[1] Assuming 333 customers per section, from https://icecalculator.com/interruption-cost

FLISR Success Stories

Electric Power Board (EPB): 43% CMI reduction [1]

~$26.8 million/year in savings

City of Naperville: 85% CMI reduction [2]

SAIDI improved from 120 min (1992) to 18 min (2010)

Survey of 5 Utilities: 51% CMI reduction [3]

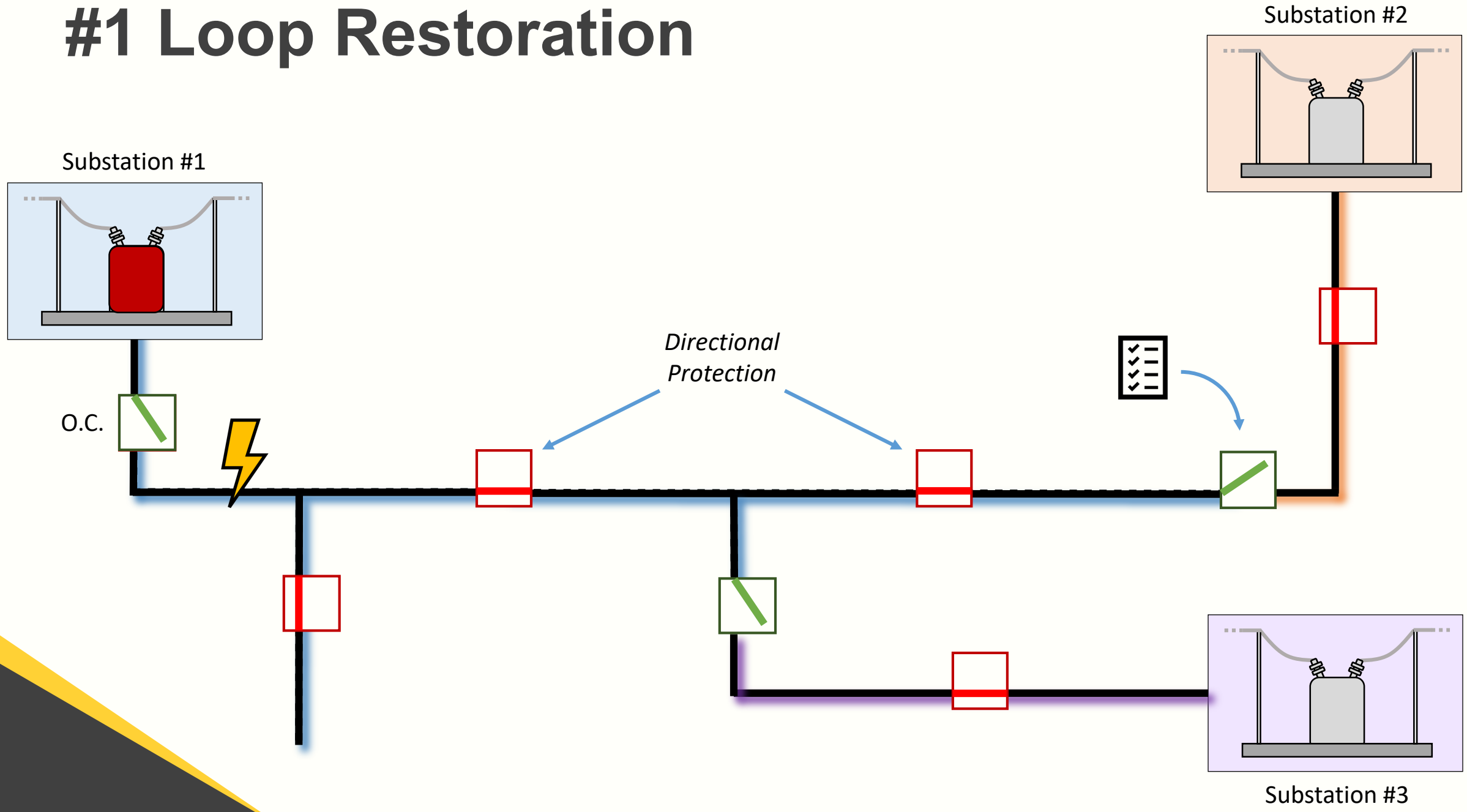
Customer Interruptions (CI) reduced up to 45%

[1] "Chattanooga Electric Power Board Case Study—Distribution Automation" (ornl.gov)
[2] "The Naperville Smart Grid Initiative" (smartgrid.gov)
[3] "Fault Location, Isolation, and Service Restoration Technologies Reduce Outage Impact and Duration" (smartgrid.gov)

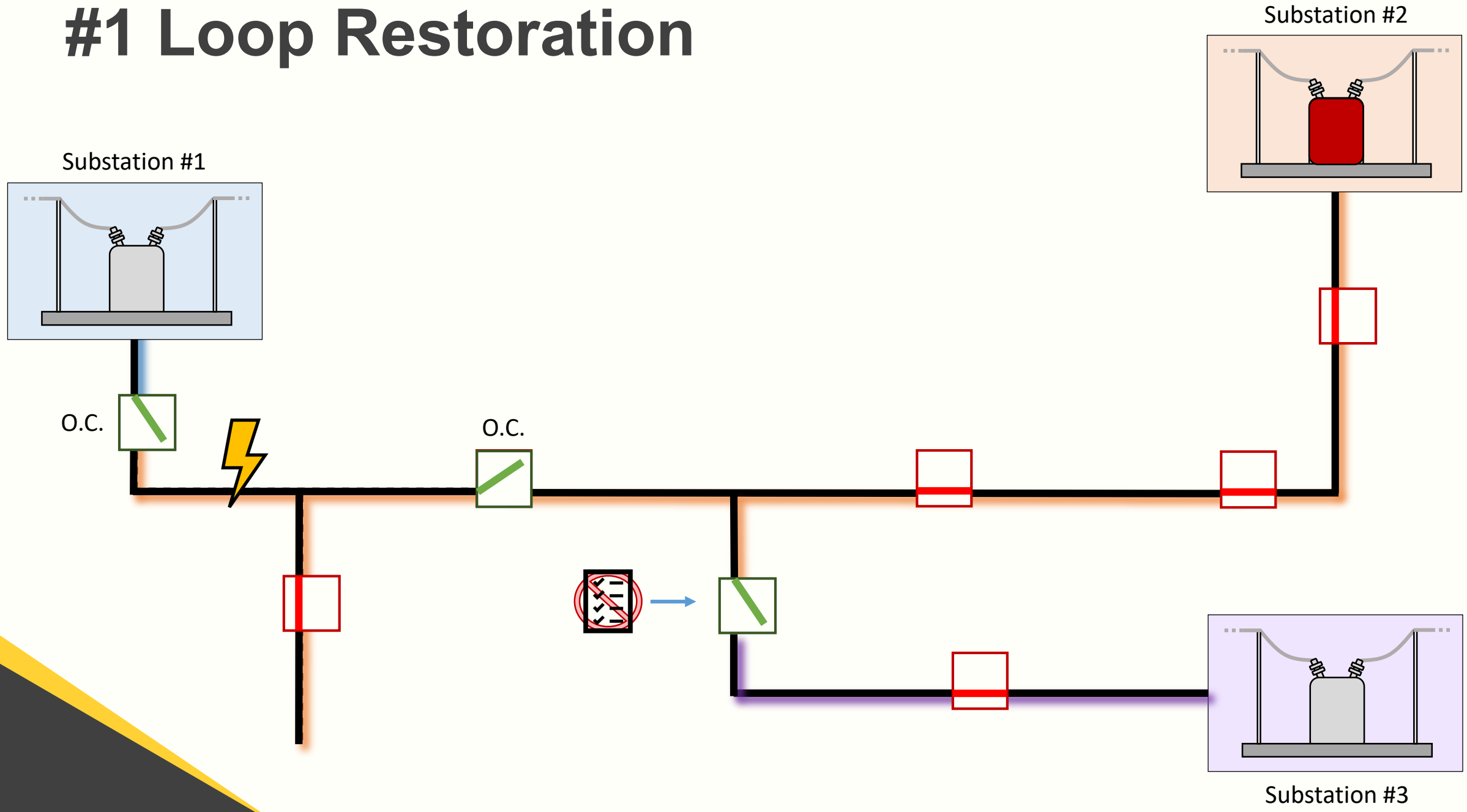
Approaches

1. Loop Restoration
2. Substation Automation
3. Distributed Intelligence
4. Advanced Distribution Management System (ADMS)

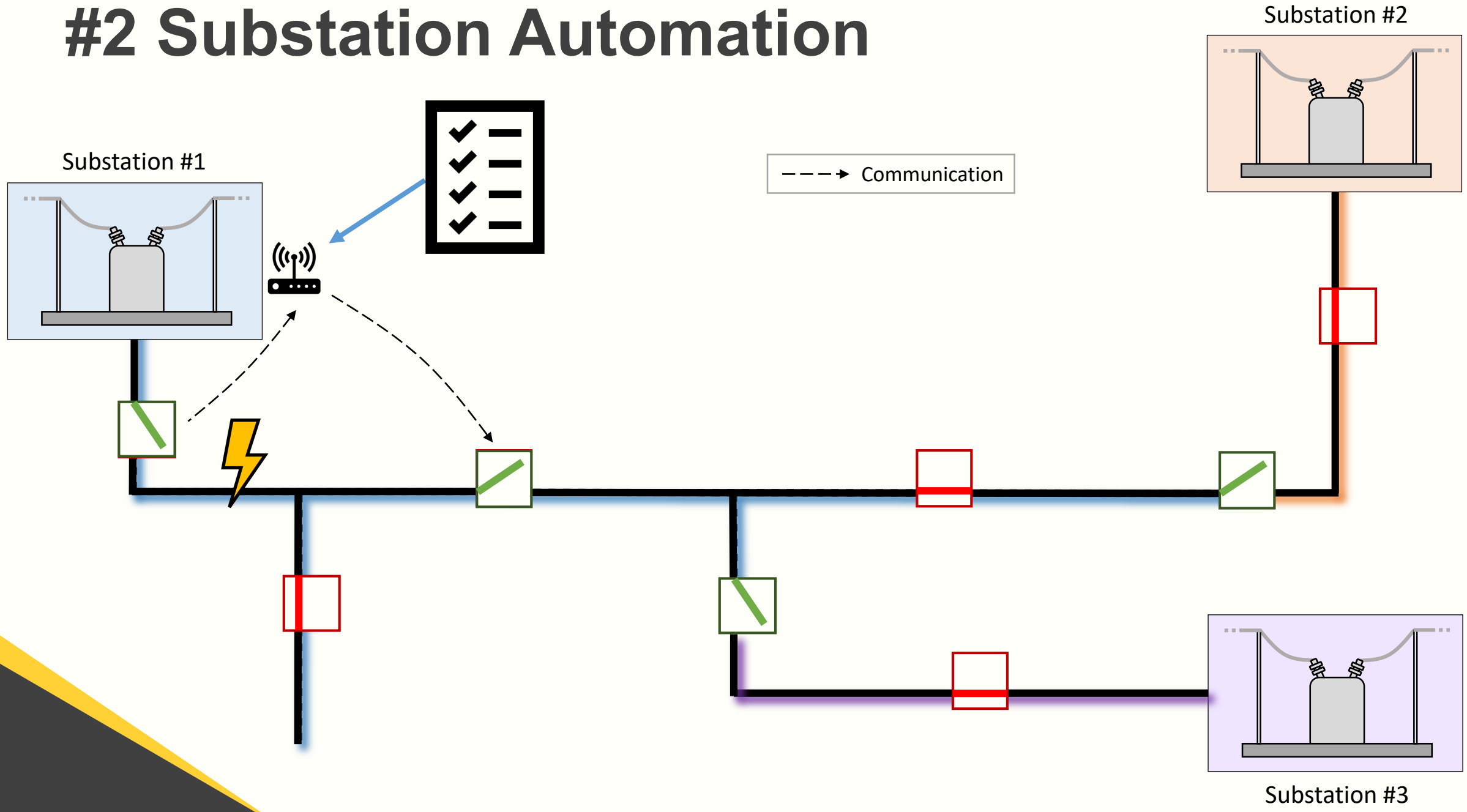
#1 Loop Restoration



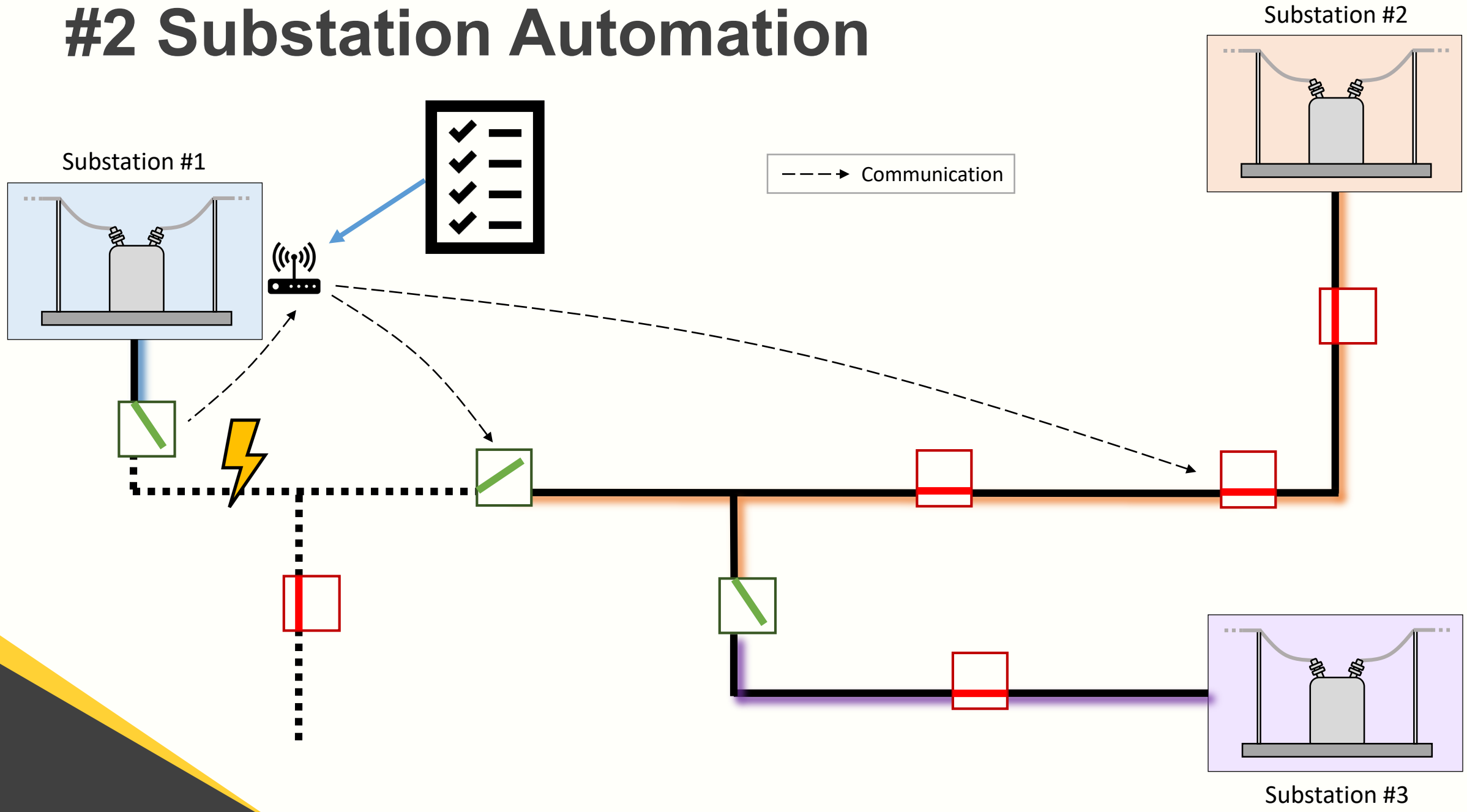
#1 Loop Restoration



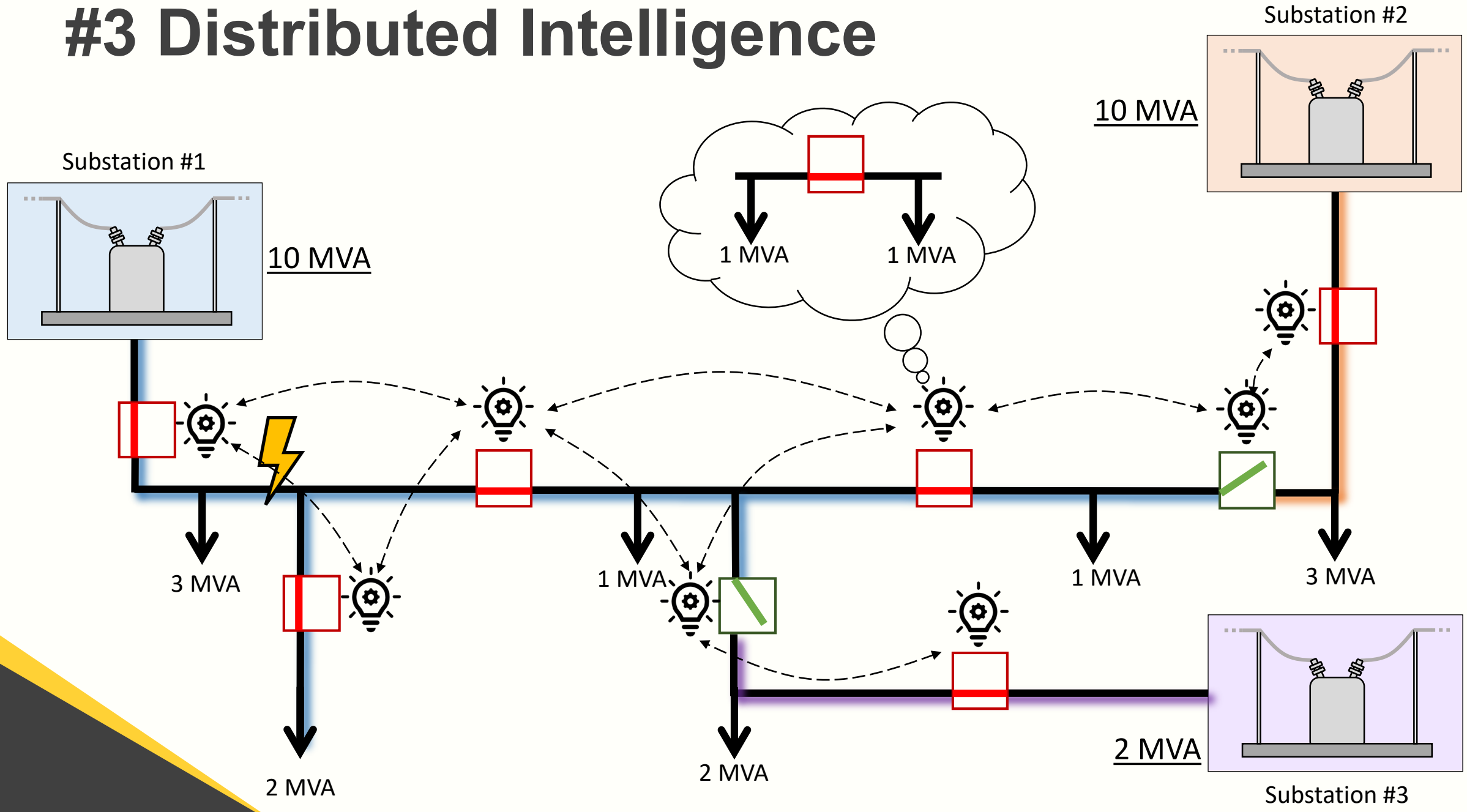
#2 Substation Automation



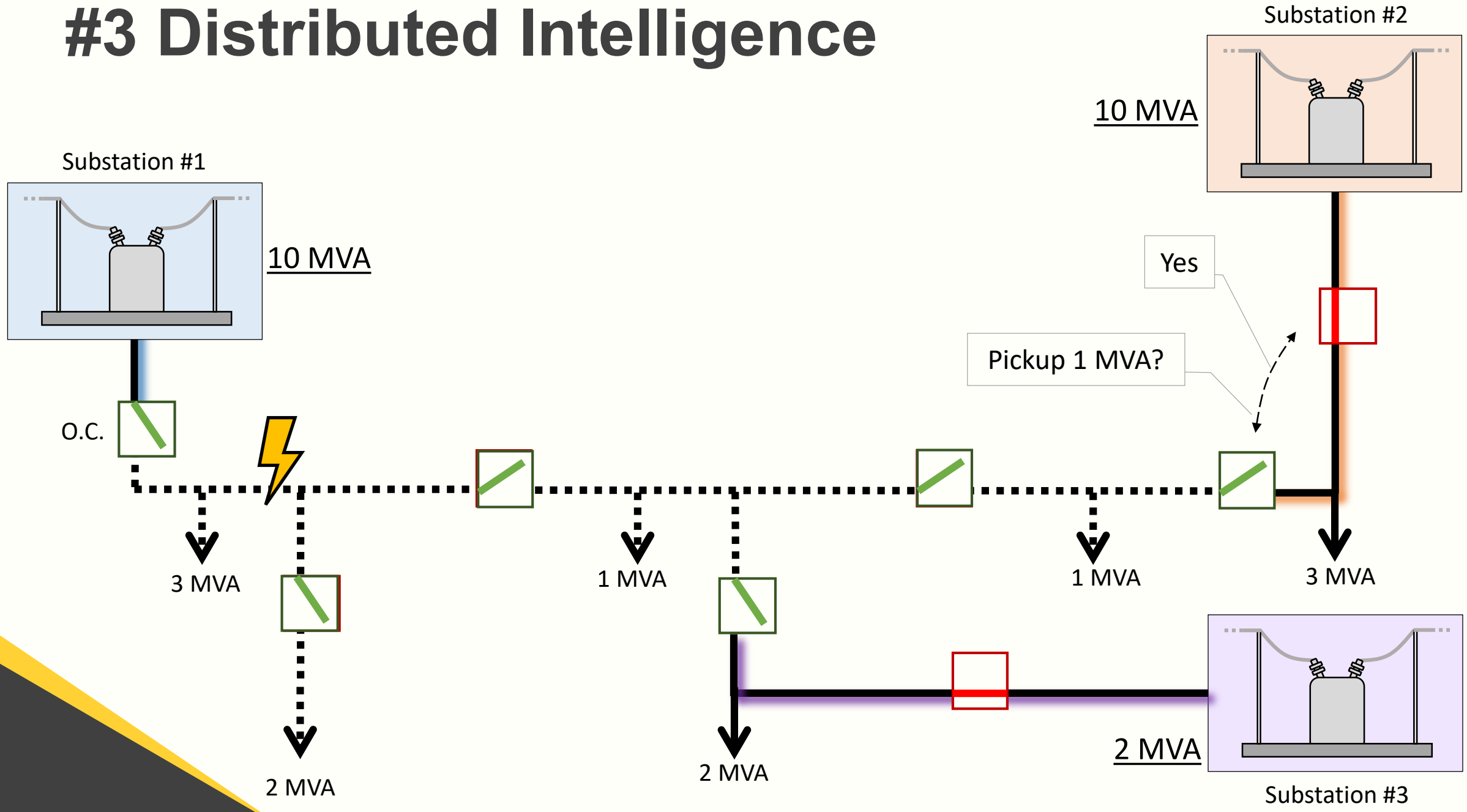
#2 Substation Automation



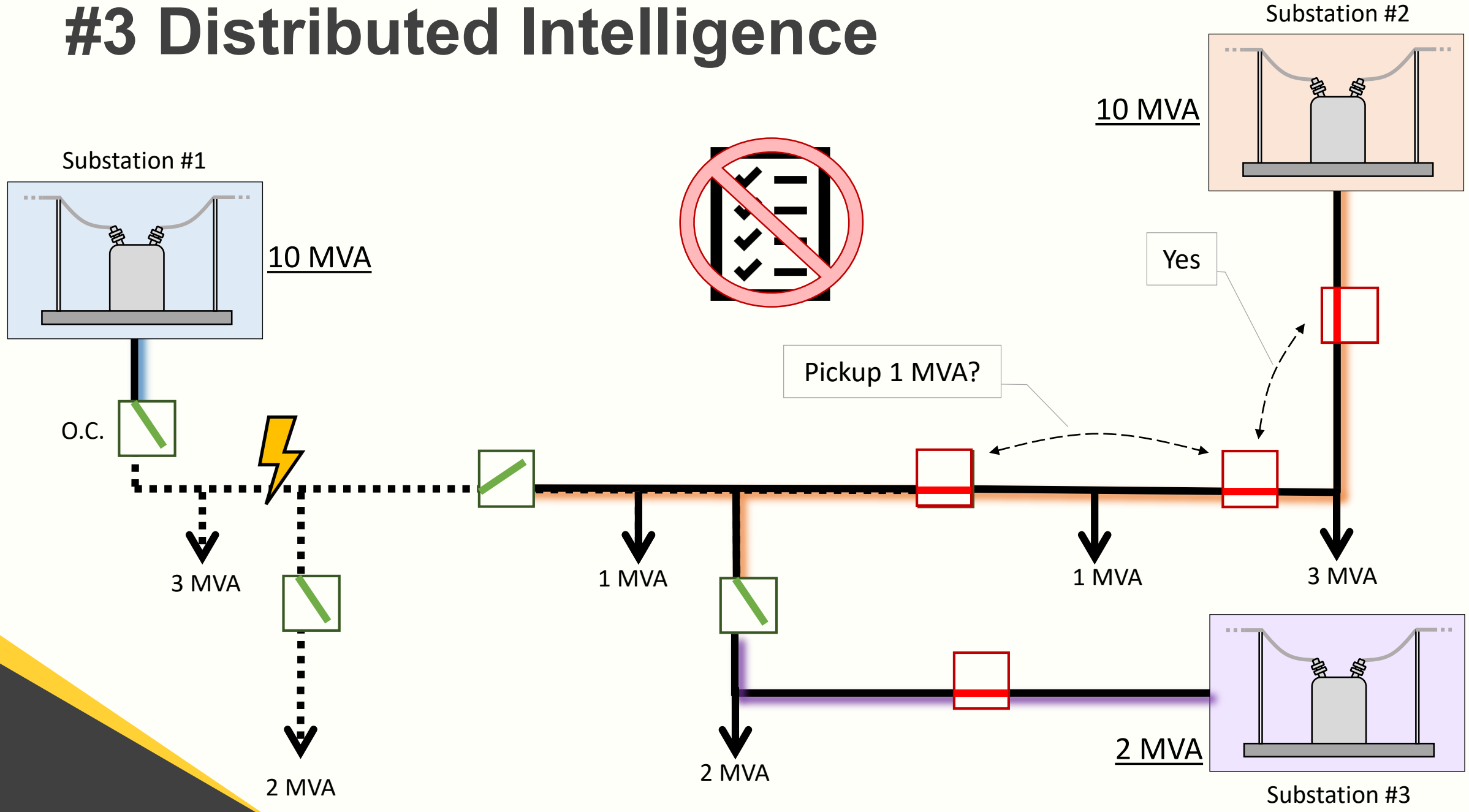
#3 Distributed Intelligence



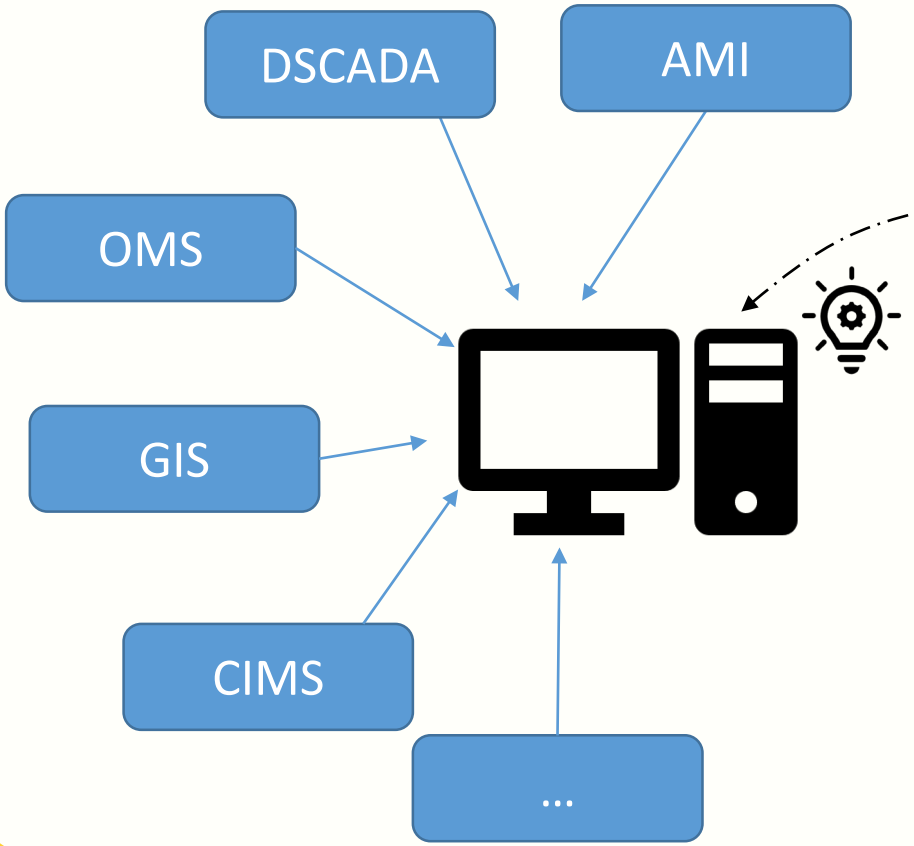
#3 Distributed Intelligence

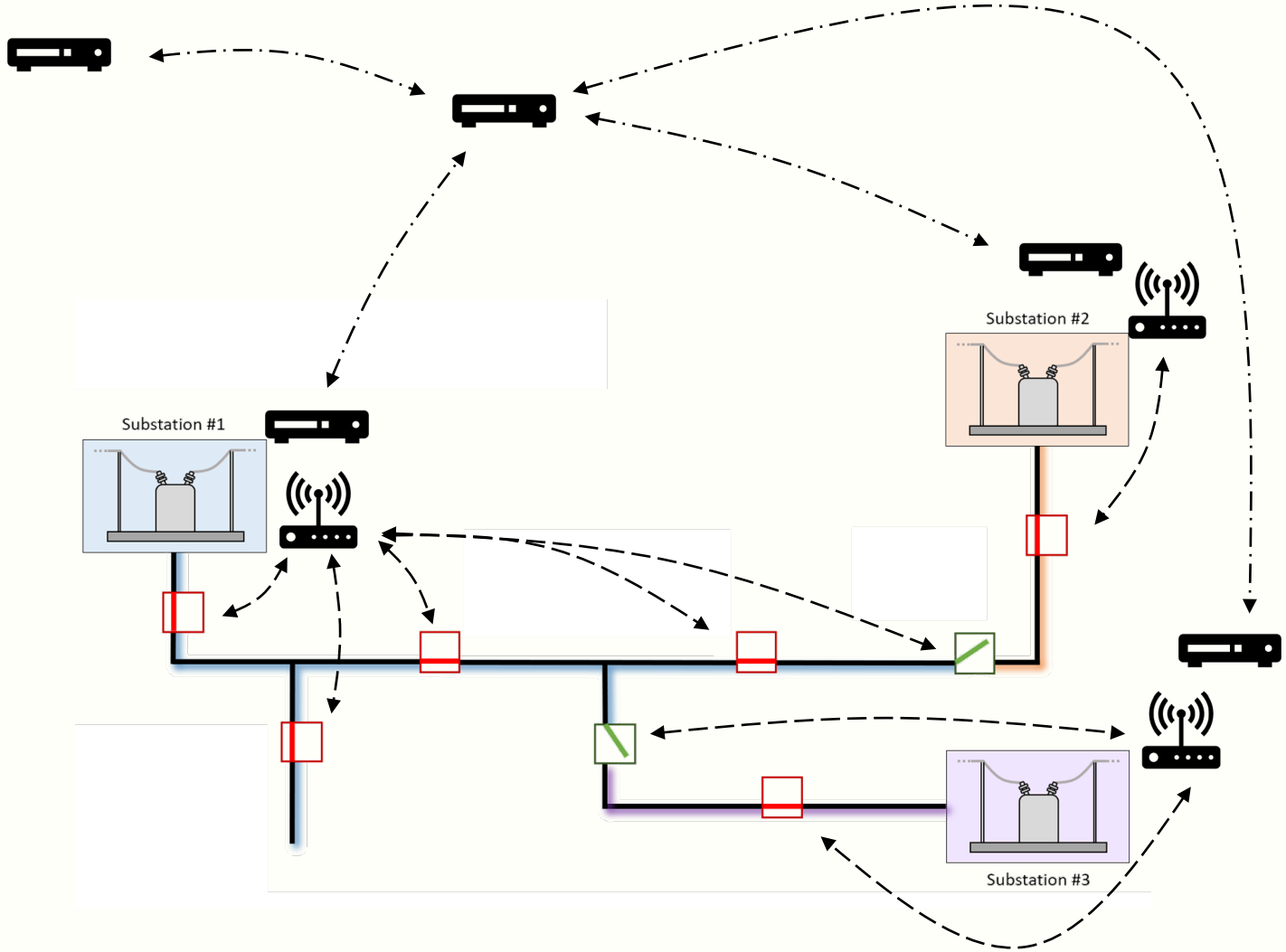


#3 Distributed Intelligence



#4 ADMS


DSCADA
AMI
OMS
GIS
CIMS
...

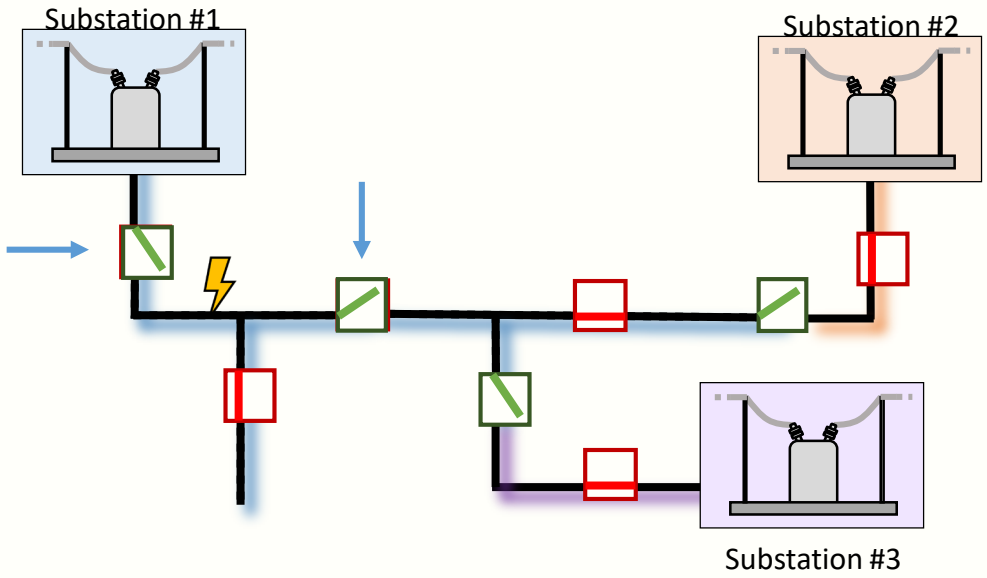

Substation #1
Substation #2
Substation #3

Performance vs. Cost

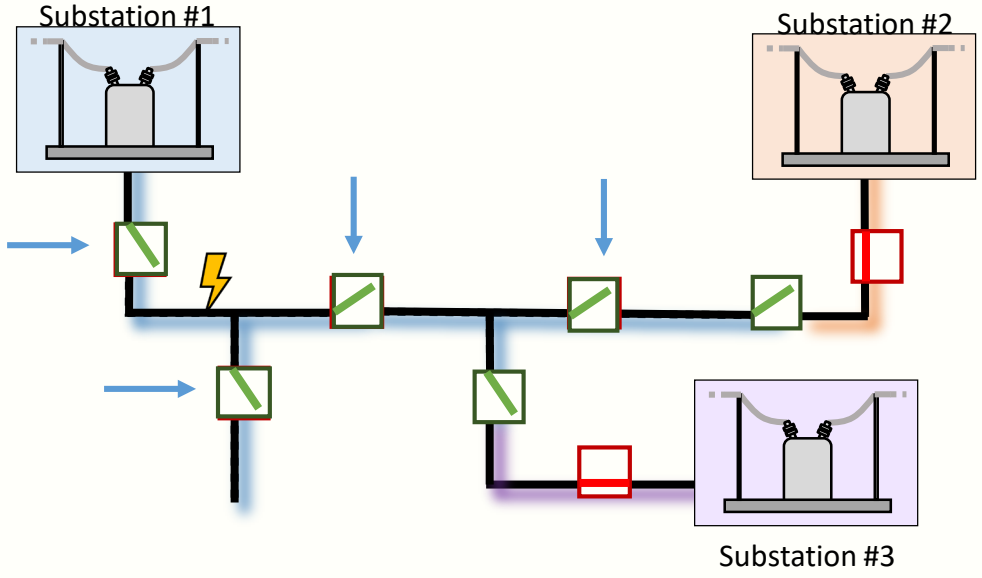
	Loop Restoration	Substation Automation	Distributed Intelligence	ADMS
Speed				
Customers Restored				
Reliability				
Setup				
Maintenance				
Scalability				

Distributed Intelligence Scope

Feeder Level Restoration

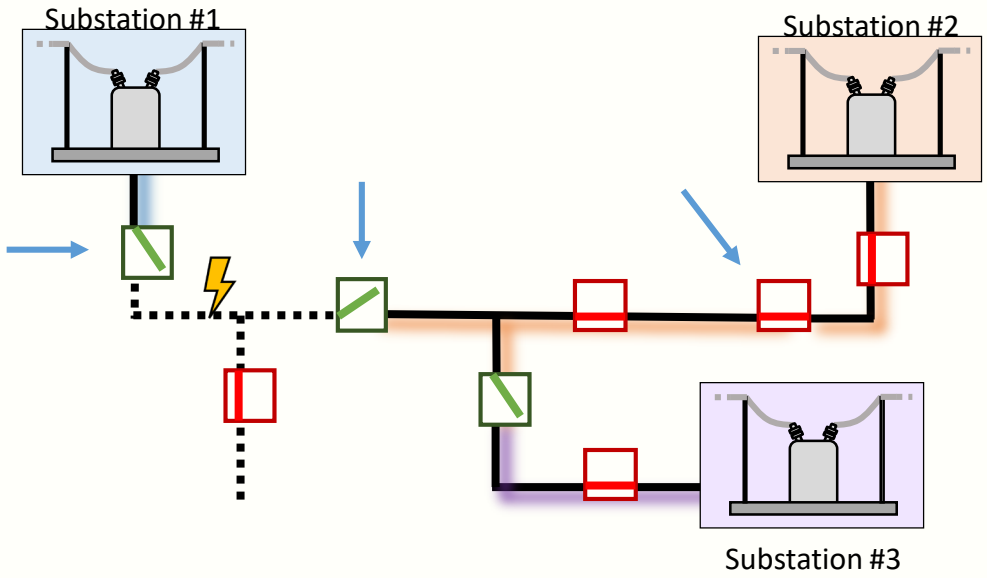


Segment Level Restoration



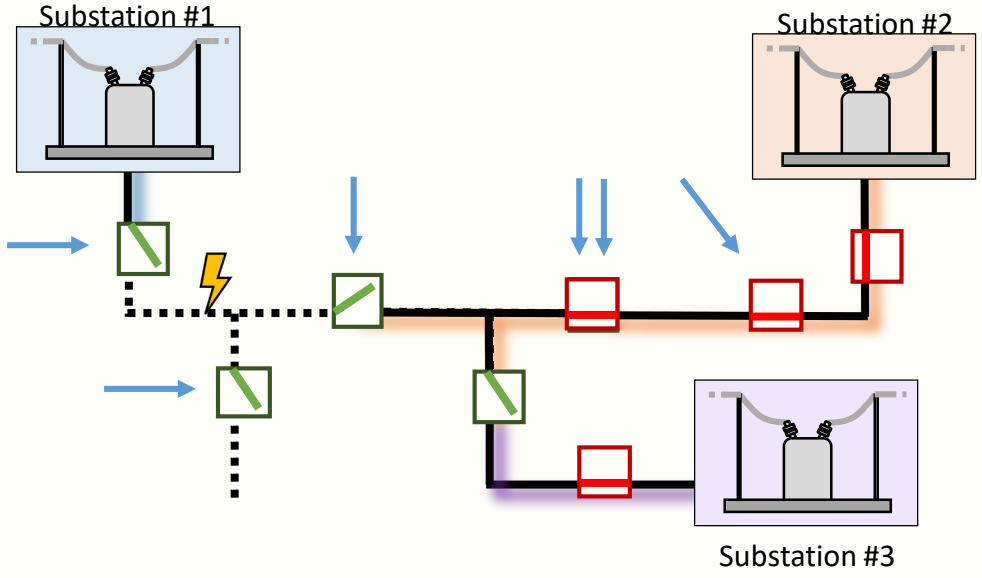
Distributed Intelligence Scope

Feeder Level Restoration



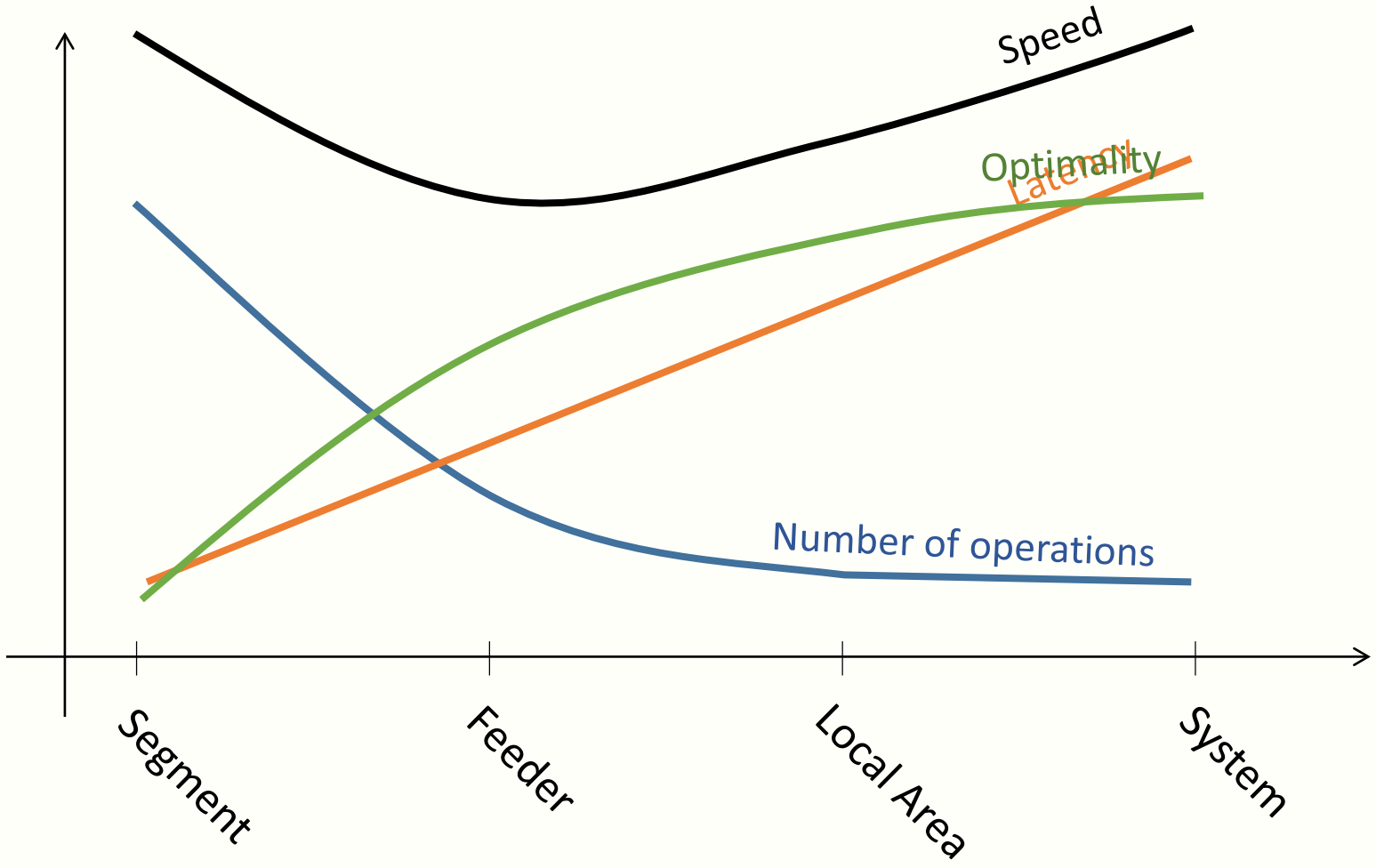
Number of operations: 3
Number of steps: 3

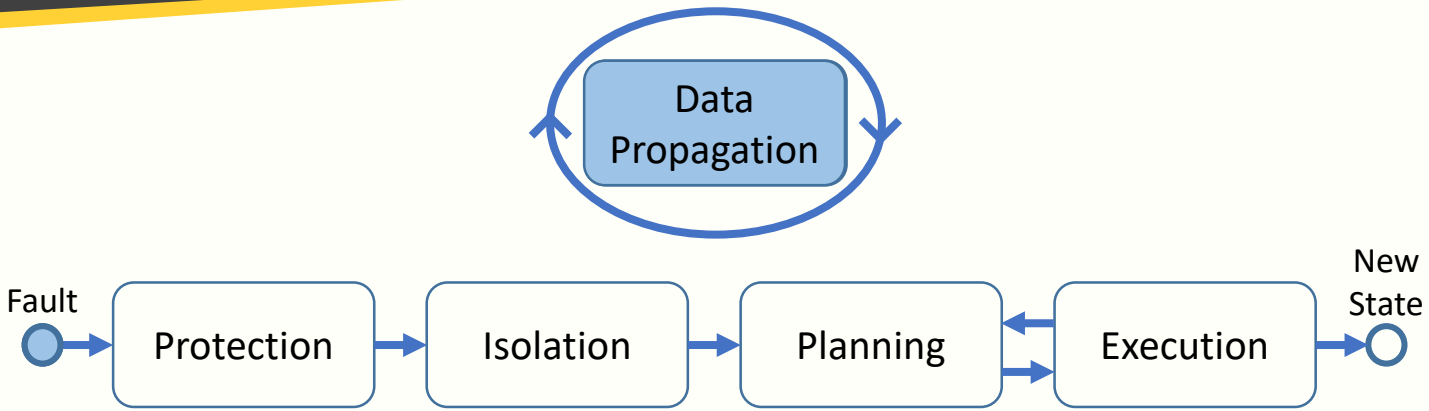
Segment Level Restoration

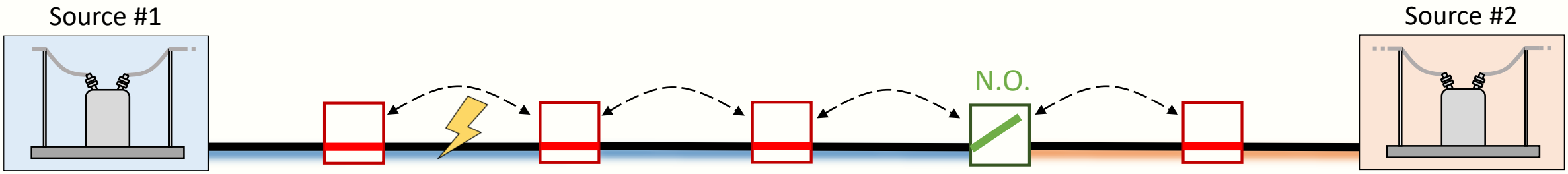


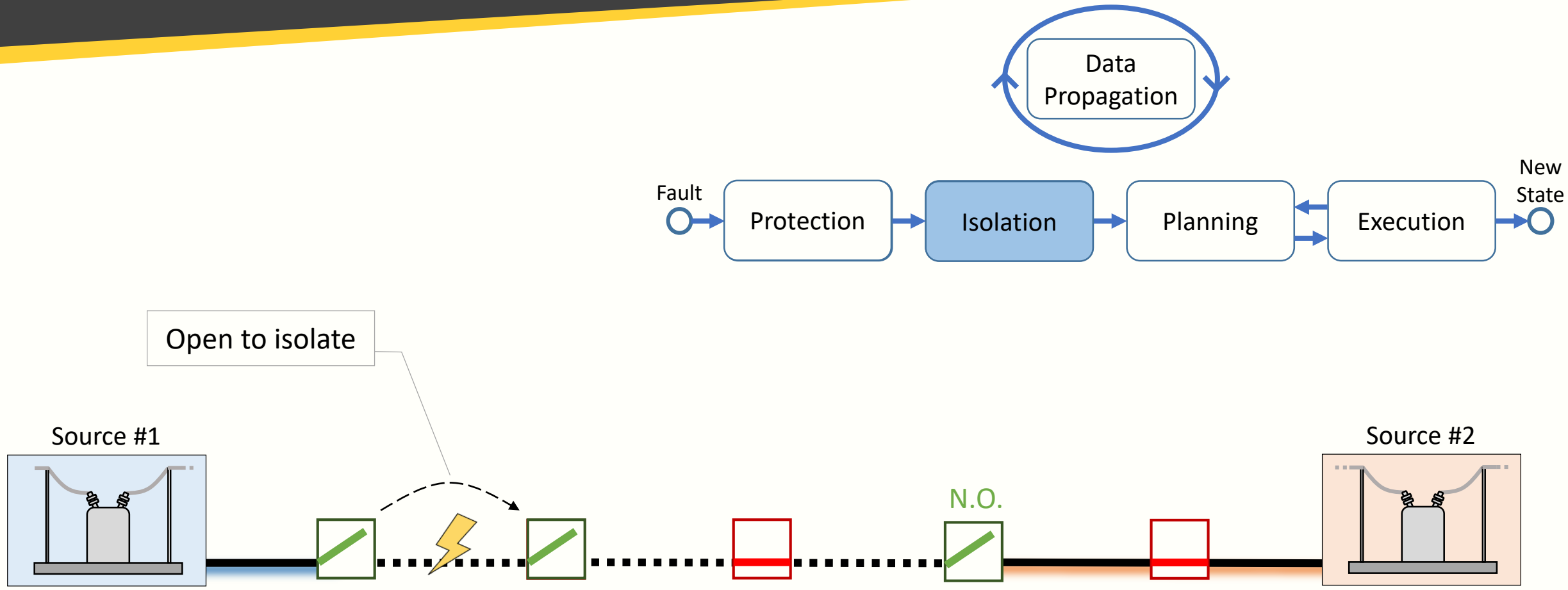
Number of operations: 6
Number of steps: 4

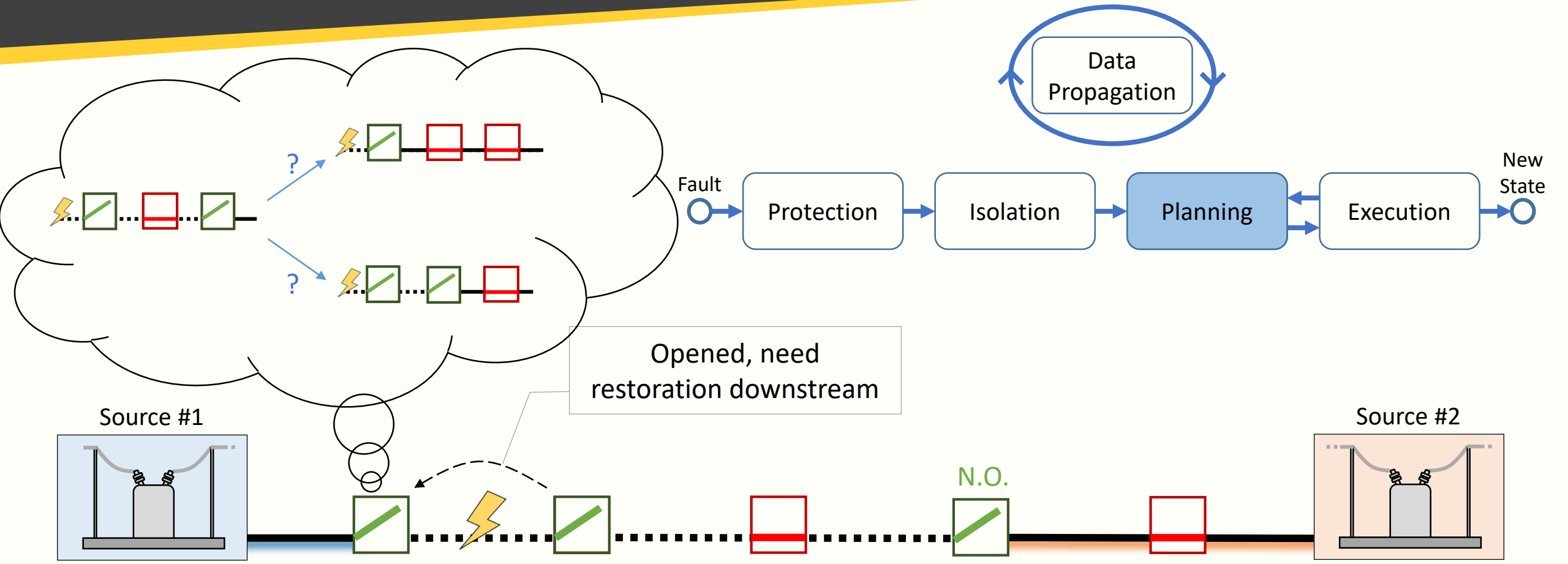
Scope of Distributed Intelligence

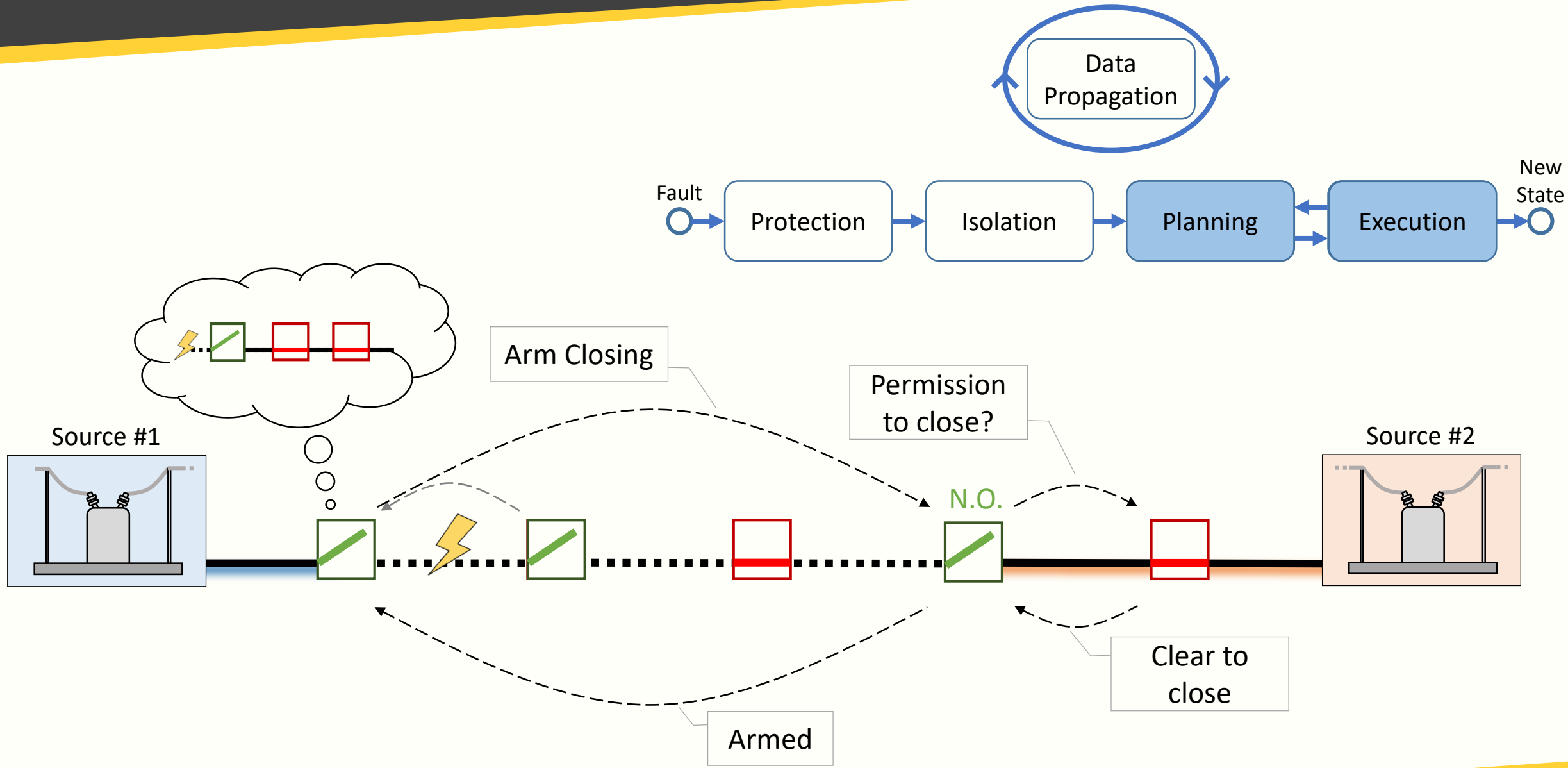


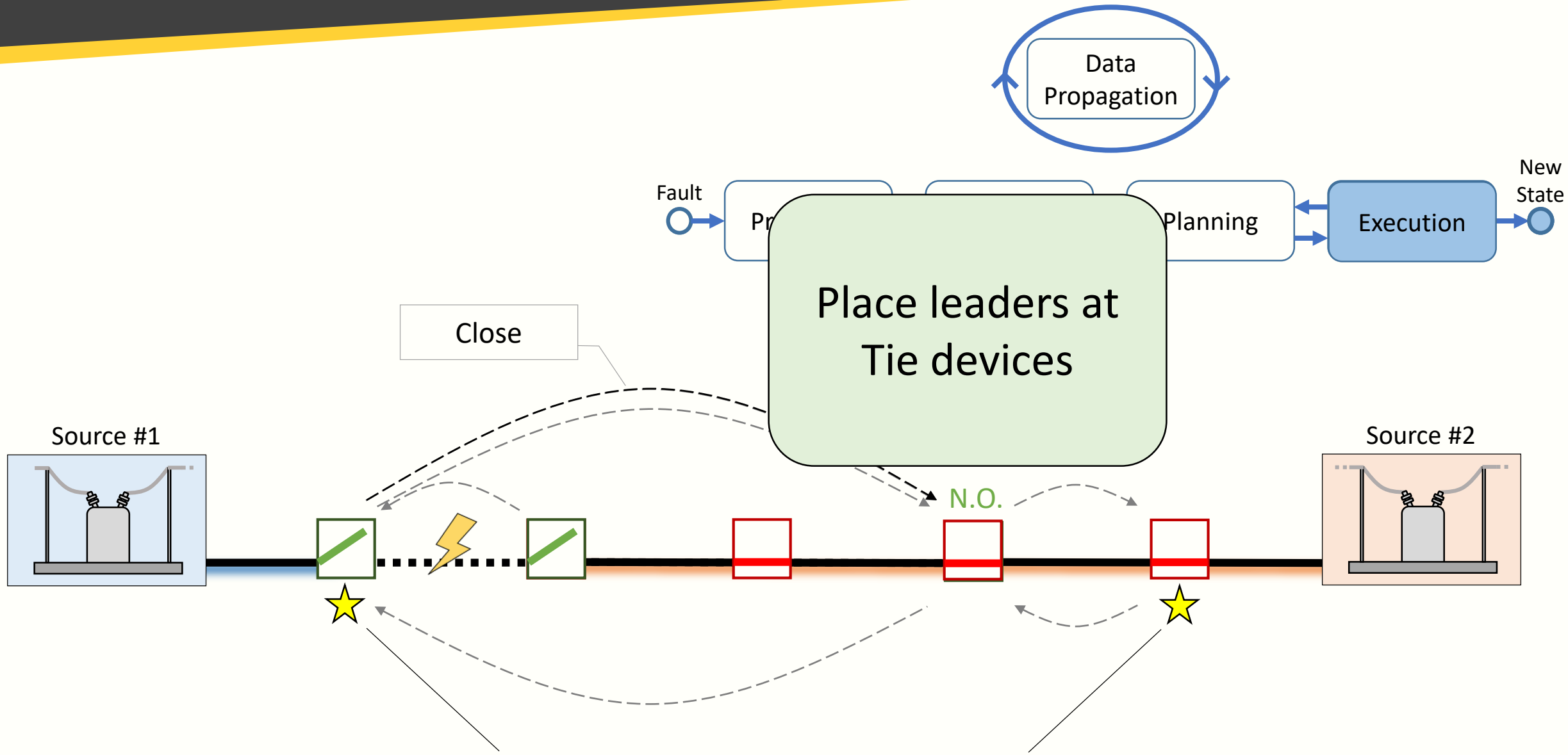

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State


Source #1
N.O.
Source #2

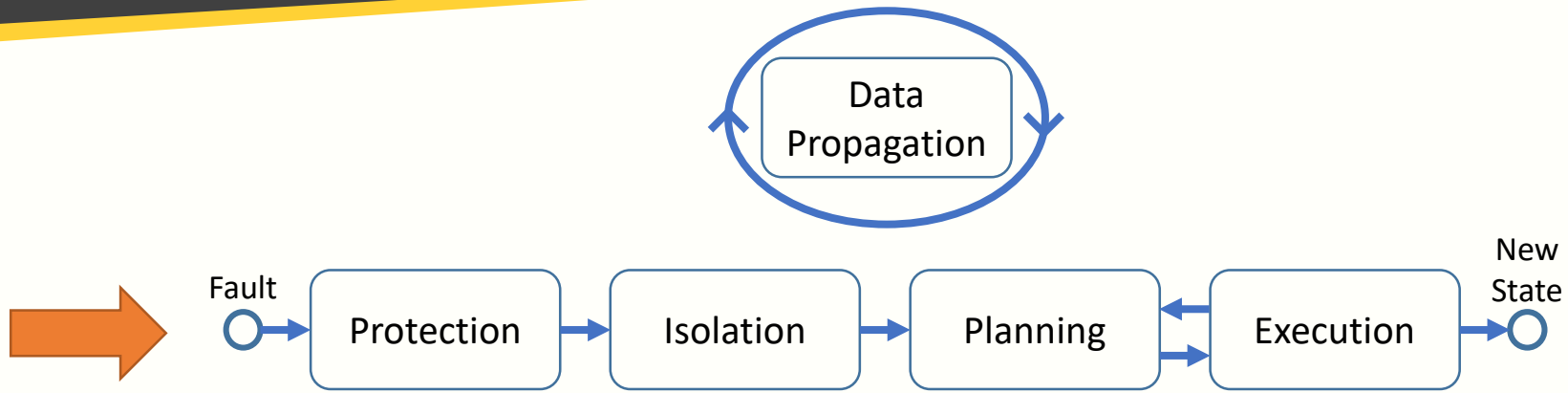

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State
Open to isolate
Source #1
N.O.
Source #2

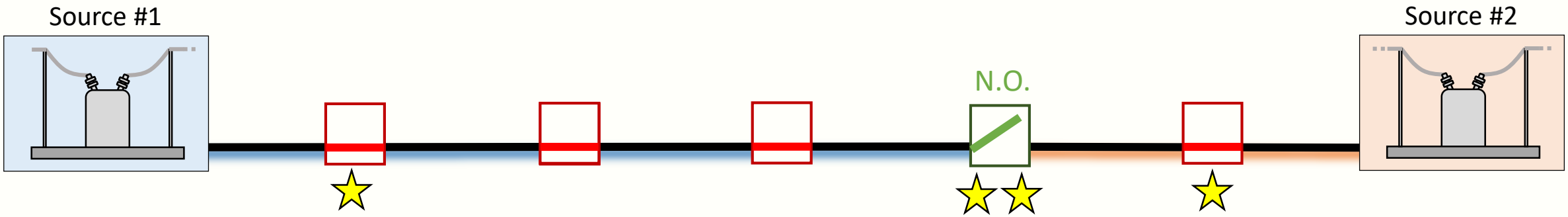

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State
?
?
Opened, need restoration downstream
Source #1
Source #2
N.O.

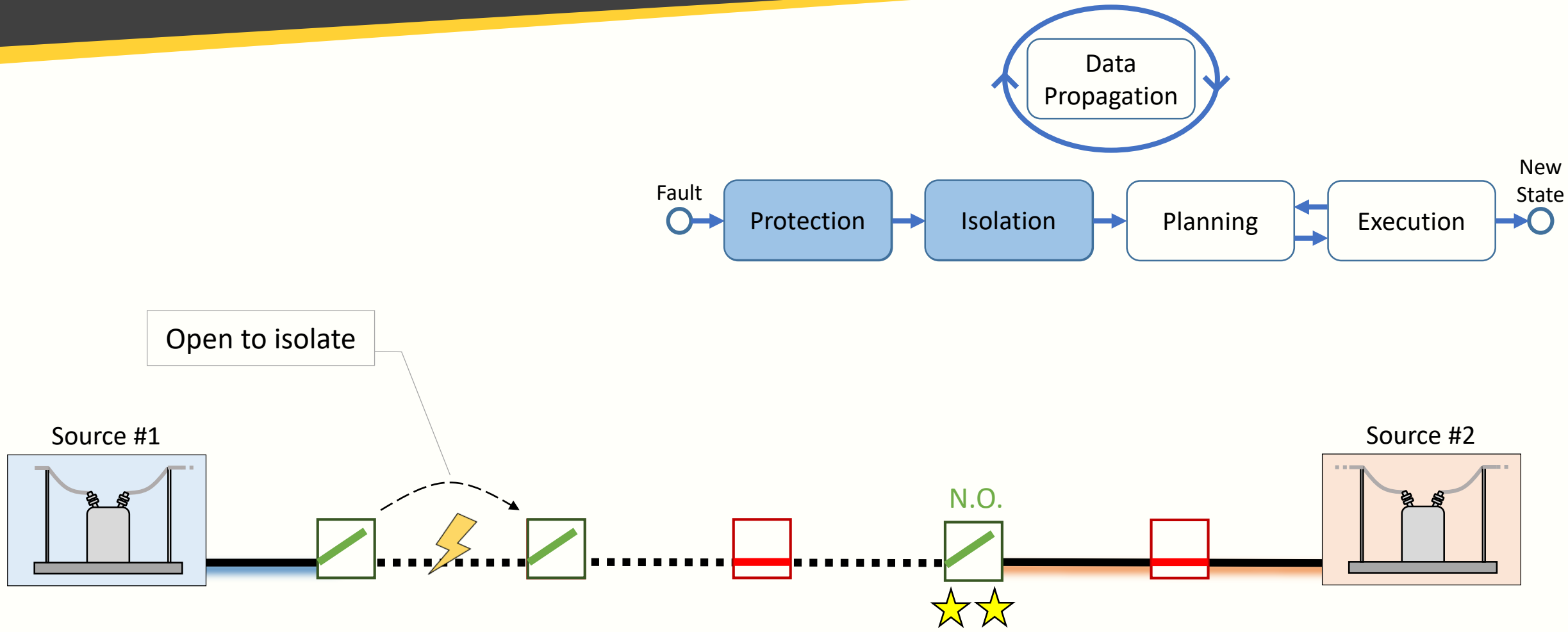

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State
Arm Closing
Permission to close?
Source #1
Source #2
N.O.
Clear to close
Armed

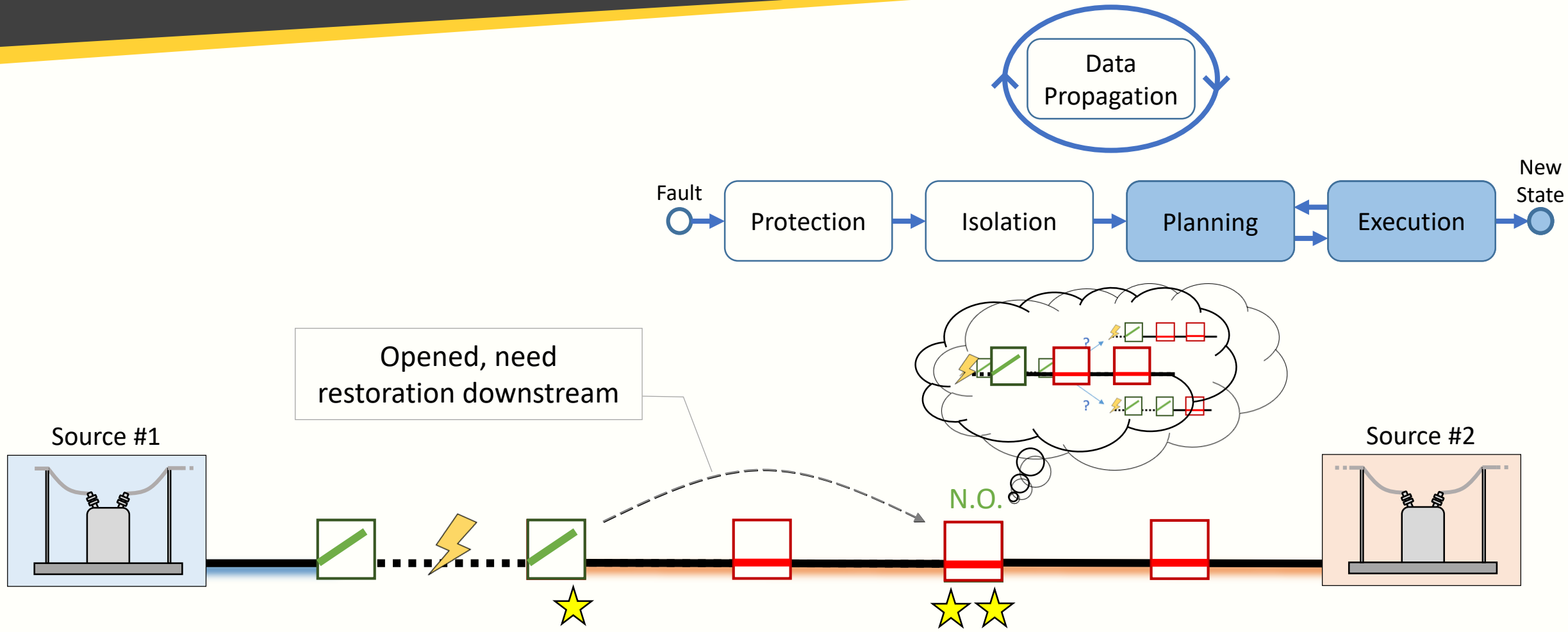


Leader: coordinate restoration for a feeder

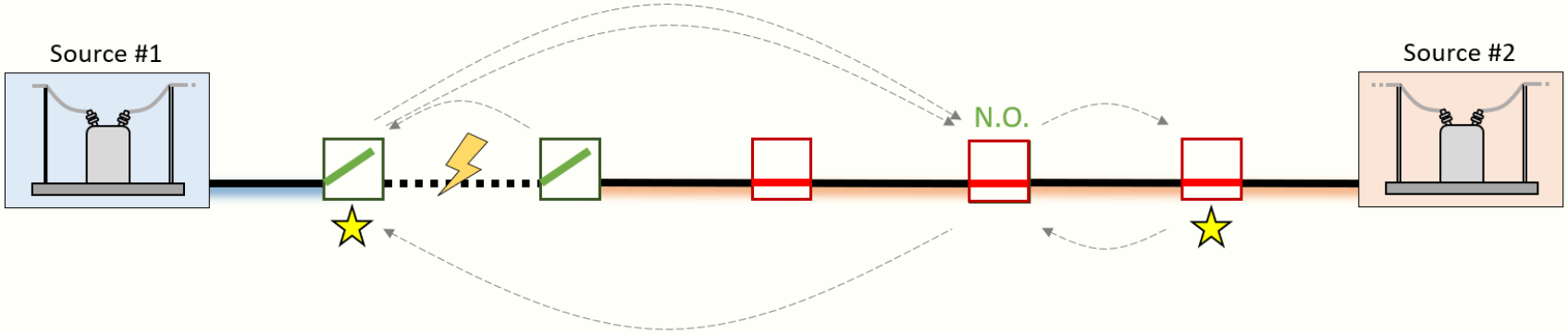

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State


Source #1
N.O.
Source #2


Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State
Open to isolate
Source #1
Source #2
N.O.

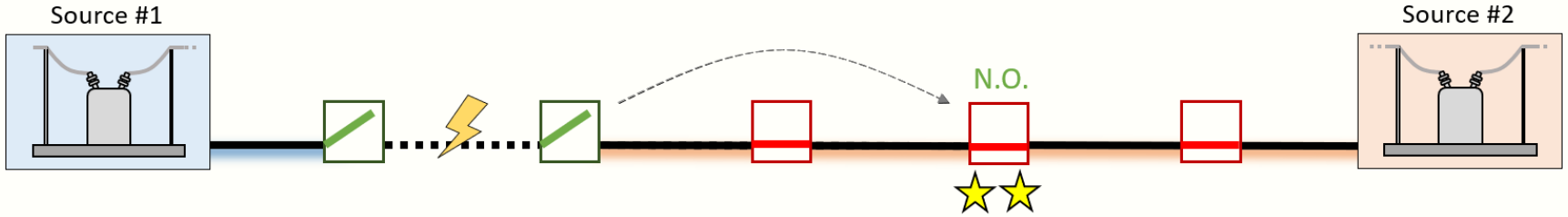

Data Propagation
Fault
Protection
Isolation
Planning
Execution
New State
Opened, need restoration downstream
Source #1
Source #2
N.O.

Dynamic Leader Allocation to Tie Switches



Decreasing the number of messages

Reducing the number of critical devices to minimum

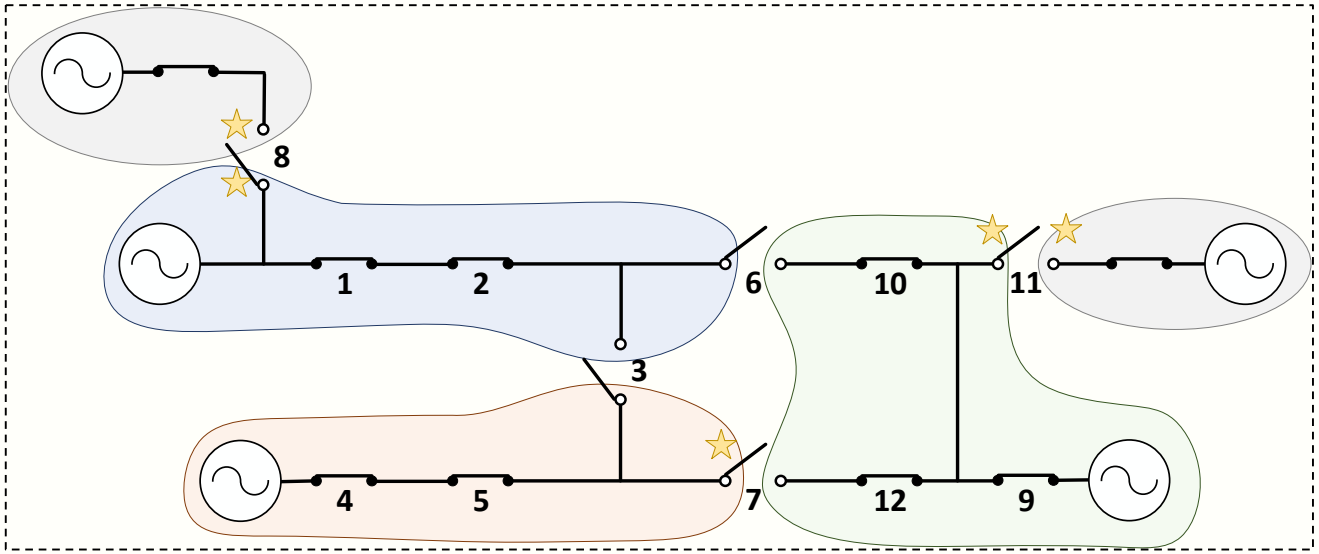


Summary

- Comparison of different FLISR approaches
  - Loop Restoration
  - Substation Automation
  - Distributed Intelligence (DI)
  - ADMS
- Diminishing returns with increasing scope of DI
- Benefits of *dynamically* assigning ties as leaders

Additional Information in Paper

- Detailed comparison of the different FLISR approaches
- Detailed procedure of feeder level distributed intelligence
- Review of fault location schemes
- Other benefits of leaders in the ties
- More complex scenarios



Michael.Quinlan@sandc.com

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