Point-to-Point Digital Secondary System Design for a Transmission Substation at Duke Energy: Challenges and Solutions

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Outline

- Case study overview
- Potential benefits of copper reduction
- Why P2P DSS approach?
- Transmission substation under study
- P2P DSS design
- Comparative evaluations
  - Device count
  - Protection scheme unavailability
  - Protection system operation speed
- Lessons learned and future plans
- Conclusion

Case study overview

- Evaluate P2P DSS to reduce amount of copper used in protection design
- Detail P2P DSS design for existing 100 kV transmission substation
- Compare evaluations between traditional and P2P DSS design
  - Device count
  - Protection scheme unavailability
  - Protection system operation speed

Current state use of fiber and copper

Fiber optics

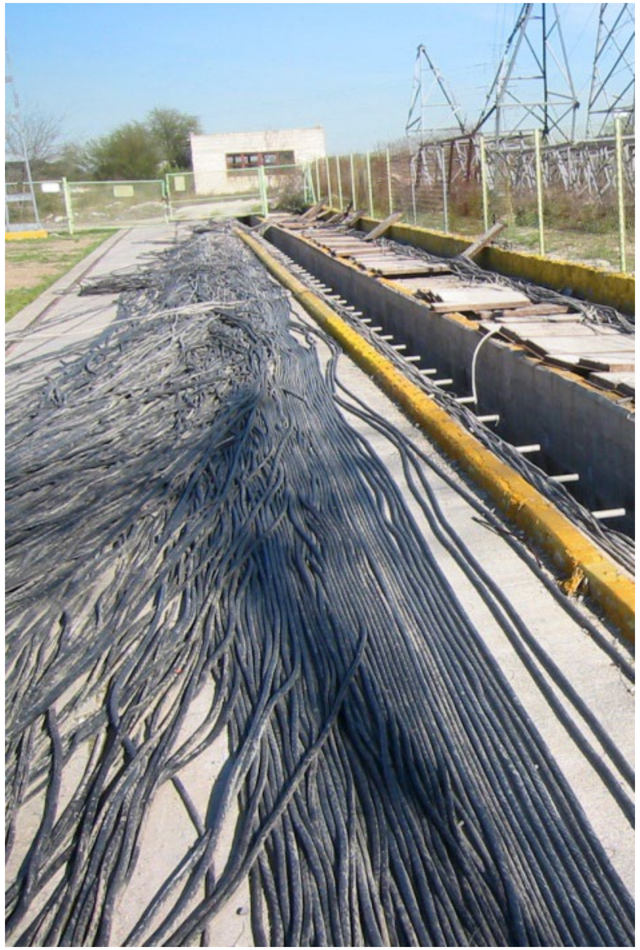
- Control
- Alarming
- Communication schemes
- Limited in tripping applications where electrical isolation is required

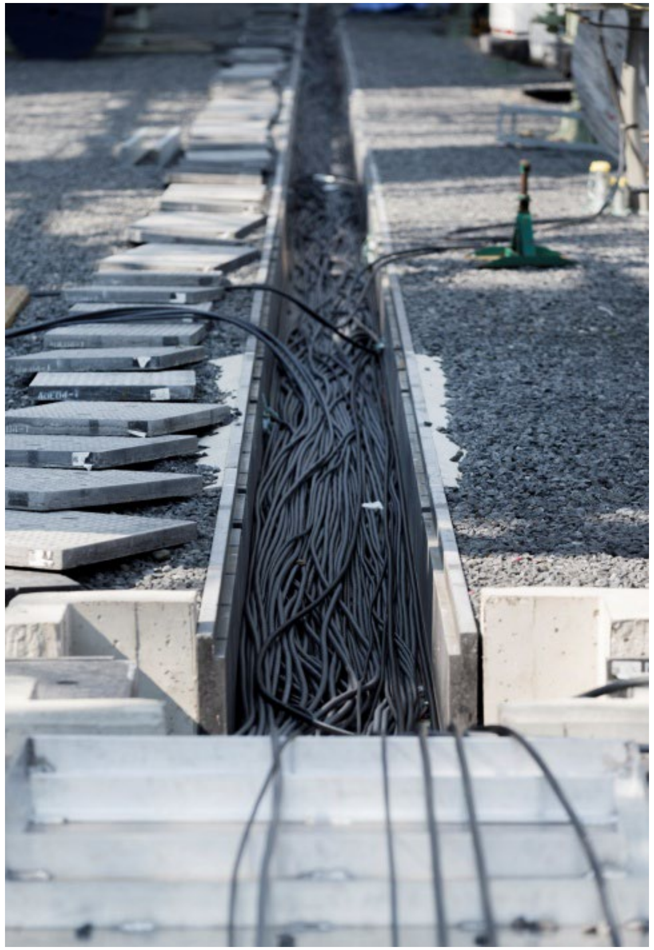
Copper

Connection of instrument transformers to protective relays and metering devices

- CTs
- PTs

Example of full cable tray/trench



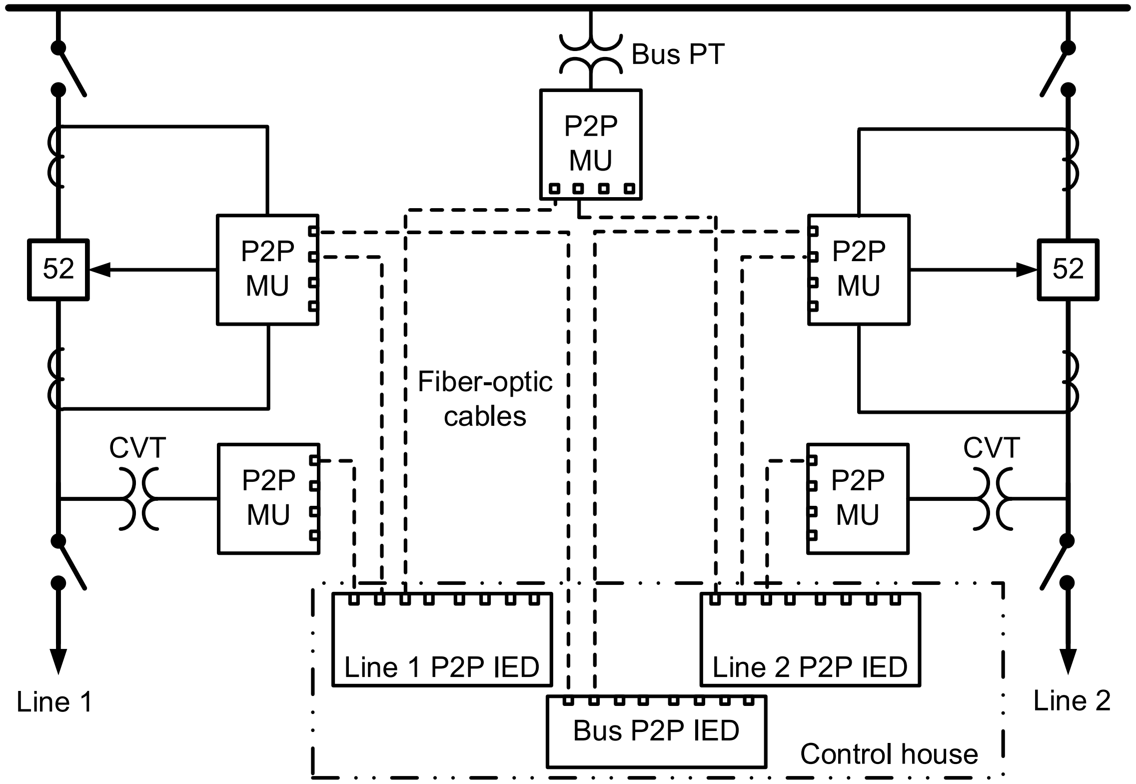


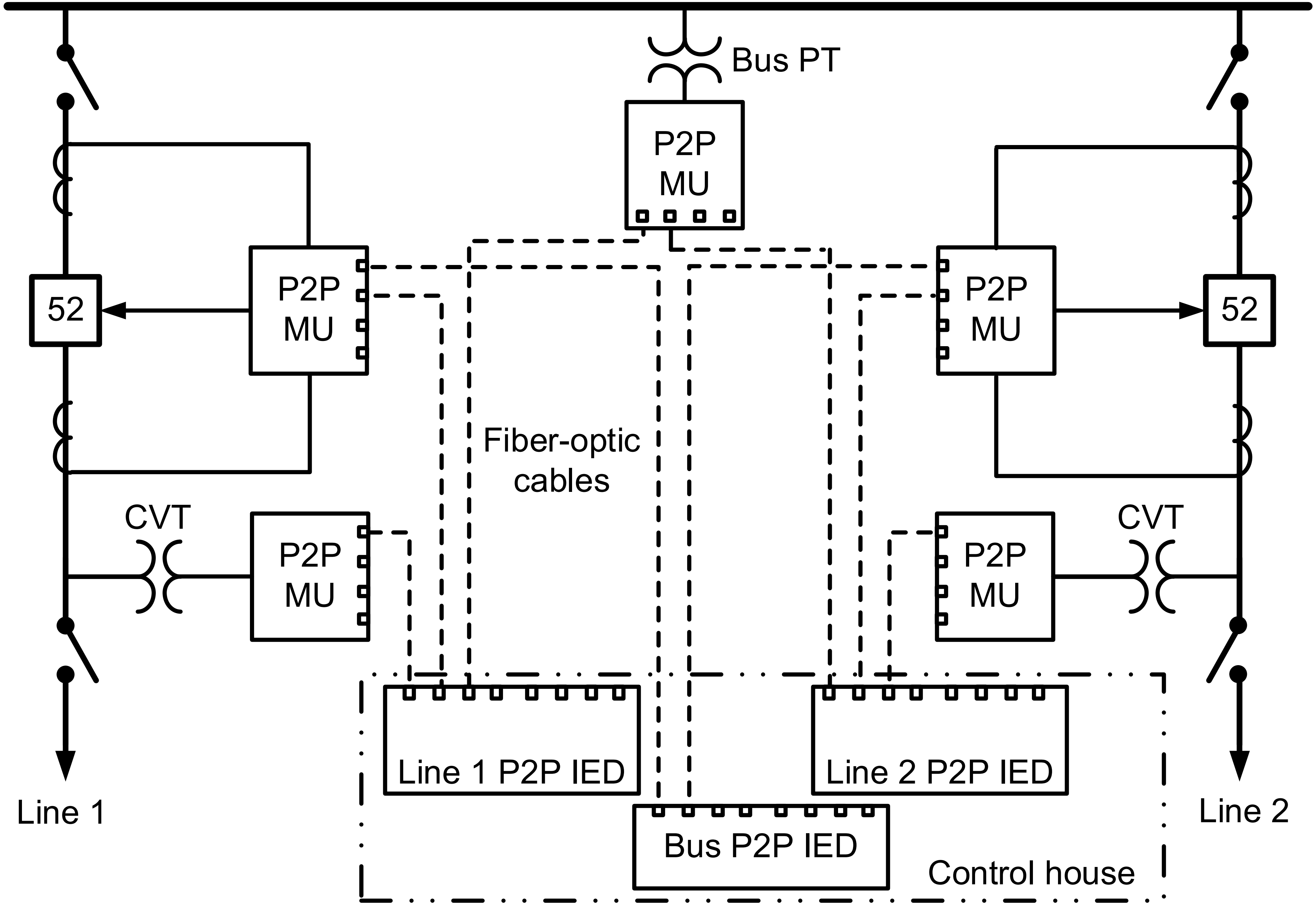
Potential benefits of copper reduction

- Physically large substations with substantial system fault duties introduce design challenges by requiring large current transformer cables installed over long distances
- Older substations requiring installation of new cables often meet challenge of full yard cable trays/trenches that require significant switchyard modifications above and beyond adding additional cable
- Potential cost savings – lower substation construction costs, reduced construction time
- Reduction in number of CT secondaries within control house

Why P2P DSS approach?

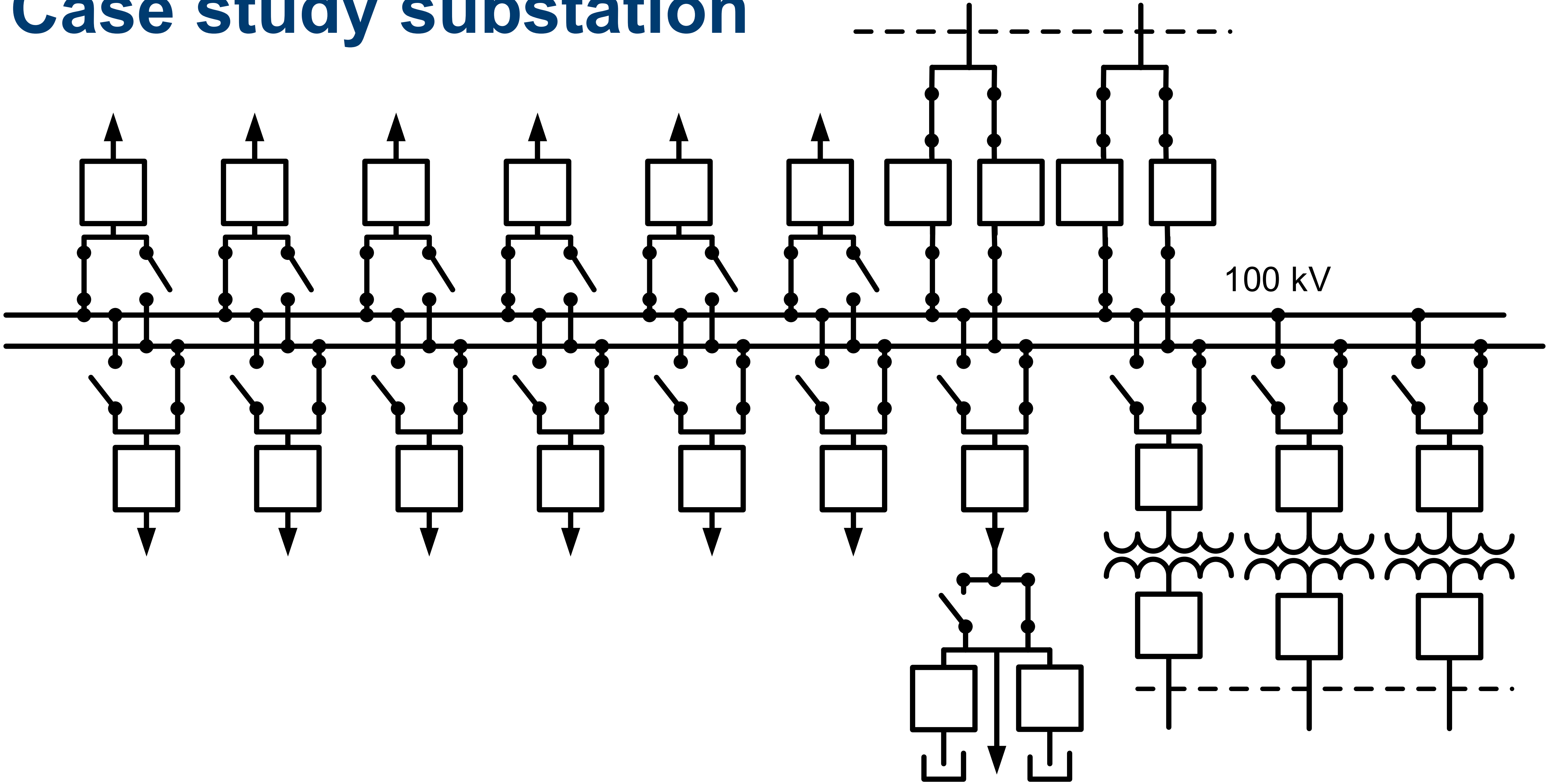
- Obtain benefits from reducing copper usage
- Use fewer components (no network switches and clocks)
- Eliminate need for network engineering skills
- Minimize changes to existing settings templates and designs
- Simplify MU configuration and commissioning



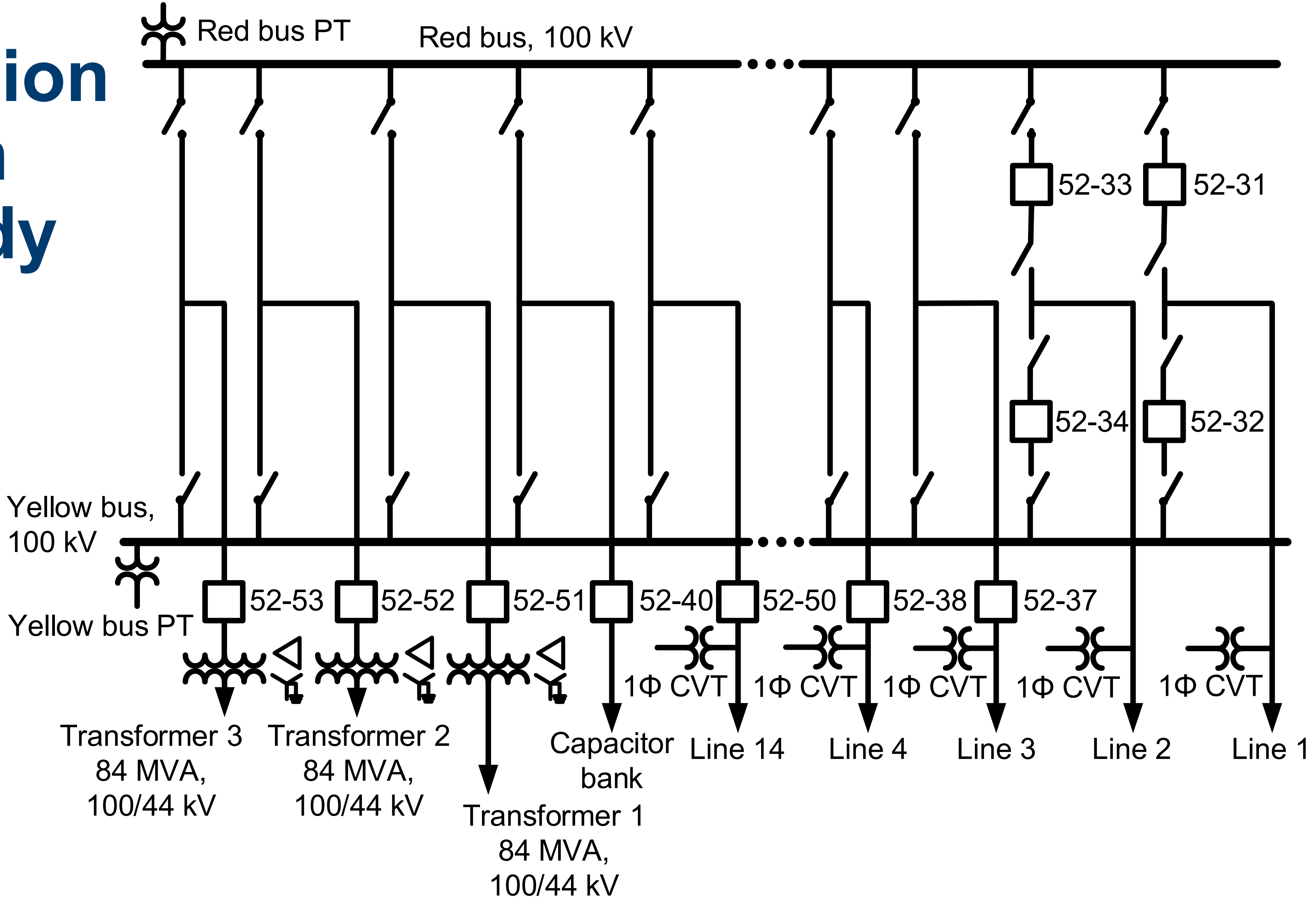


Bus PT
P2P
MU
52
P2P
MU
P2P
MU
52
Fiber-optic
cables
CVT
P2P
MU
CVT
P2P
MU
Line 1 P2P IED
Line 2 P2P IED
Bus P2P IED
Line 1
Line 2
Control house

Case study substation

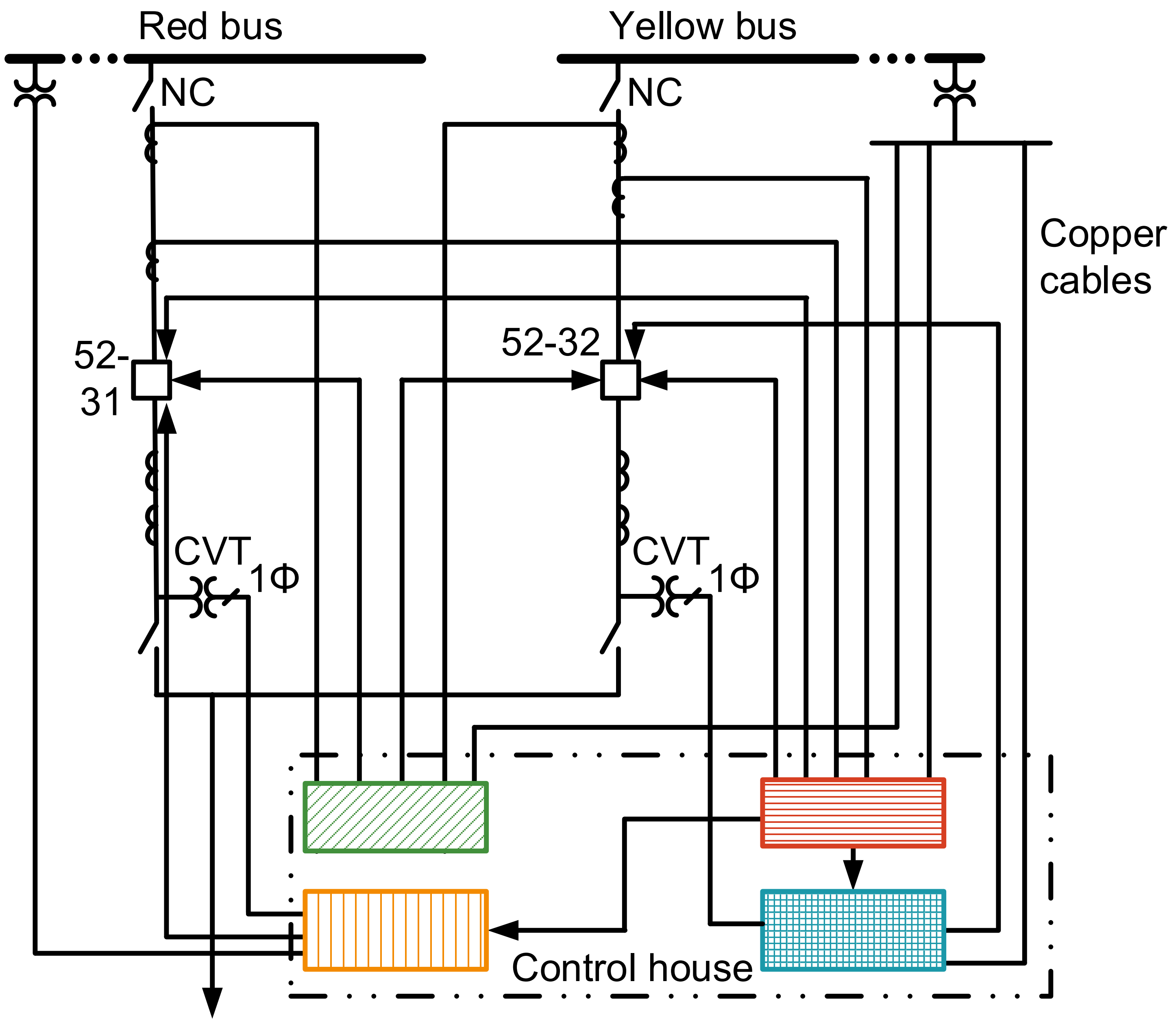


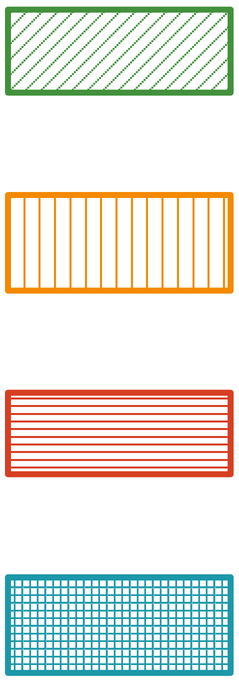
Transmission substation under study



Traditional secondary system

Line 1





Traditional line IED (primary)

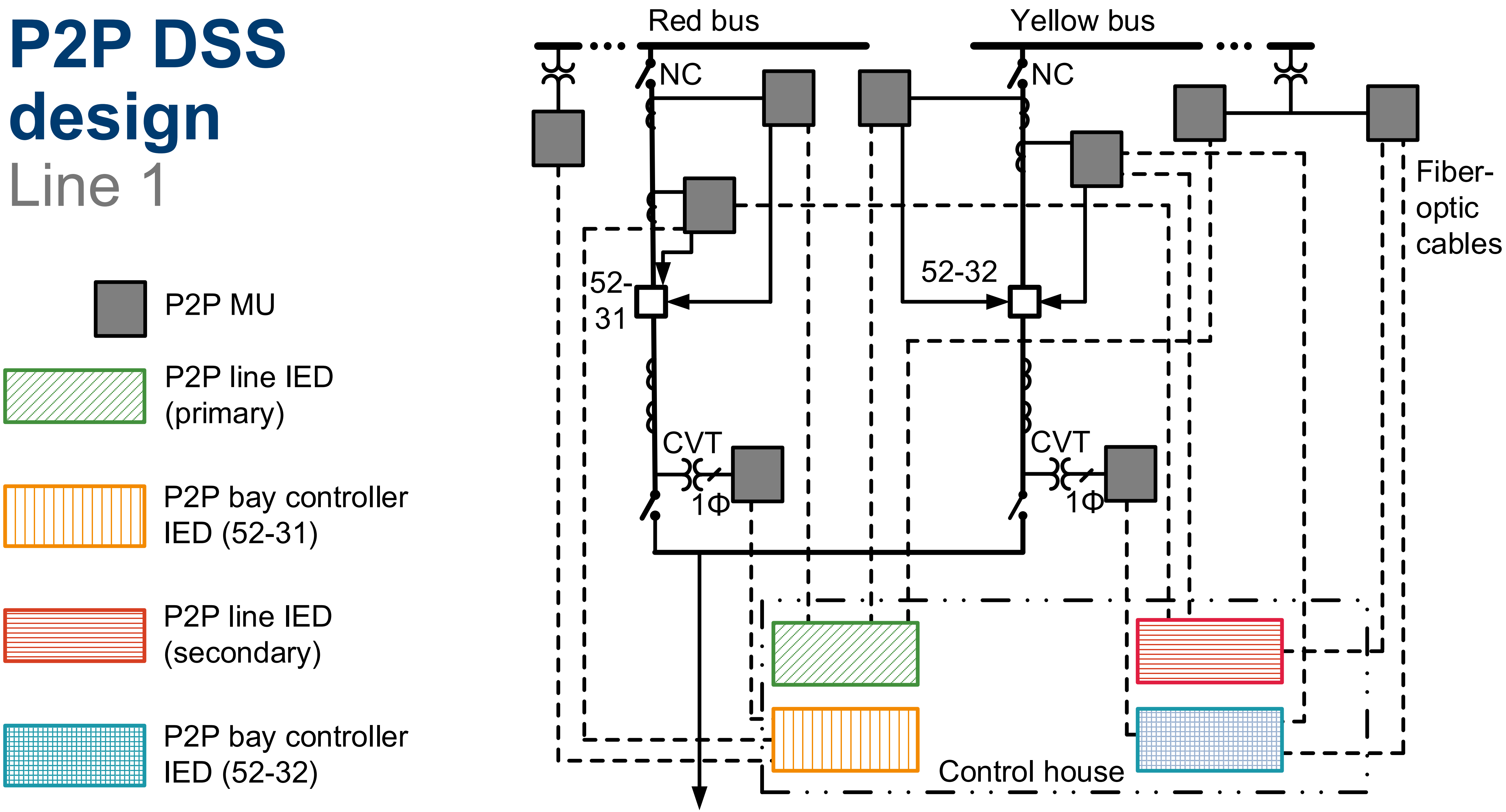
Traditional bay controller IED (52-31)

Traditional line IED (secondary)

Traditional bay controller IED (52-32)

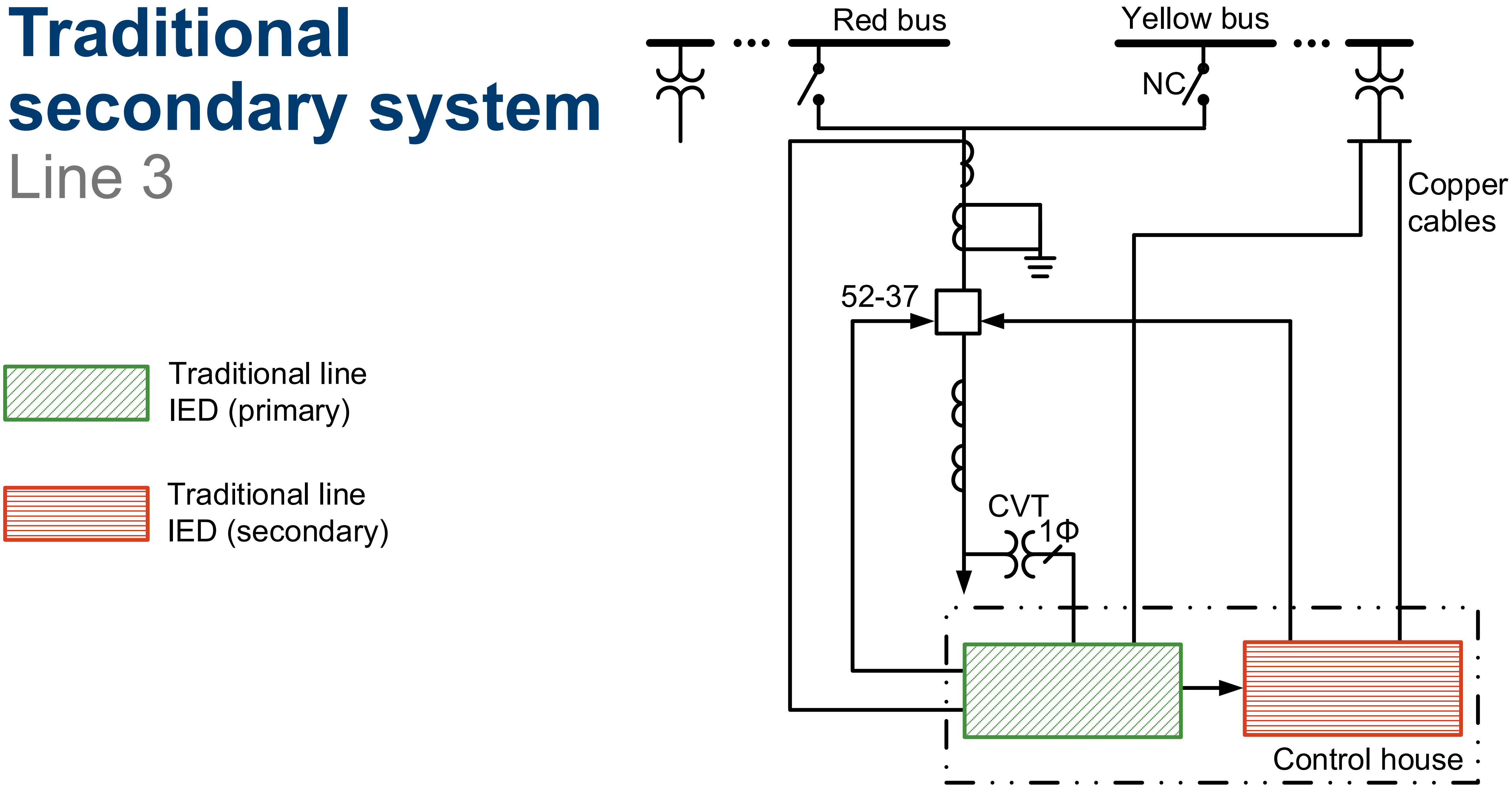
P2P DSS design

Line 1



Traditional secondary system

Line 3



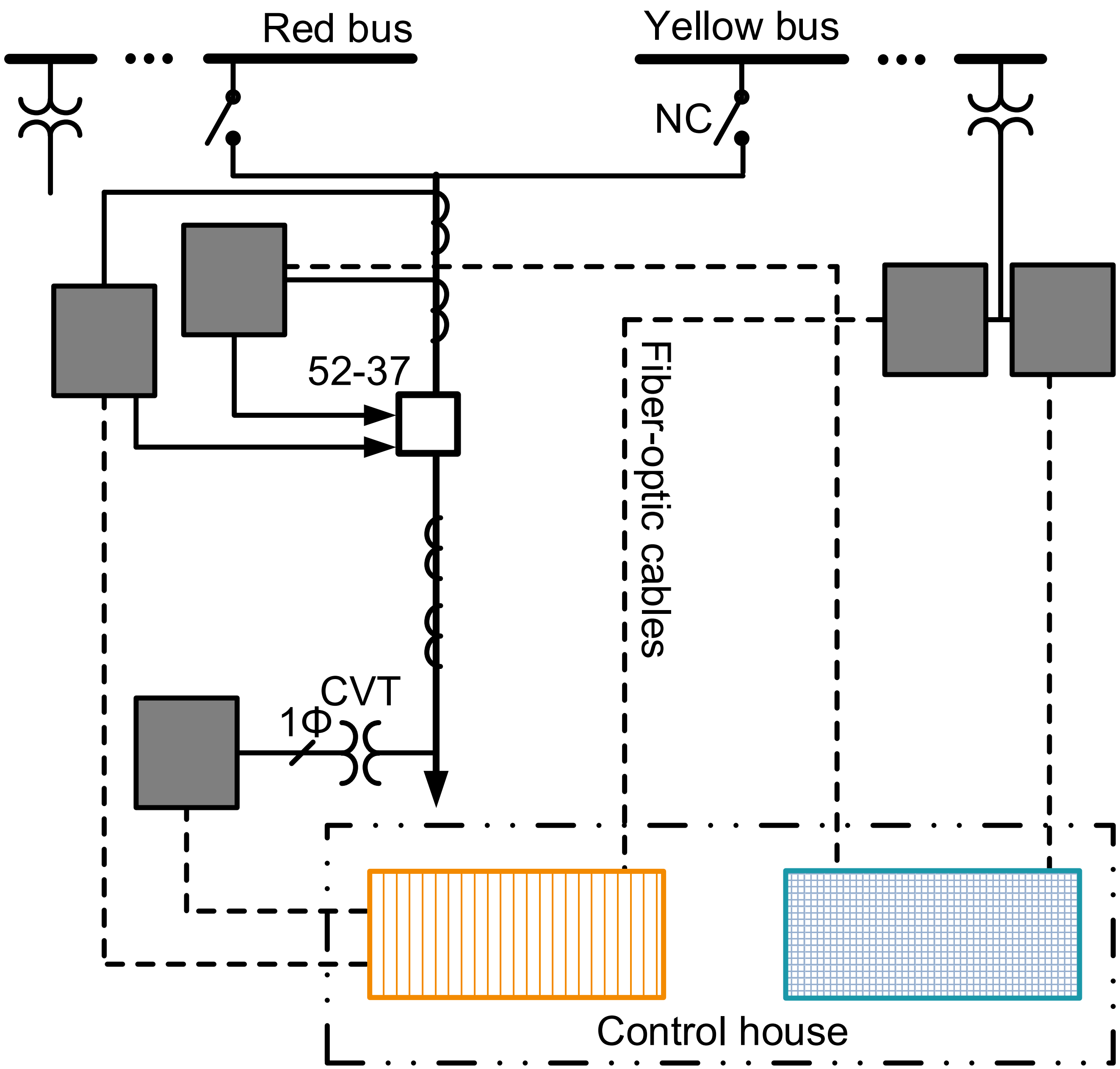
P2P DSS design

Line 3

P2P MU

P2P line IED
(primary)

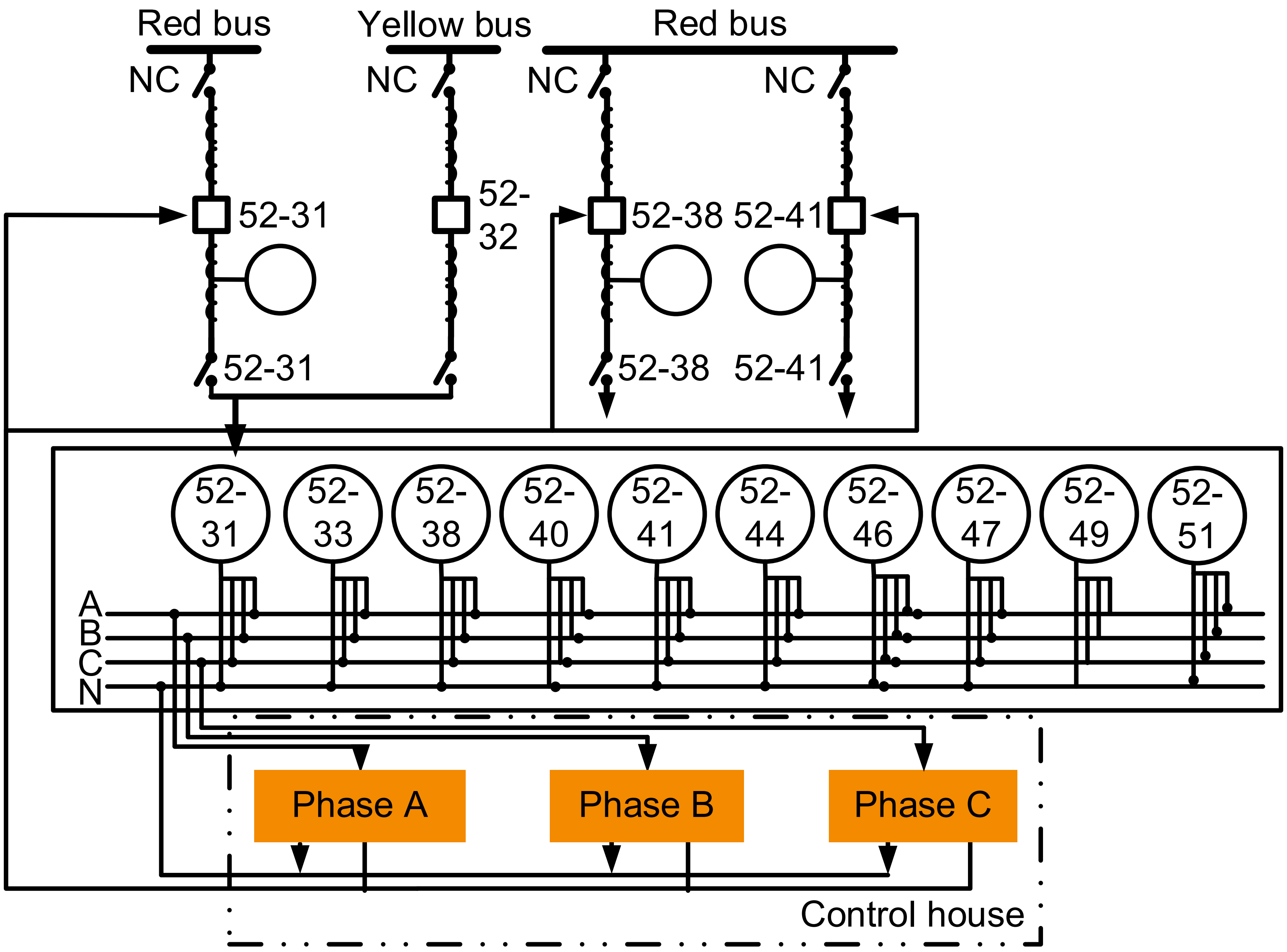
P2P line IED
(secondary)



Traditional secondary system

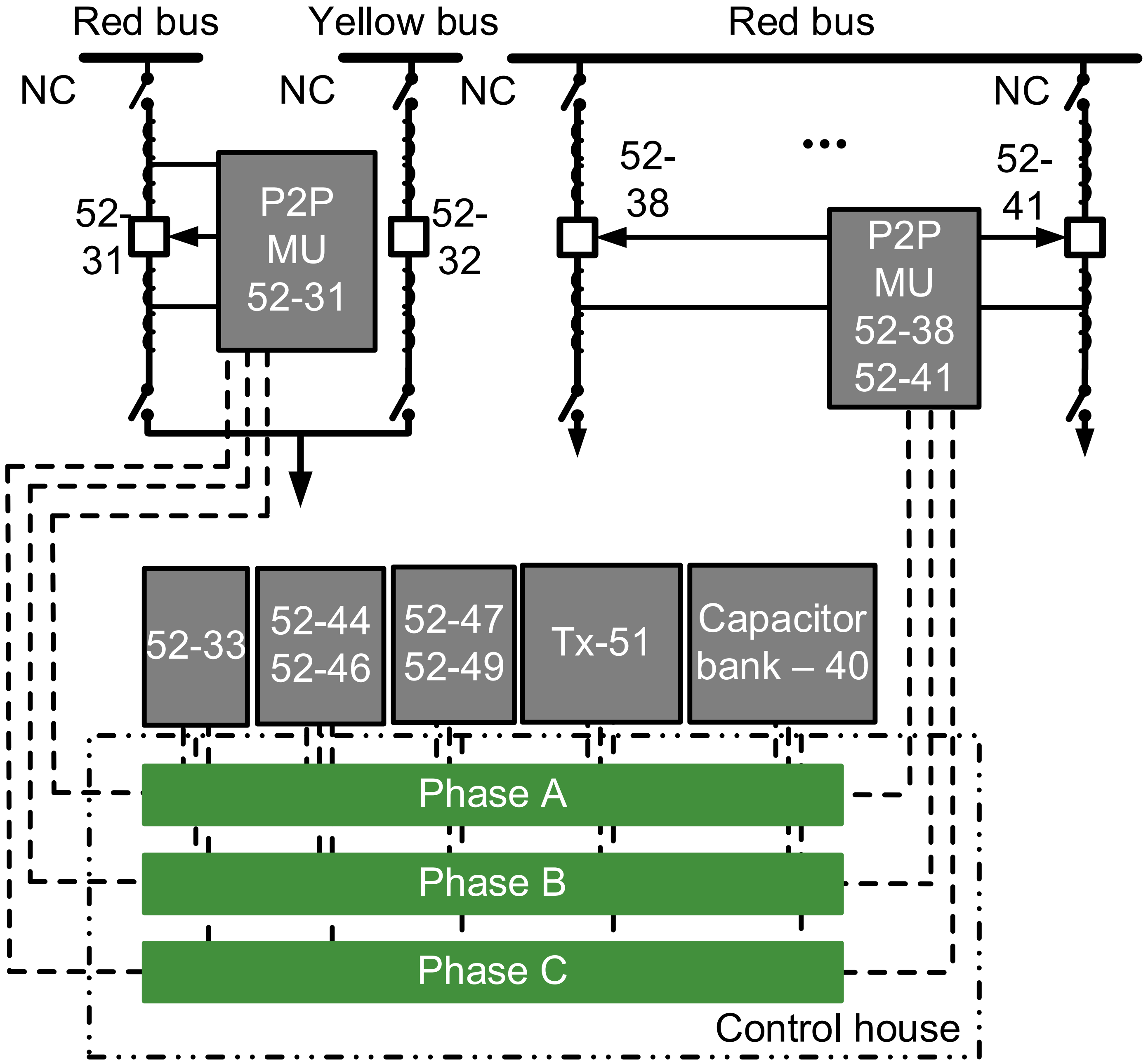
Bus differential configuration

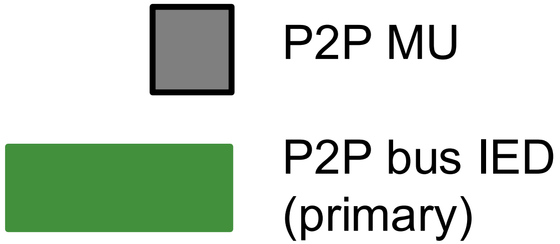
Traditional bus IED (primary)



P2P DSS design

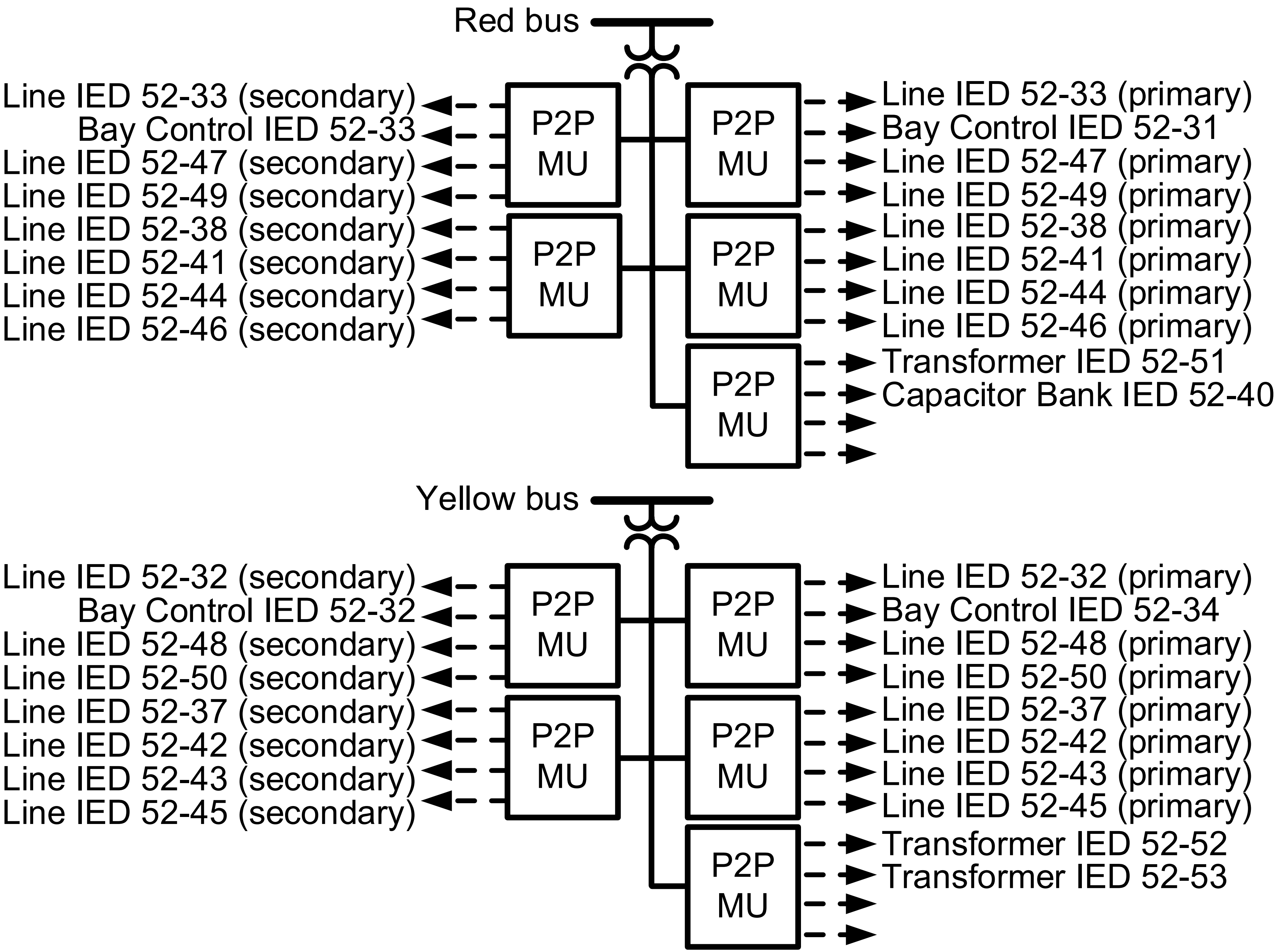
Bus differential configuration





P2P DSS design

Bus PT configuration



Comparative evaluation

Device count

Traditional

Description	Units
Copper cables	73,342 ft
Test switch	80
Line differential IED	4
Distance IED	24
Overcurrent IED	9
Transformer IED	3
Bus differential IED	12
Lockout IED	10

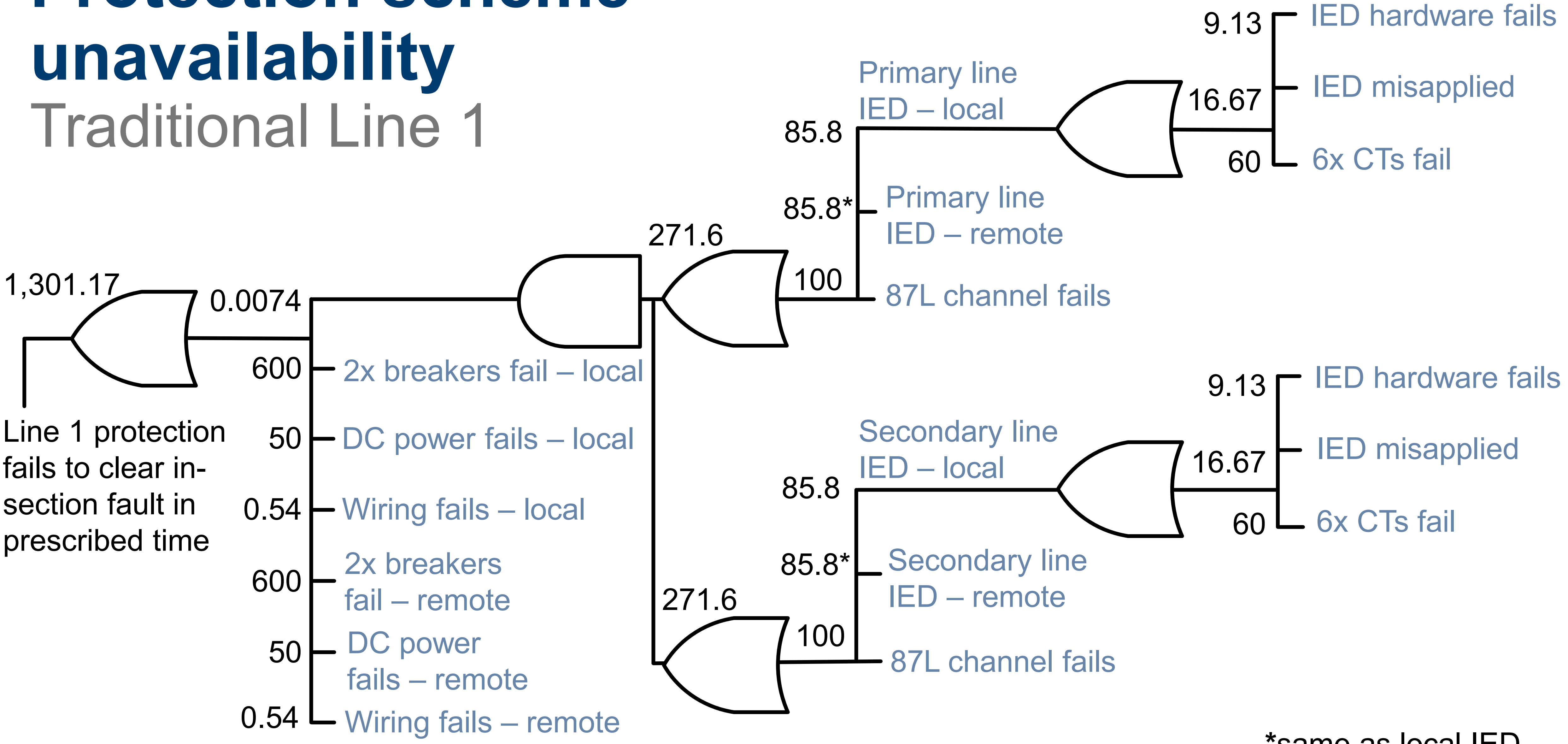
P2P DSS design

Description	Units
Fiber-optic cables	67,775 ft
MU	69
Line differential IED	4
Distance IED	24
Overcurrent IED	9
Transformer IED	3
Bus differential IED	12

Protection scheme unavailability

Traditional Line 1

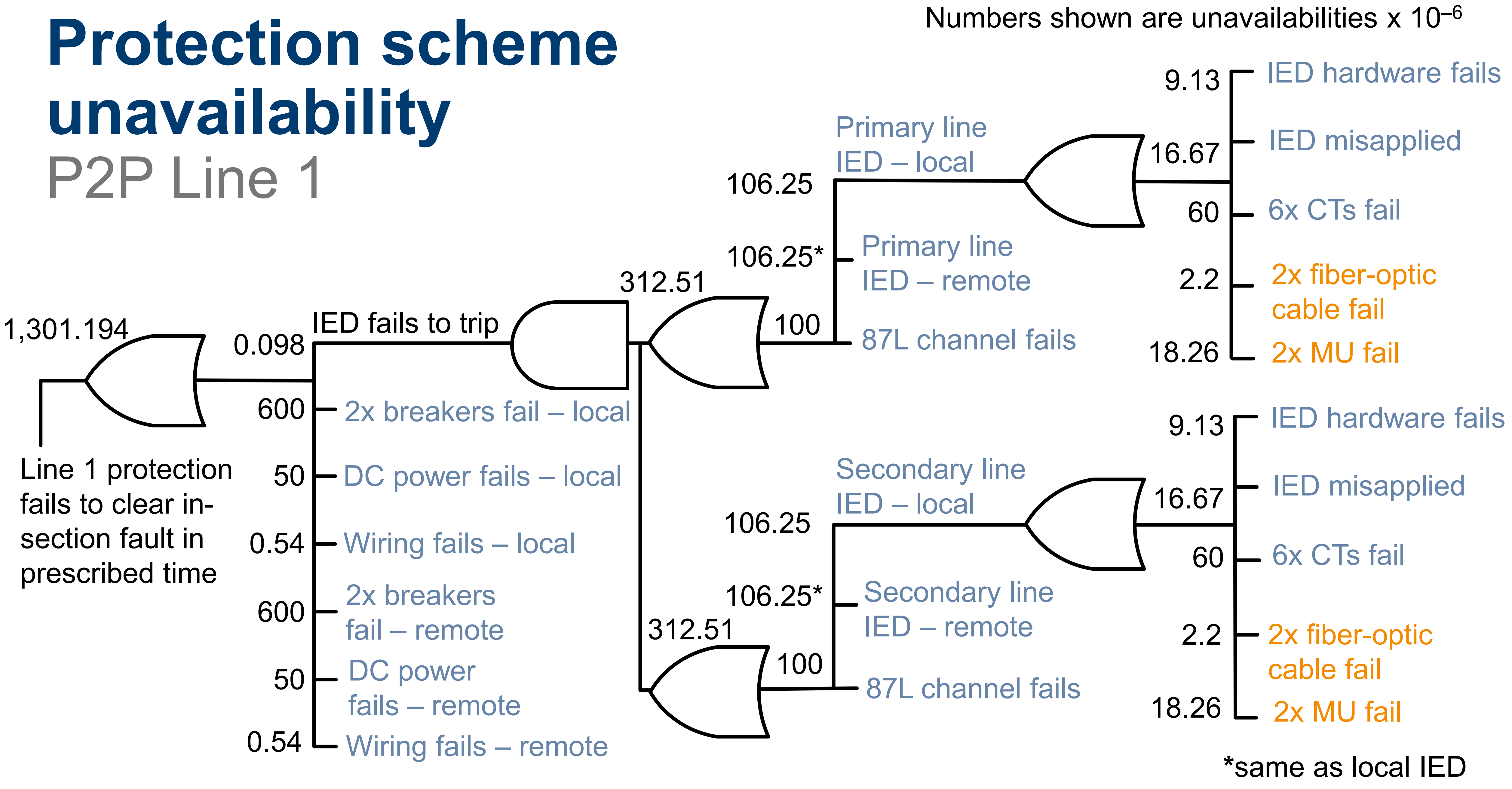
Numbers shown are unavailabilities x 10^{-6}



*same as local IED

Protection scheme unavailability

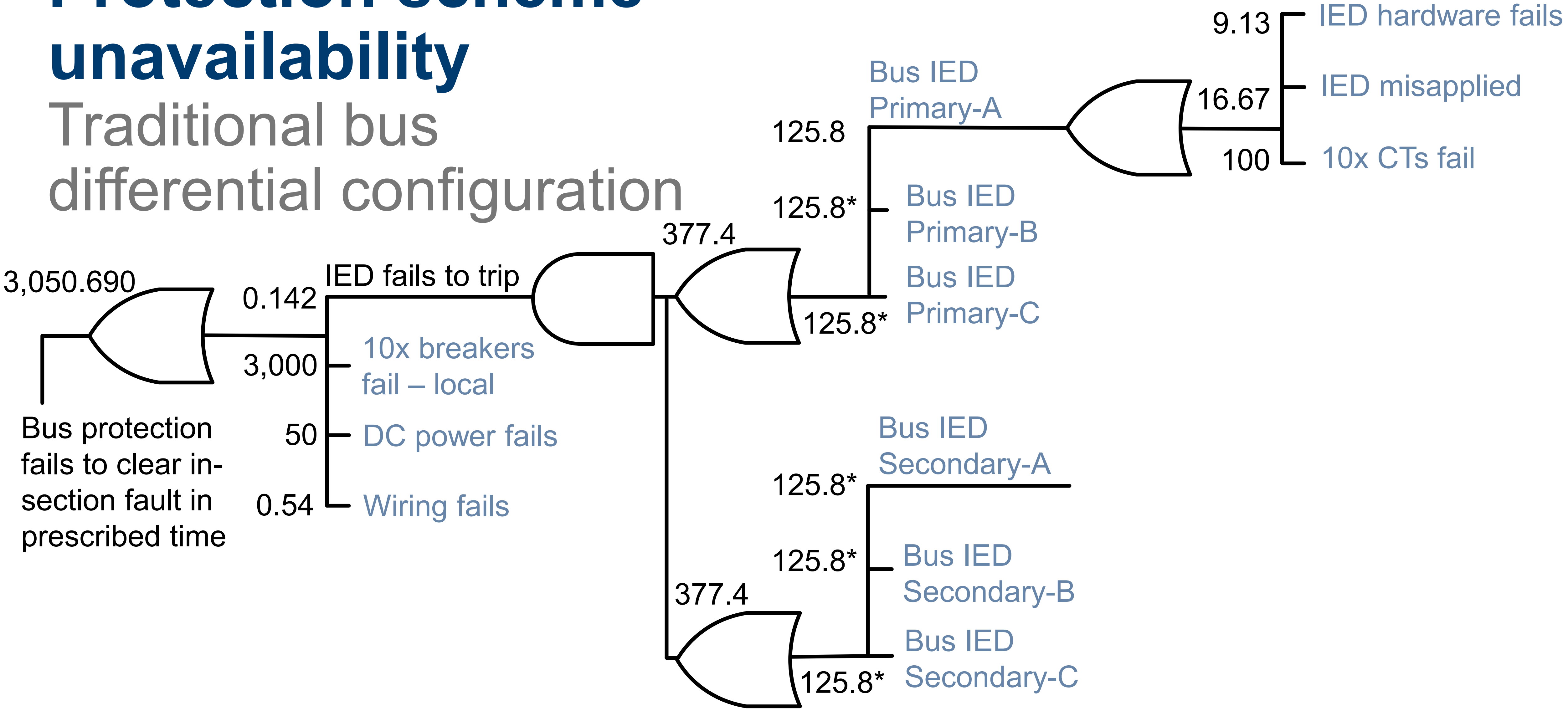
P2P Line 1



Protection scheme unavailability

Traditional bus differential configuration

Numbers shown are unavailabilities x 10^{-6}

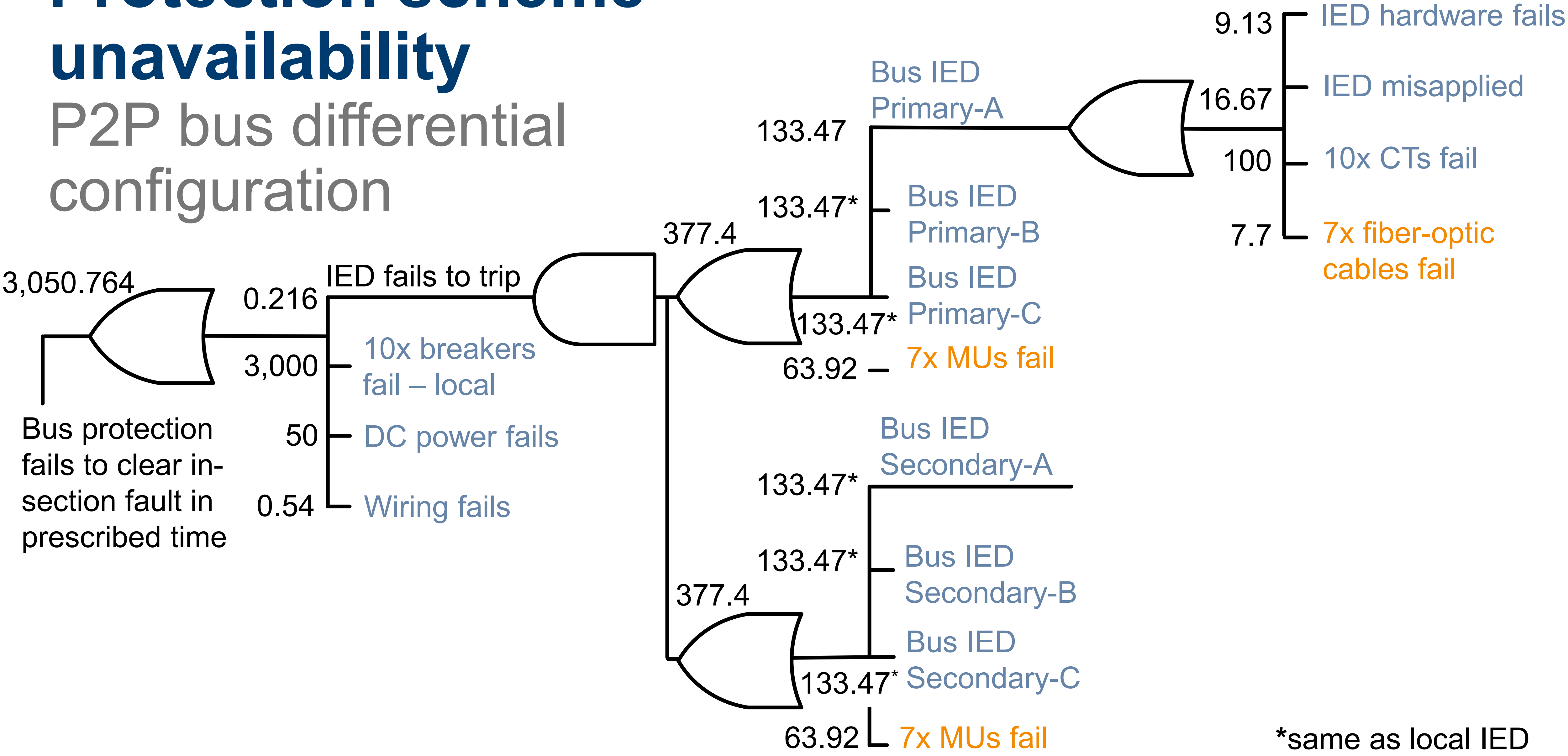


*same as local IED

Protection scheme unavailability

P2P bus differential configuration

Numbers shown are unavailabilities x 10^{-6}



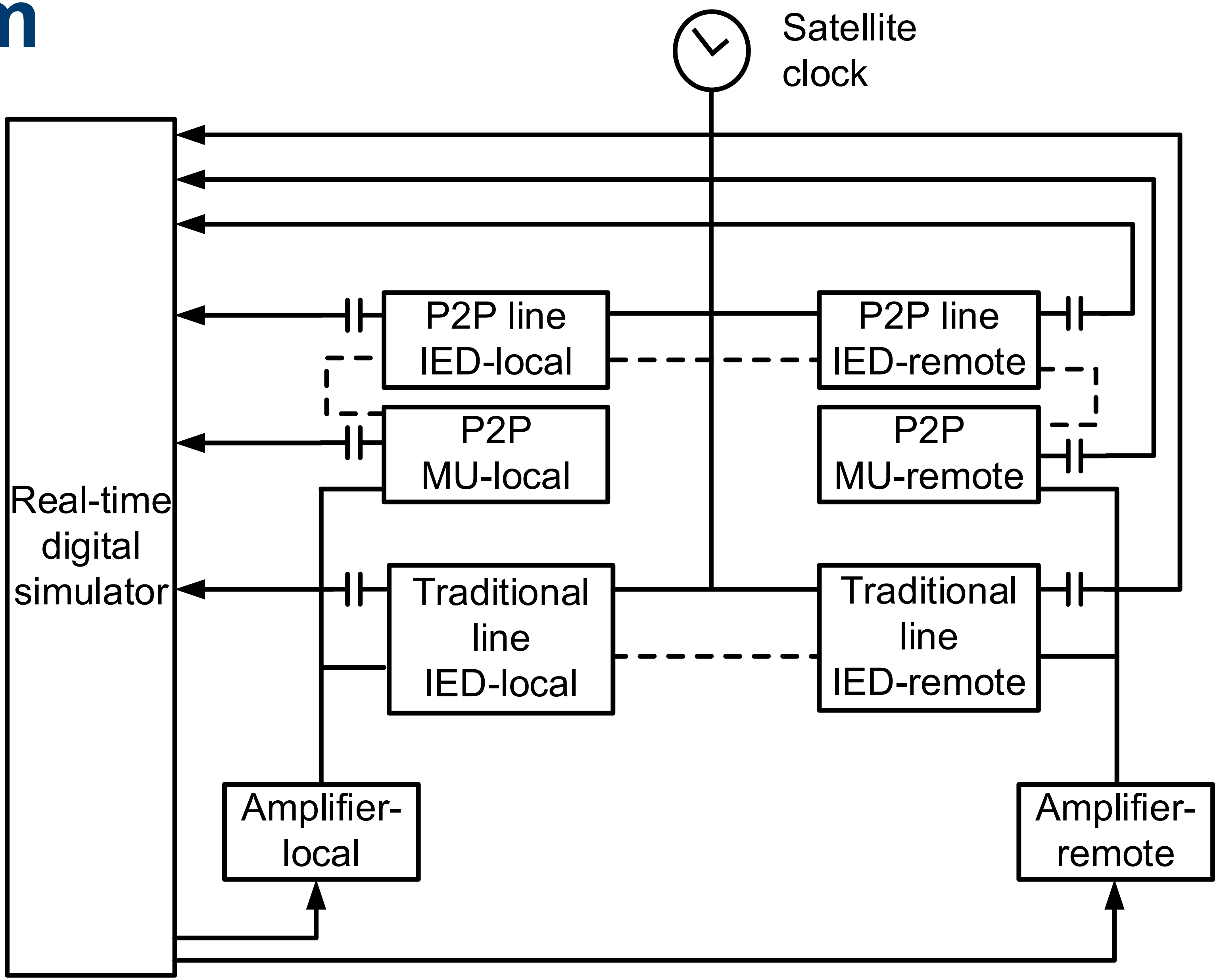
Protection scheme unavailability

Overall unavailability (10^{-6})

Solution	Line 1 protection	Bus differential protection
Traditional	1,301.170	3,050.690
P2P-based solution	1,301.194	3,050.764

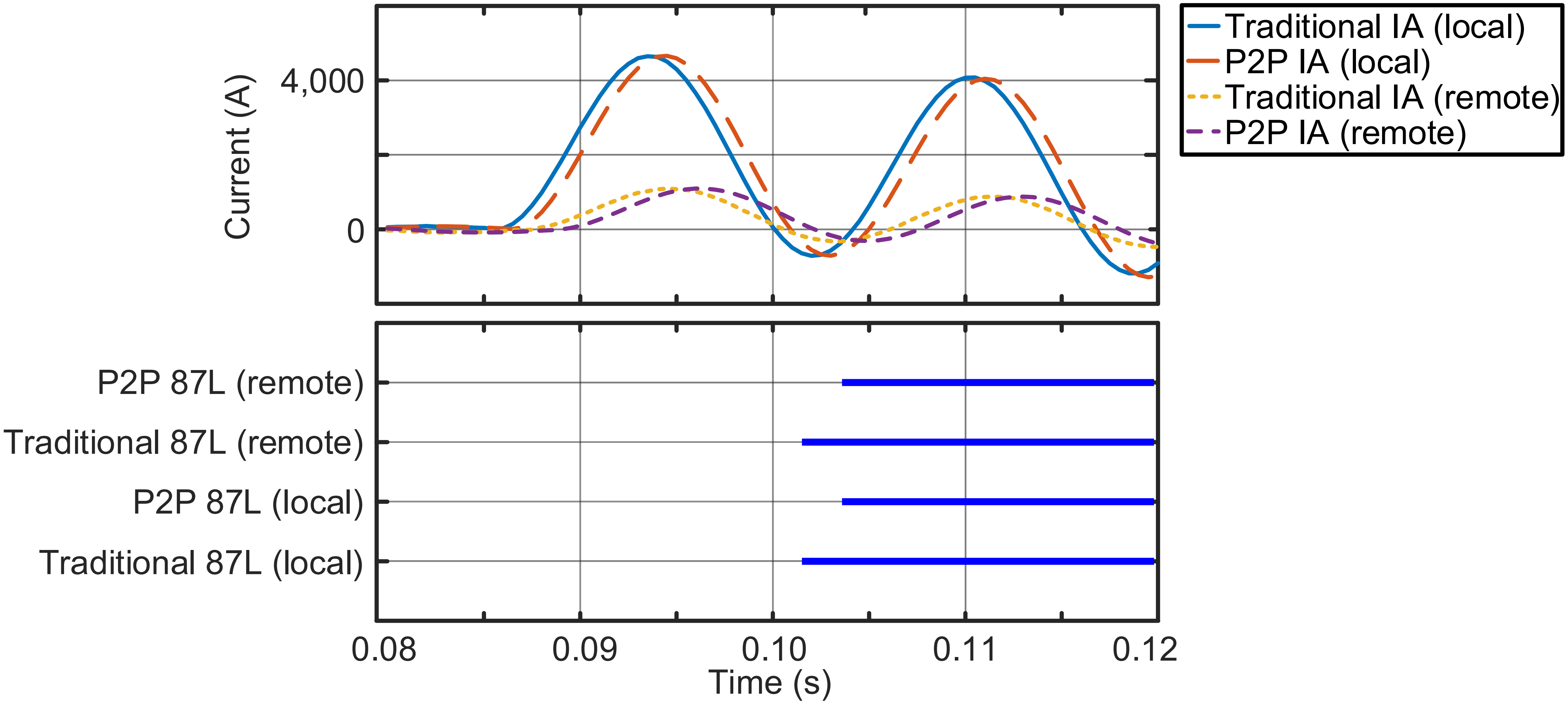
Protection system operation speed

Test setup



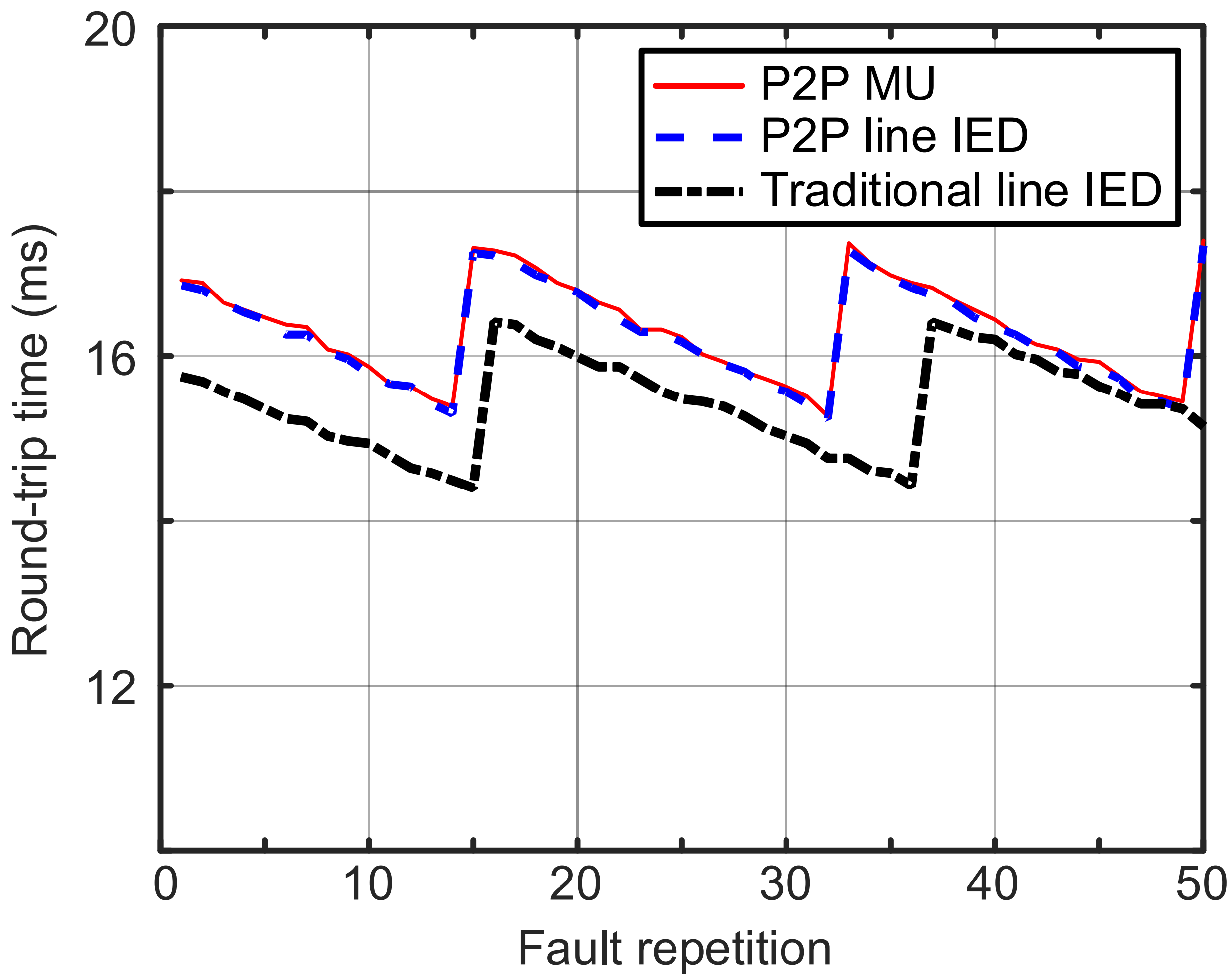
Protection system operation speed

87L element operation time



Protection system operation speed

Round-trip time



Protection system operation speed

Solution	87 element		21 element	
	Trip time (ms)	Difference (ms)	Trip time (ms)	Difference (ms)
Traditional IED	15.427	NA	21.251	NA
P2P IED	16.261	0.834	21.965	0.714
P2P MU	16.316	0.889	22.025	0.774

Lessons learned

- With design requiring full redundancy in all protection, number of MUs and relays required was significant (52 IEDs and 69 MUs)

  Design observation: would require larger substation battery

- No significant impact on protection unavailability: full redundancy requirement with P2P provided highly reliable design

- Limitations were noted with number of ports on MUs and relays when applied to substation layout/design used in this study
  - One set of bus potential transformers tied to many protective relays
  - Substation design had large number of breakers (and current transformers) per bus section

Future plans

- **Start with lab testing P2P technologies**

  Allow setting engineers opportunity to convert existing setting templates to what would be required for P2P technology

- **Introduce new technology to field resources**

  Determine testing requirements and how commissioning would occur in the actual substation

Future plans

- **Key commissioning questions would need to be answered**
  - How can current transformer connections to MUs be verified?
  - Will test blocks for injecting test currents at the MUs be required?
  - How will settings/configuration data on MUs be captured and stored in relay databases?
  - Will any additional security measures be required to secure physical access to MUs to ensure all compliance requirements are met?
- **Pre-deployment**

Conclusion

- Limited number of ports on MU/relays pose unique challenge
  - Implementing bus differential protection for 10 breakers
  - Supplying bus voltages to 18 relays requires multiple MUs connected to same PT
- Little impact to protection reliability: protection scheme unavailability is very close between traditional and P2P DSS design
- Protection system operation speed of P2P DSS design is slightly slower than traditional design (around 1 ms)

Questions?