SDG&E Relay Standards – Updating Tertiary Bus and Reactor Protection

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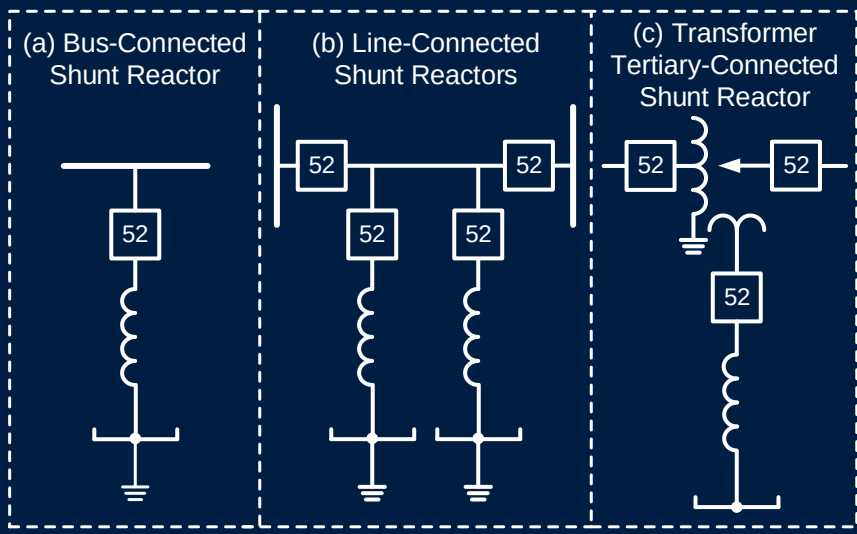
Introduction

- Overview of shunt reactor design
- Shunt reactor protection and design
- Tertiary-connected, air-core shunt reactor
- Overview of SDG&E system and standards
  - Existing standards
  - Future standards
  - Protection scheme and set points

Overview of Shunt Reactor

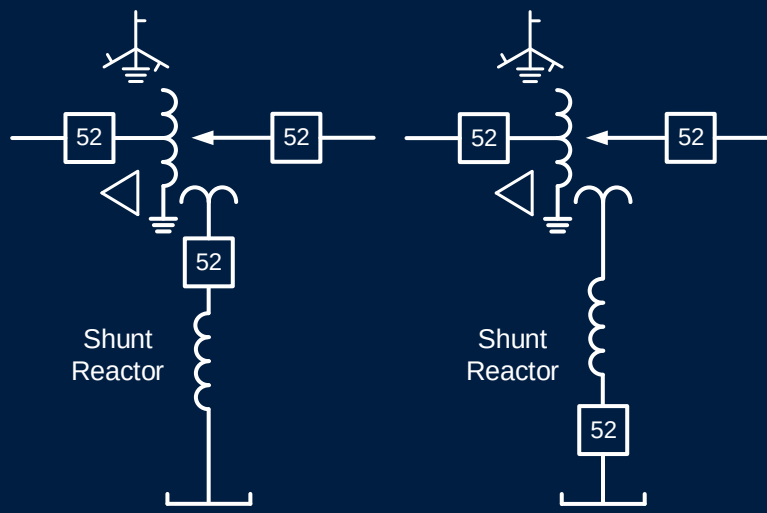


- Above 52 kV usually directly connected at bus
- Typical reactor size 30–300 MVAR
- Single phase 125–375 MVAR

Overview of Shunt Reactor

- Three-legged gapped iron core
- Five-legged gapped iron core
- Shell-type gapped iron core
- Coreless (air core)

Tertiary-Connected, Dry-Type Reactor Protection



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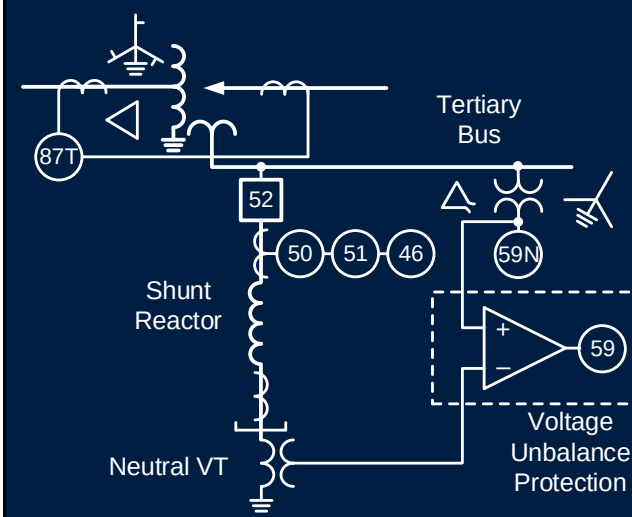
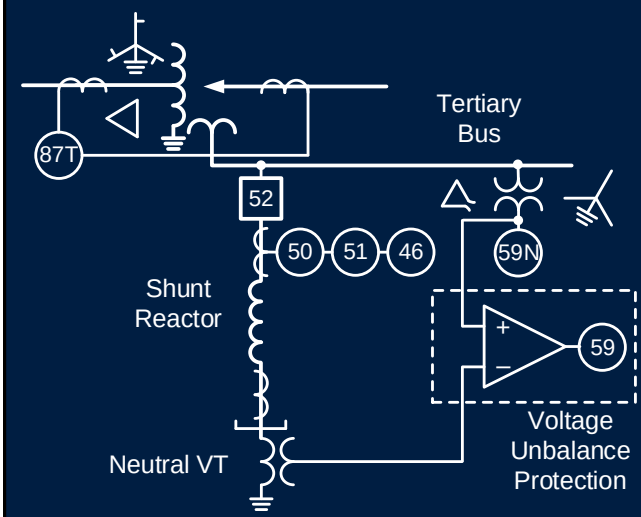


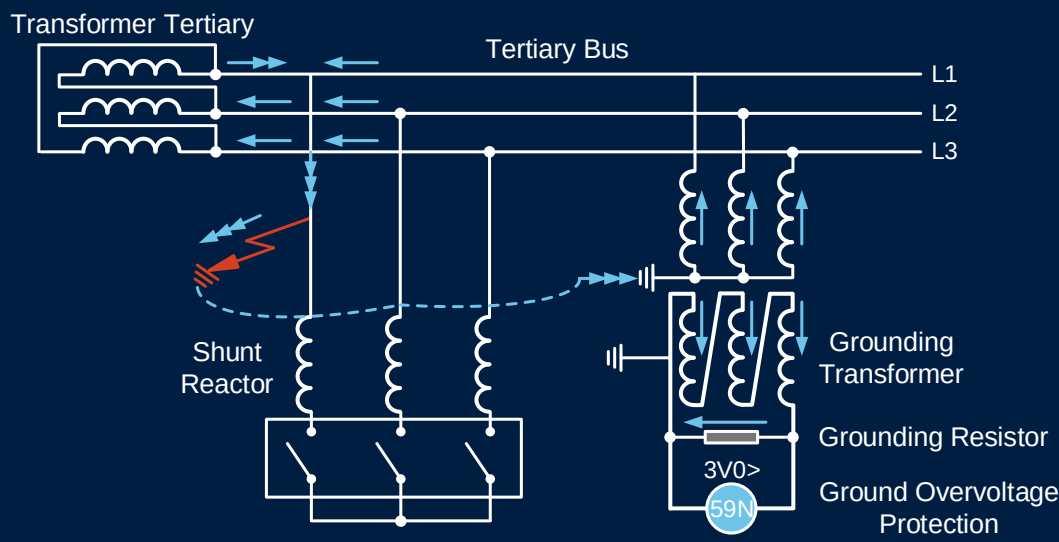
- Instantaneous overcurrent (50)
- Time-delayed overcurrent (51)
- Negative-sequence (46)
- Ground overvoltage (59N)
- Special schemes: turn-to-turn (T-T) faults

Tertiary-Connected, Dry-Type Reactor Protection

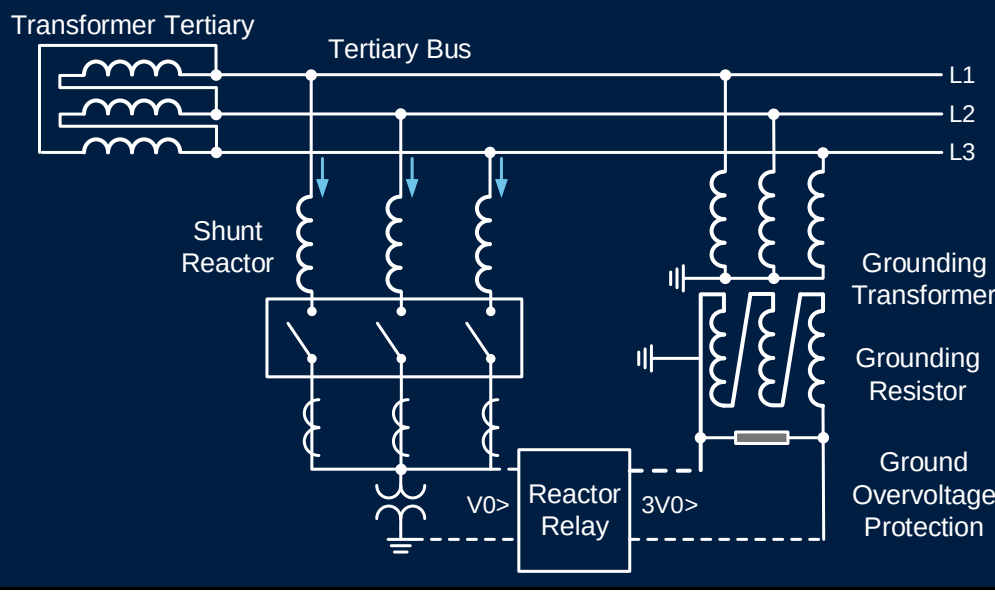


- Phase differential
  - Transformer differential (87T) when shunt reactor included in power transformer
  - Separate reactor phase differential protection
- Breaker failure (50BF)

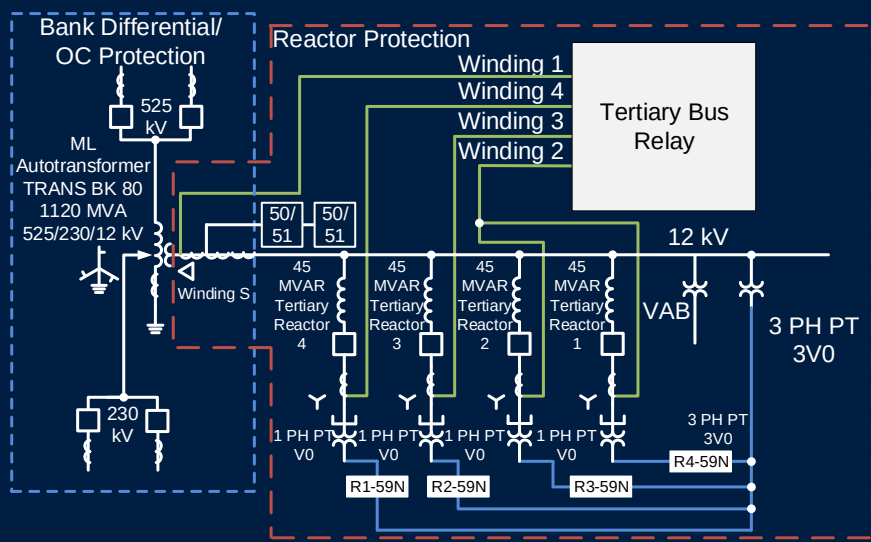
Tertiary Bus Ground Voltage



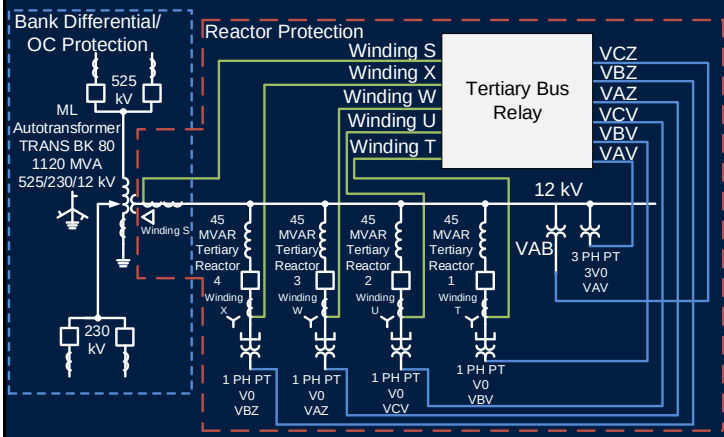
Tertiary Reactor – Normal and Fault Scenarios



SDG&E Shunt Reactor Upgrade 1 – 2004

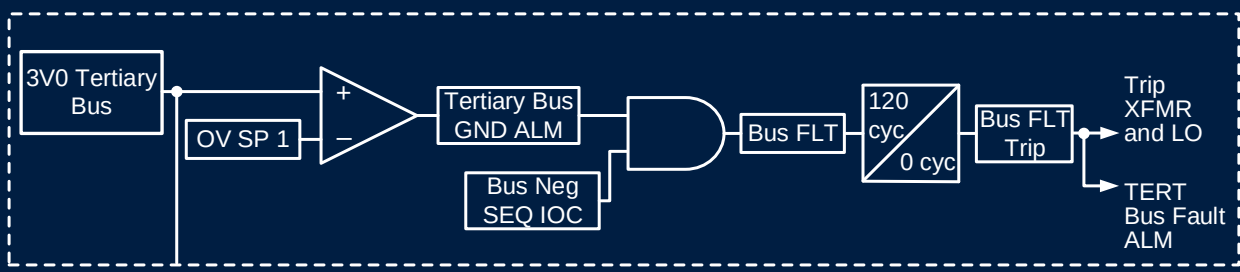


SDG&E Shunt Reactor Upgrade 2 – 2019



Winding / Connection	Device	Comments
Wdg. S	12 kV bus	3-phase CT, delta
Wdg. T	Reactor 1	3-phase CT, wye
Wdg. U	Reactor 2	3-phase CT, wye
Wdg. W	Reactor 3	3-phase CT, wye
Wdg. X	Reactor 4	3-phase CT, wye
VAV	12 kV ground detection	3-phase PT = 3V0
VBV	Reactor 1	1-phase PT = V0
VCV	Reactor 2	1-phase PT = V0
VAZ	Reactor 3	1-phase PT = V0
VBZ	Reactor 4	1-phase PT = V0
VCZ	VAB 12 kV bus	Voltage reference

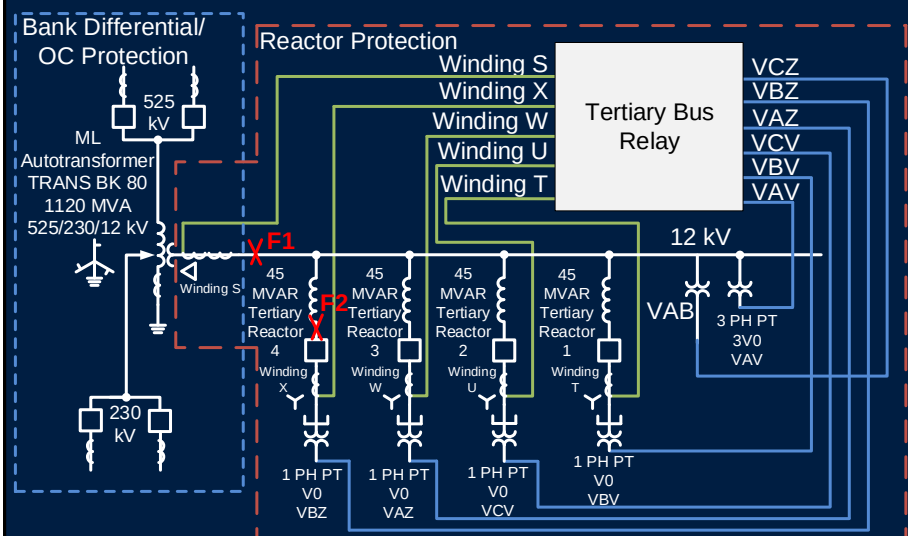
Tertiary Fault – Neutral Side of Reactor



Front-Panel Design Details

ENABLED		TARGET RESET	
TRIP			
TER BUS GND		TER BUS DIFF	
REAC1 CB STATUS		TER BUS OC	
REAC2 CB STATUS		TER NEG SEQ	
REAC3 CB STATUS		SPARE	
REAC4 CB STATUS		SPARE	
SPARE		SPARE	
REAC1 TT FAULT		REAC3 TT FAULT	
REAC1 CB FAIL		REAC3 CB FAIL	
REAC1 BF		REAC3 BF	
REAC2 TT FAULT		REAC4 TT FAULT	
REAC2 CB FAIL		REAC4 CB FAIL	
REAC2 BF		REAC4 BF	

F1 / F2 and Protection Discussion



- F1 fault
  - 3P – 87R / 50P
  - PP – 87R / 50P
- F2 fault
  - 3P – 87R
  - PP – 87R / 50Q / 51Q

F1 / F2 faults require opening high-side breakers

Protection Element Guidelines

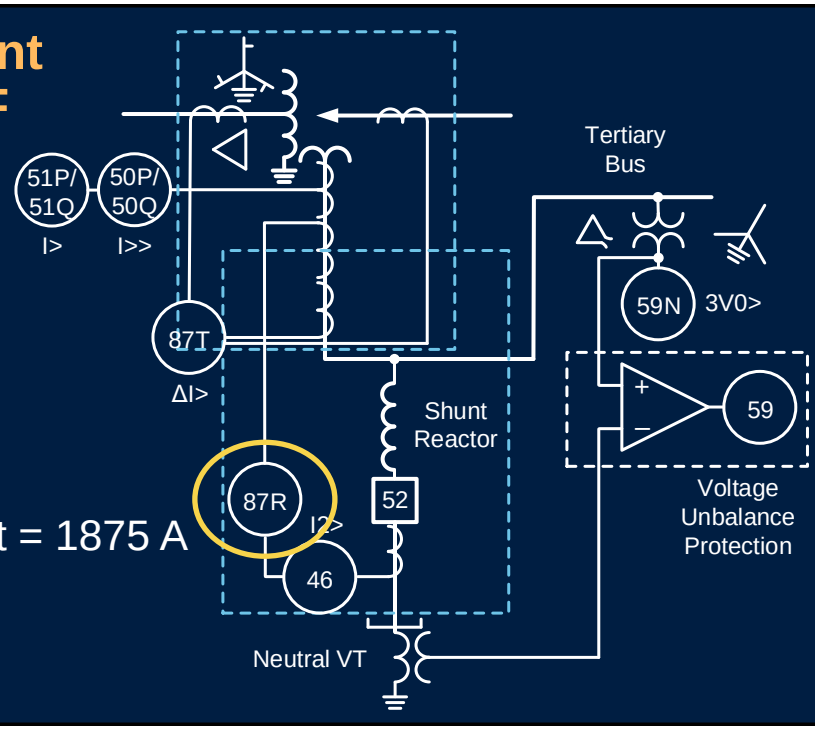
- Differential (87P)
- Phase overcurrent (50P / 51P) on bank tertiary current transformer (CT) winding
- Negative-sequence (50Q / 51Q) on bank tertiary CT winding
- T-T (50 / 51Q) on reactor breaker CTs
- V0 and 3V0 (59 ground detection, custom logic)

Protection Element Guidelines – DIFF

Differential (87R)

O87P = 0.2 • INOM
= 0.2 • 8660 A
= 1732 A

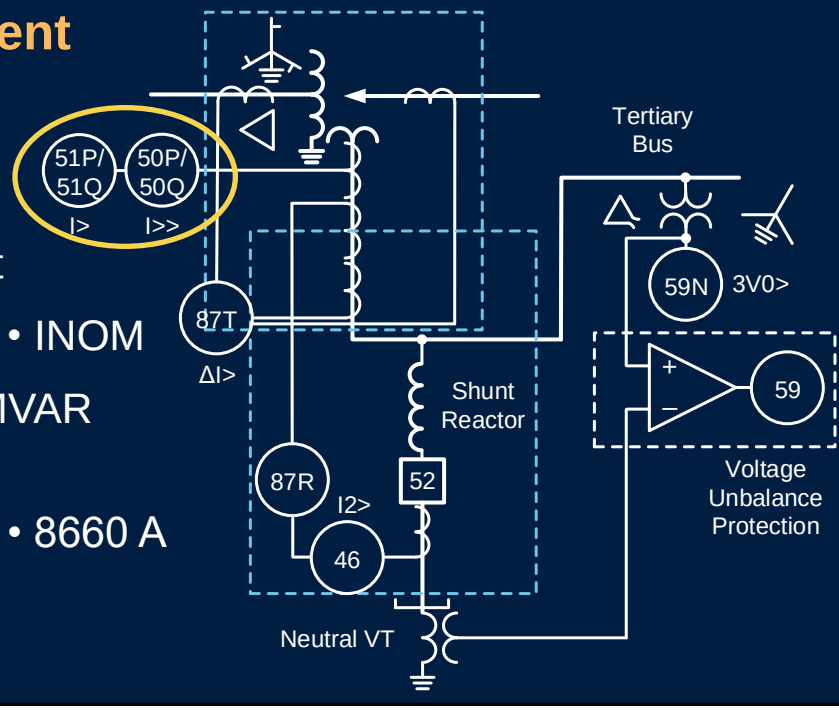
- Adaptive slope
- Phase-to-phase fault = 1875 A
- SLP1 = 15%
- SLP2 = 50%



Protection Element Guidelines – Overcurrent

50P / 51P element

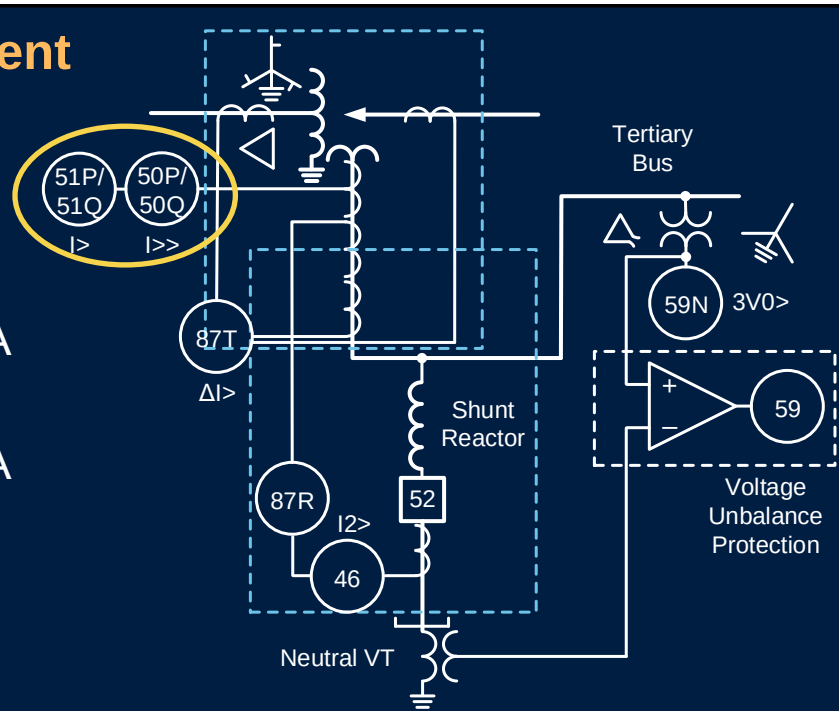
- 50P = 1.1 • 1.25 • INOM
- INOM = 4 • 45 MVAR
  = 8660 A
- 50P = 1.1 • 1.25 • 8660 A
  = 11,900 A
- 51P OFF



Protection Element Guidelines – Overcurrent

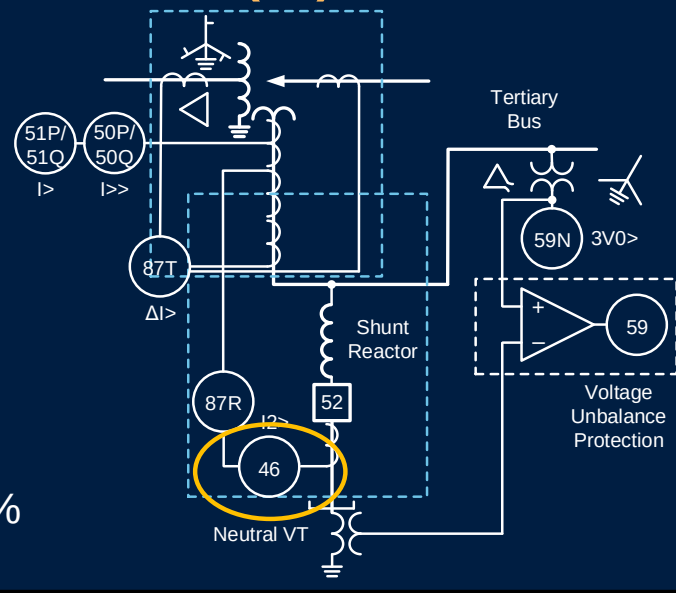
50Q / 51Q element

- 50Q = 0.4 • 3264 A
  = 1300 A
- 51Q = 0.2 • 3264 A
  = 650 A
- IEEE Inverse and time dial = 0.5



Reactor Breaker Turn-to-Turn Fault Negative-Sequence Overcurrent (46)

- Breaker on neutral
- Opening breaker clears T-T fault
- Inductance varies with turn short
  - $(0.95)^2 \cdot X_L = 0.9\ X_L$
  - $(0.90)^2 \cdot X_L = 0.8\ X_L$
- 150 A pickup provides 2.6% T-T, 2 seconds



Conclusion

- Dry-type tertiary bus and reactor protection standards
- SDG&E protection design using modern relays
- Improved redundancy and simplified design
- Negative-sequence overcurrent with ground detection
- Protection element selection and settings
- Design and documentation

Questions?