



POWER SYSTEMS ENGINEERING

CIRCUIT BREAKER CONTROL SCHEME



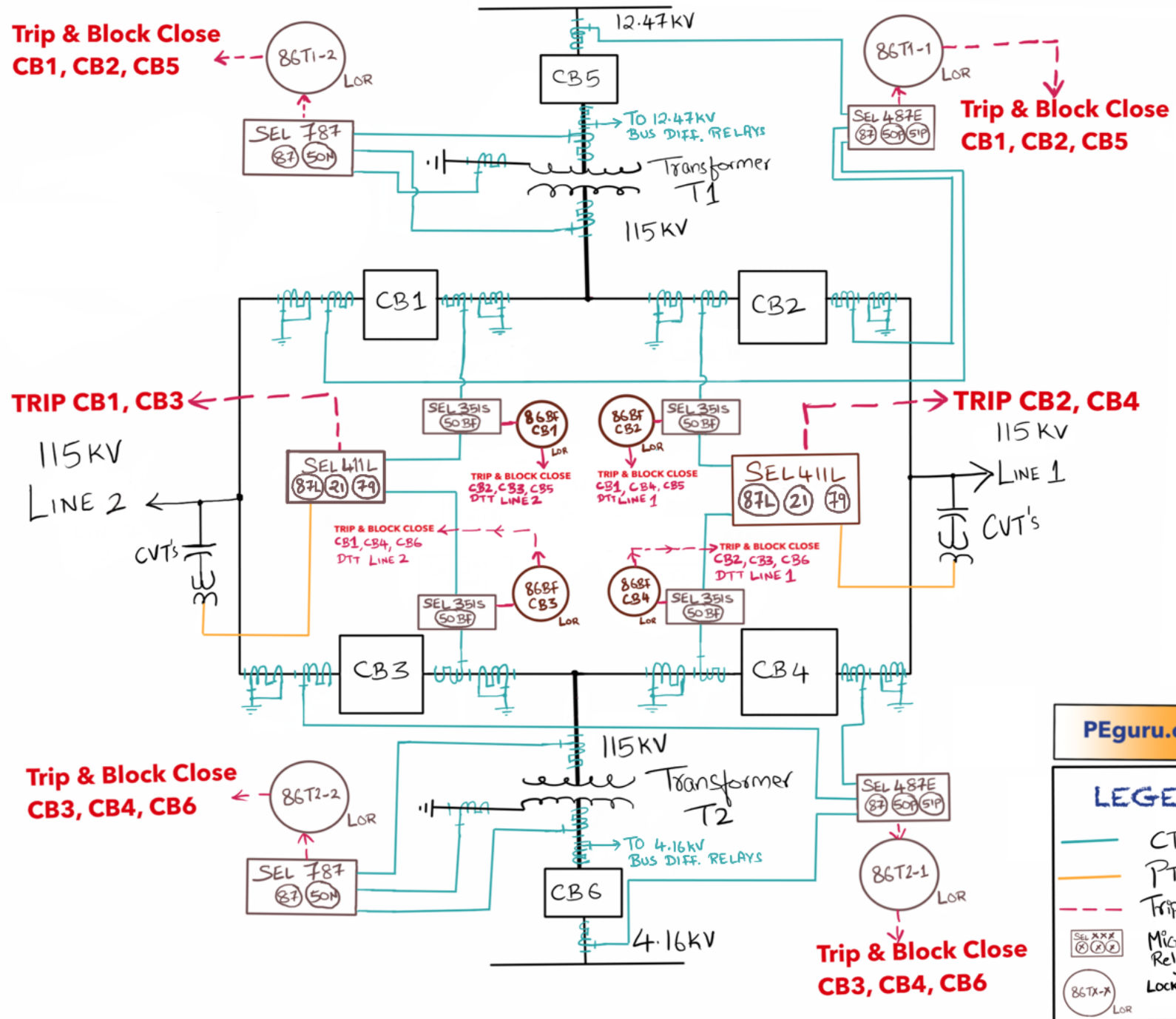
LEARN TO WIRE LOCKOUT RELAYS
AND MICROPROCESSOR RELAYS

ALEEN MOHAMMED

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Test your knowledge

01 THE RING SUBSTATION



02 METHODOLOGY

OBJECTIVE:

- Develop breaker control scheme of 115kV circuit breaker CB1 from the Ring Substation. Schematic drawing will show how to connect trip contacts and close (or block close) contacts of relays.
- Test your knowledge using a different substation layout (included).

Making sense of the Ring substation online

Why ring layout?

- Ring layout is chosen for most new substations. Not too elaborate and very reliable (from operation standpoint).

What is the methodology for relay selection?

- Current differential is the best form of protection. Any relay with this functionality should be your first choice. There are exceptions, will be described below.
 - For **Transformer protection** –
 - Schweitzer SEL787 chosen. It implements current differential using current transformers (CT) on the power transformer bushings.
 - Schweitzer SEL487E also chosen. CT's from breaker bushing chosen in this case. Zone of protection is much larger and encapsulates the one from SEL787.
 - Both relays can implement overcurrent protection 50 and 51 on phase and neutral/ground as backup.
 - Not shown, the sudden pressure relay – internal to transformer, trips the 86T lockout relay directly.

02 METHODOLOGY

- For **Bus protection** –
 - Ring layouts do not need separate relays for bus protection. All pieces of bus fall inside either transformer or transmission line zone of protection.
 - For any other bus layout (straight, breaker-and-a-half, etc), bus differential relay is required. A short-circuit on a bus generates incredibly high fault currents. If CT saturation is possible then use high impedance bus differential relay like SEL587Z. Otherwise a low impedance relay like SEL487B works just fine.

- For **Line protection** –
 - Relay choice for line protection cannot automatically be a line differential relay. It is driven by following reasoning
 - Which relay is at the remote-end? Different relays at each end of transmission line will not work. Most times the concerned party will upgrade the relays at the remote-end substation to match the ones at the new substation.
 - How will relays communicate - Fiber, power-line carrier, microwave, leased telephone lines? Implementing current differential on a transmission line requires a high bandwidth – high throughput communication medium. Fiber is popular medium in this regard. It allows relays like SEL411L to communicate the phase current information to each end.
 - When fiber is not present, power-line carrier is the next best option. However, line differential protection scheme cannot be implemented. With this medium, distance (a.k.a. impedance) relaying using pilot schemes is used. Popular pilot protection scheme is Directional Comparison Blocking.
 - Distance relaying requires line potentials (because $Z=V/I$ ohms).

02 METHODOLOGY

- For **Breaker protection** –
 - Schweitzer SEL351S chosen. A breaker fail check is initiated every time a high voltage breaker is asked to trip. SEL351S relay checks if the breaker has opened or not. If not then it trips breaker failure lockout relay.
 - Some relays like SEL487E include breaker failure functionality of SEL351S. However, the choice to discard 351S and implement its functionality in another multifunction relay is at engineer's discretion.

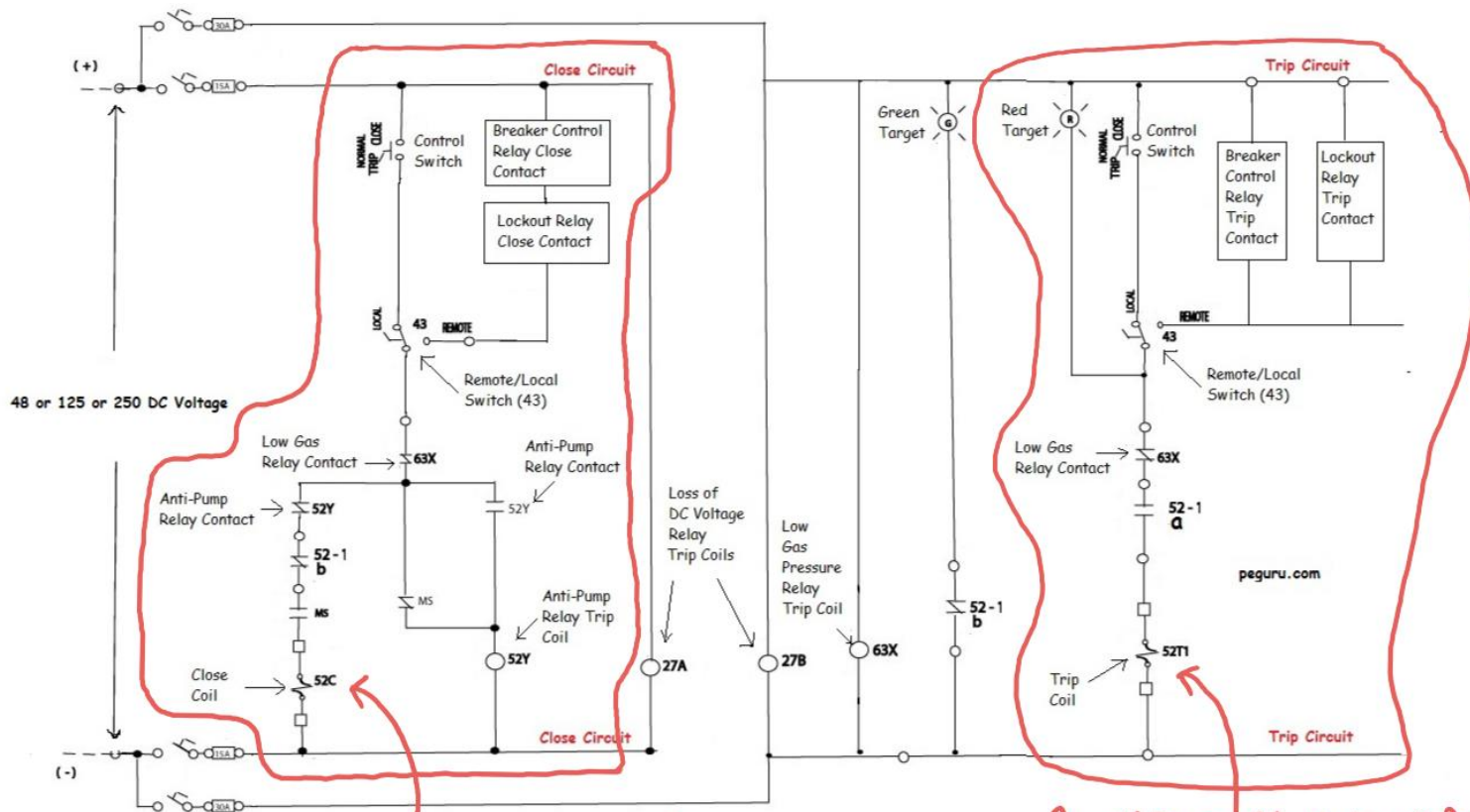
The Fine Print

The relaying oneline shown above will be used to explain the breaker control scheme. As such it omits additional details like

- Backup protection relays not shown.
- 12.47kV & 4.16kV bus protection not shown.
- Auxiliary tripping relays not shown.
- Equipment rating and CT ratios not shown.

03 BREAKER CONTROL SCHEME

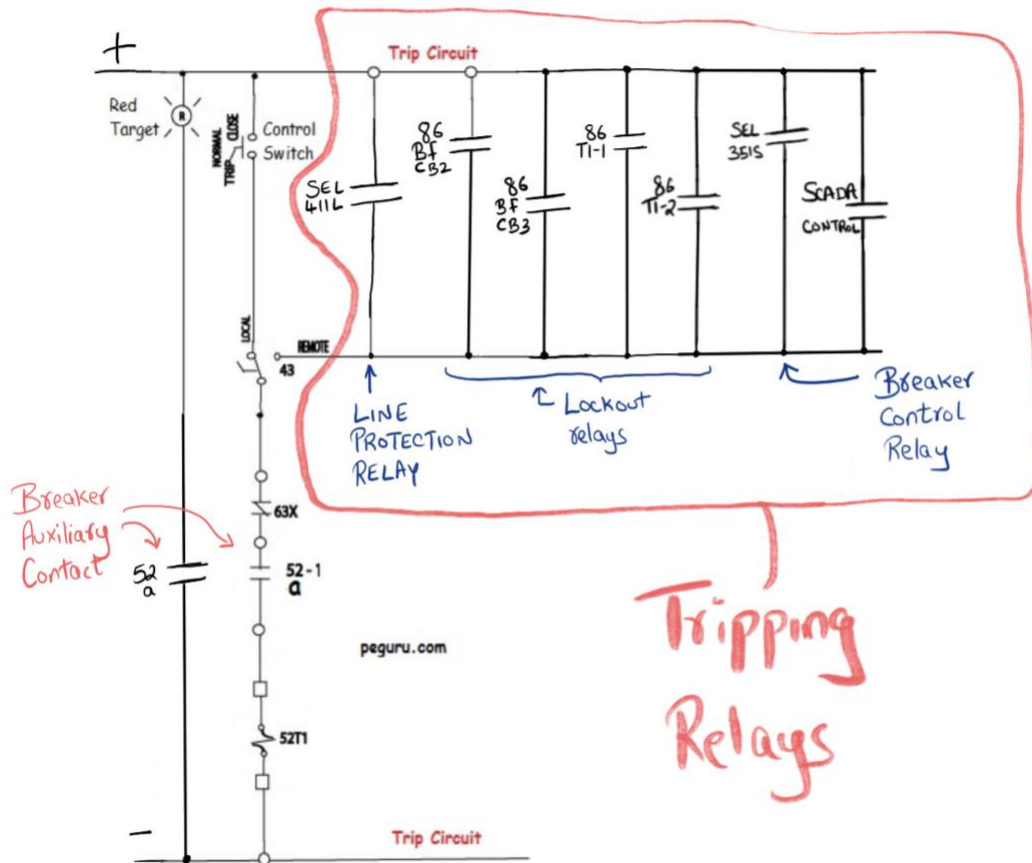
Generic breaker control scheme. Details of this schematic drawing are [provided here](#).



Anything tied to close coil is part of Close circuit

Anything tied to trip coil is part of trip circuit

03 BREAKER CONTROL SCHEME



Tripping scheme for 115kV circuit breaker CB1

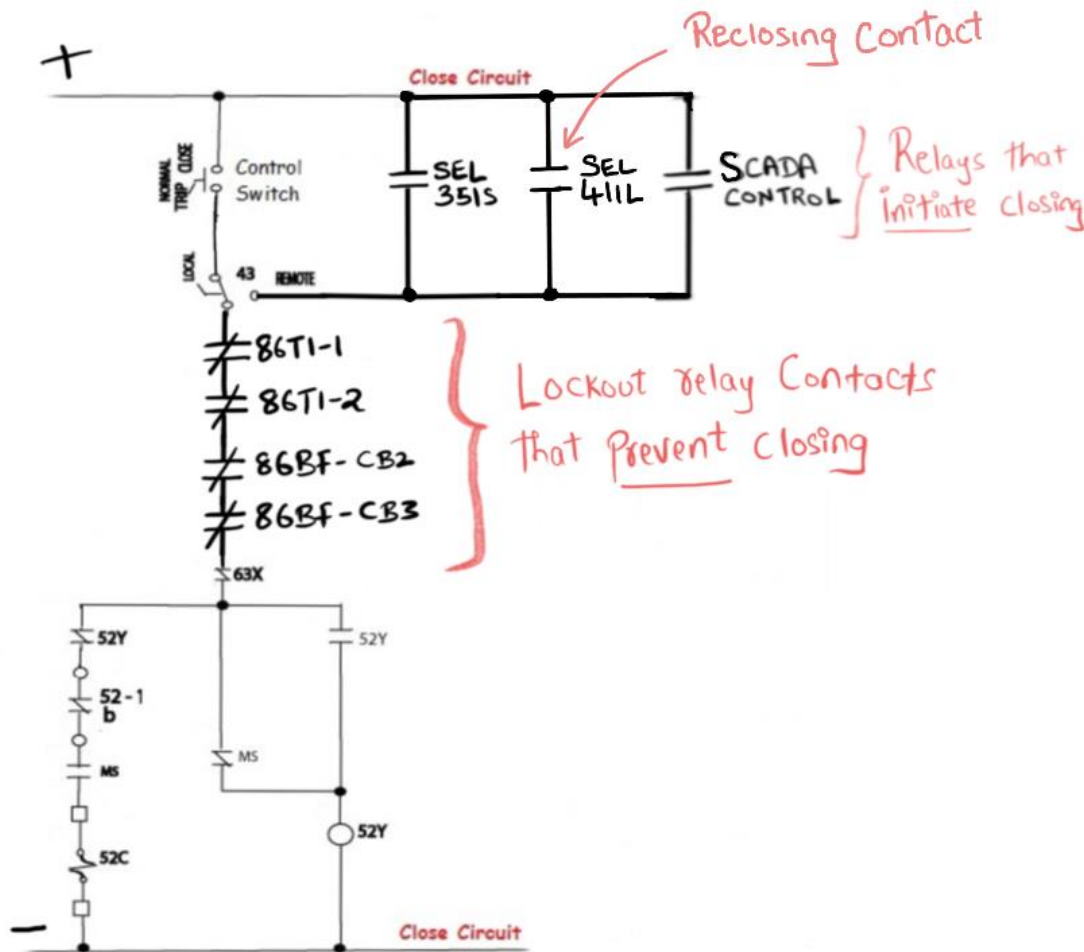
115kV circuit breaker CB1 from the ring bus substation is chosen.

Note this breaker is in the 115kV Line 2 zone of protection and transformer TR1 zone of protection.

Reasoning for selecting shown relays to trip the breaker:

- SEL411L: Needs to trip this breaker to protect transmission line 2.
- SEL351S: Needs to trip this breaker to protect it. Implements breaker failure logic.
- Lockout 86 relays: Need to trip this breaker to isolate the equipment it is protecting. For instance, 86T isolates transformer, 86BF-CB3 isolates CB3, etc.

03 BREAKER CONTROL SCHEME

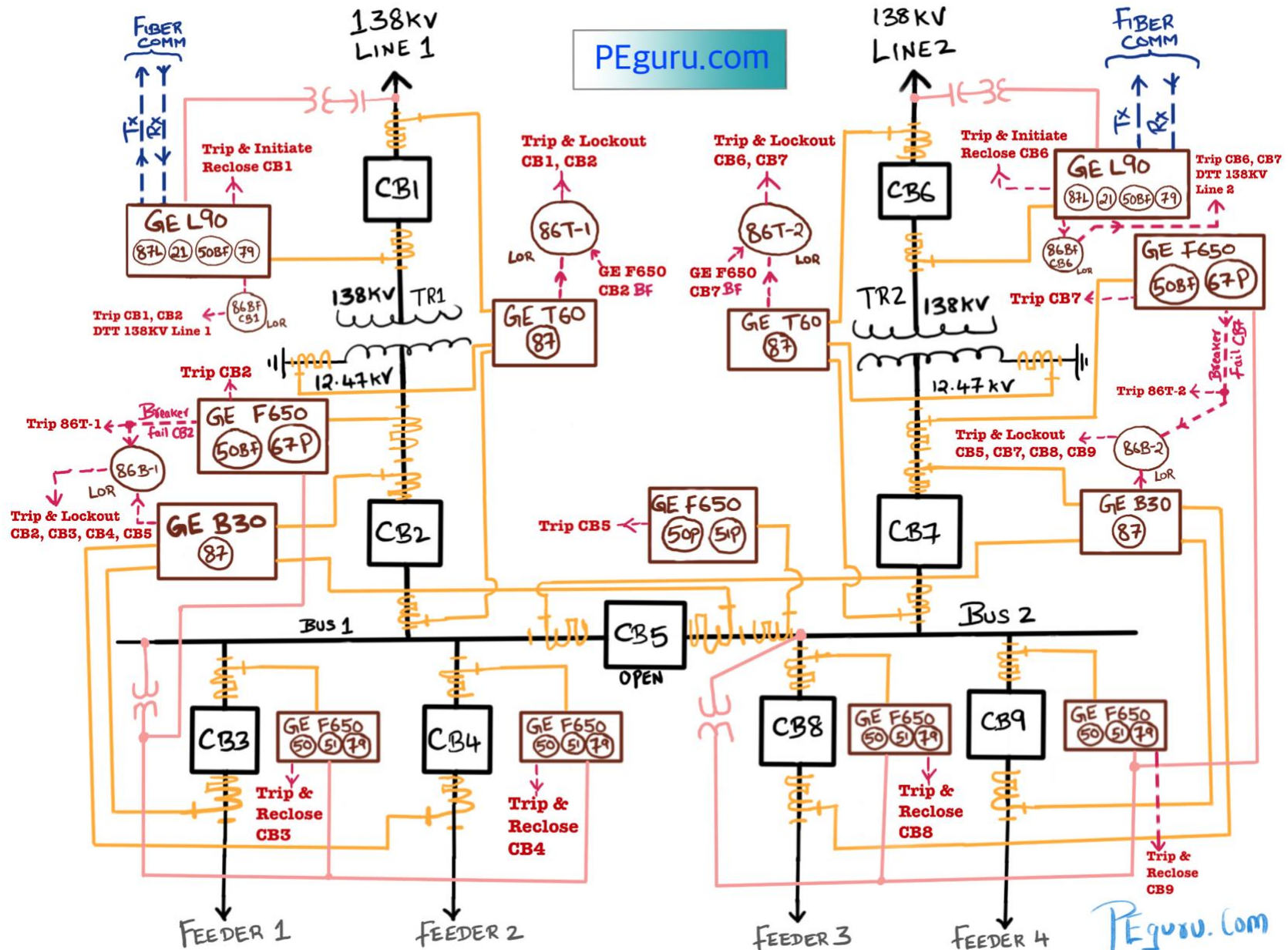


Closing scheme for 115kV circuit breaker CB1

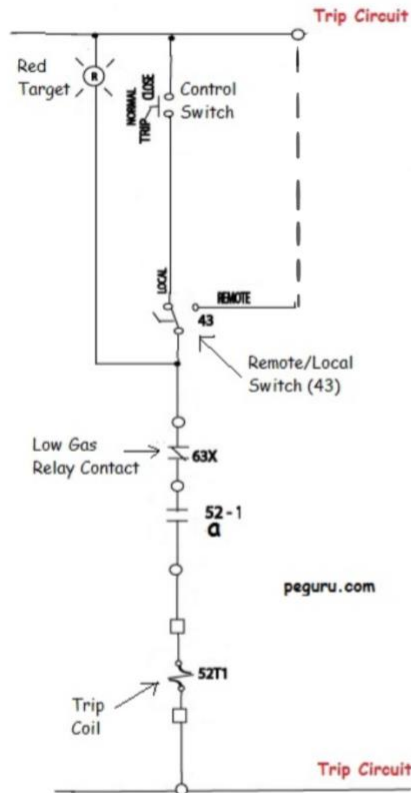
Reason for selecting relays as shown

- SEL351S: Dedicated breaker control relay, controls close of CB1 either through push button or logic.
- SEL411L: This is a line protection relay but is capable of implementing reclosing. Therefore, it is wired in parallel with SEL351S. Reclosing relay requires voltage input.
- Lockout 86 relays: Transformer T1 failure, fault within overall transformer differential scheme, breaker CB2 failure, breaker CB3 failure prevent CB1 from closing.

04 THE STRAIGHT BUS SUBSTATION

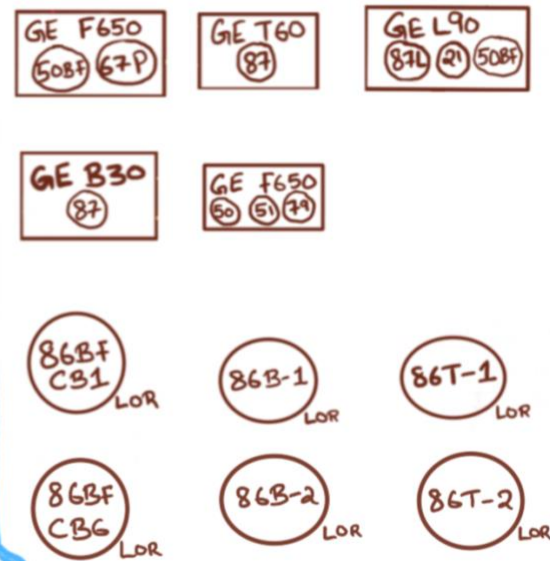


Practice problem - CB2 Trip Circuit



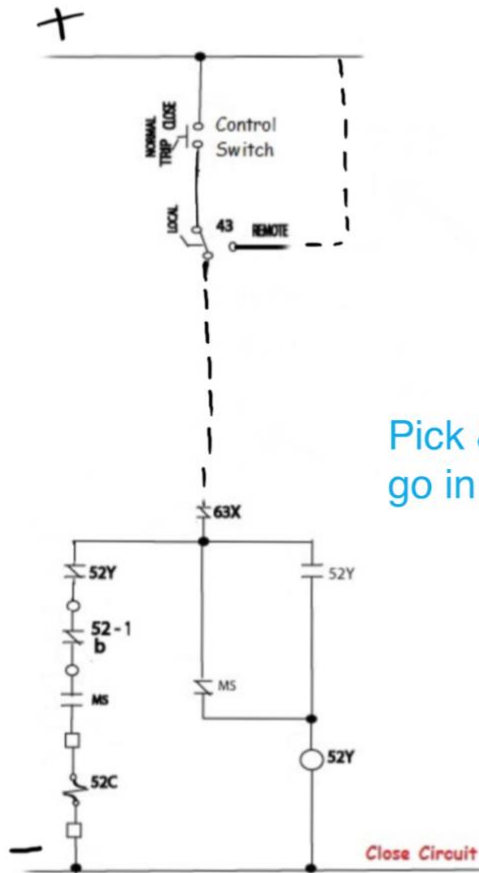
Pick & choose relays that go in the dotted area

All relays from straight bus substation



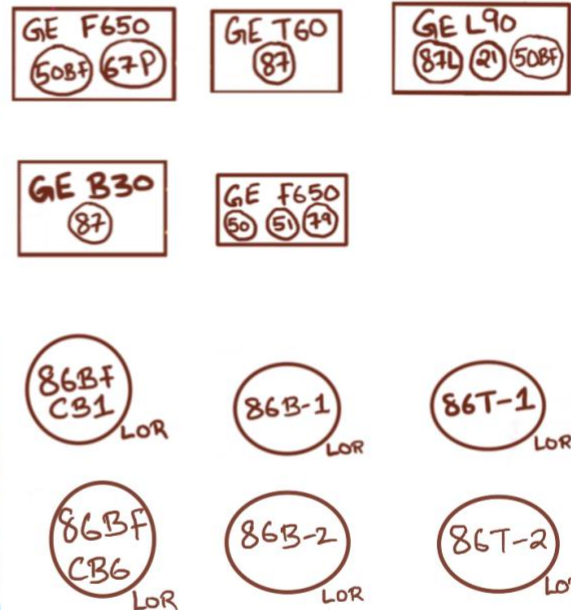
05 EXERCISE

Practice problem - CB2 close circuit



Pick & choose relays that go in the dotted area

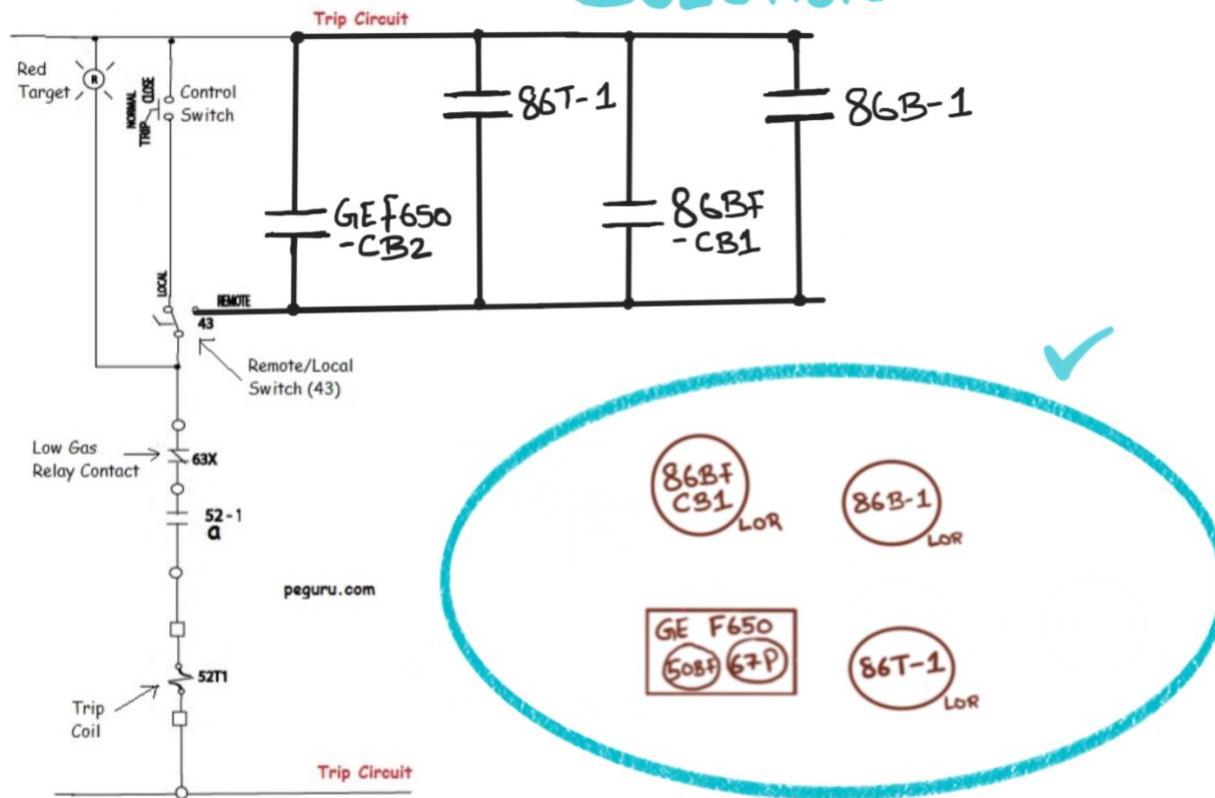
All relays from straight bus substation



SOLUTION

Practice problem - CB2 Trip Circuit

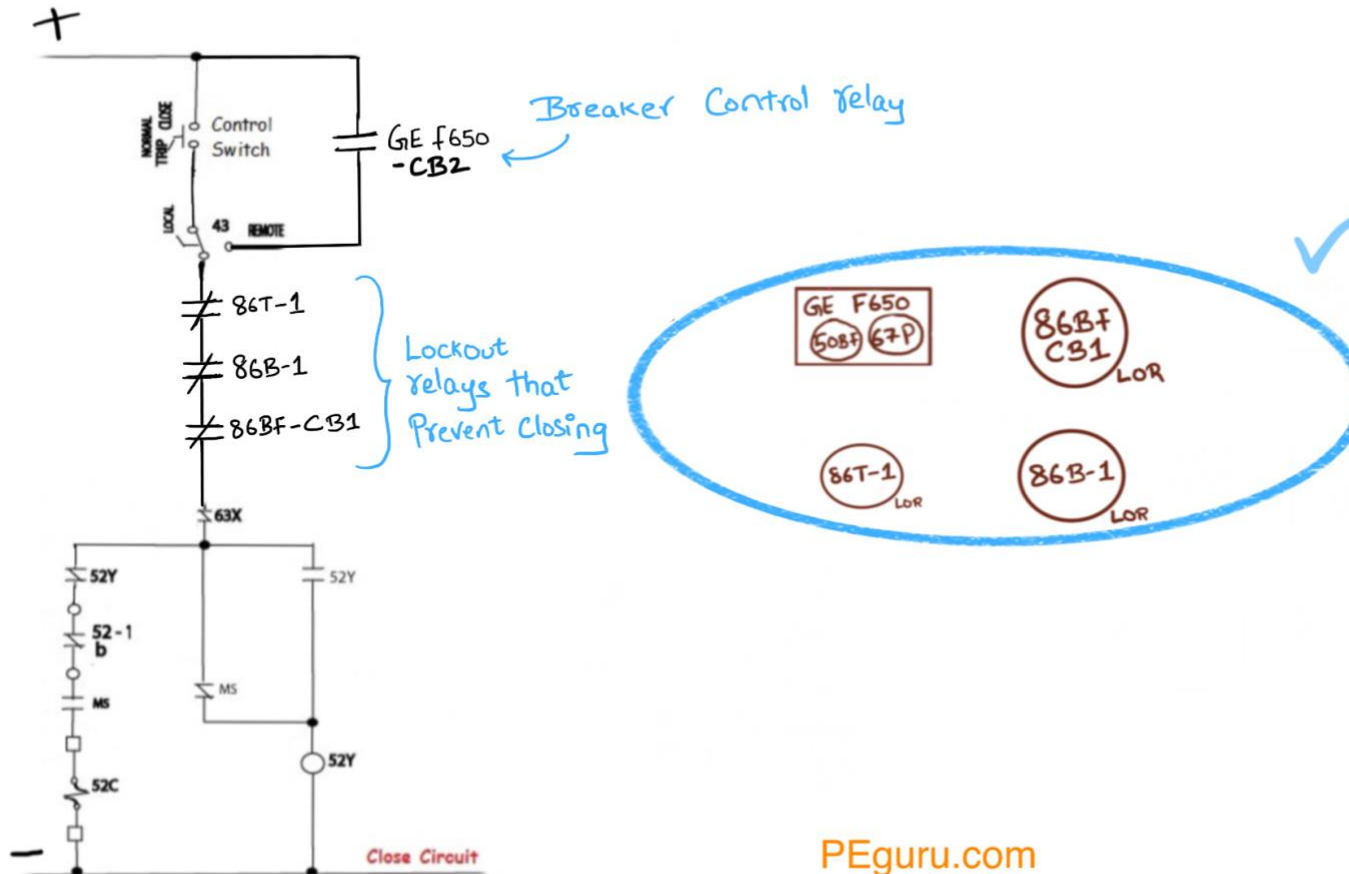
SOLUTION



PEguru.com

Practice problem - CB2 close circuit

SOLUTION

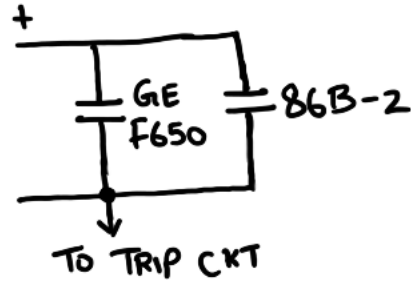
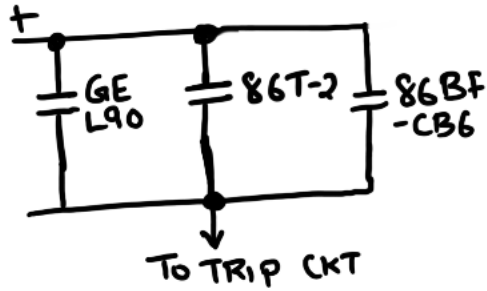


BONUS INFORMATION

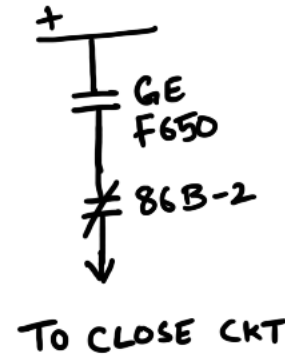
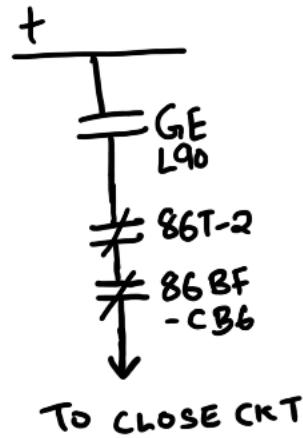
CB6 CONTROLS

CB8 CONTROLS

TRIP



CLOSE



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For additional information on substation engineering, visit <https://peguru.com>