# Modern Capacitor Bank Protection Methods

Ryan Bowersox, Joe Schaefer - Florida Power and Light
Daniel Ransom - GE Grid Solutions
Presenter: Mike Ramlachan - GE Grid Solutions

# Our discussion today

**Capacitor and capacitor-bank** fundamentals and operation

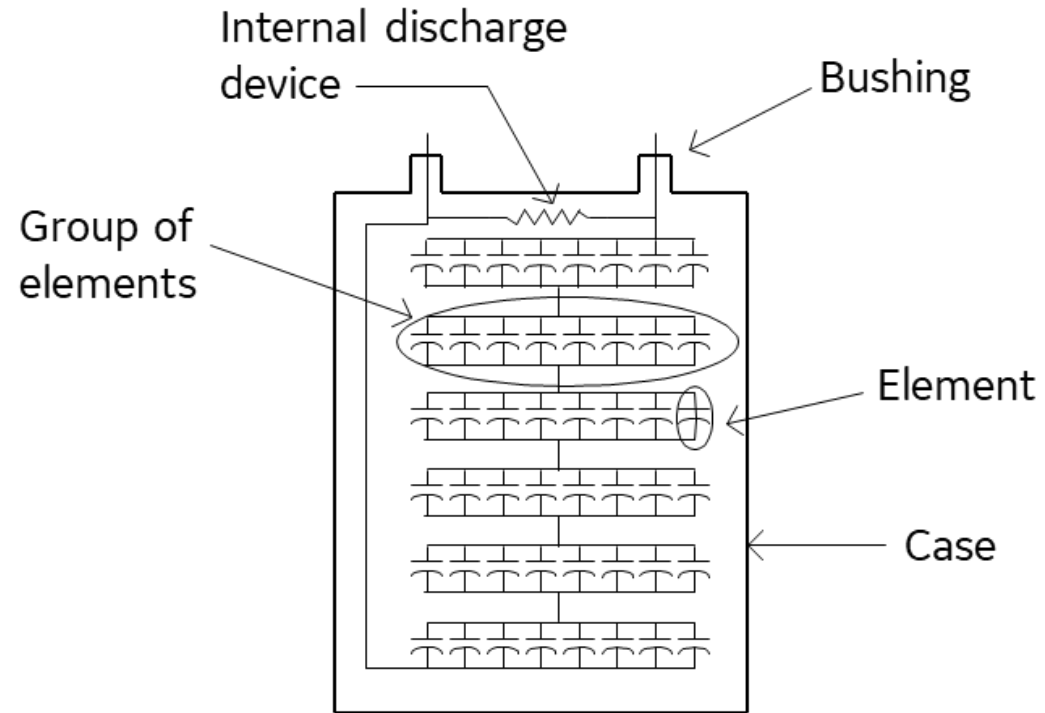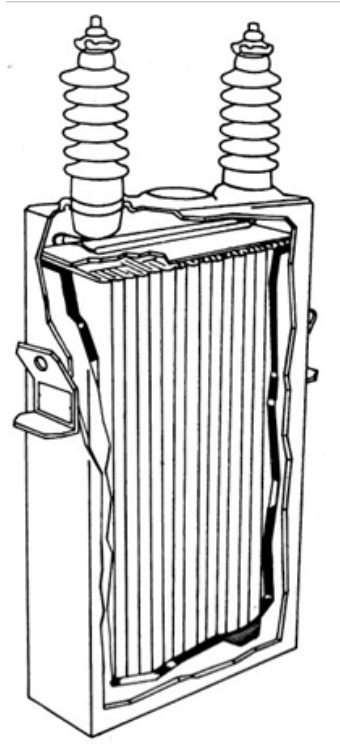Capacitor-bank protection
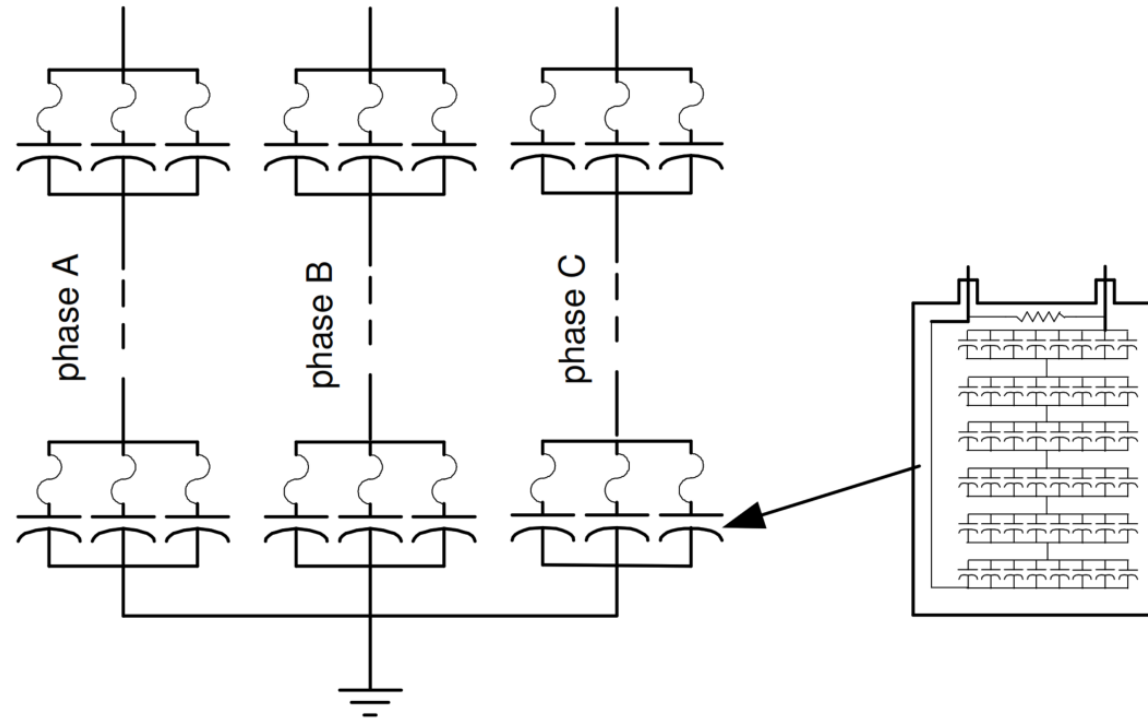
Real-world examples

# Capacitor and capacitor-bank fundamentals and operation

# Capacitor unit



Internal discharge device

Bushing

Group of elements

Element
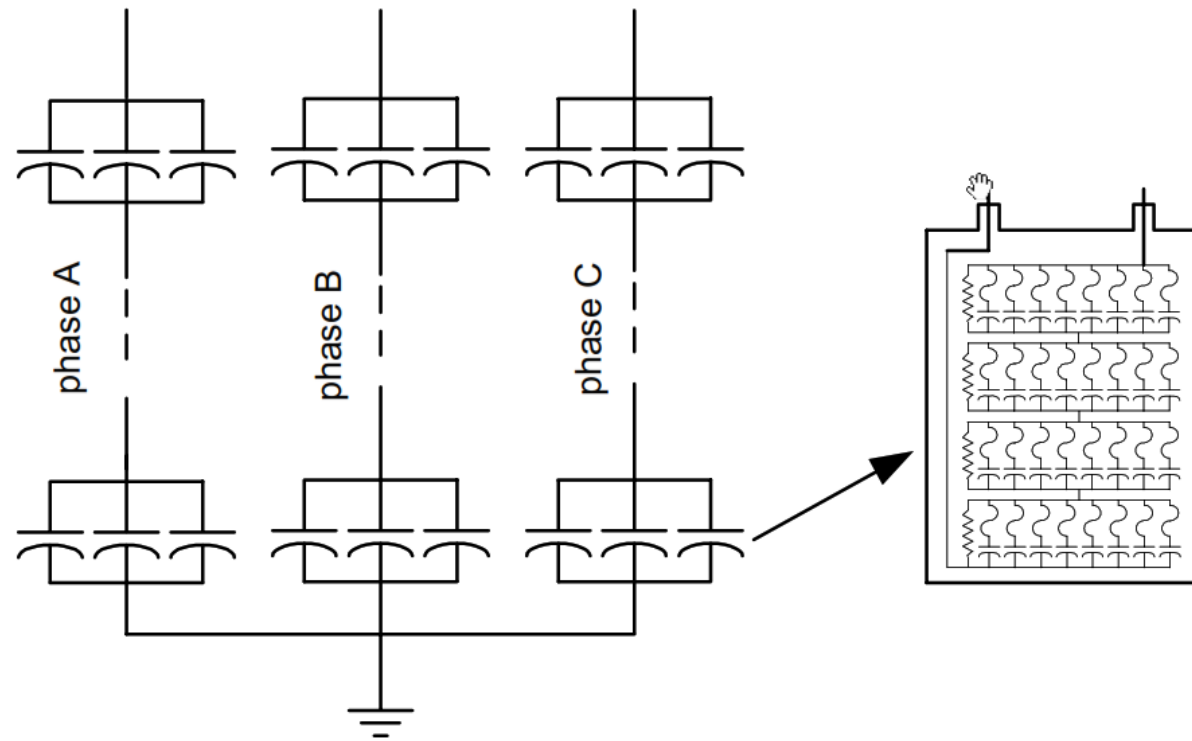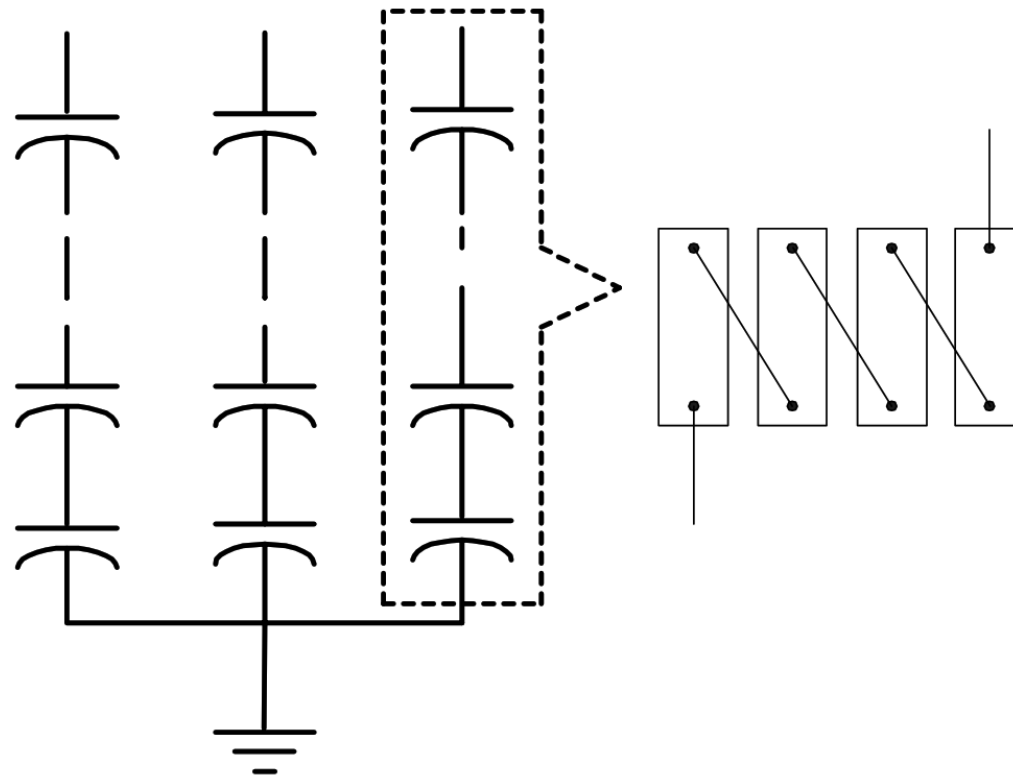
Case

# Externally fused shunt capacitor bank and capacitor unit

# Internally fused shunt capacitor bank and capacitor unit

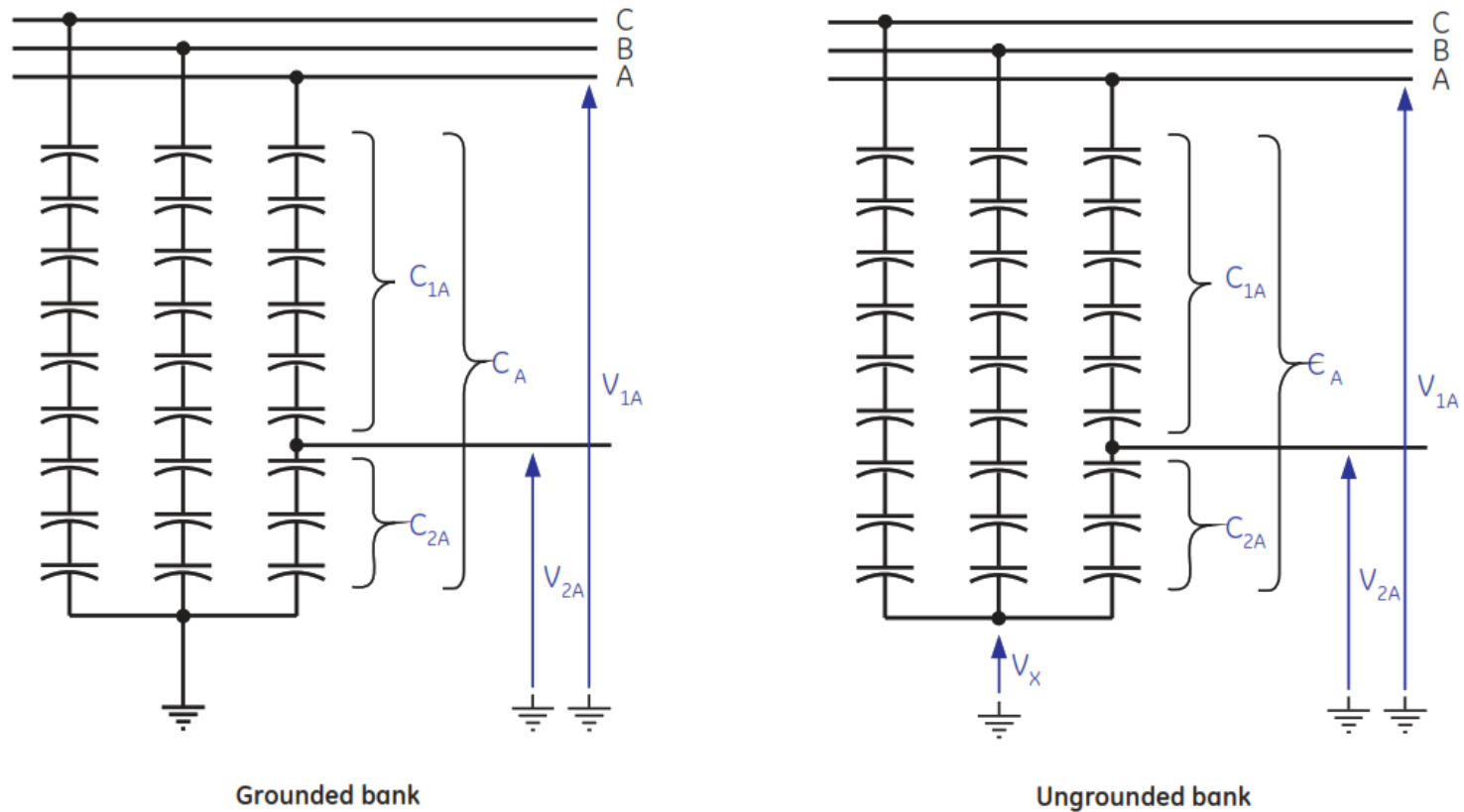# Fuseless shunt capacitor bank and series string

Modern Capacitor Bank Protection Methods

# Capacitor bank protection

# Measuring points for voltage differential 87V protection
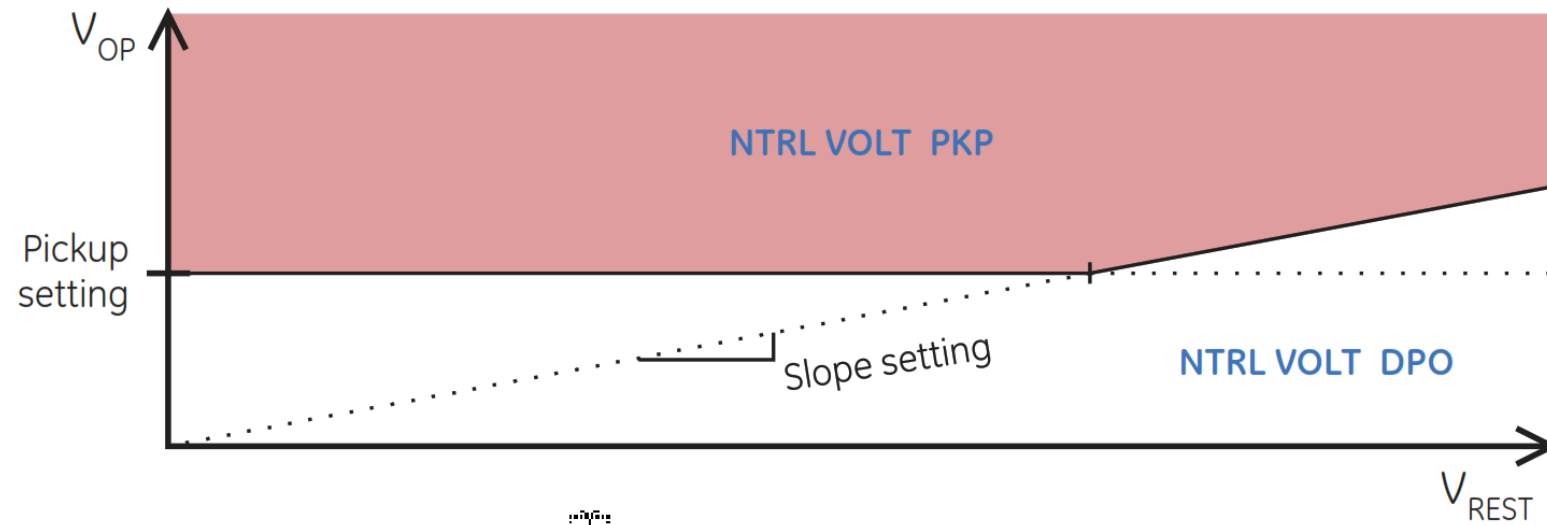


Grounded bank

Ungrounded bank

834750A1.CDR

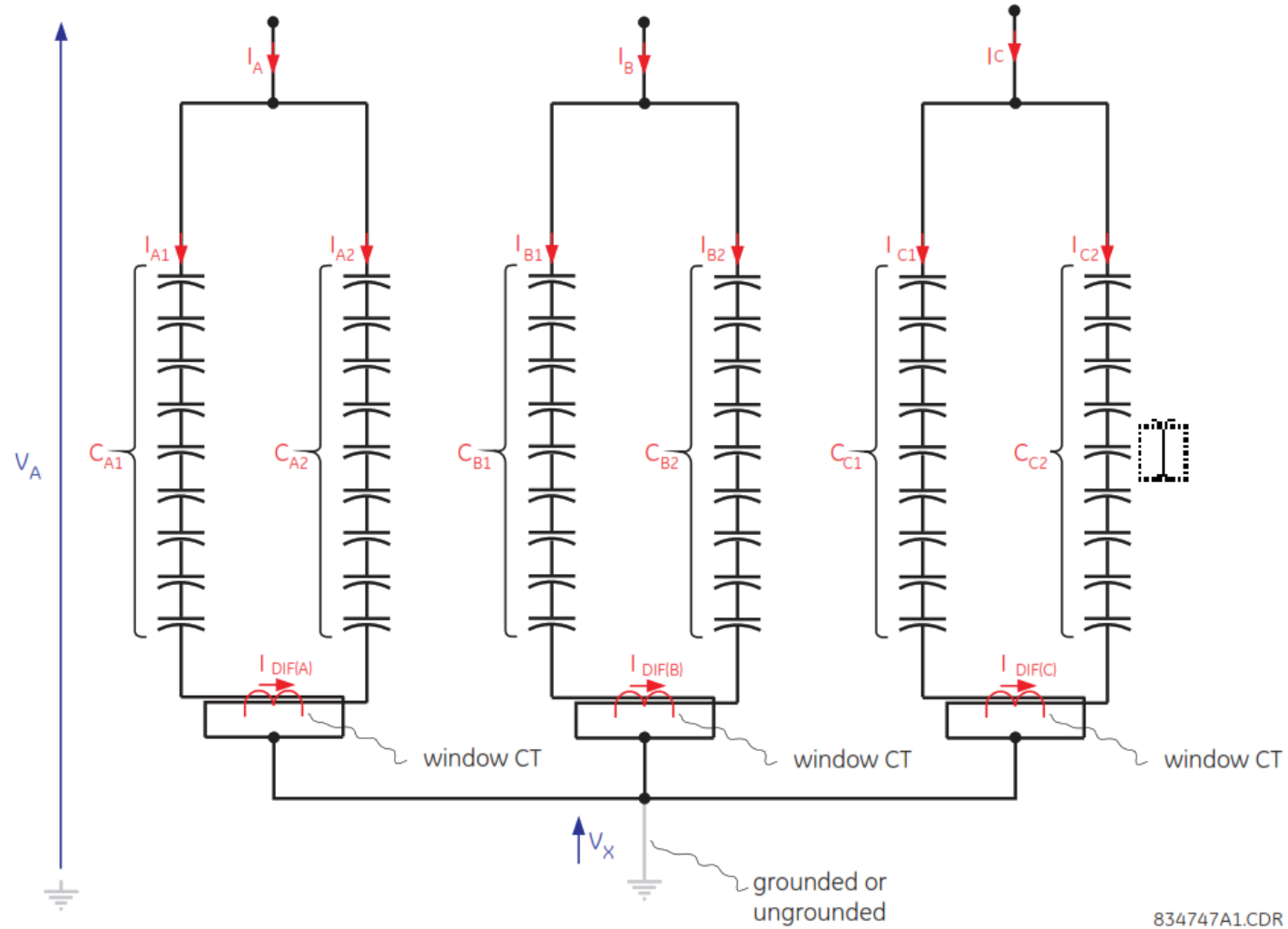# Compensated bank neutral overvoltage 59NU
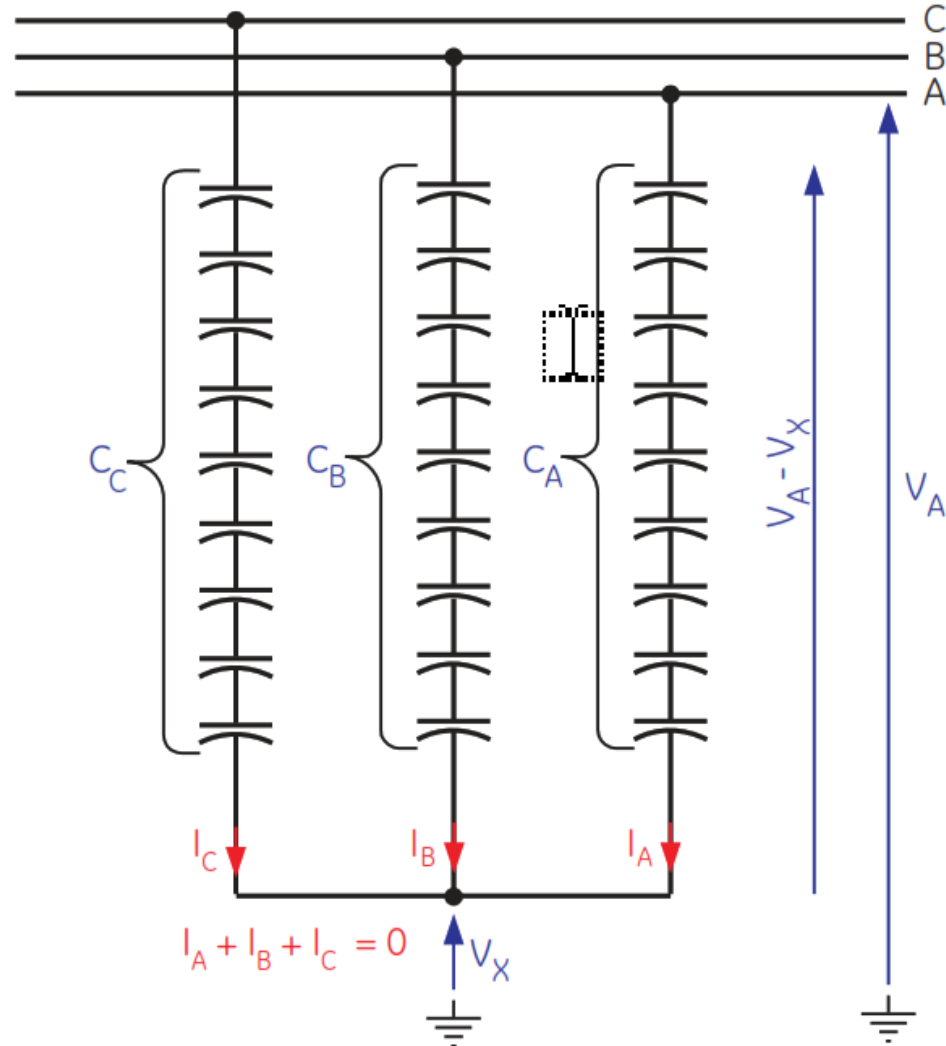
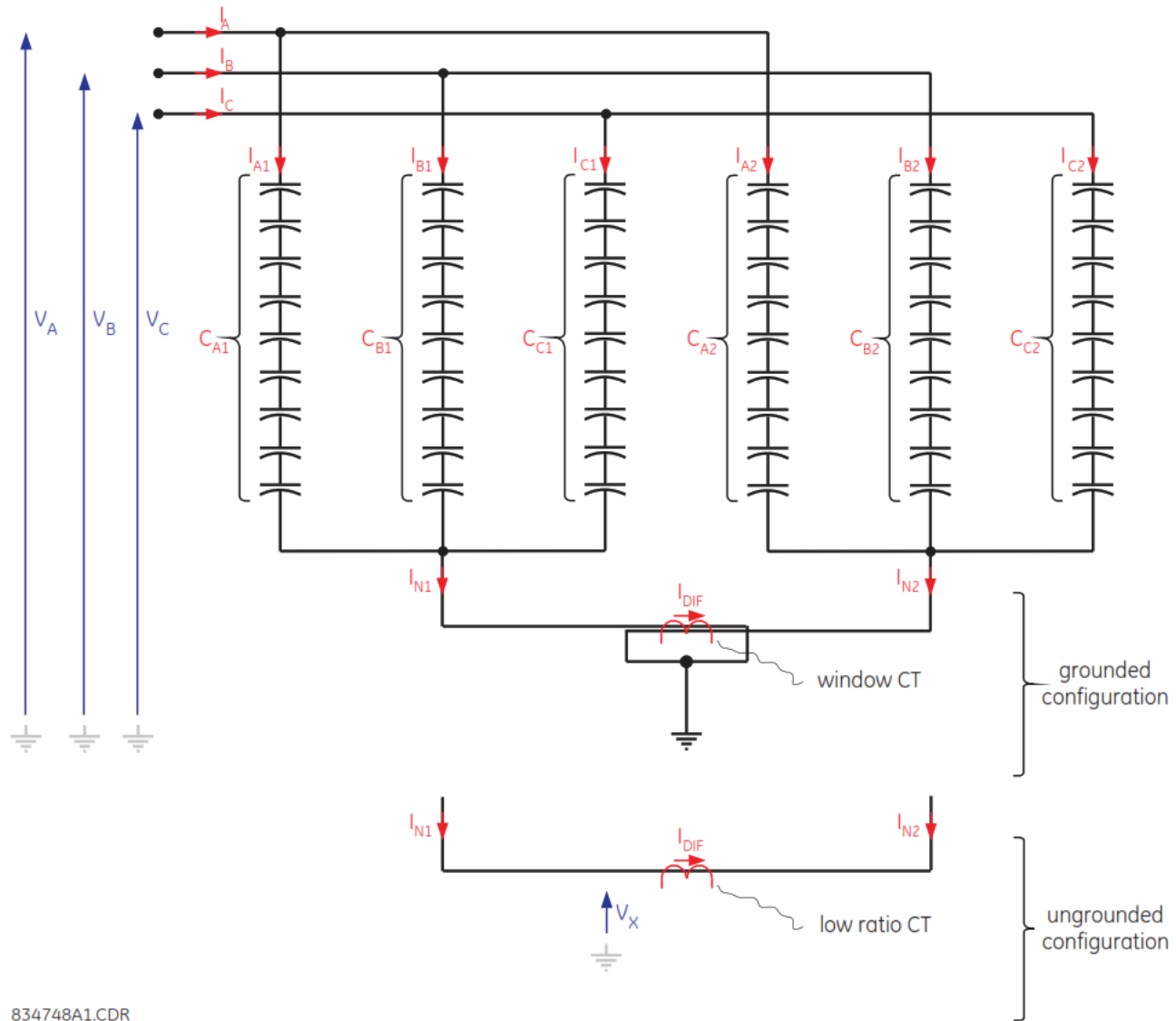# Neutral overvoltage 59NU restraint



834746A1.CDR

# Phase current unbalance 60P

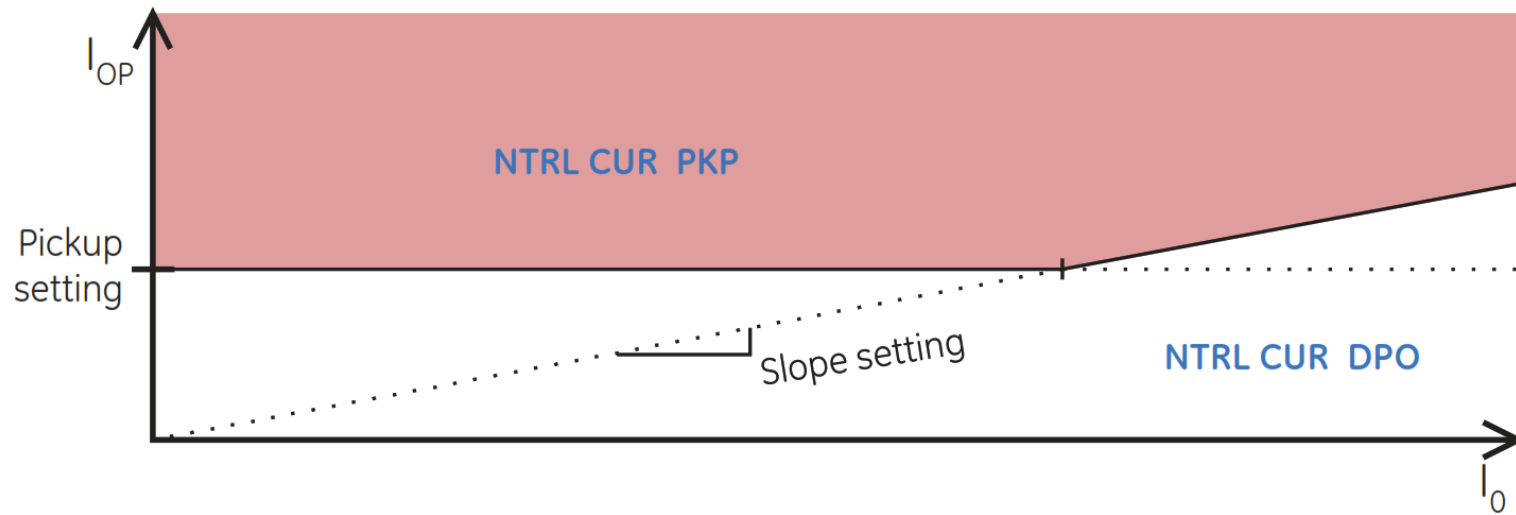# Neutral current unbalance 60N
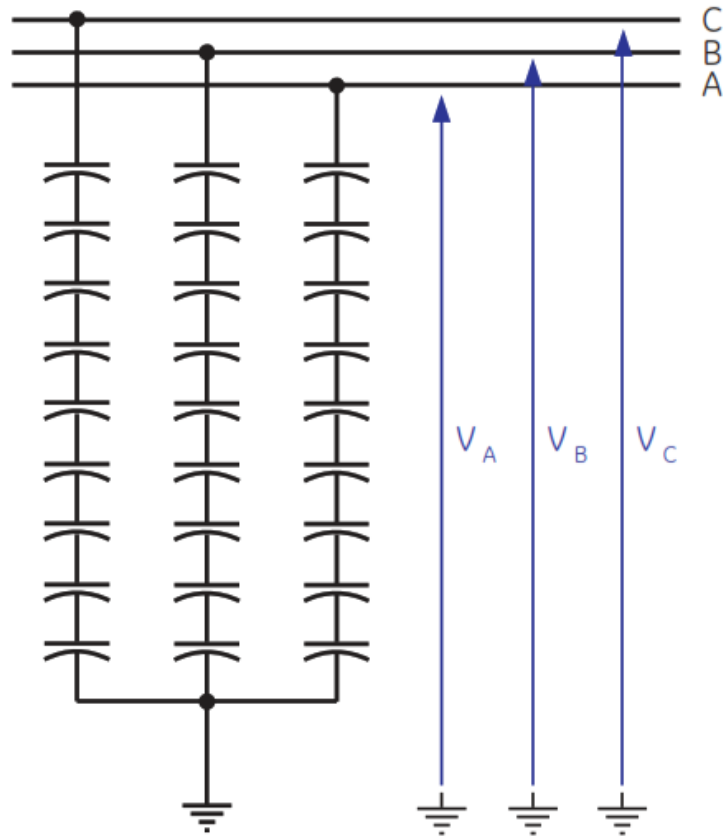

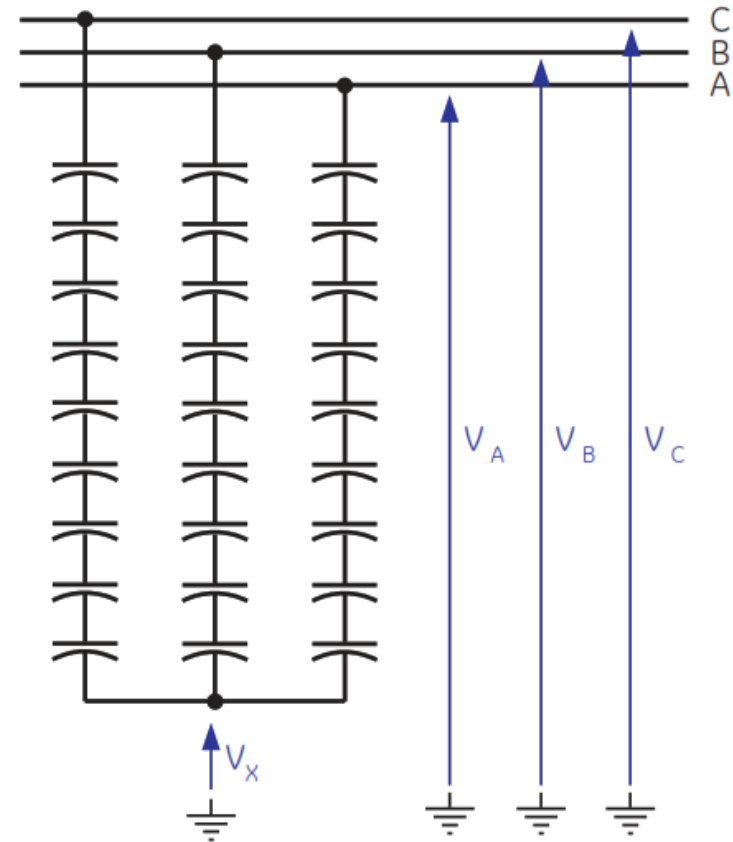
834748A1.CDR

# Neutral current unbalance 60N restraint

# Bank overvoltage 59B for grounded and ungrounded banks



Grounded bank

Ungrounded bank

834744A1.CDR

# Sensitivity stages

## Set relay elements in multiple stages

Provides sensitivity across large voltage or current range

Complies with standards or manufacturer specifications

Example, manufacturer spec

- 1.25 pu overvoltage for 5 minutes (300 s)
- 1.5 pu overvoltage for 15 seconds
- 2 pu overvoltage for 0.25 second

| 59B | Amplitude calculation | Pickup setting | 50 percent of maximum time (s) |
|-----|----------------------|----------------|--------------------------------|
| Stage 1 | 0.9 • 1.25 | 1.125 pu | 150 |
| Stage 2 | 0.9 • 1.5 | 1.35 pu | 7.5 |
| Stage 3 | 0.9 • 2 | 1.80 pu | 0.125 |

Bank Overvoltage //

Save | Restore | Default | Reset | VIEW ALL mode

| SETTING | PARAMETER |
|---------|-----------|
| Bank OV 1 Function | Enabled |
| Bank OV 1 Bus Source | Bank (SRC 1) |
| Bank OV 1 Ntrl Source | Bank (SRC 1) |
| Bank OV 1 Bank Ground | Grounded |
| Bank OV 1 Curve | Flexcurve A |
| Bank OV 1 Curve Time Multiplier | 1.00 |
| Bank OV 1 STG 1A Pickup | 1.125 pu |
| Bank OV 1 STG 2A Pickup | 1.350 pu |
| Bank OV 1 STG 3A Pickup | 1.800 pu |
| Bank OV 1 STG 4A Pickup | 1.050 pu |
| Bank OV 1 STG 1B Pickup | 1.125 pu |
| Bank OV 1 STG 2B Pickup | 1.350 pu |
| Bank OV 1 STG 3B Pickup | 1.800 pu |
| Bank OV 1 STG 4B Pickup | 1.050 pu |
| Bank OV 1 STG 1C Pickup | 1.125 pu |
| Bank OV 1 STG 2C Pickup | 1.350 pu |
| Bank OV 1 STG 3C Pickup | 1.800 pu |
| Bank OV 1 STG 4C Pickup | 1.050 pu |
| Bank OV 1 STG 1 Pickup Delay | 150.00 s |
| Bank OV 1 STG 2 Pickup Delay | 7.50 s |
| Bank OV 1 STG 3 Pickup Delay | 0.12 s |
| Bank OV 1 Dropout Delay | 0.25 s |
| Bank OV 1 BLock | OFF |
| Bank OV 1 Target | Self-reset |
| Bank OV 1 Events | Enabled |

Grouped Elements: Group

# Auto-setting / self-tuning

Relay measures unbalance on in-service capacitor bank

Relay calculates unbalance k-factor settings per phase, determining "zero-ed" point

Apply with manual supervision, or automatically apply calculated factors

After auto-set, relay measures changes to issue alarms and trips

```
VOLTAGE DIF1 AUTO
SETTING: Enabled
```
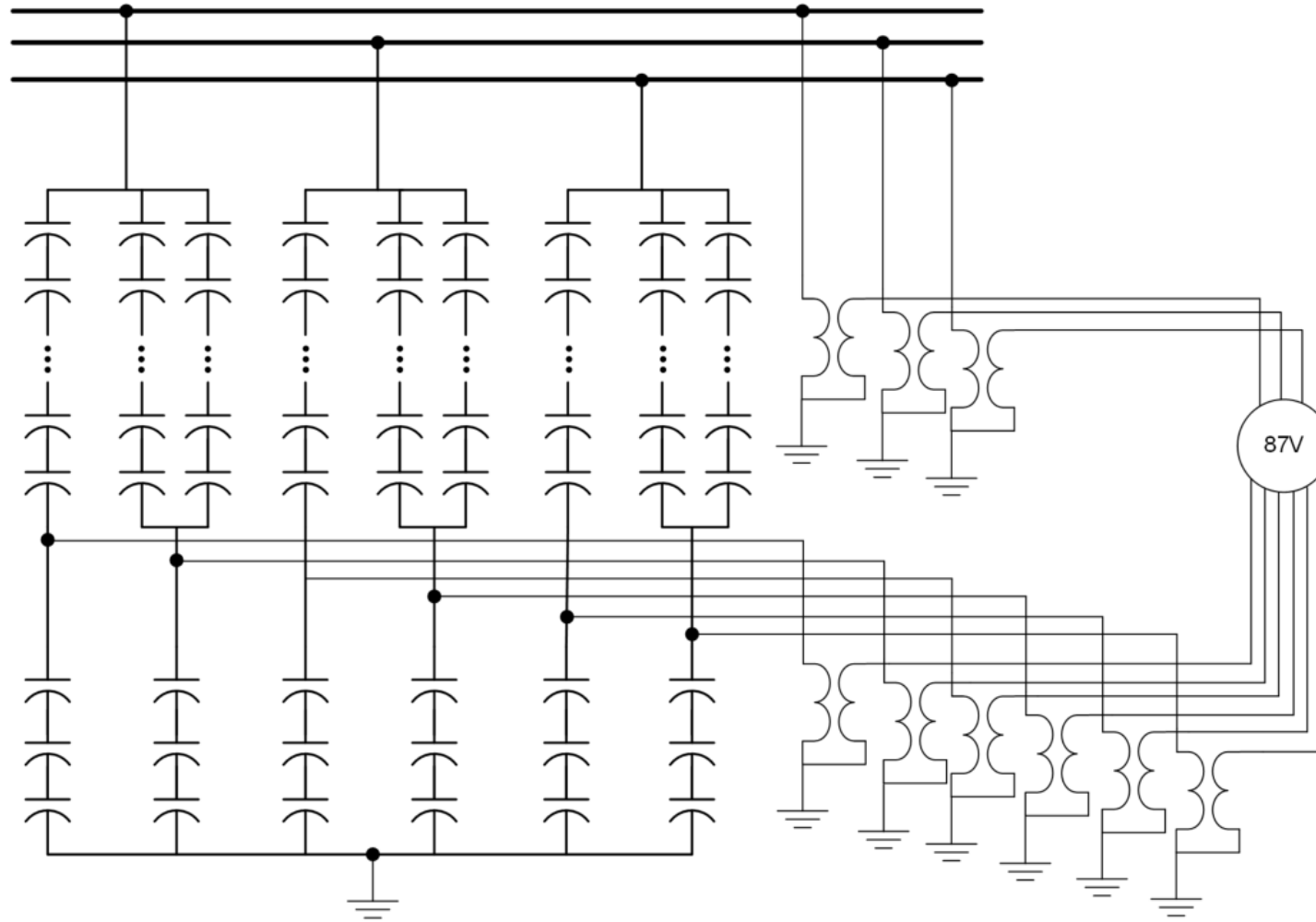
```
VDIF1A k=0.0249
APPLY IN PHS A? Yes
```

```
VDIF1A k=0.0249
APPLY IN PHS B? Yes
```

```
VDIF1A k=0.0249
APPLY IN PHS C? Yes
```

# Voltage differential trip upon switching

# 87V differential connections, grounded wye bank

# 87V operation event record

# 87V operation from lack of source VC
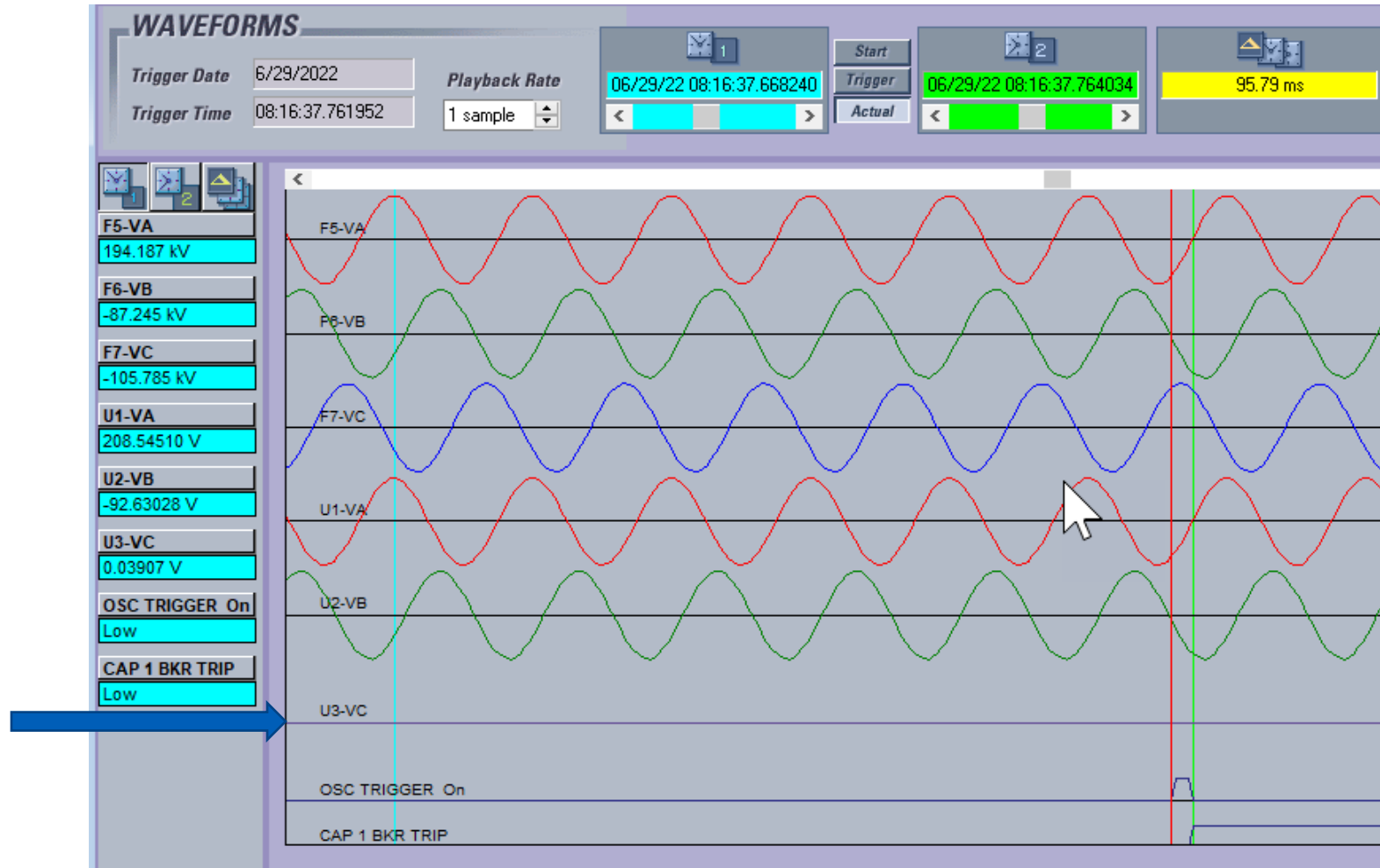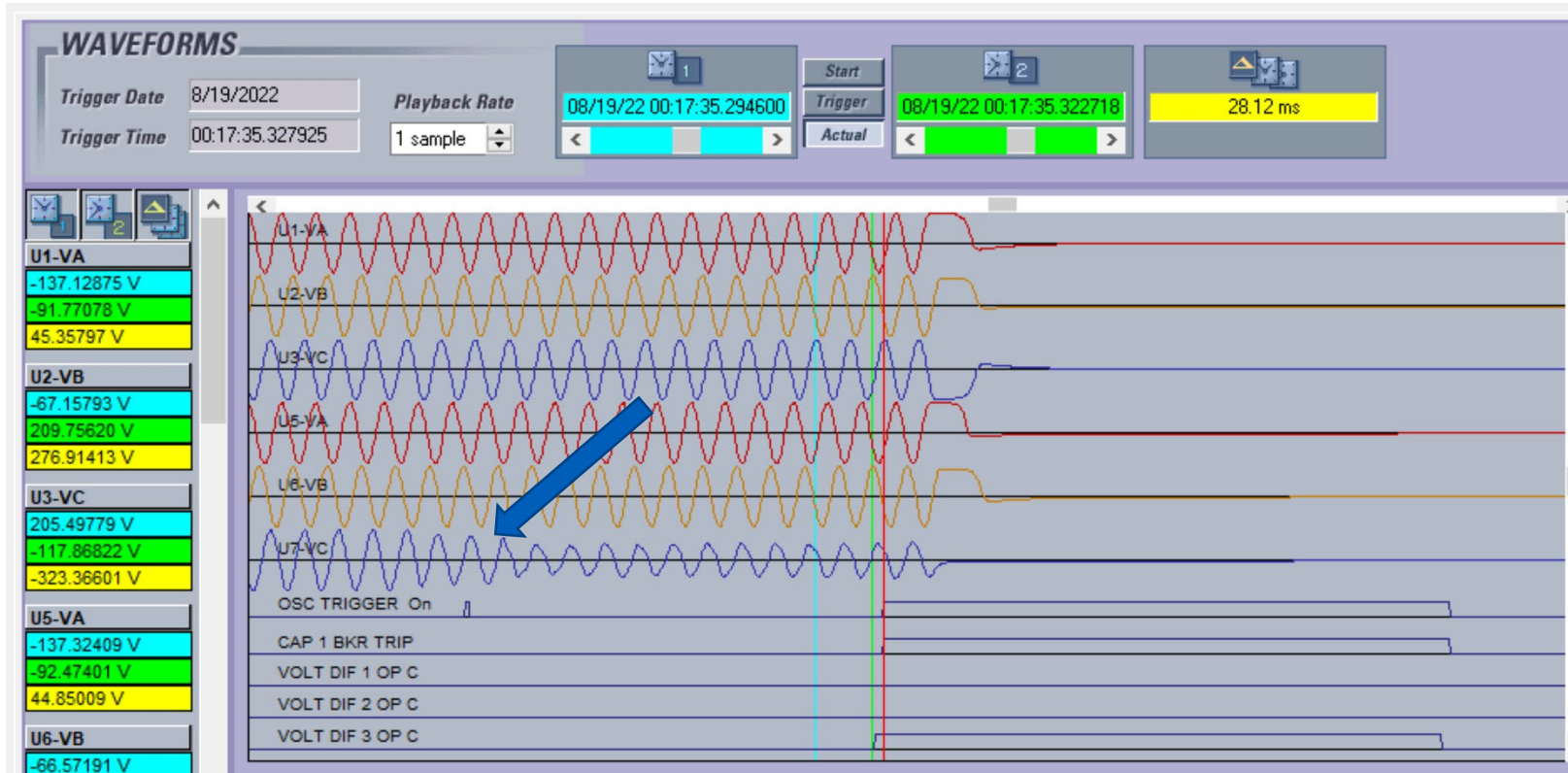
# 87V settings



| SETTING | PARAMETER |
|---|---|
| Voltage Differential 1 Function | Enabled |
| Voltage Differential 1 Bus Source | Bank (SRC 1) |
| Voltage Differential 1 Tap Source | SinglC (SRC 2) |
| Voltage Differential 1 Bank Ground | Grounded |
| Voltage Differential 1 Match Factor A | 957.0000 |
| Voltage Differential 1 Match Factor B | 957.0000 |
| Voltage Differential 1 Match Factor C | 957.0000 |
| Voltage Differential 1 Stage 1A Pickup | 0.029 pu |
| Voltage Differential 1 Stage 2A Pickup | 0.075 pu |
| Voltage Differential 1 Stage 3A Pickup | 0.108 pu |
| Voltage Differential 1 Stage 4A Pickup | 1.000 pu |
| Voltage Differential 1 Stage 1B Pickup | 0.029 pu |
| Voltage Differential 1 Stage 2B Pickup | 0.075 pu |
| Voltage Differential 1 Stage 3B Pickup | 0.108 pu |
| Voltage Differential 1 Stage 4B Pickup | 1.000 pu |
| Voltage Differential 1 Stage 1C Pickup | 0.029 pu |
| Voltage Differential 1 Stage 2C Pickup | 0.075 pu |
| Voltage Differential 1 Stage 3C Pickup | 0.108 pu |
| Voltage Differential 1 Stage 4C Pickup | 1.000 pu |
| Voltage Differential 1 Stage 1 Pickup Delay | 60.00 s |
| Voltage Differential 1 Stage 2 Pickup Delay | 10.00 s |
| Voltage Differential 1 Stage 3 Pickup Delay | 1.00 s |
| Voltage Differential 1 Stage 4 Pickup Delay | 0.20 s |
| Voltage Differential 1 DPO Delay | 0.25 s |
| Voltage Differential 1 Stg 1 Block | 89 A STATUS Off(P8a) |
| Voltage Differential 1 Stg 2 Block | 89 A STATUS Off(P8a) |
| Voltage Differential 1 Stg 3 Block | 89 A STATUS Off(P8a) |
| Voltage Differential 1 Stg 4 Block | ON |
| Voltage Differential 1 Target | Self-reset |
| Voltage Differential 1 Events | Enabled |

Voltage Differential //      230kV CB3...

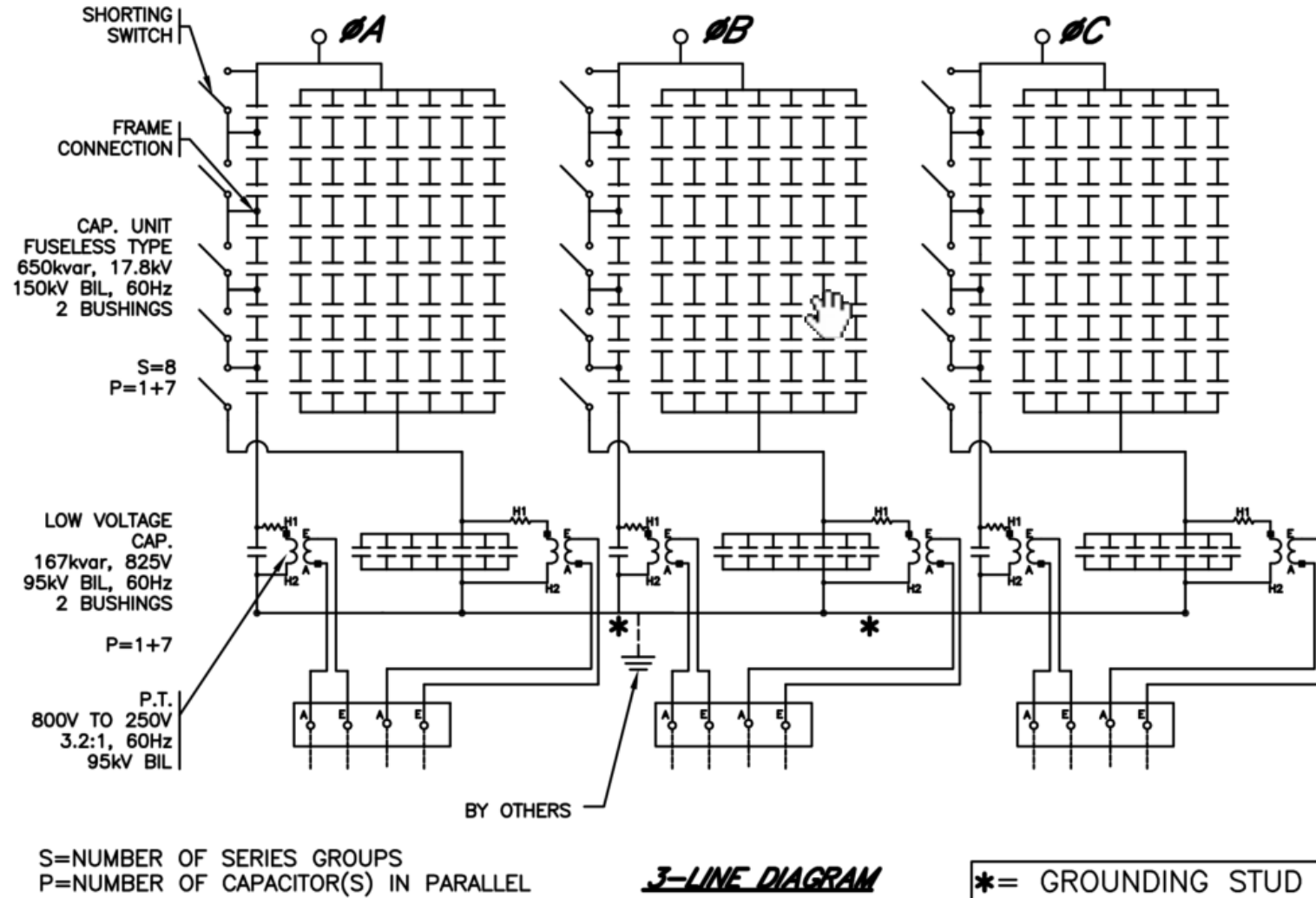230kV CB3 2014-3-20.urs   Grouped Elements: Group

Modern Capacitor Bank Protection Methods

# Voltage differential trip

while in service

# Phase C voltage drop during operation

# Grounded-wye bank detail



SHORTING SWITCH

ØA  ØB  ØC

FRAME CONNECTION

CAP. UNIT
FUSELESS TYPE
650kvar, 17.8kV
150kV BIL, 60Hz
2 BUSHINGS

S=8
P=1+7

LOW VOLTAGE
CAP.
167kvar, 825V
95kV BIL, 60Hz
2 BUSHINGS

P=1+7

P.T.
800V TO 250V
3.2:1, 60Hz
95kV BIL

BY OTHERS

S=NUMBER OF SERIES GROUPS
P=NUMBER OF CAPACITOR(S) IN PARALLEL

*3—LINE DIAGRAM*

*= GROUNDING STUD

# Compensated bank neutral voltage unbalance (ANSI 59NU) upon closing

# Ungrounded SCB and neutral voltage sensing



Resistive potential device

834757A1.CDR
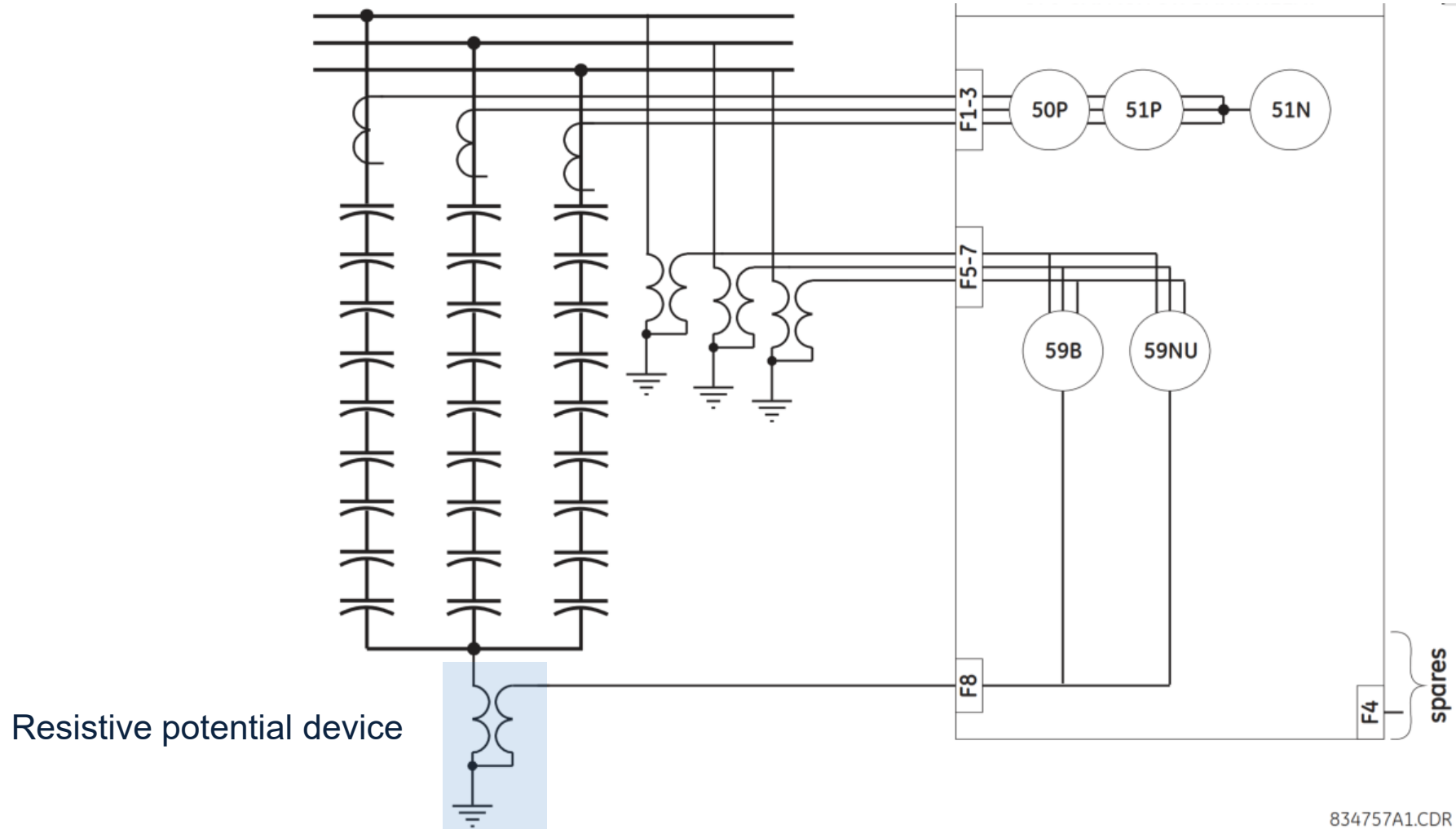
# Neutral voltage unbalance 59NU settings



Neutral Unbalance // 

| SETTING | PARAMETER |
|---|---|
| Neutral Current Unbalance 1 Function | Enabled |
| Neutral Current Unbalance 1 Bank Source | NeutUn (SRC 2) |
| Neutral Current Unbalance 1 k MAG | 0.0000 |
| Neutral Current Unbalance 1 k ANG | 0 deg |
| Neutral Current Unbalance 1 STG1 PKP | 0.048 pu |
| Neutral Current Unbalance 1 STG1 SLOPE | 0.0 % |
| Neutral Current Unbalance 1 STG2 PKP | 0.072 pu |
| Neutral Current Unbalance 1 STG2 SLOPE | 0.0 % |
| Neutral Current Unbalance 1 STG3 PKP | 0.072 pu |
| Neutral Current Unbalance 1 STG3 SLOPE | 0.0 % |
| Neutral Current Unbalance 1 STG4 PKP | 0.072 pu |
| Neutral Current Unbalance 1 STG4 SLOPE | 0.0 % |
| Neutral Current Unbalance 1 STG1 DEL | 1.00 s |
| Neutral Current Unbalance 1 STG2 DEL | 0.17 s |
| Neutral Current Unbalance 1 STG3 DEL | 0.17 s |
| Neutral Current Unbalance 1 STG4 DEL | 0.17 s |
| Neutral Current Unbalance 1 DPO DEL | 0.25 s |
| Neutral Current Unbalance 1 STG1 Block | 89H-a2 Off(P8a) |
| Neutral Current Unbalance 1 STG2 Block | 89H-a2 Off(P8a) |
| Neutral Current Unbalance 1 STG3 Block | ON |
| Neutral Current Unbalance 1 STG4 Block | ON |
| Neutral Current Unbalance 1 Target | Self-reset |
| Neutral Current Unbalance 1 Events | Enabled |

Grouped Elements: G

# Events for neutral unbalance 59NU

# Bank overcurrent 60N upon closing

# Current balance protection 60N and 60P



Resistive potential device

834761A1.CDR
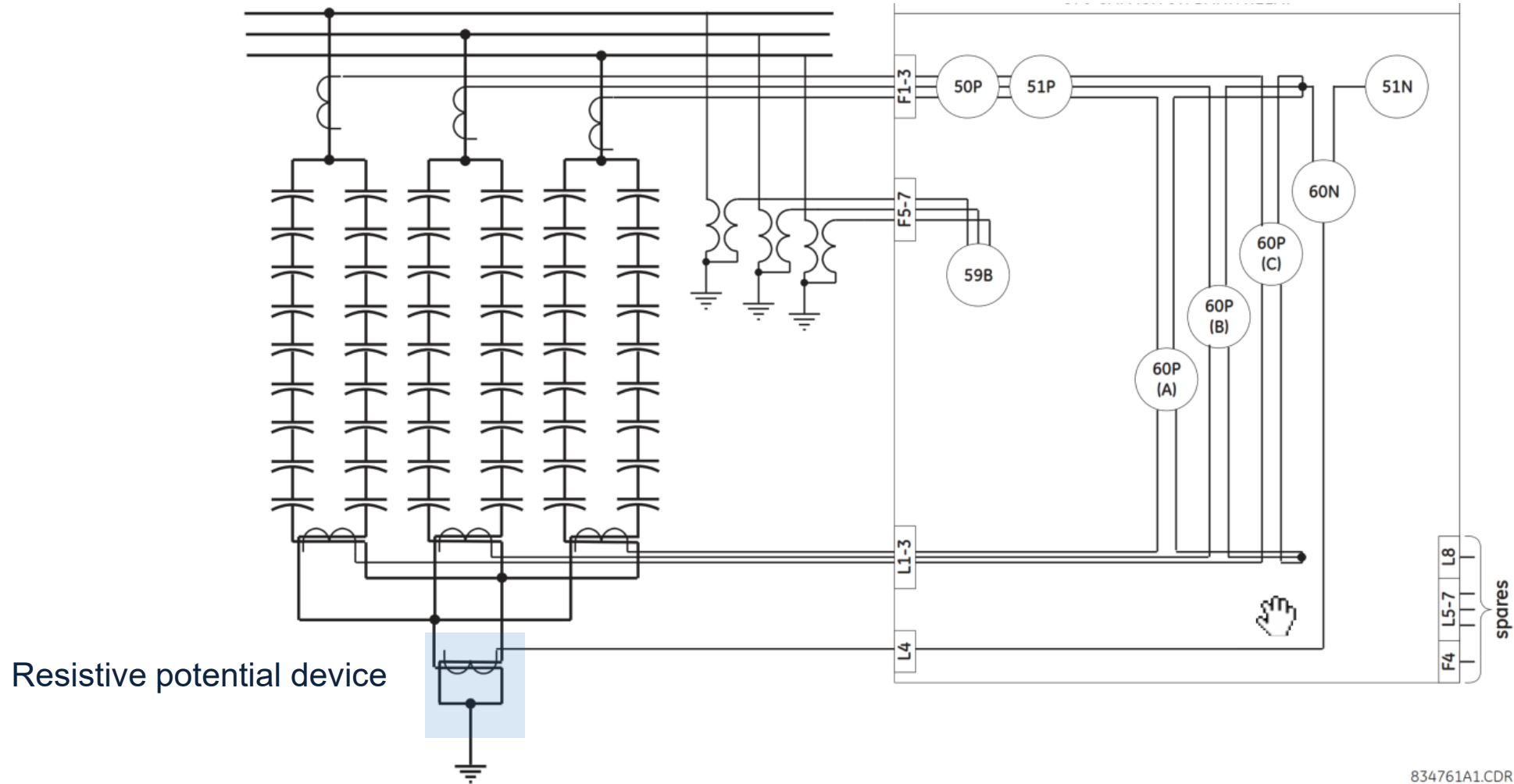
# Closing SCB event
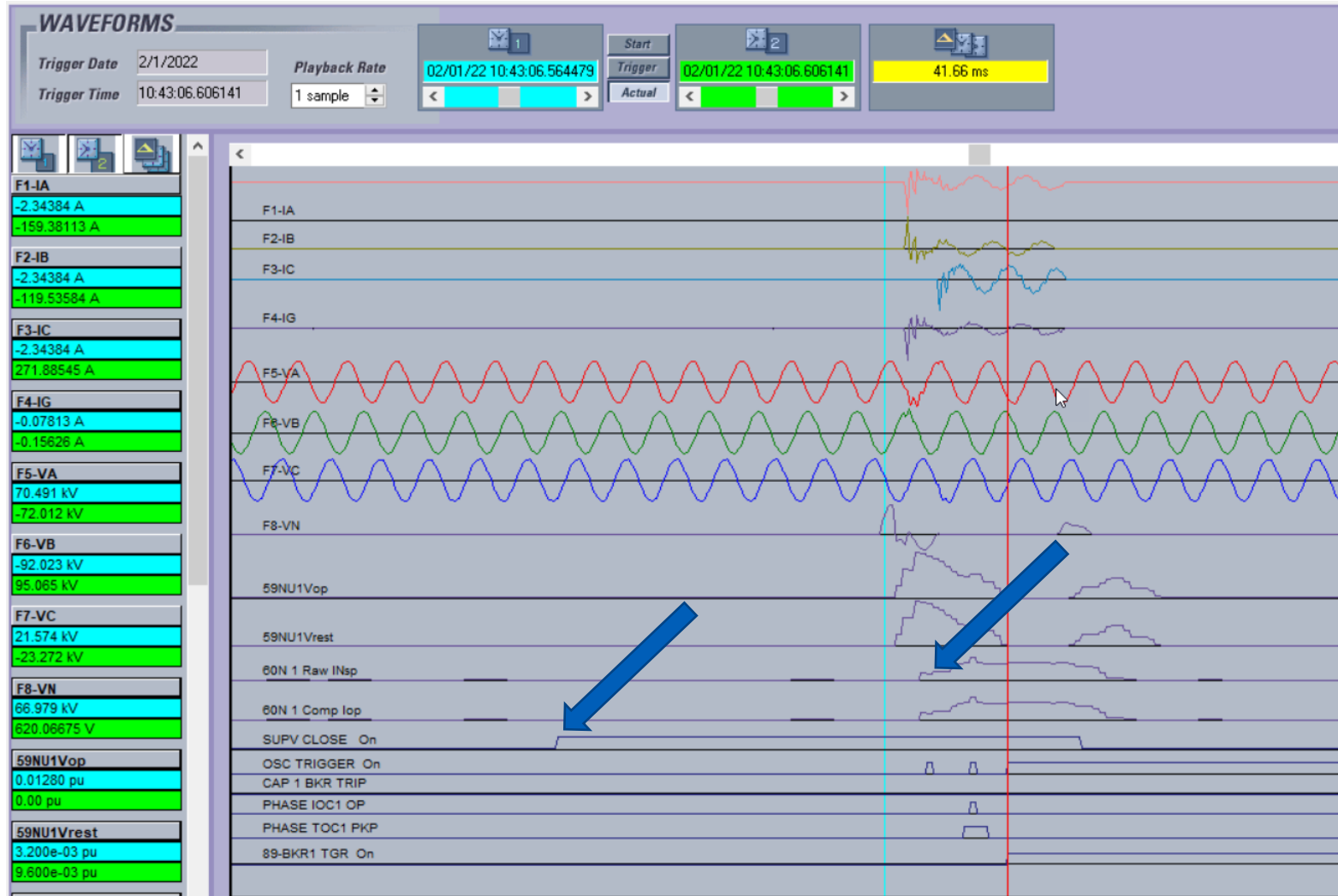
# Conclusions

Protecting capacitor banks is challenging

Effective protection methods

- Voltage differential (87V)
- Neutral-voltage unbalance (59NU)
- Phase-current unbalance (60P)
- Neutral-current unbalance (60N)
- Bank phase overvoltage (59B)

Compensate for unbalances through auto setting and self-tuning

Real-world examples showed applications of protection methods

# Questions?