From Leakage-to-Frame (LTF) to High Impedance Busbar Protection (HZBBZ)

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Busbar Protection

Busbar faults

- Rare, but the consequences of not having a proper busbar protection schemes are tremendous
- Causes of busbar faults:
  - Insulation failures
  - Circuit breaker failure
  - Falling debris
  - Isolator operated outside ratings
  - safety earths left connected
  - CT failures

Requirements of a busbar protection scheme

- Complete reliability
  - Security - Completely stable under all through fault conditions
  - Dependability - Able to detect all busbar faults
- Capable of complete discrimination between sections of busbars.
- Operate with high speed to minimize damage & maintain system stability

Busbar Protection

Completely stable under all through fault conditions

- Through fault stability limit based on maximum through fault current.
- The value is derived from the associated switchgear rating.
- Actual fault level is not used $\Rightarrow$ enable application when the system expansion develops up to the rating limit.

Ability to detect all busbar faults

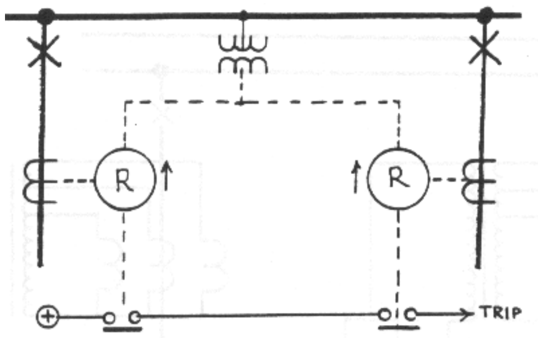
- Sensitivity - primary operating current:
  - Sufficient level to ensure positive relay operation.
  - Ensure high speed operation.
  - Aim at 30% of the minimum fault current available.

Schemes available:

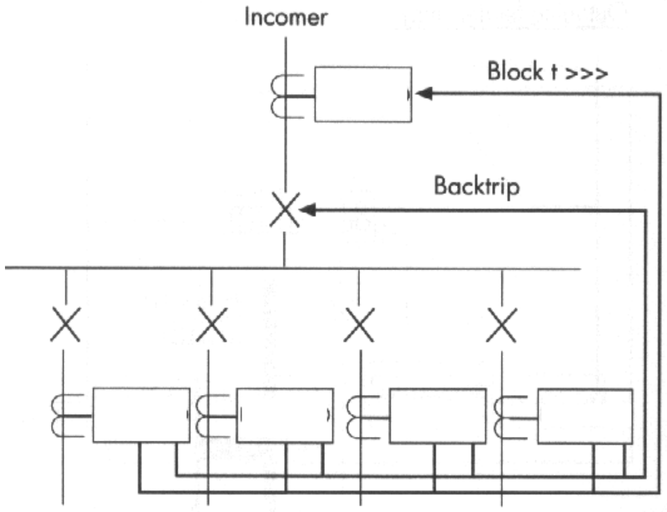
- Leakage to Frame earth (LTF) scheme: Non-Zone Discriminative vs Zone Discriminative at 33kV
- High impedance scheme (HZBBZ) at 11, 33, 132, 400kV
- Biased current differential scheme (LZBBZ: NR RCS915) at 132kV
- Interlock Overcurrent (ILOC) scheme at 11kV for replacement of LTF
- Phase comparison (EBBZ) at 132kV

Busbar Protection: Different Schemes

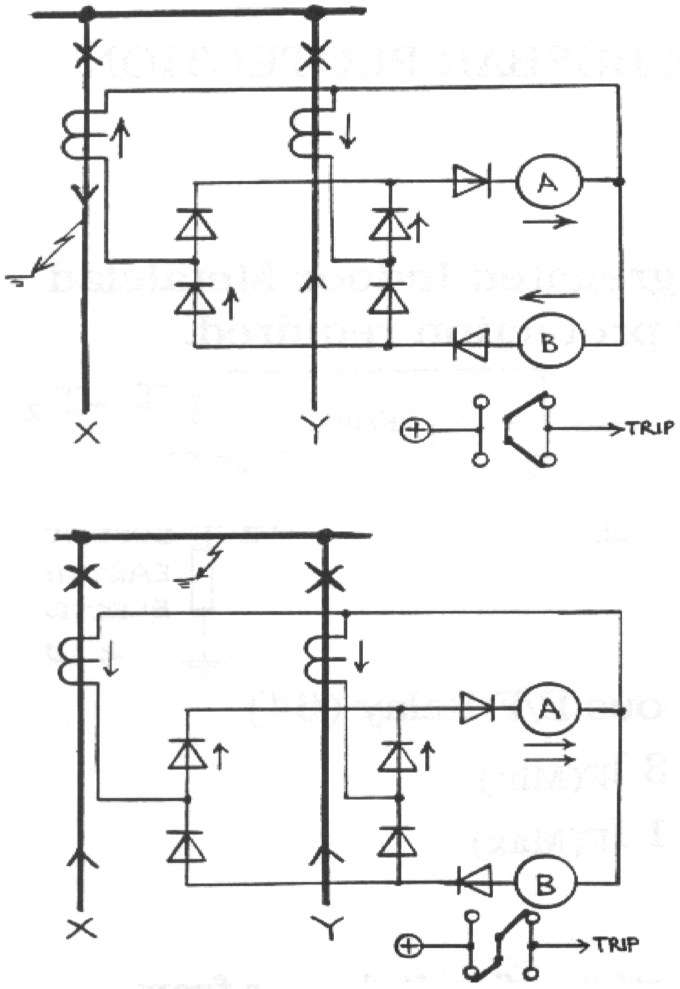
Directional Comparison



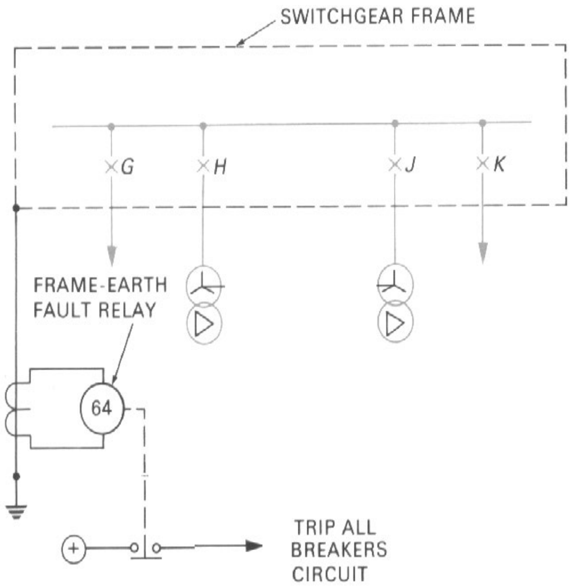
Interlock Overcurrent



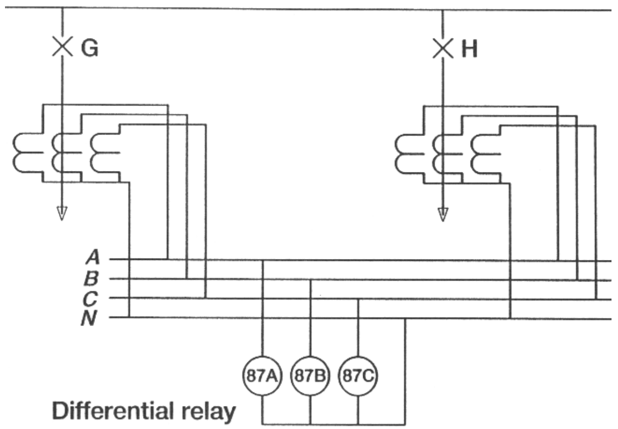
Phase Comparison



Leakage to Frame



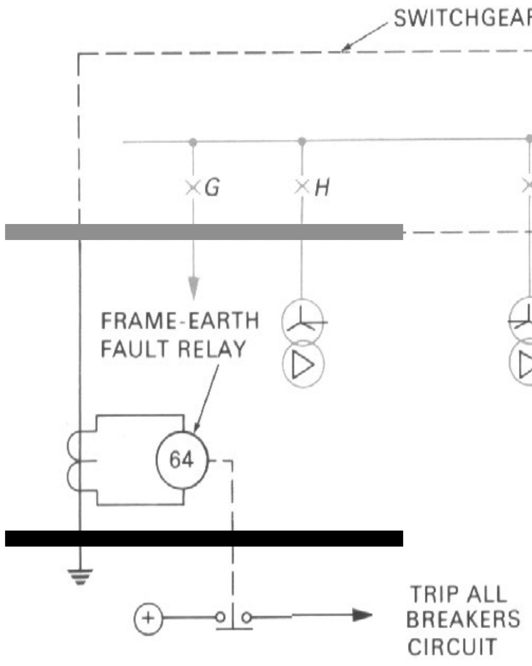
High Impedance Busbar Zone

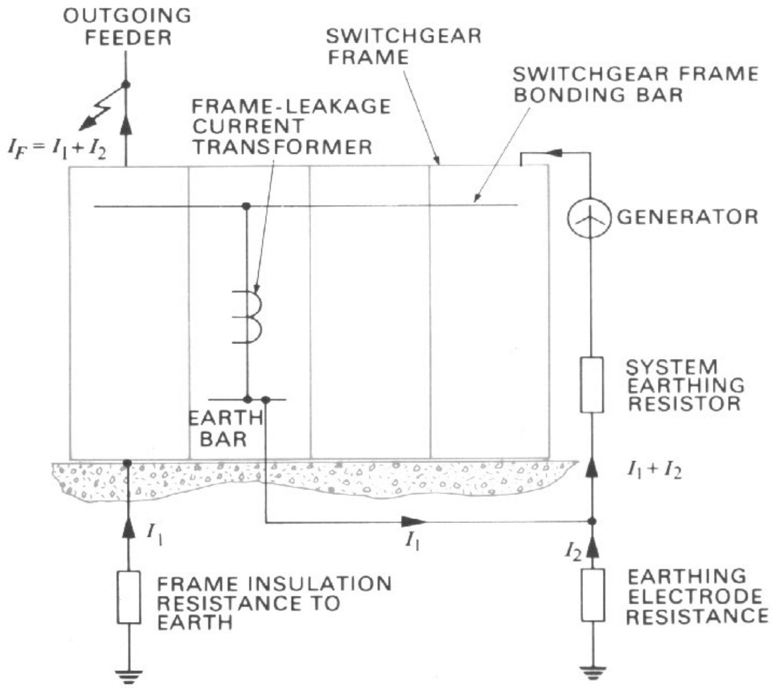


Leakage to Frame (LTF) Protection

- Can only detect earth faults
- The switchgears must be insulated from the earth with only one earthing point allowed.
- A CT is mounted on the single earth conductor and energizes an instantaneous current operated relay.
- Earth-faults are detected by the earth leakage current flowing from switchgear to earth via the single earthing path.
- Simple & economical
- Requires:
  - Insulation of switchgear frame and between sections $\Rightarrow$ **Ageing Issue**
  - Insulation of cable grands to prevent spurious currents during through faults

Relay setting: $10\% \, I_{F,\,MAX} < I_{SET} < 30\% \, I_{F,\,MIN}$

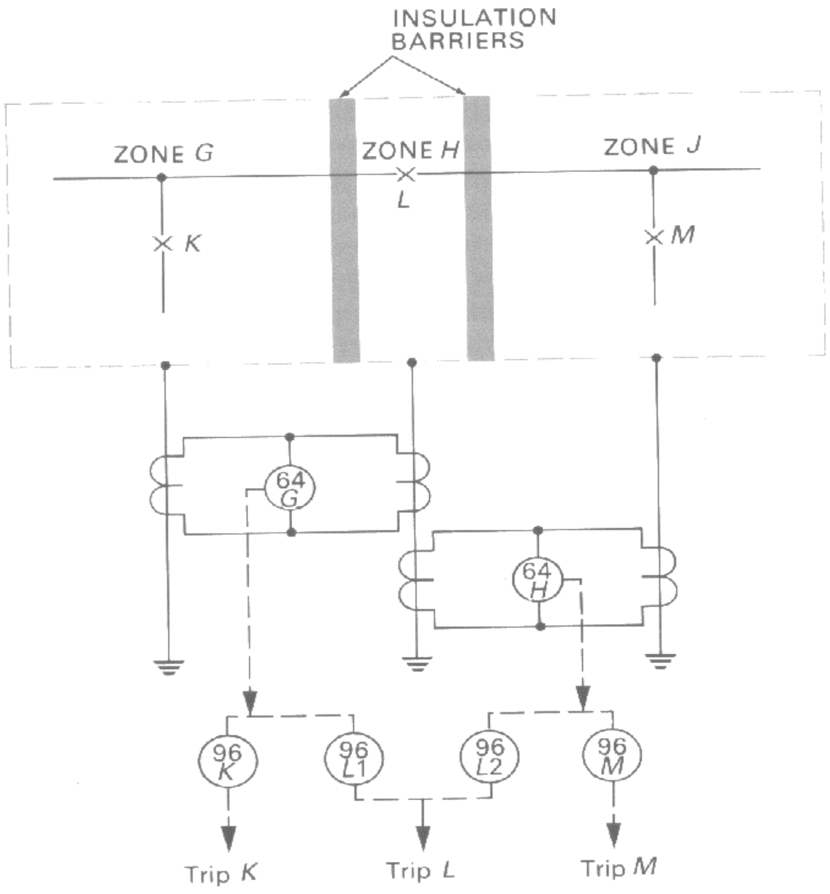




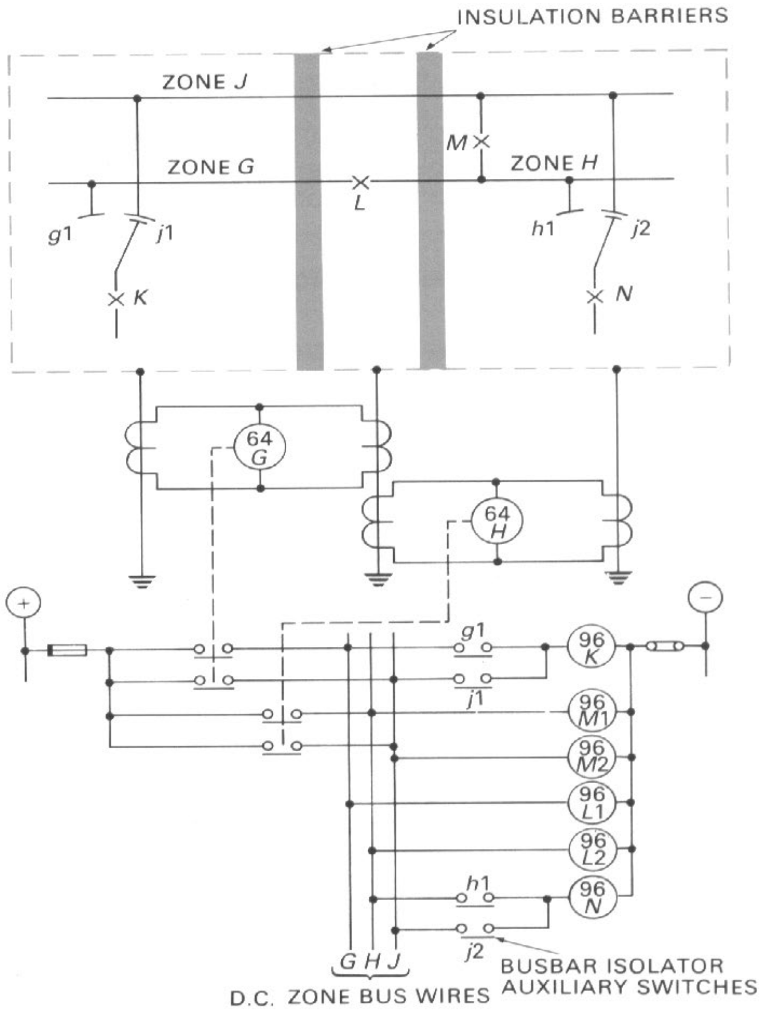
Insulation Barrier to Leakage to Frame (LTF)

Simple Zone Discriminative Leakage to Frame with Insulation Barrier

Double Insulation Barrier

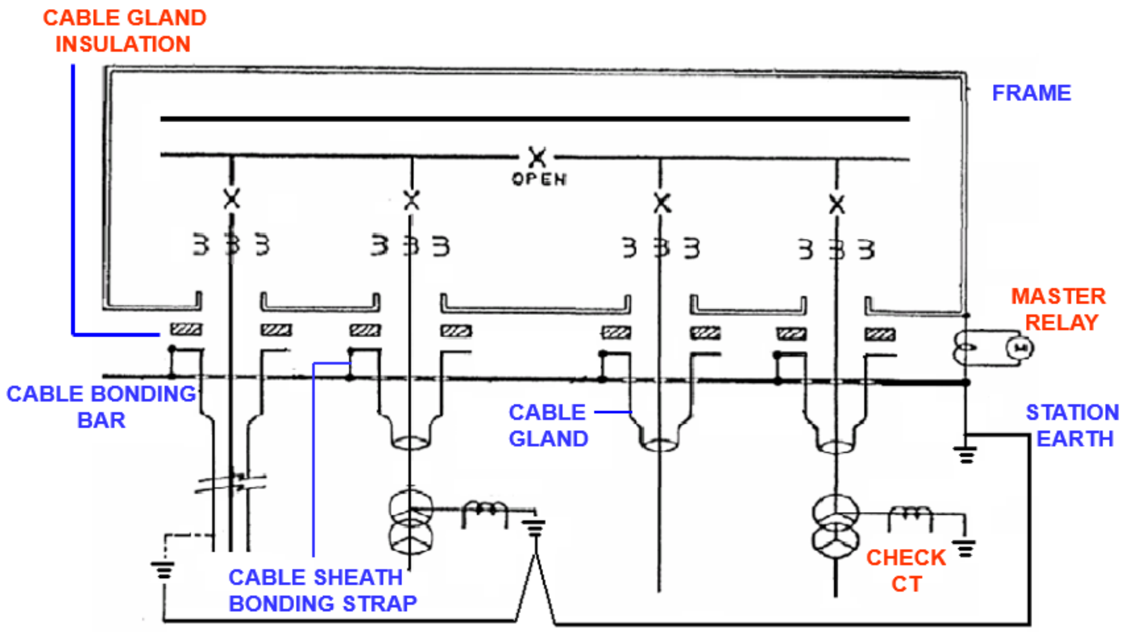


Double Insulation Barrier at Double Busbar

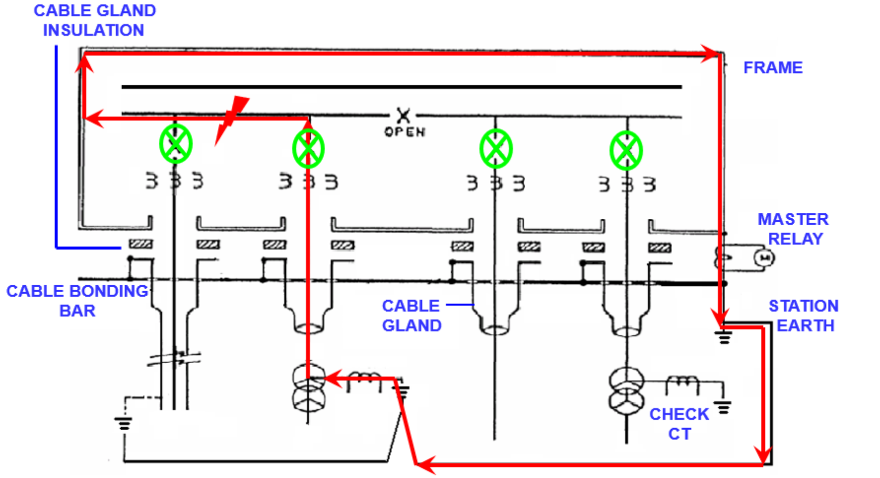


Leakage to Frame (LTF) Protection

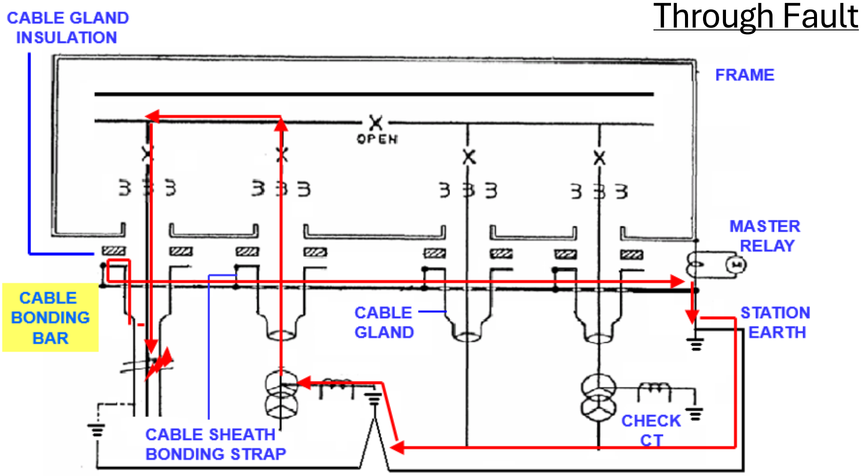
- Switchgear frame insulated from earth with 10 Ohm insulation material.
- Fault current between life part and frame will flow through Master Relay and Check CT, tripping all CB.
- For Through Fault, no fault current flow through master relay, LTF will not operate.



In Zone Fault



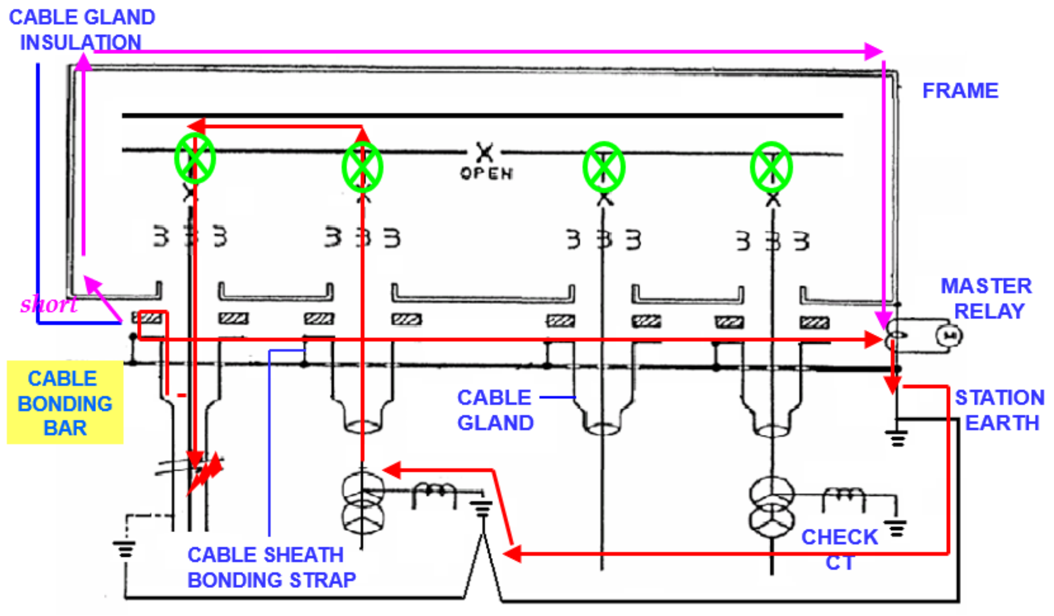
Through Fault



Unfavored Condition with Leakage to Frame (LTF) Protection

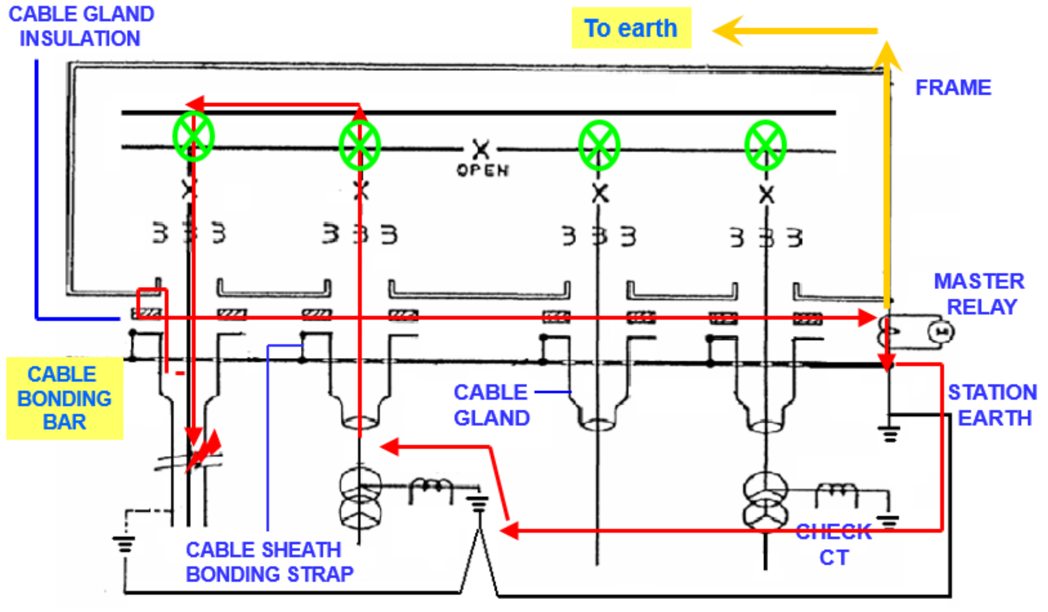
Case 1: Through Fault Unstable due to Incorrect Connection of Cable Sheath Bonding

- Originally, cable gland is insulated from frame and earthed via cable bonding bar
- Due to incorrect termination of cable sheath, or accidental earthing to frame causes LTF to mal-operate.



Case 2: Frame Earth Insulation Deterioration

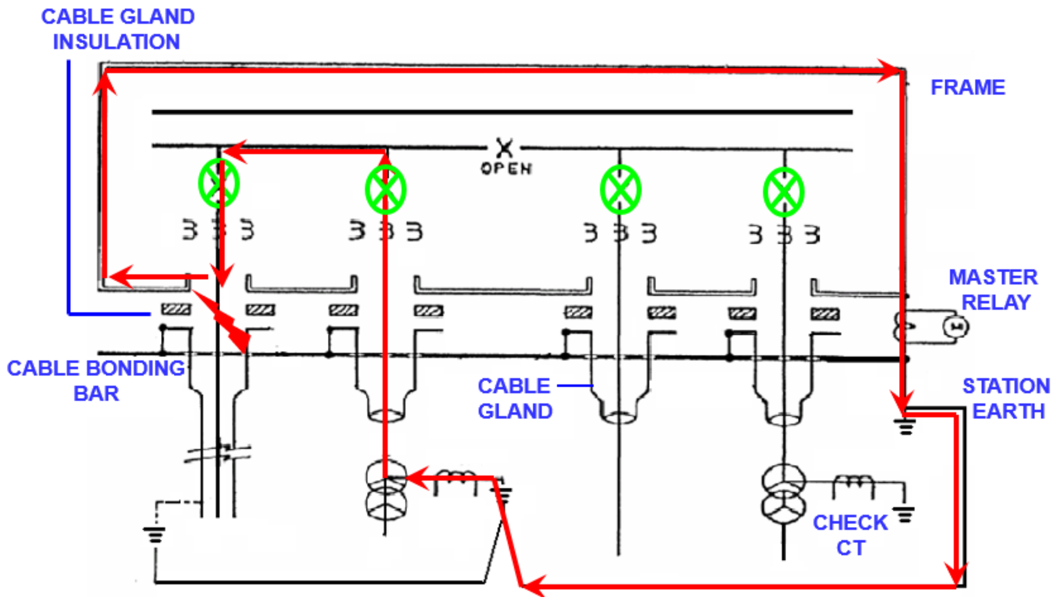
- Frame to earth insulation deteriorates due to weather and geographical conditions
- When Master Relay and Check CT sense fault current, all CB will trip
- Fault current may pass through Master Relay and earthed, although it is not designed to do so



Unfavored Condition with Leakage to Frame (LTF) Protection

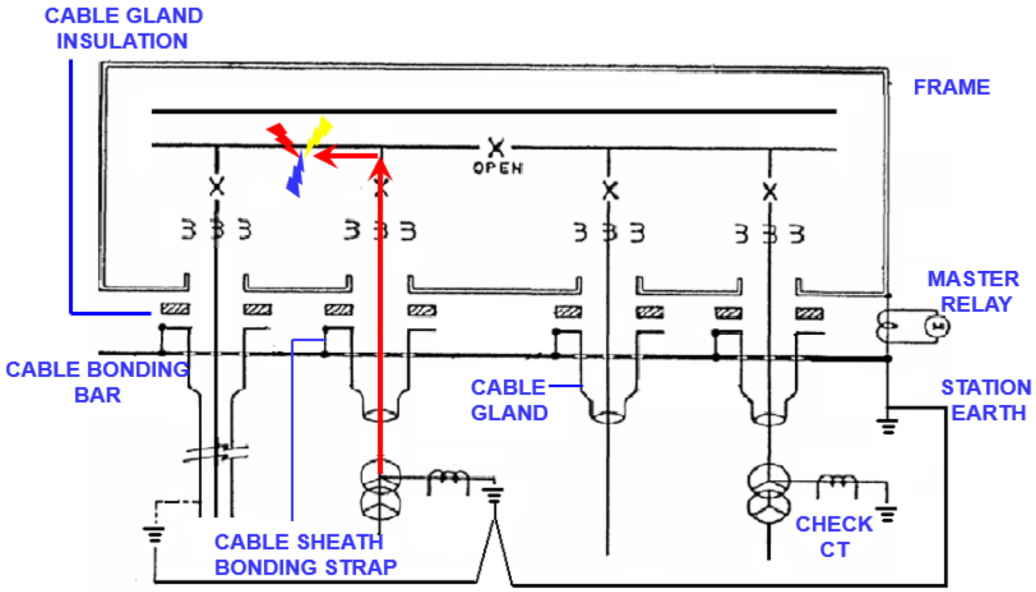
Case 3: LTF Misinterpret Cable End Box Fault as Busbar Fault

- Cable end box fault should be cleared by its own PW protection
- It possibly flashes over to frame, which makes it look like BB fault, causing LTF to operate



Case 4: Phase-to-Phase or Balanced Fault goes undetected

- Flashover to frame takes time.
- Undetected fault causes damage to system and equipment.

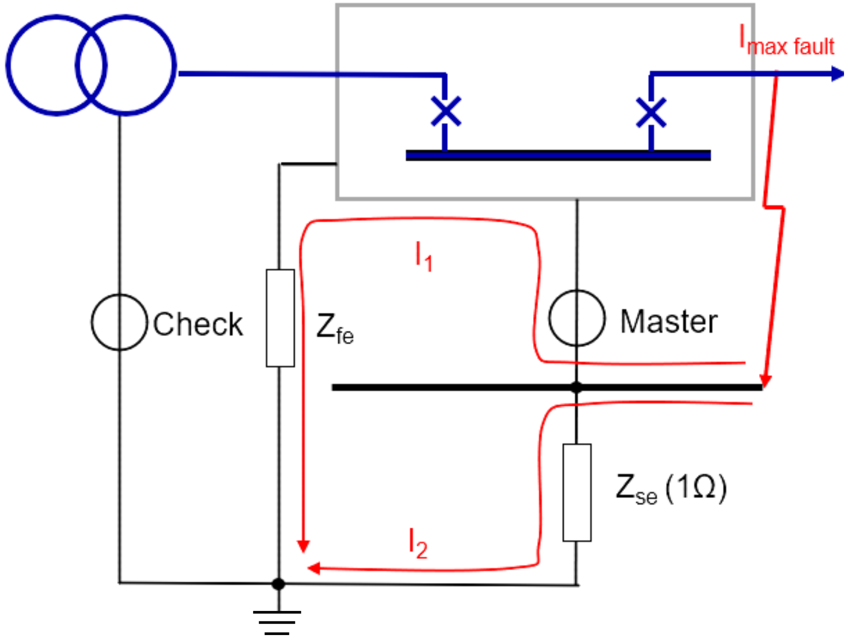


Leakage to Frame (LTF) Protection

Through Fault Stability with Poor Frame Insulation

- LTF BBP shall NOT operate at max through fault.
- Assume station earth impedance (Z_{SE}) = 1Ω.
- Master Relay pick up = 2000A
- Max fault current = 18.4kA

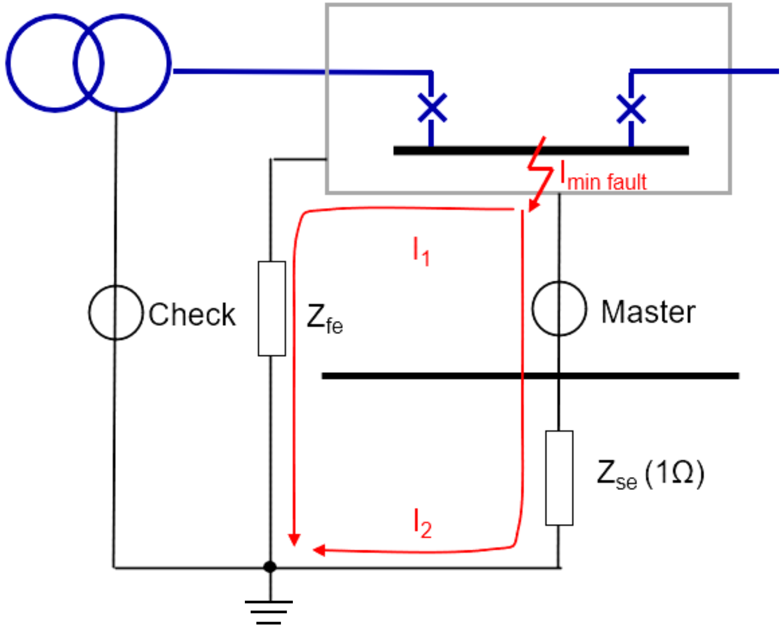
$$I_{F,MAX}\,\frac{Z_{SE}}{Z_{SE}+Z_{FE}} = I_1 < I_{PU} \;\rightarrow\; Z_{FE} > 8.2\Omega$$



Internal Fault Dependability with Poor Frame Insulation

- LTF BBP shall operate at min internal fault.
- Assume station earth impedance (Z_{SE}) = 1Ω.
- Master Relay pick up = 2000A
- Min fault current = 3.6kA

$$I_{F,MIN}\,\frac{Z_{FE}}{Z_{SE}+Z_{FE}} = I_2 > I_{PU} \;\rightarrow\; Z_{FE} > 1.25\Omega$$



From LTF to ZD-LTF

Leakage to Frame (LTF) Summary

LTF requires fault to its frame to be detected by Master Relay.

- Only earth-fault is detected, Ph-Ph / Balanced fault undetected ... **Case 4**
- 150ms delay operation of the Master Relay

Once LTF operates, all incoming and outgoing CBs will trip.

- There is no zone discriminative fault clearance
- Situation can be improved on Zone Discrimination LTF scheme

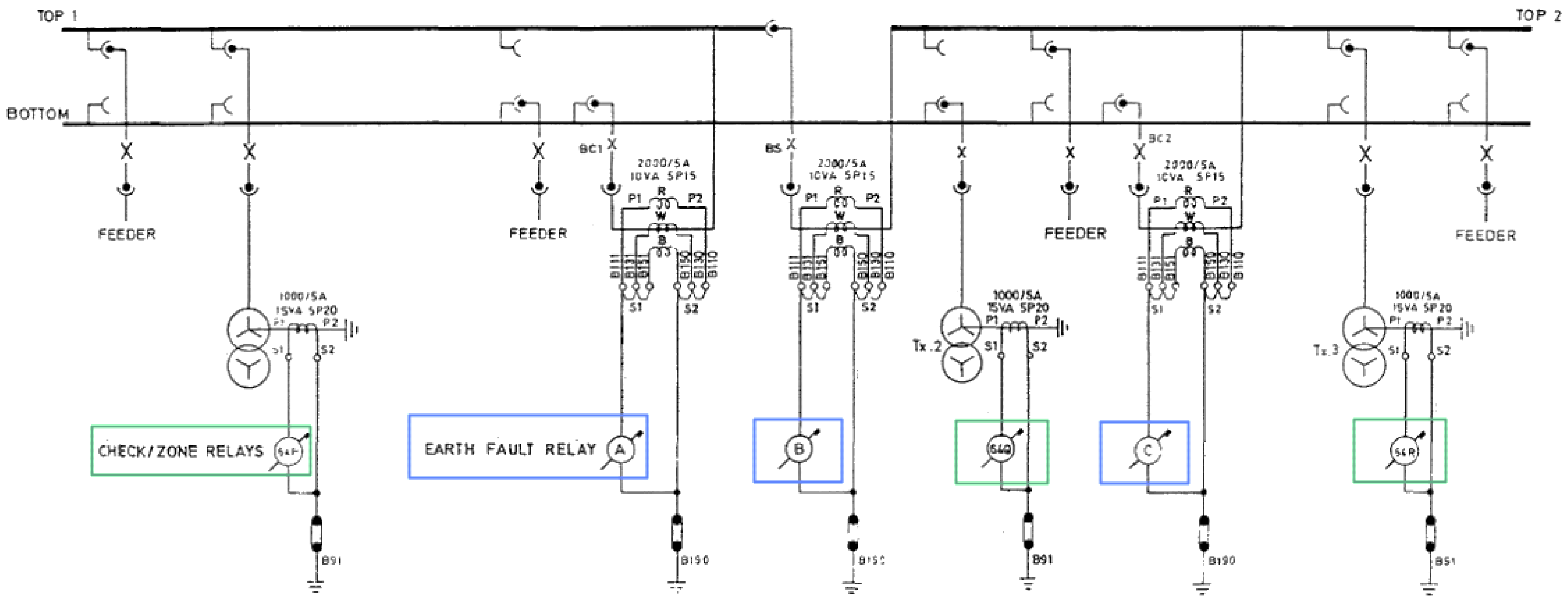
Sometimes, LTF mal-operates

- when cable gland accidentally touches frame, due to incorrect improper insulation ... **Case 1**
- when cable end box is misinterpreted as BB fault ... **Case 3**
- when frame-earth insulation deteriorates ... **Case 2**

Zone Discriminative Leakage to Frame (ZD-LTF)

- An improved version of conventional LTF scheme
- Check Relays are provided for each transformer (as LV neutral CT)
- Fault Direction Indication Relay with respective CT on trucking of Bus Sections and Couplers
- Dummy Bar detection circuit with logic structured by CB racking and auxiliary switches at Incomers, BS and BC
- During a busbar fault, all dummy busbar will be tripped indiscrimatively as dummy busbar fault does not have fault current reaching the check CTs, hence the scheme is designed to isolate the dummy busbar during busbar fault, even if there is no check CTs activated.
- A more complex design compared with conventional LTF

From LTF to ZD-LTF



- Dummy busbar used as an interconnection bus from one substation to another substation.
  During busbar fault, the master relay can sense the fault, but none of the check CT can operate, as the transformer source is at another substation. LTF is inoperative this case. The fault should be cleared by feeder protection.
- Busbar fault directional relay (A, B, C, D) are driven by CTs installed at BC/BS and controlled by contact of master relay.
- Disagreement timer is used to check contact status of master relay.

Setting

- Master Relay = DTL 200% 0.2s (delay to differentiate CEB fault with fast operating feeder protection)
- Check Relay = DTL 200% 0s (50MVA) or 100% 0s (35MVA).

From LTF to ZD-LTF

ZDLTF Operation - Scenario 1: Busbar Fault

- Flashover to case → Fault Current flowing through Master CT
- LTF Master Relay Operate → Trip panels connected to the Dummy Bar (Section of busbar not connected with Tx Incomer Panels)
- Fault Current flowing through Tx LV Neutral → Earth Fault Detection Check Relay for transformers operate
  - → Trip the respective Tx Incomer CB (with operation of Master Relay)
  - → Inter-trip Send to HV side
  - → Trip panels connected to the busbar
- Panels on the busbar sections connected to the faulty one would be tripped → respective Fault Direction Indication Relays operate
- Panels on the busbar sections NOT connected to the faulty one and supplied with separate Tx incomer would NOT be affected

ZDLTF Operation - Scenario 2: Cable End Box Fault

- Flashover to Cable End Box → Fault Current flowing through the Insulated Cable End Box case DIRECTLY to station earth (in case not to frame earth then station earth)
- LTF Master Relay NOT Operate
- Fault Current flowing through Tx LV Neutral → Earth Fault Detection Check Relay for transformers operate
  - → Tx Incomer CBs NOT tripped as Master Relay NOT operate
  - → NO Operation on the Fault Direction Indication Relays
  - → NO Operation on the Trip Relays of the panels
- Panels with Cable End Box on fault to be tripped by own protection scheme (Pilot Wire / OCEF)

From LTF to ZD-LTF

ZDLTF Operation - Scenario 3: Flashover on VCB

- Flashover from 1 phase to case

  → Same operation as single phase to ground busbar fault (Scenario 1)

  → Master CT would operate
- Phase to Phase Fault / 3 Phase Balanced Fault

  → No fault current flowing through the case to ground

  → No operation of Master Relay

  → Same situation for Phase to Phase / 3 Phase balanced busbar fault

ZDLTF Operation – Non-fault relay operation

- Through Fault Situation

  → Fault Direction Indication Relay will not operate (required simultaneous operation of Master Relay)

  → Transformer Earth Fault Detection may operate (depends on fault current level / type of fault)
- Protection Defective Alarm

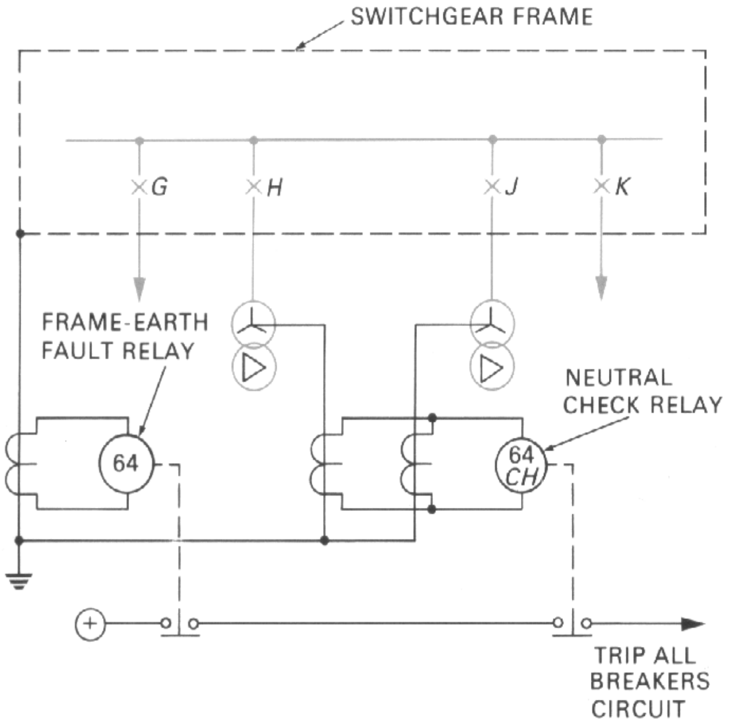
  → Watchdog alarm of digital relay operate

  → Protection Supply Supervision Relay Operate

Insulation Barrier to Leakage to Frame (LTF)

Check Zone Feature

- Neutral current check by a current operated relay in the earthing path
- Residual current check by a current operated relay in the residually connected CT's of e.g. a feeder.
- Residual voltage check by a voltage operated relay from a broken delta VT supply.
- The output from check relay is normally self reset.

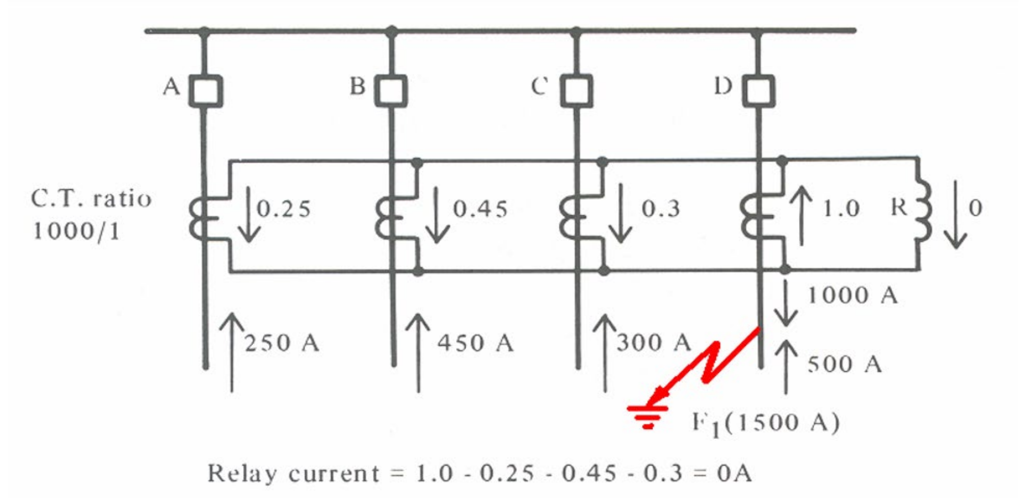


To solve LTF problems there are several considerations:
1. Impossible to lift the SWGR & Re-make insulation material
2. Future maintenance problem in fundamental
→ Frame-earth insulation can't be improved hence can't be used in the future.

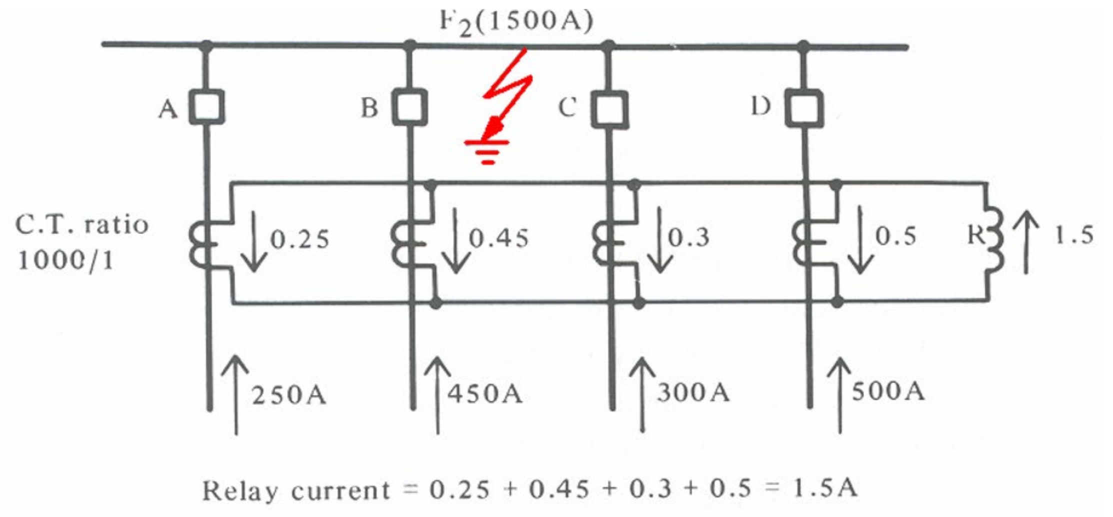
2 choices: Replace LTF with HZBBP or ILOC
→ HZBBP and ILOC both can prevent misinterpretation of fault and indiscriminative fault isolation, also they detect all fault types.
→ HZBBZ requires installation of additional CTs and Racking Switches (not feasible for old substation due to long circuit / busbar outage)
→ ILOC requires only additional DOC relay to current OCEF CT.

High Impedance Busbar Zone (HZBBZ) – Principles

- HZBBZ uses parallel CT network to sum up all current through a common bus (or a ring) at 11kV (or 132kV) switchgear, before having summed current flowing from switchgear room to protection panel.
- The relay obtains only information on summed current, not individual current. Hence, the scheme cannot provide individual supervision / blocking against any unfavored condition (e.g. CT saturation).
- Under through fault, CT output was distorted with CT saturation, HZBBZ employs harmonic rejection philosophy (large instantaneous voltage across shunt branch leading to all CT saturation hence no differential current) to maintain its stability.



Circulating current busbar protection stabilising on an external fault



Circulating current busbar protection operating on an internal fault

High Impedance Busbar Zone (HZBBZ) – Principles

Why **High Impedance** (or Series Resistance)?

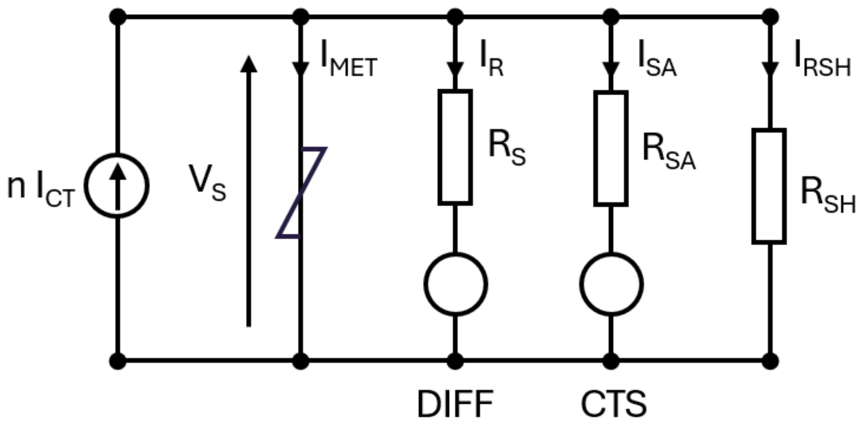
- CT gets saturated at any condition. It is hard to differentiate if it is an external fault with CT saturation, or internal fault at high load.
- High impedance scheme = adding an additional resistance such that any differential current can lead to high voltage at shunt branch.
- High voltage at shunt branch = all parallel CT connected get saturated.
- Once when all parallel CT get saturated, there will be no differential current flowing through the shunt path and the scheme remained stable.
  [Note – in theory BBZ CT must get saturated during fault]

Why **Shunt Resistance**?

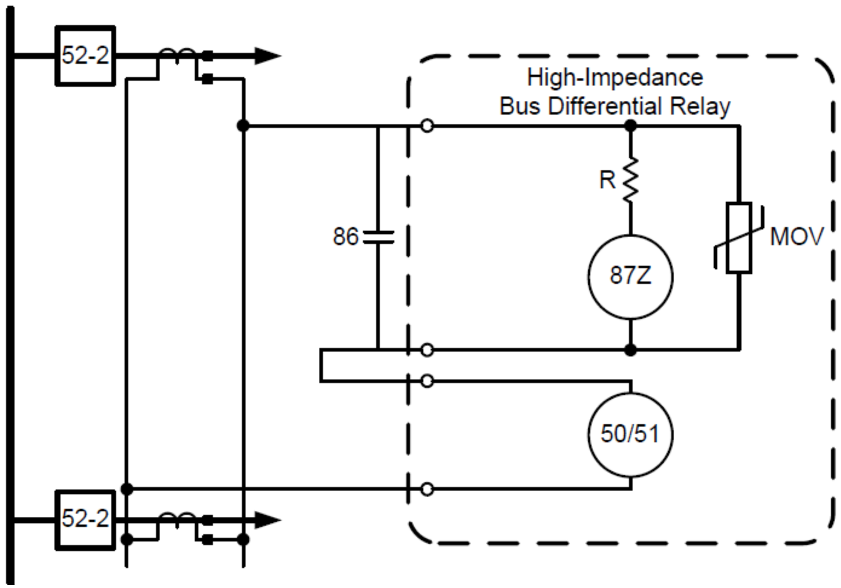
- It is to divert the current flowing through the relay path.
  [Note – normally half current flowing through]
- Yet it also reduces the equivalent impedance at the shunt path. Hence it also reduces the voltage across the shunt path, and it requires a higher current (doubled) flowing into the shunt path to make operative.

Why **MOV** across the shunt path (including shunt and series impedance)?

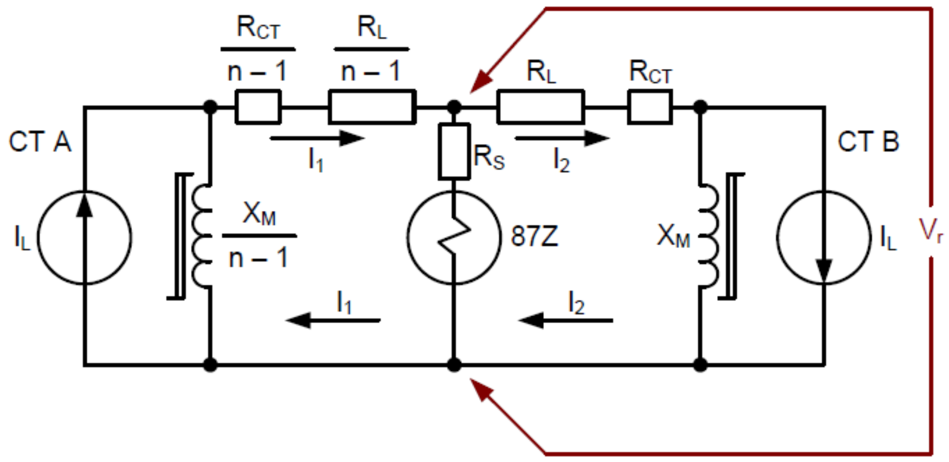
- It is to provide a short path against high voltage. As secondary fault current flowing through the shunt path can be large, the shunt voltage across could lead to equipment insulation failure (e.g. wire, resistor or relay). It is required to provide certain voltage protection to all equipment.



High Impedance Busbar Zone (HZBBZ) – Principles



Normal Load Condition



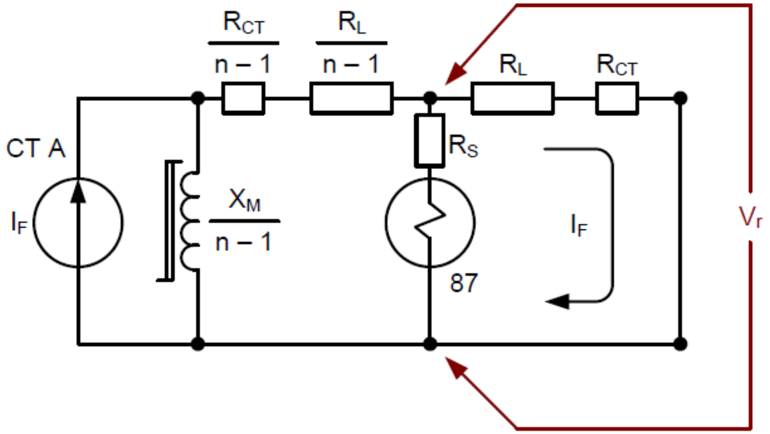
- 87Z element is a sensitive, low impedance, adjustable, pickup current element with voltage setting.
- MOV is connected across the high-impedance circuit to prevent high voltage from damaging the relay and CT circuitry for a period of several cycles (e.g. 20 – 30 cycles).
- Others reduce the MOV energy absorption requirements by connecting a lockout relay (86) contact across the high-impedance branch of the relay to bypass the differential current.

Normal Load Condition

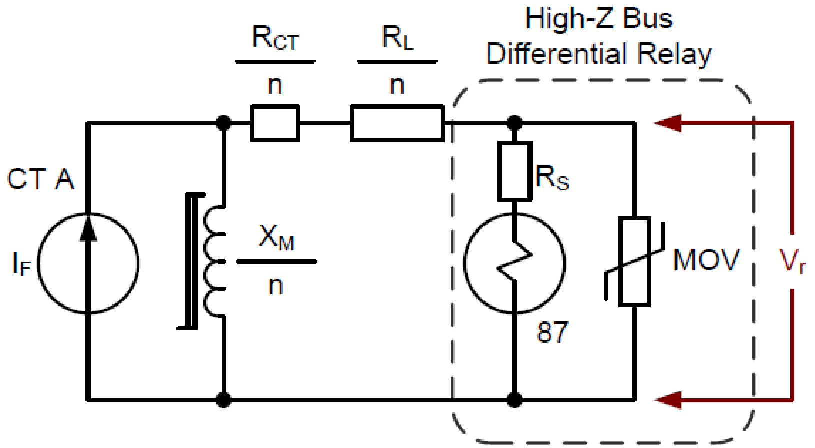
- If CTs do not saturate and all CTs have the same ratio, $I_{CTA} = I_{CTB}$. Current circulates among the CTs, and NO current will flow through the high-impedance relay path.

High Impedance Busbar Zone (HZBBZ) – Principles

Through Fault Condition



Internal Fault Condition



Through Fault Condition

- Faulted circuit CT carries the most current, making it the most likely to saturate.
- A completely saturated CT produces no voltage output (equivalent to short circuit). The saturated CT circuit becomes a simple current path with the internal CT resistance, R_{CT}.
- External Fault Security Requirement:

$$V_t = \frac{I_F}{N} \bullet (R_{CT} + R_{LEAD} \bullet k)$$

k = 1 with three-phase fault; k = 2 with SLG.

Internal Fault Condition

- CT circuit forces the equivalent total secondary current into HZBBZ relay.
- High impedance path represents an open circuit to parallel CTs, producing extremely high voltages that could be damaging. In this case, the MOV safely clamps the voltage spikes every half cycle.

High Impedance Busbar Zone (HZBBZ) – Principles

Advantage

- High performance, including high speed, high sensitivity, and high security.
- Virtually no limit on the number of branch circuits on the bus.
- Simple CT wiring with CTs wired to a summing junction and a single set of leads brought from local control panel (LCP) or switchboard (at BC) to Protection Panel.
- Extremely simple setting calculations.

Scheme Comparison

Consideration	Application	High-Impedance	Percentage-Restrained
Bus arrangement	Fixed	R	R
Low short-circuit level	NA	R	
Dedicated CTs available	Yes	R	R
CTs with mismatched ratios	Yes	N[1]	R
CTs with low accuracy class	NA	R[2]	R[3]

R = Recommended, N = Not recommended, NA = Not applicable

[1] There are techniques to deal with CT mismatch in HZBBZ (e.g. addition of tapped CT (high tap to low tap), use of auxiliary CT to match the ratio) but other techniques (e.g. low impedance) can tackle this issue easily.

[2] Assume CT knee point voltage is high enough to satisfy both security and dependability criteria.

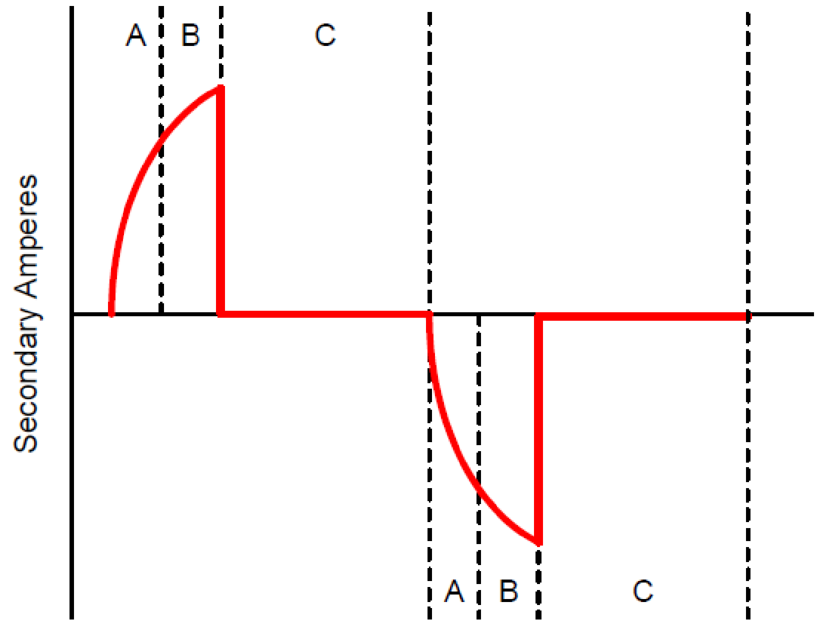
[3] Assume differential relay has functionality to put it into high security mode if CT saturation is detected, or fault is determined to be external.

High Impedance Busbar Zone (HZBBZ) – Principles

- Fundamental assumption: A saturated CT produces no voltage contribution to the circuit (or isolated its primary part from the circuit).
- Security issue: 1. In-zone surge arrester could cause a trip under normal operation when it is conducted to clamp a surge.
  2. Fault on VT secondary effectively shorted the primary.
  3. Impedance grounded system may not have enough internal fault current to conduct MOV
- Dependability issue: must catch the fault with CT saturation – 10kA CT: 1/1000 with Req = 50Ω → V_{SH} = 5kV > MOV on $600V_{PK}$.

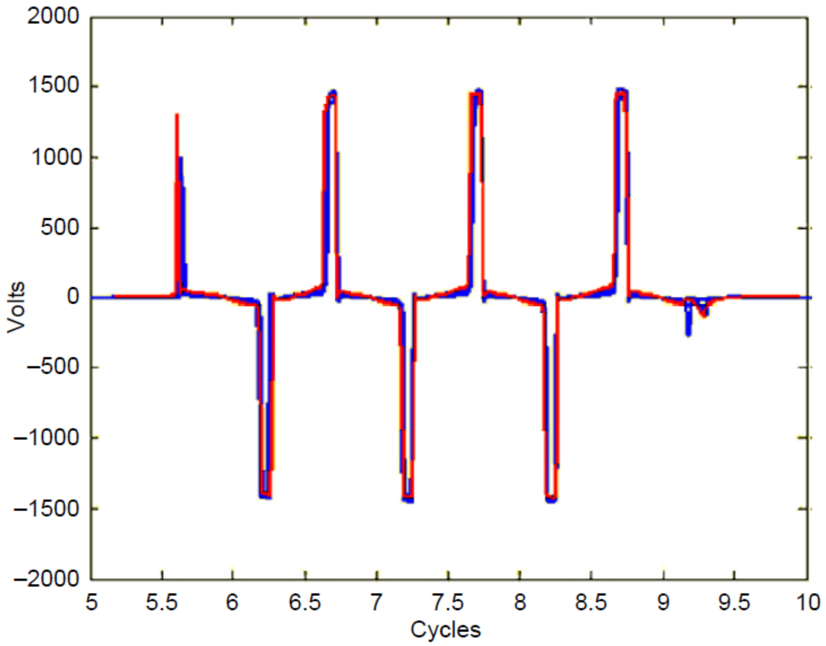
Problem: What will occur during internal fault?

- The voltage rapidly rises with internal fault current to secondary to MOV conduction. **- Zone A**
  [Note – While the curve shape during this rise is sinusoidal, its steepness on the way to 50kV makes it appear vertical.]
- The MOV clamps its voltage by conducting the fault current until a CT in the circuit saturates and create a short path. **- Zone B**
- The CTs all have nearly the same voltage impressed on them. If they have the same knee point voltage, they will saturate simultaneously. If a CT has a lower knee point, it will saturate first when its volt-time area capability is exceeded.
- Once any CT saturates, the voltage in the circuit drops to nearly zero because the saturated CT effectively short-circuits the stabilizing resistor burden. Non-saturated CTs are driving current into the shorted path. **- Zone C**
- Once the primary fault current crosses zero, the CTs come out of saturation and the process begins again in the opposite polarity.

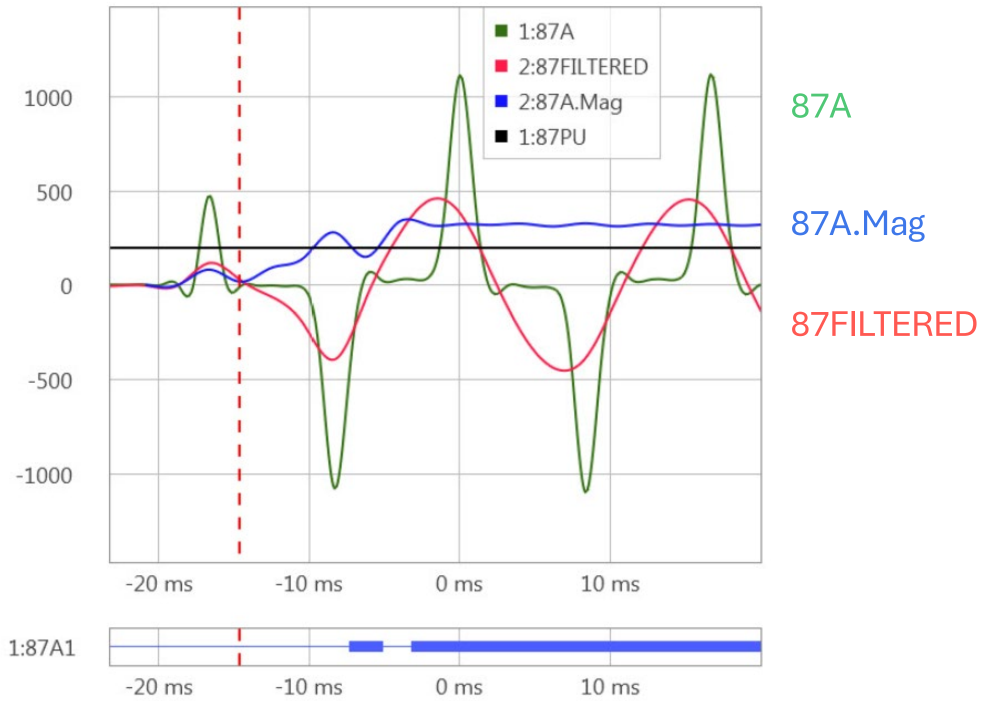


High Impedance Busbar Zone (HZBBZ) – Principles

- Signal measured by the relay for internal fault is NOT a function of fault current, but the function of lowest CT knee point in the circuit.
- DC offset of the primary fault current has an effect because the zero crossings will not be evenly spaced a half cycle apart if the primary current is offset. The result for a relay in half-cycle cosine filter (to avoid DC offset and high frequency component) is two pulses in filter window, with a higher measured voltage than for a symmetrical waveform with pulse evenly spaced.
- Primary Rating of CT should be sized > secondary rating x thermal rating factor



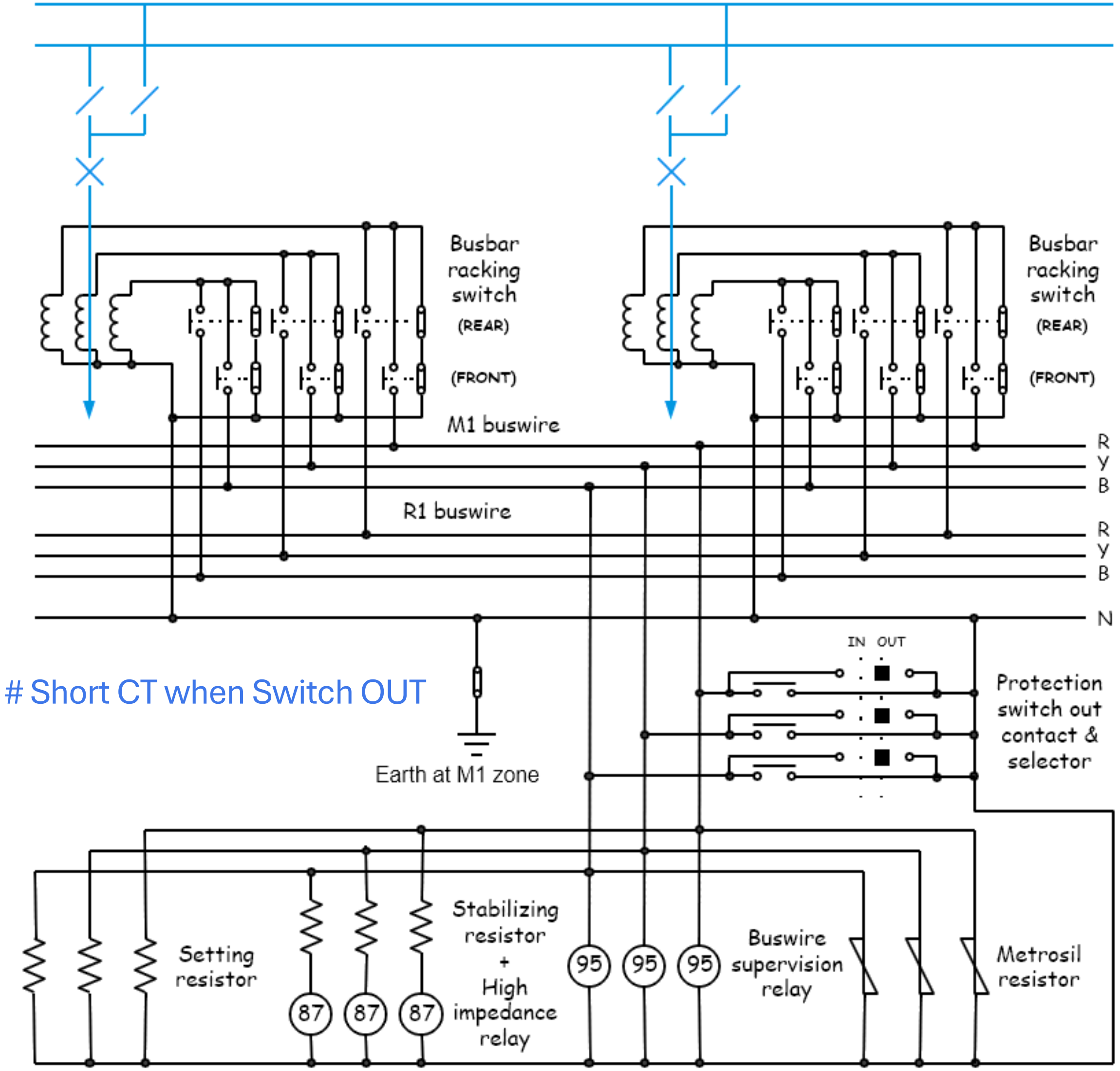
Relay Voltage with 20kA, 40kA and 60kA Fault Current



Response of Half-Cycle Cosine Filter to Pulses

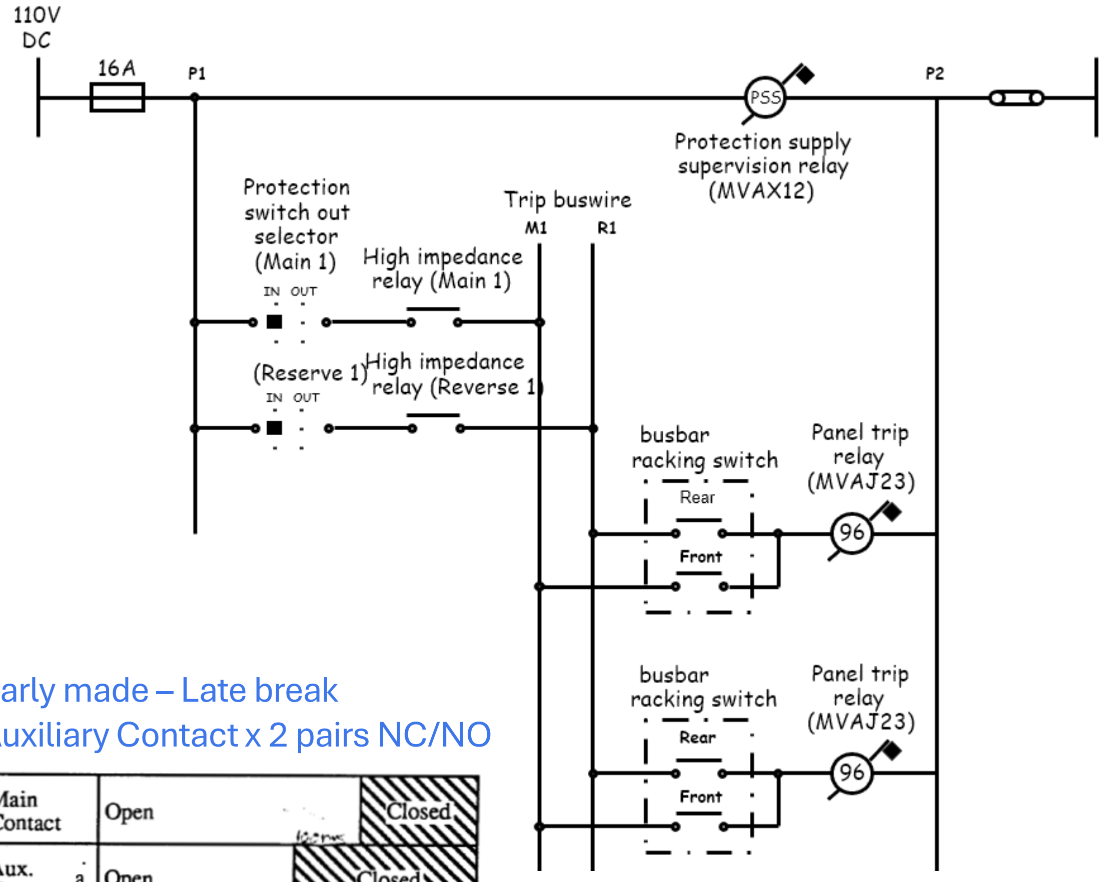
High Impedance Busbar Zone (HZBBZ) – Application (11kV)

AC Schematics



Short CT when Switch OUT

DC Schematics



Early made – Late break
Auxiliary Contact x 2 pairs NC/NO

Main Contact		Open	Closed
Aux. Contact	a	Open	Closed
Aux. Contact	b	Closed	Open

Common Trip Buswire

High Impedance Busbar Zone (HZBBZ) – CT Supervision

- Scheme performance may be predicted by calculation without heavy current conjunctive testing
  - CT specifications & selection
    (Class X CT, 1000/1 for 11kV, 1200/1 for 132kV, 2000/1 for 400kV, requirement on excitation current and knee point voltage)
  - Through fault stability limit selection
- Excitation curves, tested or published by manufacturer, are derived by applying sinusoidal voltage to the CT and measuring the resulting exciting current. In the minimum current sensitivity tests with the relay pickup voltage above the knee-point voltage on the excitation curve, the applied voltage is impulsive instead. With non-sinusoidal voltage applied to the CT, there is no simple way to minimum current sensitivity.
- Higher CT ratios N/1 will reduce the secondary CT circuit voltage developed for an external fault.
- Higher CT accuracy class also results in a slightly higher internal CT resistance because of the larger core area and length.

High impedance scheme - CT supervision:

- Open circuit connections between CT's and relay circuit $\Rightarrow$ Unbalance currents which may operate the protection
- A voltage operated supervision relay is connected across the differential relay circuit
  (POC @ 35MVA: 60A; POC @ 50MVA: 100A, aimed at detecting small differential current and block the scheme from operation)
- The supervision relay cannot stop any potential maloperation
- The operation is time delayed to differentiate with internal faults.
- Typical effective setting is 25A primary or 10% of lowest circuit rating whichever is larger.
- Output:
  - Alarm only
  - Short the bus wires to protect the differential relay circuit.

High Impedance Busbar Zone (HZBBZ) – Setting Calculation

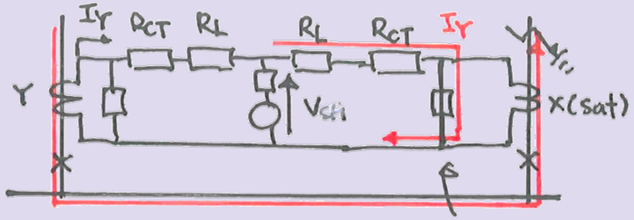
Given that

- 11kV HZBBZ with 35MVA Tx with n = 30 panels per busbar
- Maximum and Minimum Fault Level are 350MVA (18.37kA) and 115MVA (6.04kA) respectively.
- 11kV maximum circuit rating = 35MVA (1.84kA)
- CT Information: 1/1000, V_K = 250V, R_{CT} = 2.6Ω, Max magnetizing current I_E = 0.015A
- Loop resistance = 1.3Ω
- Relay resistance = 0.05Ω
- Metrosil leakage current at 70 – 80V is around 0.001A.

Question

1. Determine the relay setting [V].
2. Check if shunt resistance = 66Ω and series resistance = 165Ω is a feasible choice.

Setting Requirement 1

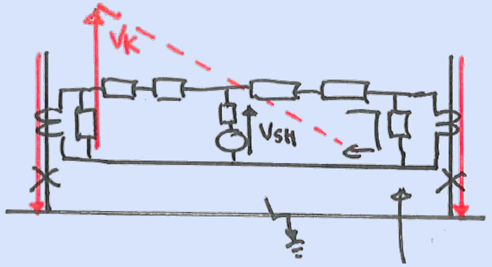


Shorted during Saturation

Normal operation *before* CT saturation under internal fault

$$\underbrace{Vm \leq \overbrace{V_{SET} \leq 1/3\, V_K}}$$

No Maloperation with CT saturation under external fault

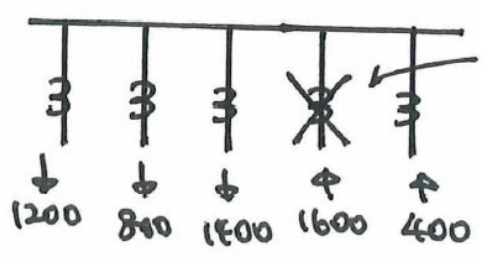


Shorted during Saturation

High Impedance Busbar Zone (HZBBZ) – Setting Calculation

Setting Requirement 2

$$\underbrace{I_{MAX\ rating} \leq I_{POC}}_{\text{Avoid Operation due to Open CT}} \leq 1/3\ I_{F,\ MIN}$$



No current into the loop (possibly due to wiring damage / CT shorted to isolate)

Note: Primary Operating Current (POC) is calculated by

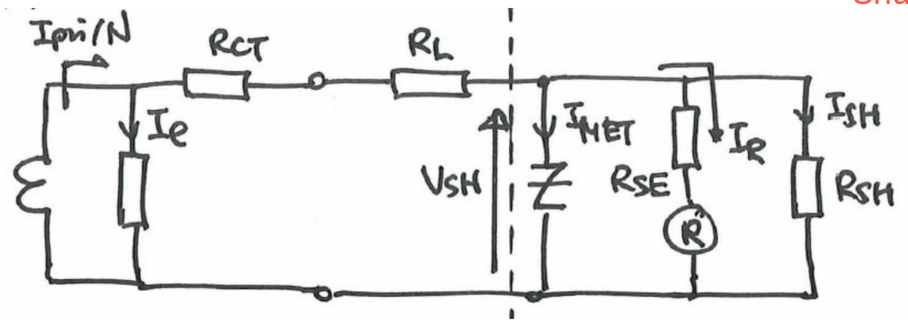
Magnetizing Current

Metrosil Current

$$I_{POC} = n\, I_e + I_R + V_{SH} / I_{SH} + I_{MET}$$

Relay Current

Shunt R Current



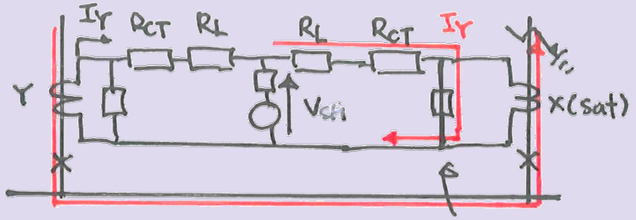
Sensitive Alarm Setting

5 – 10% of Circuit Rating

High Impedance Busbar Zone (HZBBZ) Protection

Back to the example…

Setting Requirement 1

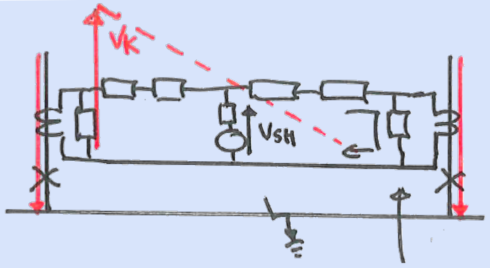


Shorted during Saturation

Normal operation during CT saturation under internal fault

$$\text{Vm} \le \text{V}_{\text{SET}} \le 1/3\ \text{V}_{\text{K}}$$

No Maloperation with CT saturation under external fault



Shorted during Saturation

Through Fault Stability Limit:

$$V_{SH} = I_Y(R_L + R_{CT}) = \frac{18370}{1000}(1.3 + 2.6) = 71.65\text{V}$$

Minimum Operating Condition for Internal Fault:

$$V_{SH} \approx \frac{1}{2}V_{K,MIN} > \frac{1}{3}V_K = \frac{1}{3}(250) = 83.3\text{V}$$

$$\text{Vm} \le \text{V}_{\text{SET}} \le 1/3\ \text{V}_{\text{K}}$$

$$71.65\text{V} \le \textbf{73V} \le 83.33\text{V}$$

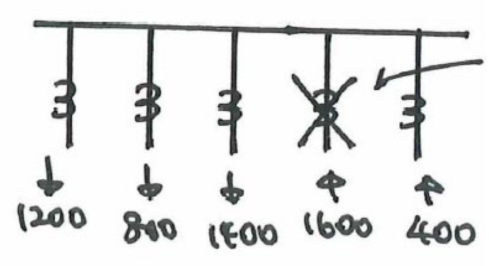
Select V_{SET} = 73V. Check if POC requirement (Setting Requirement 2) fulfilled.

High Impedance Busbar Zone (HZBBZ) Protection

Setting Requirement 2

$$\underbrace{I_{MAX\ rating} \le I_{POC}} \le 1/3\, I_{F,\ MIN}$$

Avoid Operation due to Open CT

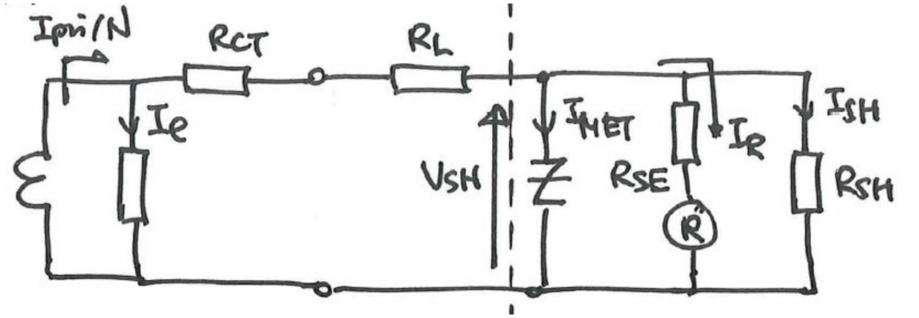


No current into the loop (possibly due to wiring damage / CT shorted to isolate)

$I_{MAX\ rating}$ = 1840/1000 = 1.84A

1/3 $I_{F,MIN}$ = 6.04kA/1000/3 = 2.01A

$$1.84A \le I_{POC} \le 2.01A$$



$$I_{POC} = nI_E + \frac{V_{SET}}{R_{SE} + R_{relay}} + \frac{V_{SET}}{R_{SH}} + I_{MET}$$

$$I_{POC} = 30 \times 0.015 + \frac{73}{165 + 0.05} + \frac{73}{66} + 0.001$$

$$= 2.00A \ \ (2000A \text{ in primary})$$

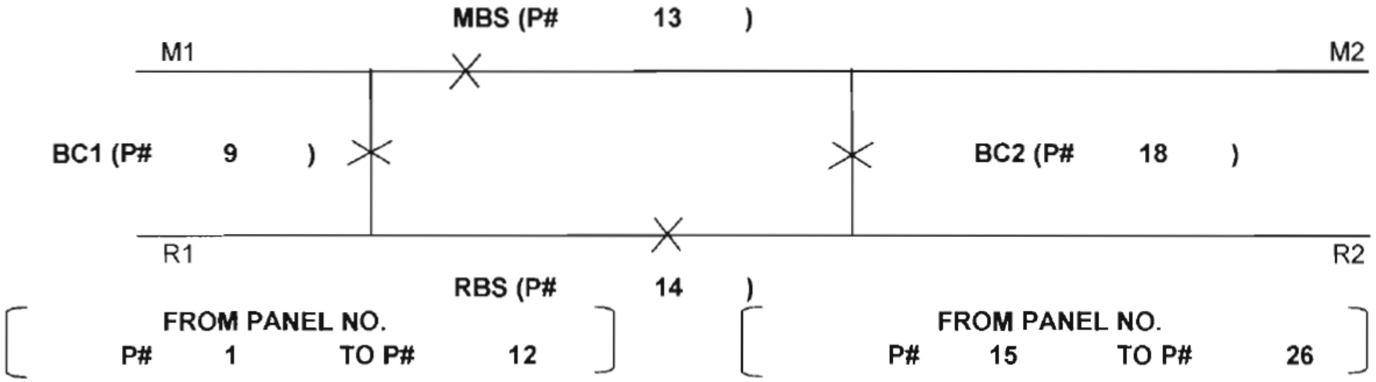
Sensitive Alarm Voltage: For 11kV, CT: 1000/1, Setting > 20mA (20A in primary), delay = 3s.

- Voltage Setting: 20mA x (165Ω + 0.05Ω) = 3.301V → Set at 4V, 3s.

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

Setting Calculation

1. Busbar and CT Information



CT Information :

CURRENT RATIO (N)	1/1200T	CLASS	X
KNEE POINT VOLTAGE (Vk)	385V	CT RESISTANCE (Rct)	1.74 Ohms
KNEE POINT CURRENT (Ie)	12mA	MAX. CT LEAD (RL)	0.3 Ohms

2. Setting Information

2a. Primary System

Maximum Fault Level ($MVA_{F\ max}$) = 6000 MVA, Equivalent to ($I_{F\ max}$) = 26243 A

Minimum Fault Level ($MVA_{F\ min}$) = 1000 MVA, Equivalent to ($I_{F\ min}$) = 4374 A

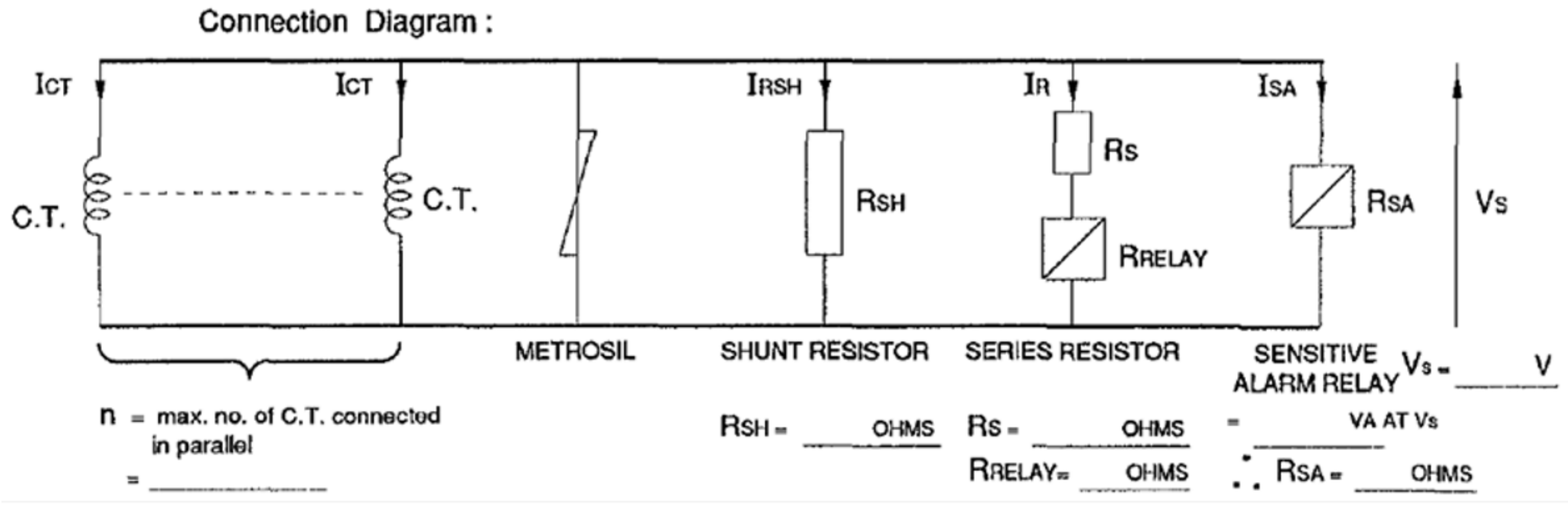
Maximum Circuit Rating = 300 MVA, Equivalent to (In) = 1312 A

Busbar Rating = 457.00 MVA, Equivalent to = 2000 A

Max Circuit for one zone (n): 13

Total TMU 132kV panels = 26

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation



2. Setting Information (cont')

2b. Relay System

Relay Type:	DADN	Setting Range:	0.005~2.0 A
Burden @ 1A :	0.2 VA	Setting Step:	0.005 A
Senstive Alarm Type:	DADN		
Burden:	0.2 VA (at 112.5 V)	0.15	VA (at 6 V)

3. Setting Calculation
    a) Calculation of Through Fault Stability Voltage
    b) Calculation of Series Resistor (Rs)
    c) Calculation of Shunt Resistor (Rsh)
    d) Determination of Primary Operating current Setting (Ipoc)
    e) Calculation of Half-Second Rating of Setting Resistor
    f) Calculation of Sensitive Alarm Relay Setting

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

3a. Calculation of Through Fault Stability Voltage (Vm)

No Maloperation with CT saturation under external fault

Vm can be calculated by:

$$Vm = \frac{I_{F\ max}}{N}(R_{CT} + \boxed{2R_L})$$

$$= \underline{50.95} \quad V$$

where

N = CT current ratio = 1200/1

$I_{F\ max}$ = max. through fault current

The criterion of protection voltage setting (Vs) is given by:

Vm	≤	Vs	≤	1/3 Vk
50.95	≤	Vs	≤	128.00

Therefore, choose Vs = 112.5 V

Normal operation during CT saturation under internal fault

For future switchgear extension, the max. allowable ($R_{CT} + R_L$) per protection zone should not be greater than:

$$\frac{N * Vs}{I_{F\ max}} = \underline{5.14} \quad \text{Ohms}$$

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

3b. Calculation of Series Resistor (Rse)

Resistor (Rs) can be calculated by:

$$Rs = \frac{Vs}{I_R} - Rrelay$$

$= 249$ Ohms

where I_R = relay operating current (where I_R = 0.45A)

Rrelay = relay internal resistance

$= \frac{\text{relay VA rating at IR}}{(I_R)^2}$ =0.987 Ohms

Assume Current Operating (or deduced with its burden and voltage setting)

Therefore, Rs (Chosen) = 250 Ohms

Rs (chosen) > Rs (calc) to maintain its stability

3c. Calculation of Shunt Resistor (Rsh)

The criterion of the selection of primary operating current (Ipoc') setting is given by:

	maximum circuit rating (In)	$\leq$	Ipoc'	$\leq$	$I_{F\,min} / 3$
Hence,	1312.00	$\leq$	Ipoc'	$\leq$	1458

Taking ultimate busbar arrangement that 'n' circuits are connected to one protection zone, and assuming Ipoc' = 1 / 3 $I_{F\,min}$, as a result,

$$\frac{1/3\ I_{Fmin}}{N} = n * I_{CT} + I_R + \frac{Vs}{\boxed{Rsh}}$$

Rsh = 159.00 Ohms

where I_{CT} = 0.0045 A per CT at voltage Vs

Therefore, Rsh (Chosen) = 200 Ohms.

N = turn ratio, n = number of circuit

Shunt out part of the current but not too much to ensure Ipoc is large enough to avoid open CT unstable, or small enough to provide sensitivity for internal fault

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

3d. Determination of Primary Operating Current Setting (Ipoc)

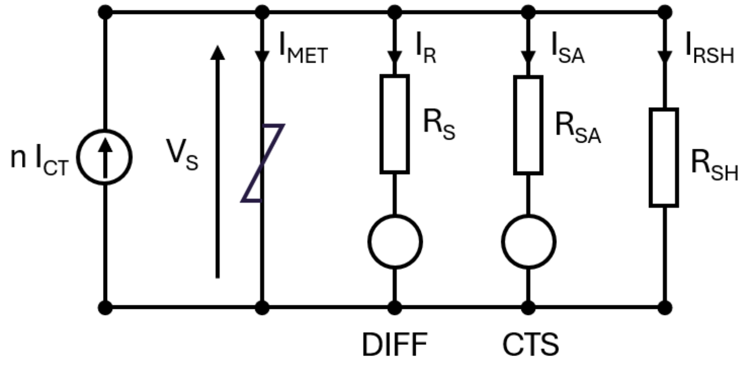
Neglect the current drawn by metrosil at Vs.
The calculated max primary operating current (Ipoc) will be:

$$Ipoc = N\left[n * I_{CT} + \frac{Vs}{Rsh} + I_R\right]$$

= 1285 A, or equivalent to 294.00 MVA

which should satisfy

Ipoc	≤	IF(Min)/3
1285	≤	1458



For the worst case when all circuits are connected to the reserve busbar with only reserve busbar isolator closed (no reserve bus-section CB), then the primary operating current (Ipoc2) setting will be:

Both R1-R2 is coupled = 2n circuits

$$Ipoc'' = N\left[n * I_{CT} + \frac{Vs}{Rsh} + I_R\right]$$

= 2570 A, or equivalent to 48.97 MVA

$= 2 * Ipoc$

which is still

	Ipoc"	≤	I_{Fmin}
i.e.	2570.00	≤	4374.00

(Assuming the total number of circuit connected in parallel is double once the reserve busbar isolator is closed)

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

3e. Calculation of the Half-Second Rating of Setting Resistors

By formula, the max r,m.s. voltage developed across the relay / resistor circuit at fault is determined by:

$$V_{rms} = 1.3 \sqrt[4]{(V_k)^3 * R * \frac{I_{Fmax}}{N}}$$

$$= 785 \text{ V}$$

Across Shunt Path

where

V_k = CT knee point voltage

N = CT current ratio

I_{Fmax} = max. through fault current

R = parallel combination of resistor / relay circuit resistance

$\boxed{R = Rsh \,//\, (Rs + Rrelay) = 200//250 = 111}$

Equivalent Resistance

For shunt resistor (Rsh), the half-second current rating will be

$$I_{1/2sec} = \frac{V_{rms}}{Rsh} = 3.93 \text{ A}$$

Therefore, choose actual shunt resistor (Rsh) half-second rating = 5.0 A

For series resistor (Rs), the half-second current rating will be

$$I_{1/2sec} = V_{rms} * \frac{Rs}{Rs+Rrelay} * \frac{1}{Rs} = \frac{V_{rms}}{Rs+Rrelay} = \frac{785}{250} \quad 3.140 \text{ A}$$

Therefore, choose actual series resistor (Rse) half-second rating = 4 A

Note: Not to overload or get your resistor burnt during maintenance injection.

High Impedance Busbar Zone (HZBBZ) Protection – Setting Calculation

3f. Calculation of the Sensitive Alarm Relay Setting

The criterion of the sensitive alarm current setting is chosen to be approximately 5% of CT rated current, I.e. 5% * CT current ratio.

For convenience, the pre-determined relay setting voltage (Va) to meet the above criterion is chosen to be $V_A = 6V$.

From CT magnetizing curve, magnetizing current (Ict) at voltage Va is 0.00045 A

Hence, the primary sensitive alarm current (Ia) setting is calculated by

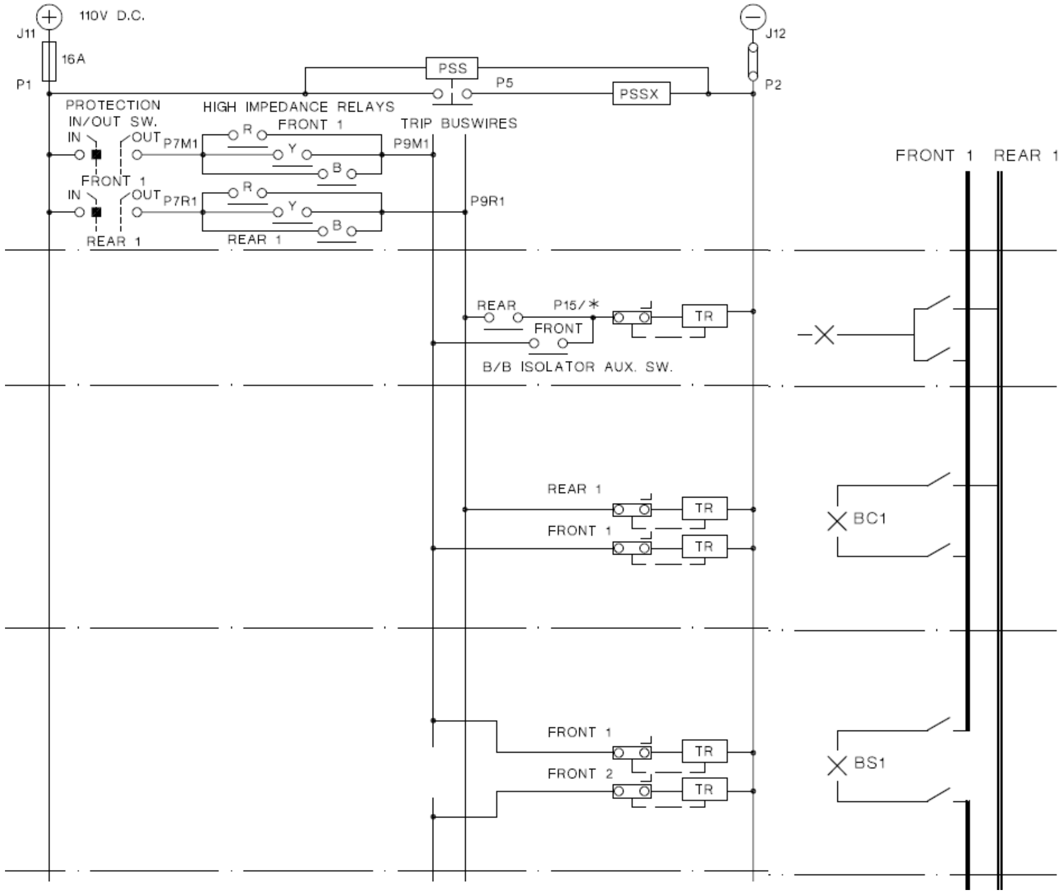
$$I_A = N \left[n * I_{CT} + \frac{V_A}{Rsh} + \frac{V_A}{Rs + Rrelay} \right]$$

$$= \underline{\quad 71.82 \quad} \text{ A}$$

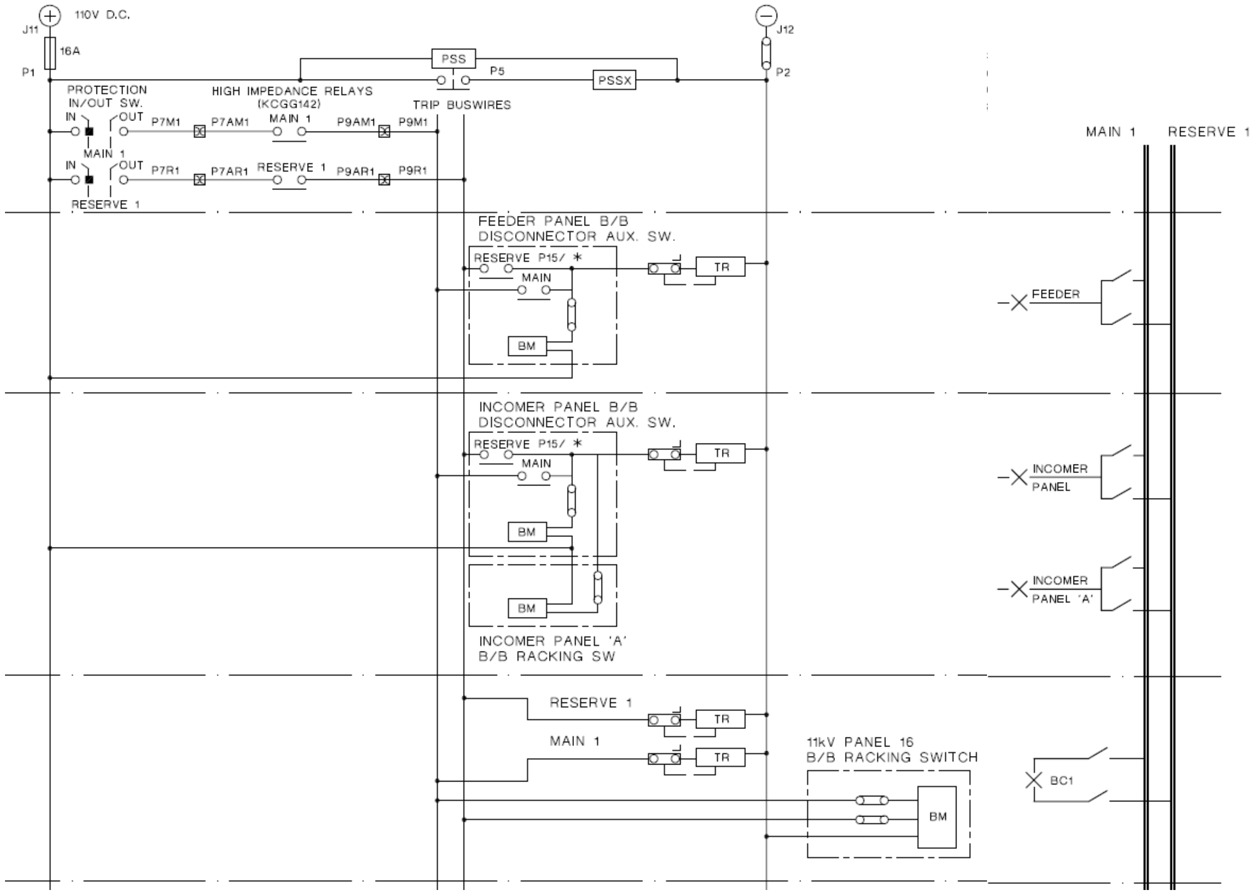
which is 5.98 % of CT rated current.

Primary Injection of > 70A will lockout the HZBBZ. (or > 35A if potential incorrect CT polarity)

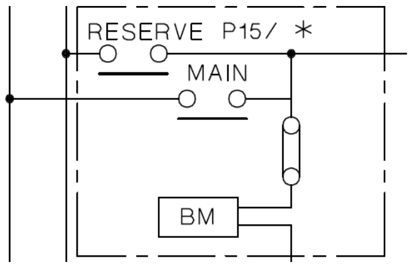
Evolution of HZBBZ Protection



1. No BFP, No IPACS
   e.g. HWL011 (2LMVP)

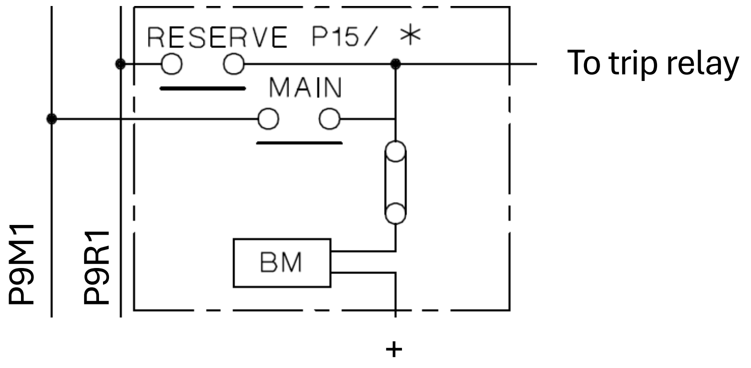


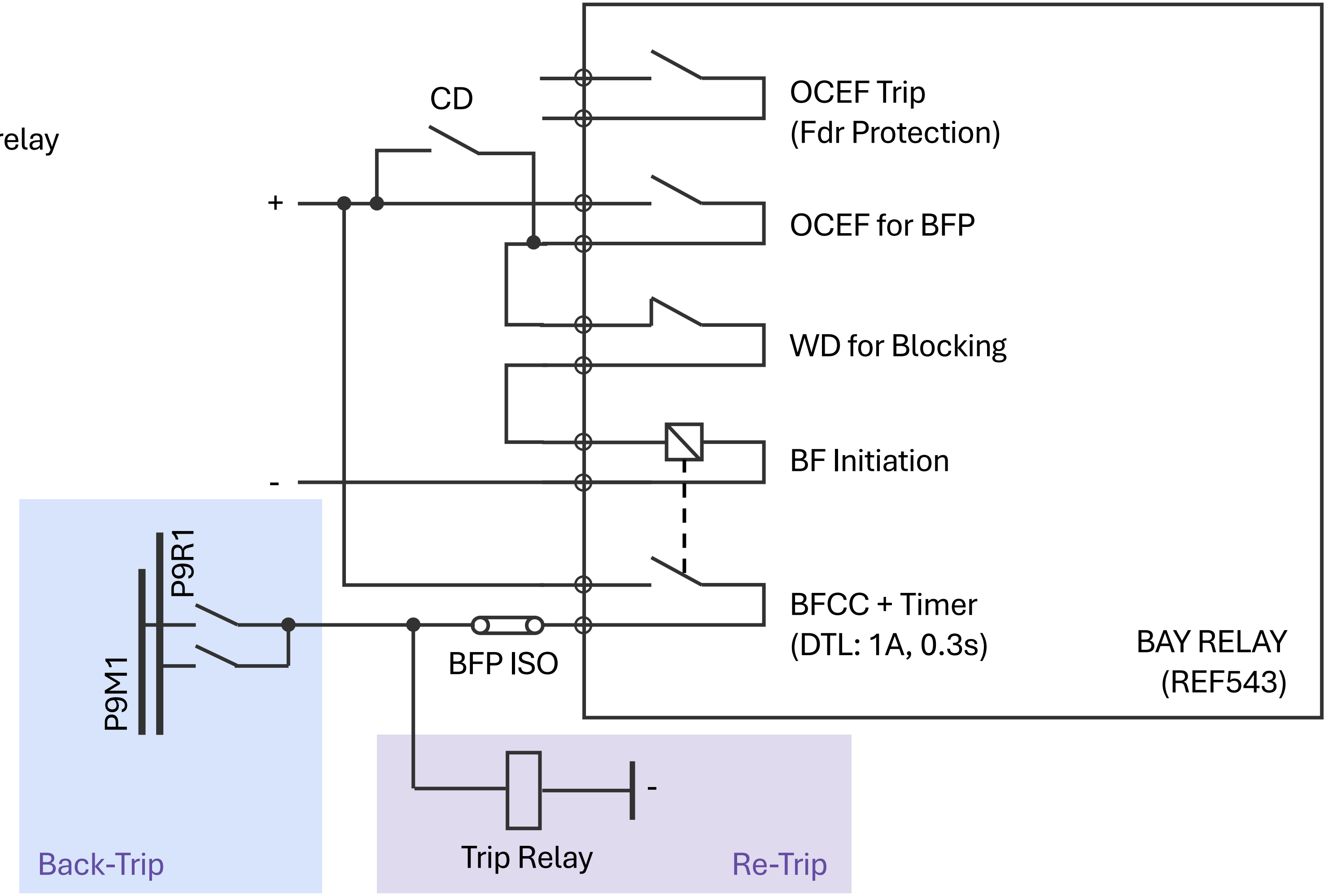
2. BFP Ready, IPACS (BFP link removed)
   e.g. PCH011 (8DB10)



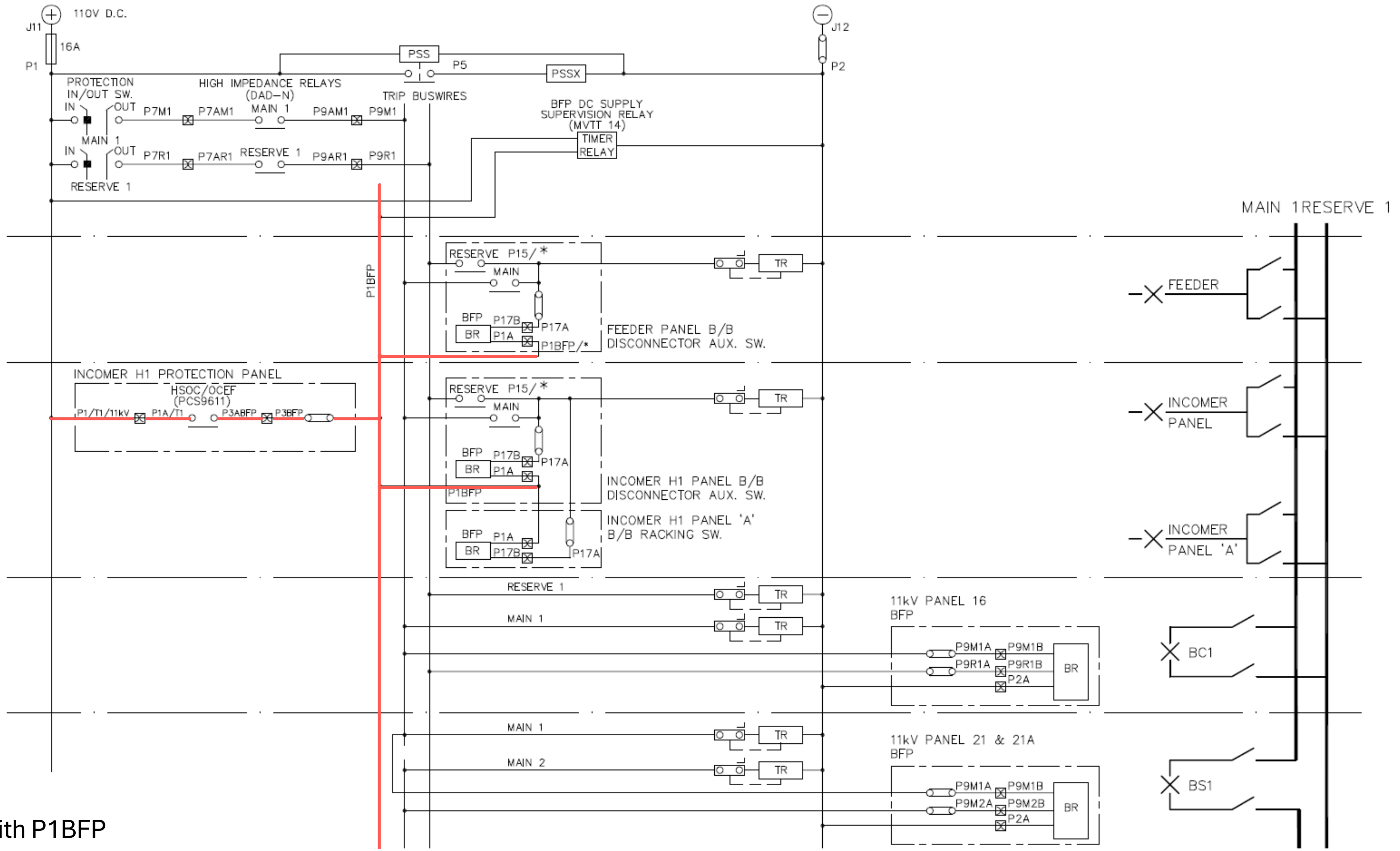
Evolution of HZBBZ Protection – Introduction to BFP

- In case of CB stuck with uncleared fault at 11kV, the only remote backup is OCEF at Tx HV (if no local backup at 11kV BBZ as BFP).
- It is not a standard provision (up to now, only for new substation) that BFP is included in HZBBZ.





Evolution of HZBBZ Protection – Introduction to BFP

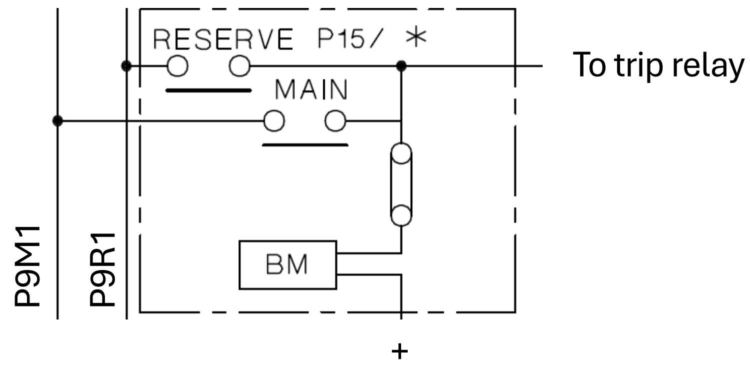


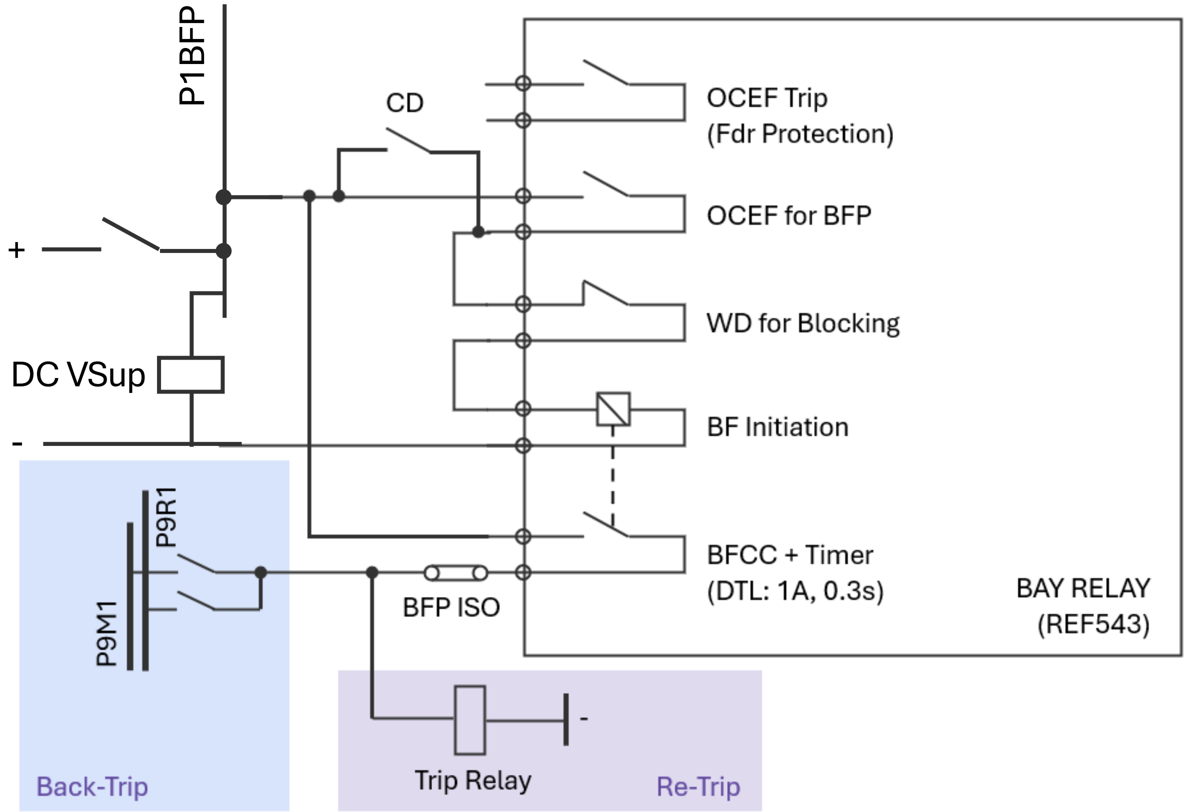
3. With BFP, With IPACS
   With HSOC2 (1A, 0s) , With P1BFP

Evolution of HZBBZ Protection – 11kV Enhanced BFP (PS – EP0052)

To further enhance the scheme security of BFP,

1. If the timer contact is made longer than 2 seconds, the BFP function on that panel will be blocked to prevent mal-operation of BFP scheme The "BFP DEF/OOC" remote alarm will be sent to System Control and a LED indication will be shown on the bay relay.
2. the " +ve" supply will only be switched to the BFP scheme through BFP bus (P1BFP) at the bay relay when the current check element of the HV OCEF relay (HSOC2) of any one of the incoming transformer circuits picks up. The setting of the current check element is set at 100% of CT rating, which is above the circuit rating. Hence, the scheme is insensitive to current less than normal circuit rating for higher security against mal-operation.

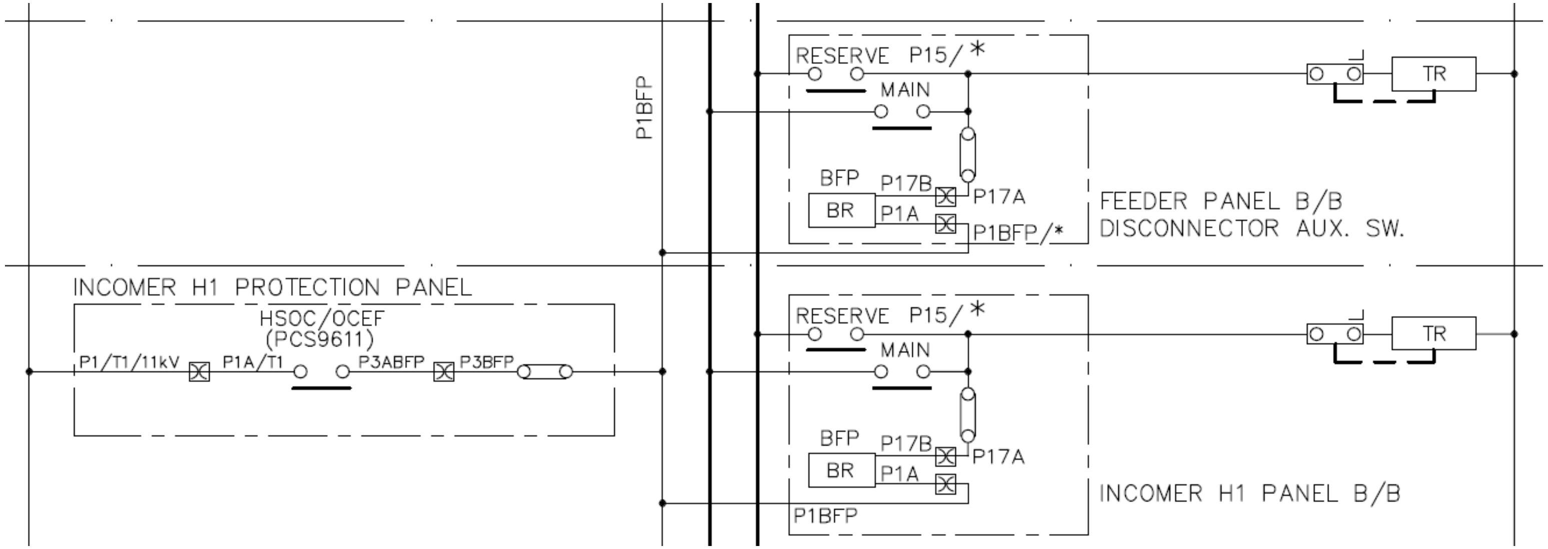




Comparison of HZBBZ at 11kV and 132kV

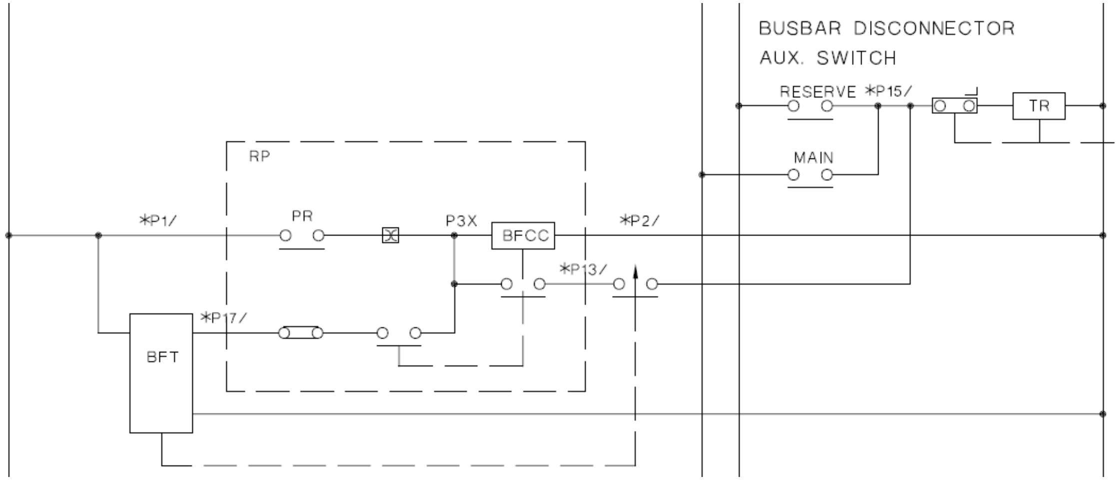
11kV HZBBZ

- 11kV employs its bay module to perform both BFCC and BFT.
- The Enhance Scheme requires additional HSOC2 element from Tx Protection as current check.
- Additional P1BFP bus is needed. Wiring modification at both switchgear panel and BBZ protection panel.



132kV HZBBZ

- 132kV employs an additional OCEF relay to perform BFCC at its protection panel, while a timer at HZBBZ panel to perform BFT.

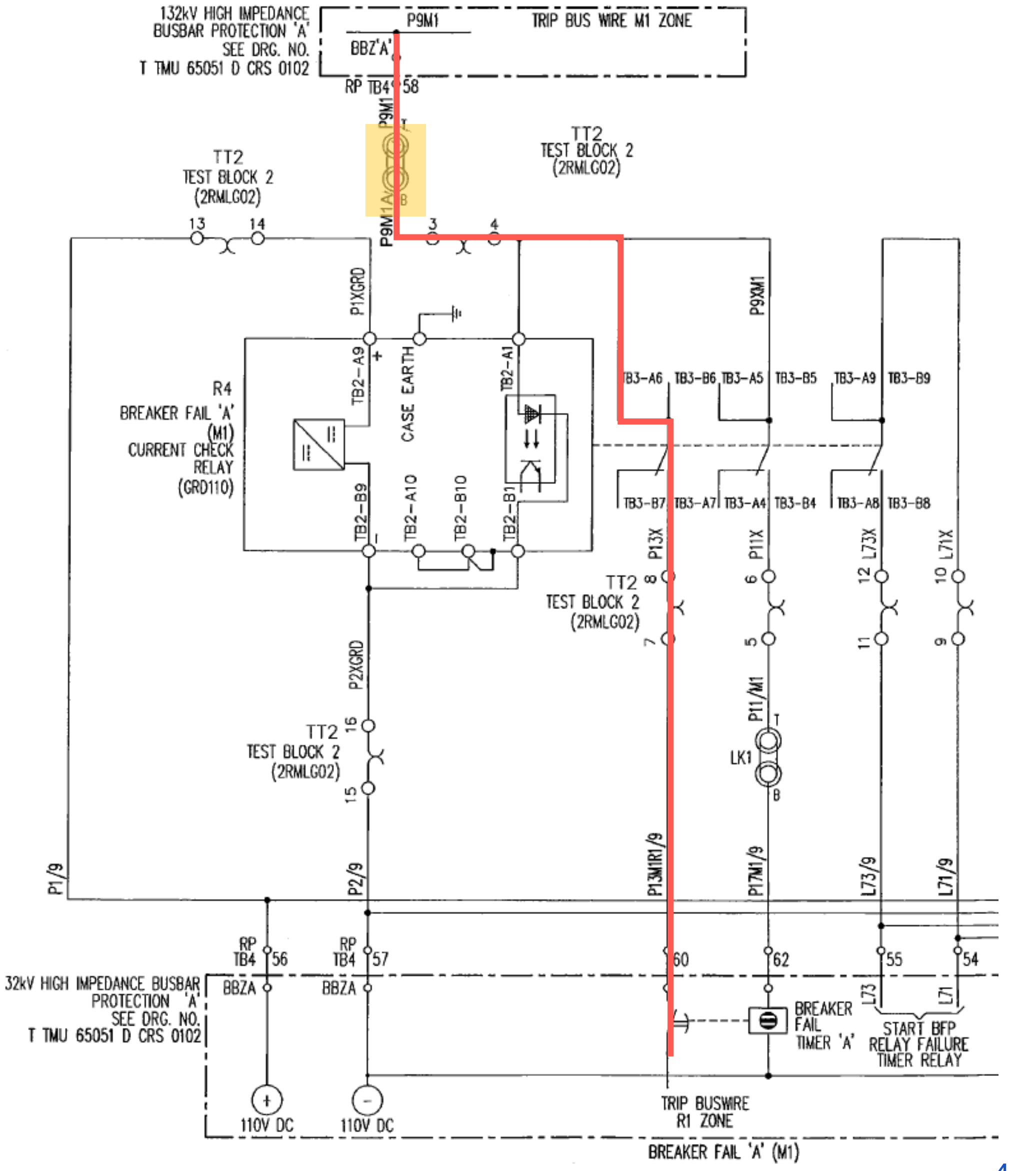


Addition of BFP Isolation Links at 132kV BC / BS

- During Protection Mtc on 132kV BC and BS, BFCC setting will be tested by injection.
- To operate the BFCC contact (TB: 4 – 8), it is required to provide a 110kV DC to binary input (BI) at TB terminal 4.
- During the disconnection of test block, the terminal 3 and 4 will be instantaneously shorted due to the design of isolation test block MMLB02. Hence, the DC will be shorted to P9M1, the trip buswire, in case the DC wire is not disconnected and removed.
- A BFP isolation link was added (at 2022 after an incident of tripping a busbar) at all 132kV BC / BS.

For 132kV HZBBZ Protection Mtc, an additional step is needed to test the BFP function on failure of tripping of BC/BS under busbar fault

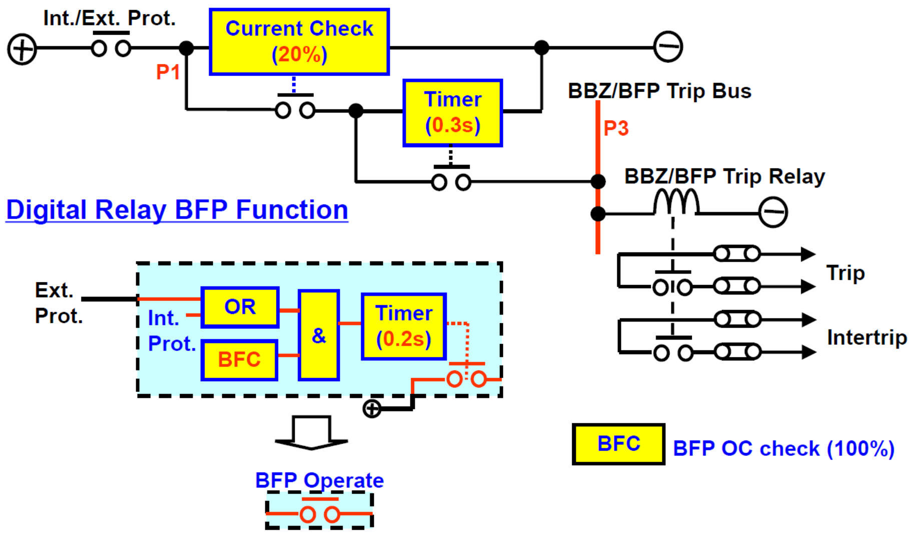
- Operate main relay for 0.4 s < t < 0.7 s. Check instantaneous tripping of corresponding protection zone
- Tripping of adjacent protection zone with the operation of BC / BS breaker failure protection timer [Setting: 0.2A, 0.4s]



132kV BFP Vs 11kV "Enhanced" BFP

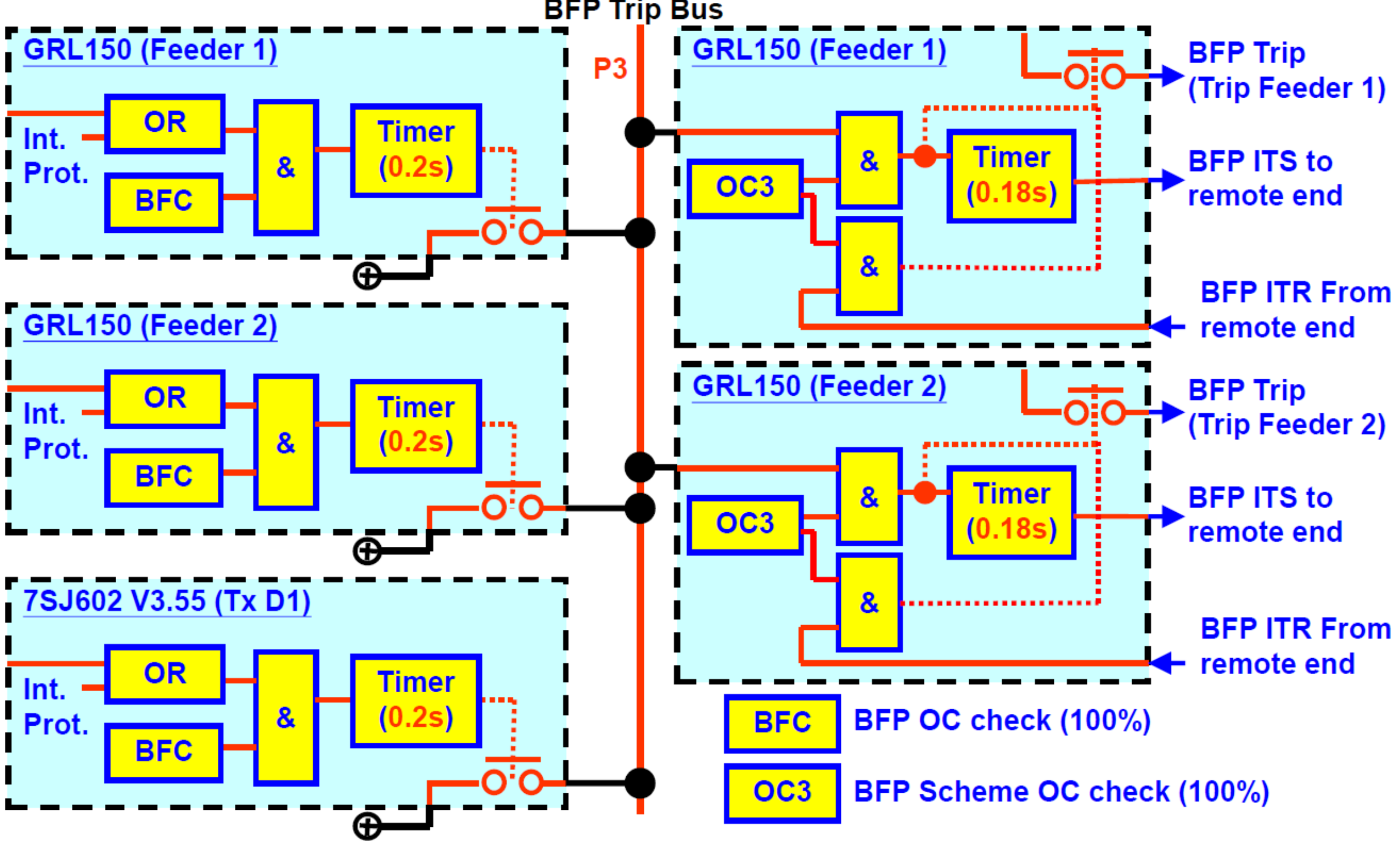
132kV BFP -

3 Criteria to Meet before Issuing BFP TRIP:
- Protection Operated + BFP OC Check (BFC, 20%) + Time Delay (0.3s).
- Disadvantage: All feeders may be tripped due to short-circuit P1 to P3 accidentally.



11kV "Enhanced" BFP -

4 Criteria to Meet before Issuing BFP TRIP/ITS of Individual Circuit:
- Protection Operated + Circuit current Check (BFC, 100%) + Time Delay (0.2s) + BFP Scheme OC Check (OC3, 100%) ---> BFP Trip
- Protection Operated + Circuit current Check (BFC, 100%) + Time Delay (0.2s) + BFP Scheme OC Check (OC3, 100%) + Time Delay (0.18s) ---> BFP ITS



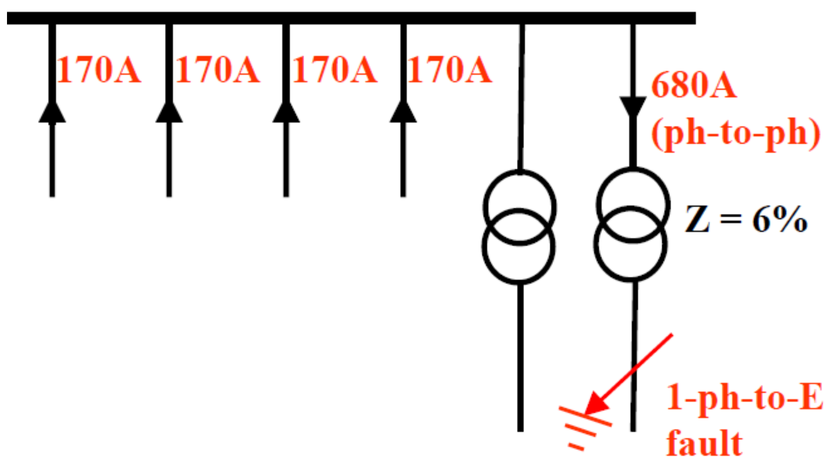
11kV BFP Current and Timer Setting

Old BFP Current Setting = 20%

- Min. LV Tx through-fault current = 680A.
- Min. fault current on a feeder = 680 / 4 = 170A(equally shared by 4 feeders).
- BFC setting < min fault current / 2 (= 170/2 = 85A).
  → BFC setting =80A(400 Feeder).
- This ensures BFP operation when there is un-cleared through LV Tx fault.

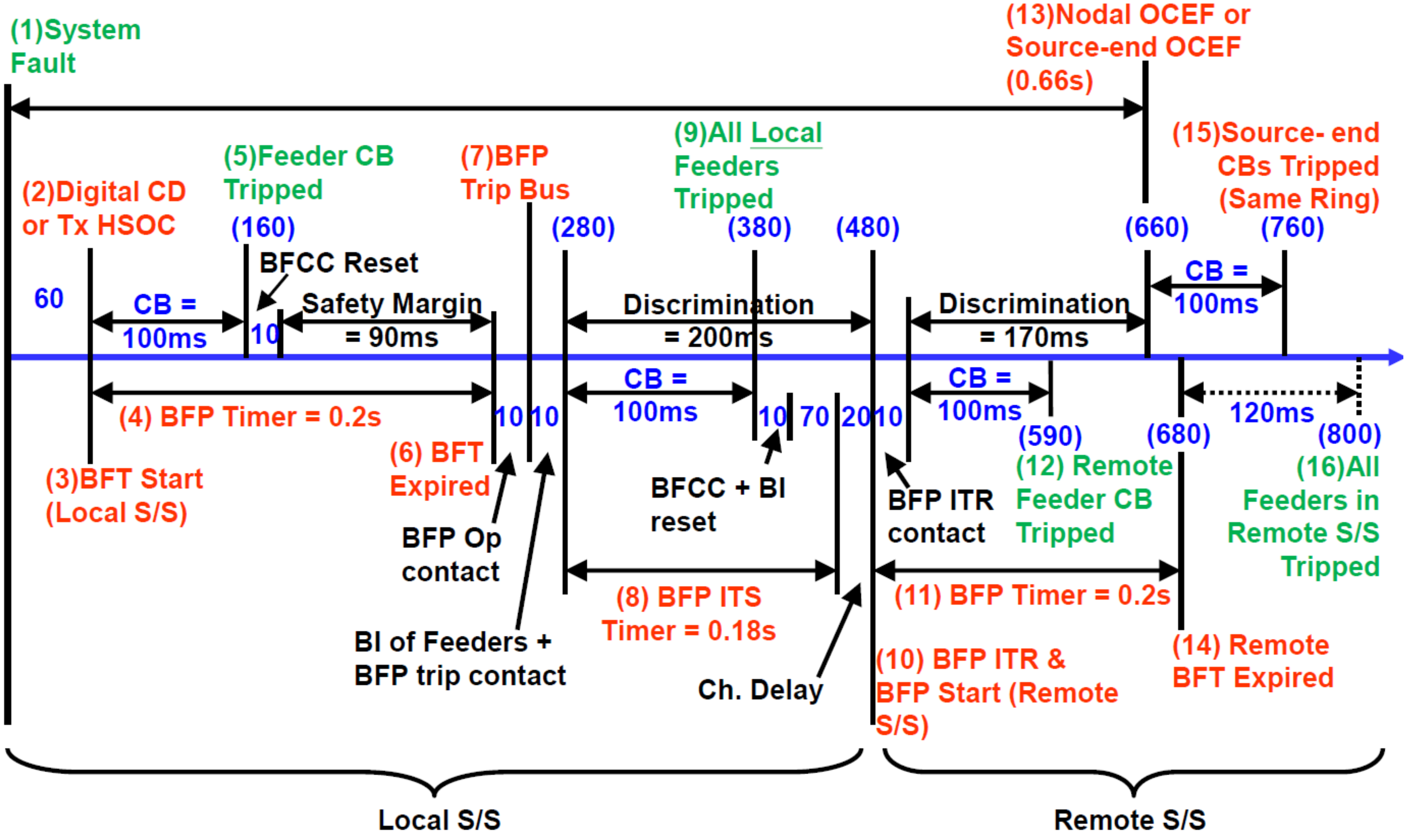
Enhanced BFP Scheme (100%)

- BFC Setting = 400A
- OC3 (BFP Scheme OC Check) = 400A
- The settings (400A) guarantees no tripping of adjacent feeders due to human error.
- BFP does not operate when HV CB stuck under min. LV Tx through-fault condition (170A).

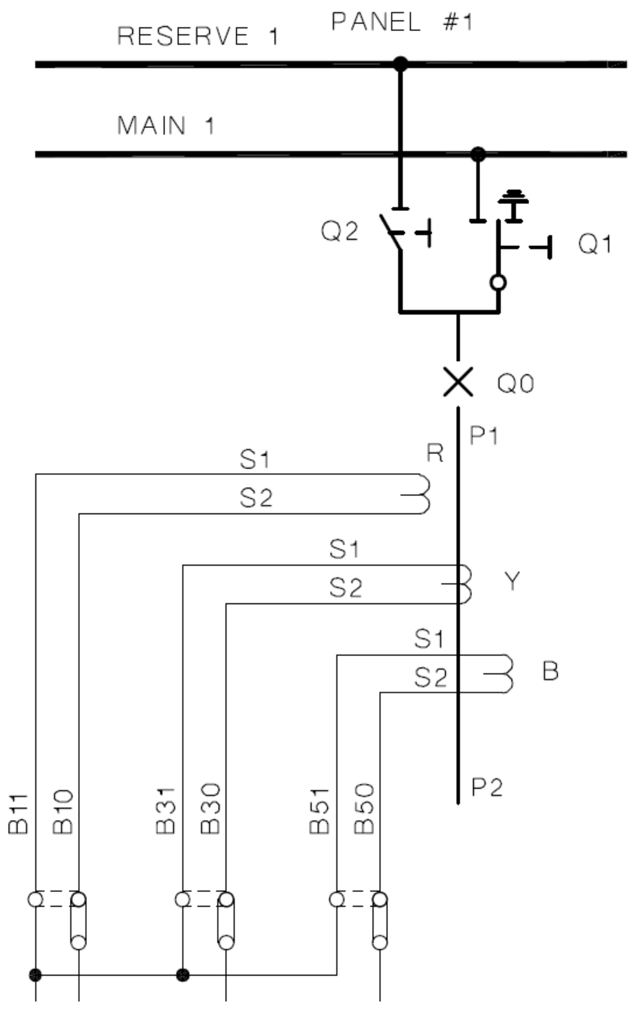


11kV BFP Current and Timer Setting

- **BFP Timer = 0.2s**
- **BFP ITS Timer = 0.18s**
- **If Source-end OCEF Time Multiplier = 0.5, fastest operating time = 1.1s.**



HZBBZ Stability Test



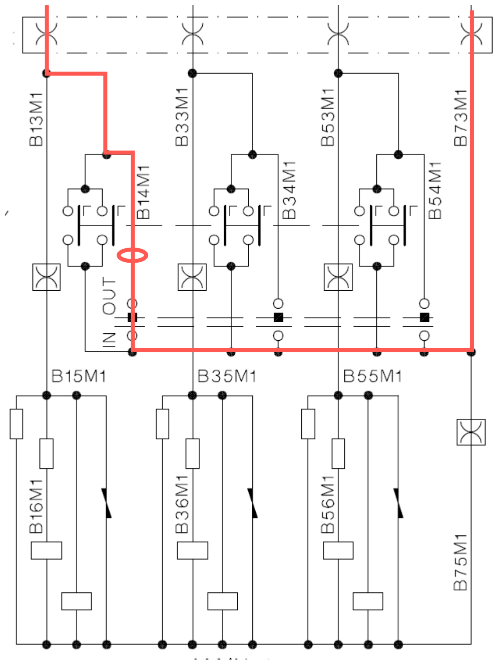
Goal: To test the integrity of CT wiring after CT wiring modification (or disconnection).

Test: 1. Measure 3 phase and neutral current before test to have pre-test stability.

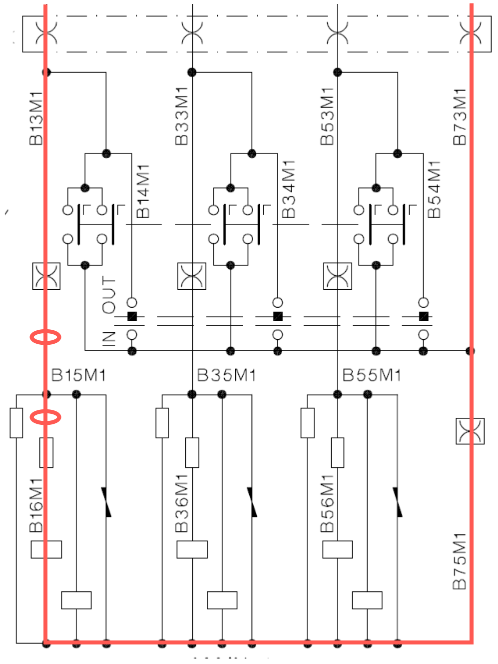
2. Short and isolate phase by phase (at switchgear side) to see if it reflects your action (at protection panel side).

3. Measure 3 phase and neutral current after test for final stability.

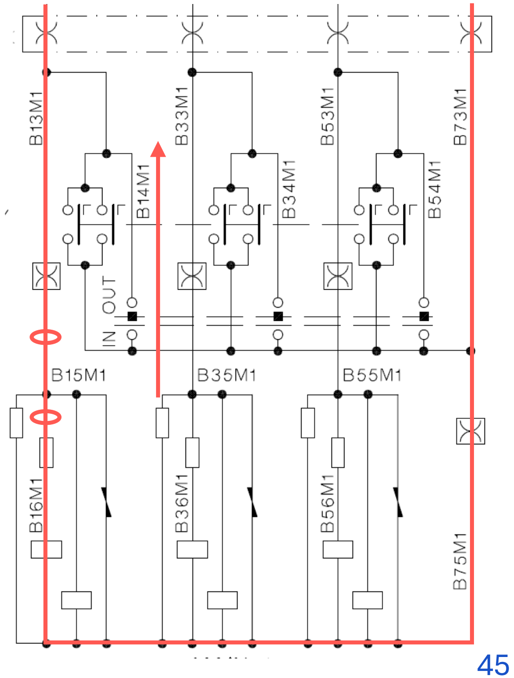
1. Switch OUT,
Measure current at B14M1



2. Switch IN,
Measure current at B15M1, B16M1

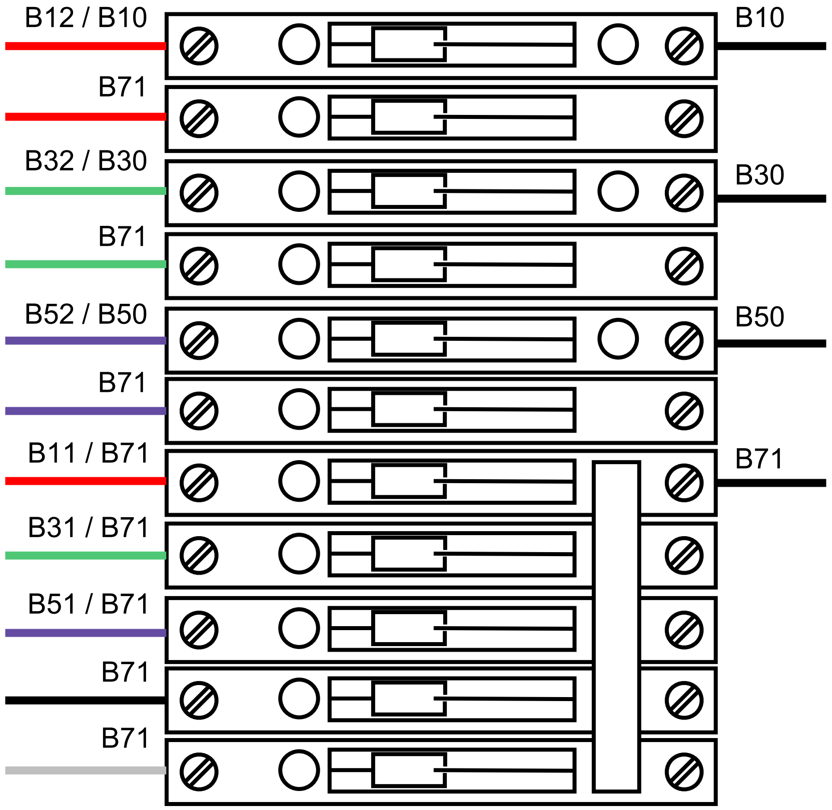


3. Switch IN,
Measure current at B15M1, B16M1
Measure voltage across shunt path



HZBBZ Stability Test (20240327 – YUE132)

1. Where to perform **short and isolation** for **132kV HZBBZ**?
   a. relay panel 4A, 4B b. switchgear LCP
   c. HZBBZ M2, R2 panel
2. Which side should be shorted, left or right at terminal block?
3. What are the problems on wiring in the LCP?
4. What could cause DEF/OOC alarm during on load transfer?
5. What are the risks of incorrect shorting CT, and what are the follow up actions?
6. What are the tests to be performed in case auxiliary switch is replaced? (Any on the DC circuit?)



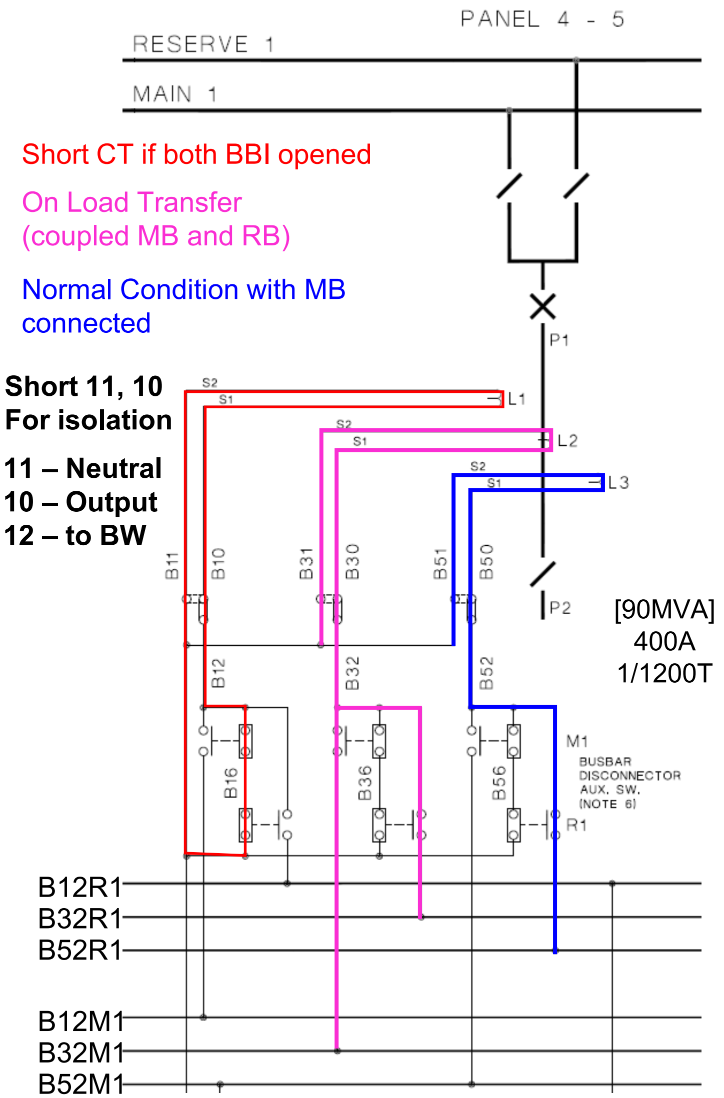
Short CT if both BBI opened

On Load Transfer (coupled MB and RB)

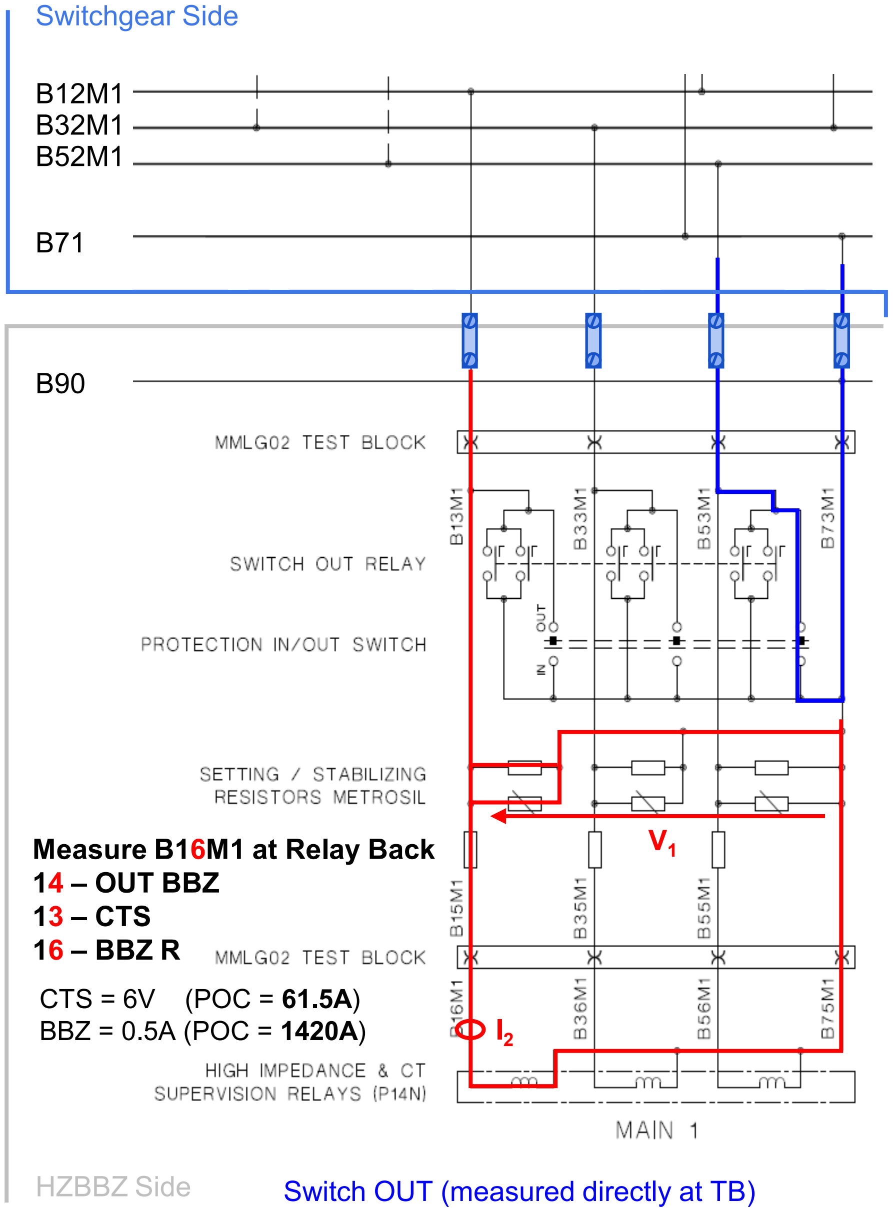
Normal Condition with MB connected

Short 11, 10 For isolation

11 – Neutral
10 – Output
12 – to BW



[90MVA]
400A
1/1200T



Measure B16M1 at Relay Back
14 – OUT BBZ
13 – CTS
16 – BBZ R

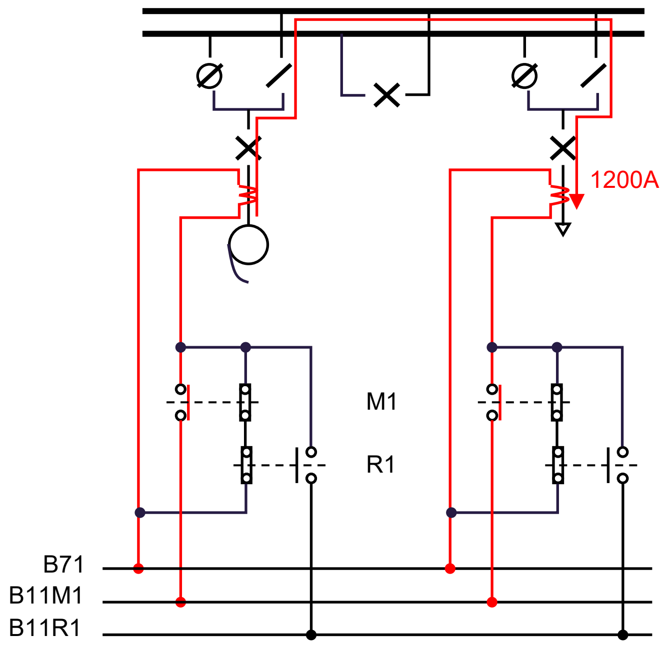
CTS = 6V (POC = **61.5A**)
BBZ = 0.5A (POC = **1420A**)

Switch OUT (measured directly at TB)

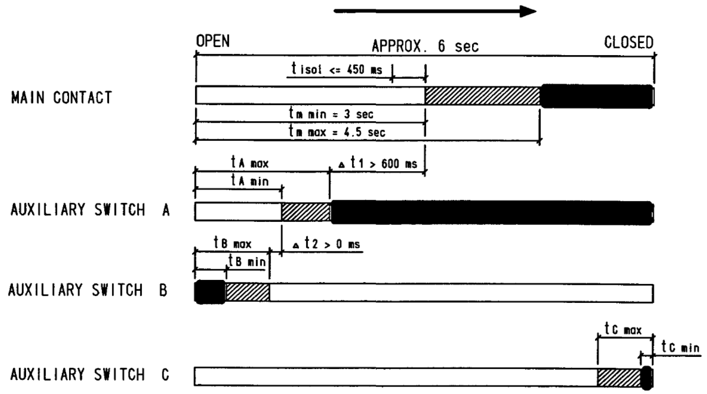
Switch IN (measured voltage V_1 at Metrosil + current I_2 at relay)

[Note: CT Supervision // BBZ Relay]

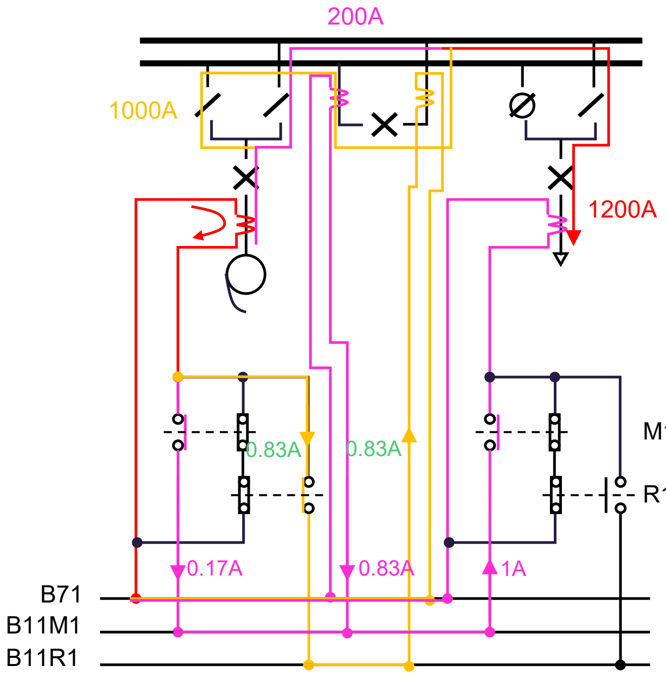
Normal Condition before On Load Transfer



MB current **circulates** from one circuit to another in secondary circuit without any problems.



Normal Condition during On Load Transfer

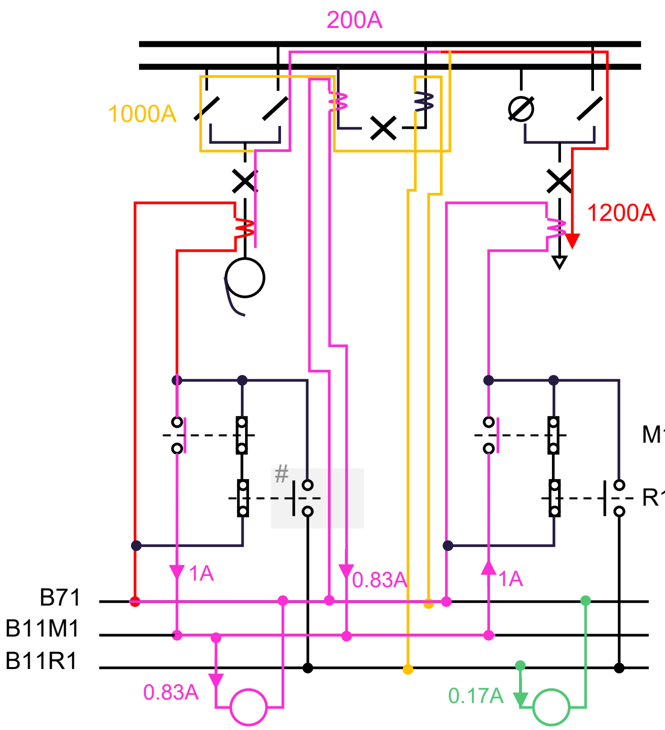


During On Load Transfer

- It is essential to make sure secondary current flow will NOT be limited by the status of MBBI and RBBI auxiliary.
- It is “early make late break” type contact. Current will flow itself. In case there is no easy current path, current flows into high impedance path (into relay)

	N.O. Aux. Switches Qty. & Type		N.C. Aux. Switches Qty. & Type	
BBZ A Protection	3	(A)	3	(B)
BBZ B Protection	3	(A)	3	(B)
BBZ Trip Selection	2	(C)	0	

Sluggish Closing of RB Aux during On Load Transfer



In case Auxiliary Contact is NOT fast enough

- Current path will stay as before On Load transfer.
- Partial current in primary flows directly to the load, and partial current flows through BC to the load.
- Current flowing through the BC catch the “additional current” to both BB. In case MBBI has a higher impedance than the RBBI + BC CB, major current flows through BC CB and the “additional current” will be larger.
- The asymmetry in primary circuit and secondary circuit activates the CT Supervision function ($61.5A_{PRI}$) and disables HZBBZ with DEF/OOC alarm.

sluggish closing of RB Aux

Incident (IDR: 1302938-1) Failure of Racking Switch leading to Open CT

Preliminary Report

Under planned outage TR22-2001A for Hammer Hill 011 Tx H1 CB roller cleaning, the CB of Bus Section No.2 was closed to facilitate switching out the Tx H1 CB. After completion of the remote switching steps, site engineer reported that there was smoke emitting from Bus Section No.2 panel.

The CB of Bus Section No.2 was opened by remote control after confirming the CB was safe for operation. Preliminary investigation revealed that the racking switch was defective and the current transformer terminal block was burnt as a result of open circuit.

TD will arrange follow up investigation and repair.

- With open CT, the HZBBZ scheme was switched out by its CT supervision function. It did not make HZBBZ to mal-operate, but it nearly caused fires with the weakest point at the CT circuit. The surrounding CT terminal block was burnt and melted.
- Later, it was decided to perform a Ductor test (contact resistance test) on all BS for substation with 2LMVP switchgear.
- A HZBBZ stability was performed after Ductor test.

3. PERFORM DUCTOR TEST AFTER RACKING OUT CB (OUT POSITION)

☑ Check CB Open, CB Racked OUT

	B12 (OUT) – B71	B32 (OUT) – B71	B52 (OUT) – B71
Contact Resistance (mΩ)	1071	1015	1257
	B12A (OUT) – B71A	B32A (OUT) – B71A	B52A (OUT) – B71A
Contact Resistance (mΩ)	1529	960	894

☑ If Ductor Test Set is not available, a current injection set can be used. Note: measure the voltage at the terminal block. (☑ NOT APPLICABLE)

☐ Normal CT after Ductor Test

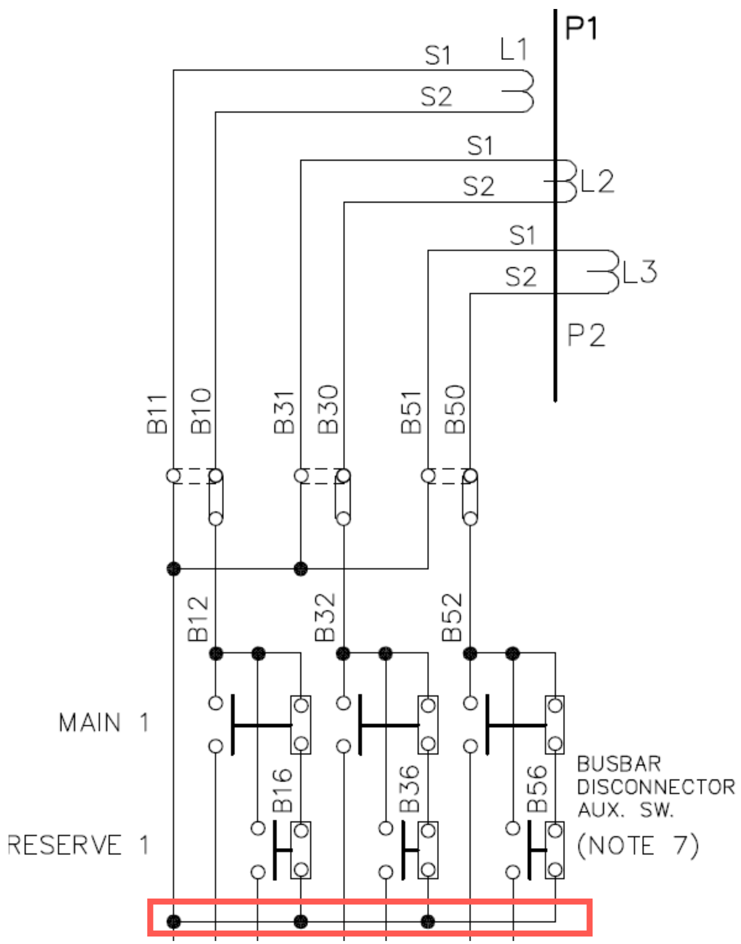
Incident (POS365) Missing Neutral CT Link leading to Maloperation at Through Fault

On 22 May 2018 at 04:55 hours, a genuine cable fault occurred on the cable section of SUNSHINE CITY BLK B and MOS I/D RERE CTR CUM LIB in LONR0003, see Appendix 1. The corresponding pilot-wire (PW) differential protection operated to clear the fault. Simultaneously, the 11kV Reserve 1 Busbar (R1BB) with its associated circuits were tripped by operation of High Impedance Busbar Zone protection (HZBBZ). Total 7 circuit breakers were tripped by HZBBZ protection during the incident causing supply interruption to R1, R2 and R3BB, see Appendix 2. Upon arrival of site staff and after confirming no sign of genuine fault on R1BB, R1BB was restored.

- Neutral link for BBZ CT in feeder panel 5 was missing. Unwanted out-of-balance current was produced and hence operated the HZBBZ protection under feeder fault.
- Prior to the incident, the out-of-balance is insufficient for operating the HZBBZ as POC = 2000A.
- When the second cable fault occurred, the ring was changed from 3 legged to 2 legged, hence the fault current is shared among panel 3 and 5, and the out-of-balance current becomes large enough to operate the HZBBZ protection.

Auxiliary contacts for BBI was reported defective at SMO011 and DBN011 (both 8DB10). With the discrepancy between aux contact and actual plant status, this may also affect the operation of HZBBZ protection.

- In addition to neutral links and CT connection check, BBI position and HZBBZ stability should also be checked.
- Measure the voltage across voltage-operated CT supervision relay or equivalent bus wire.

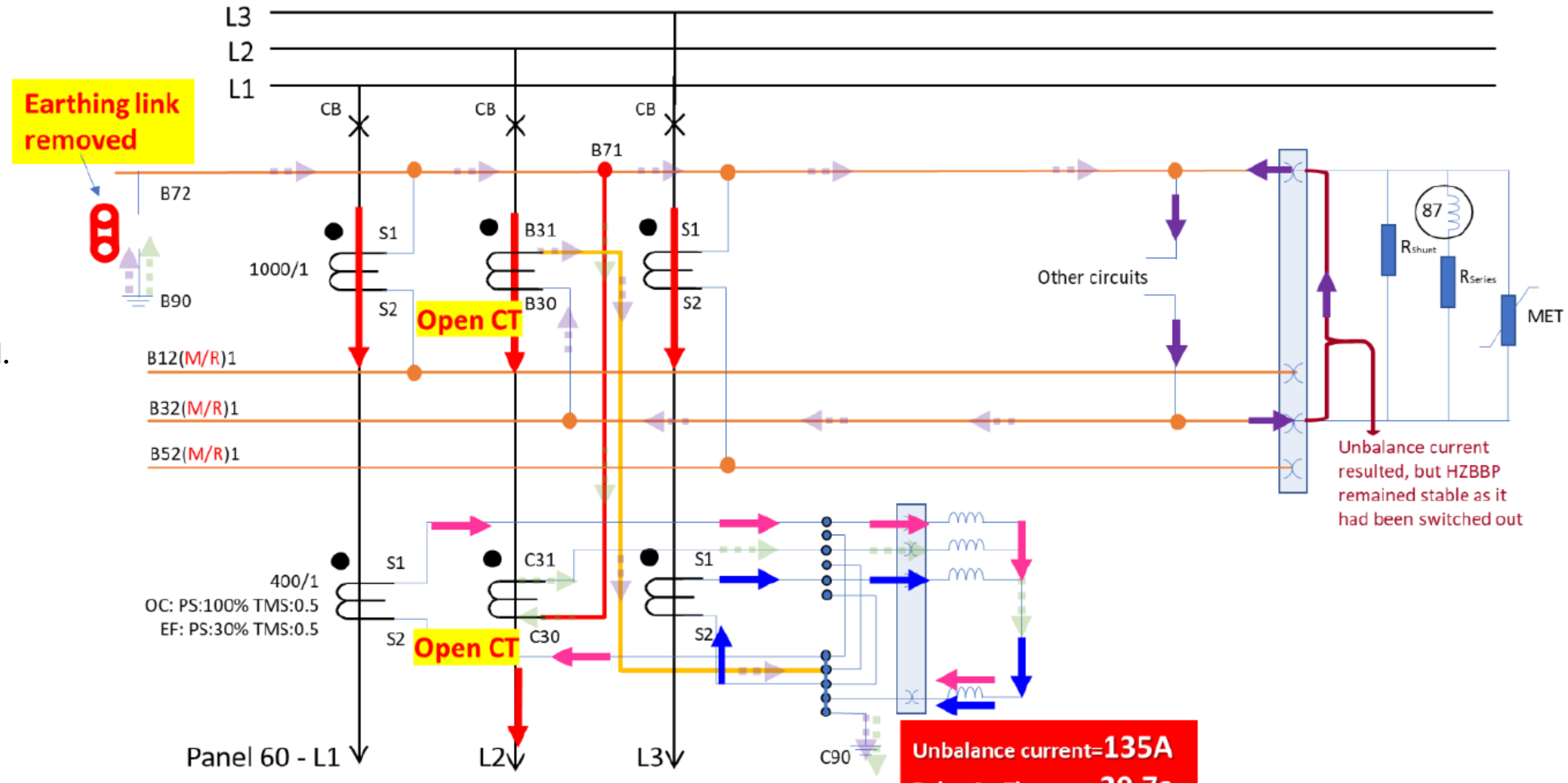


Incident (POS378) Crossed CT Wires Discovered at Maintenance

During high impedance busbar protection (HZBBP) maintenance at LON011, earthing link between B72 and B90 was removed to measure current transformer (CT) insulation. After earthing link removal, the circuit breaker (CB) of the captioned circuit at LON011 (panel 60) was tripped by earth fault protection.

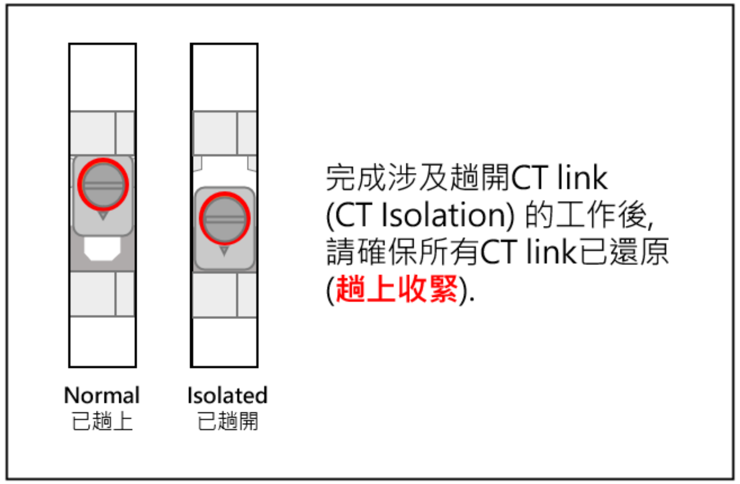
B31 and C31 was cross-connected. Current can still flow at normal operating condition through the earth link B90 and C90.

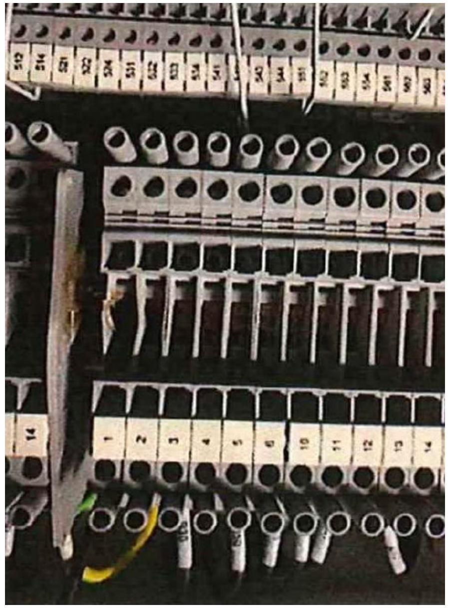
Yet, during the protection maintenance, to perform Megger test, the B90 earth link was disconnected, and the W-Ph CT of OCEF has no way to flow, hence creating an unbalance current leading to EF trip of panel 60.

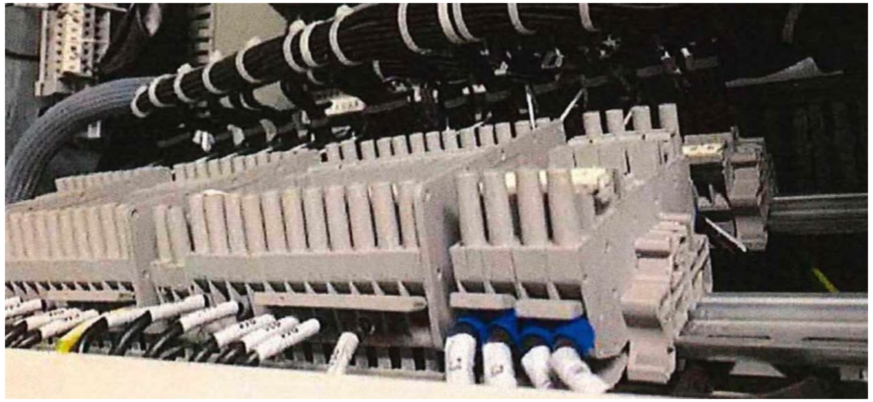


Incident (WC N2850): Incorrect installation direction of BBZ CT Terminal Block

- The CT terminal block was designed to be installed inclinedly for easier observation after several comments of difficulties in observation with horizontal position with the height of the LV compartment at 11kV switchgear (typed 8DB10).
- The CT terminal block was burnt on 2021 March at QUH011 due to the inversed installed position of CT terminal block, such that the isolation link at CT terminal block will slide down with gravity and leading to open CT.
- With open CT, the defective alarm will be activated with internal CT supervision logic, hence discovering the incident.
- After the incident, there were comments that the CT terminal block should either made horizontal, or in correct installation direction. Yet, it will affect the isolation position and wiring termination direction. From commissioning experience, the problem still exists.

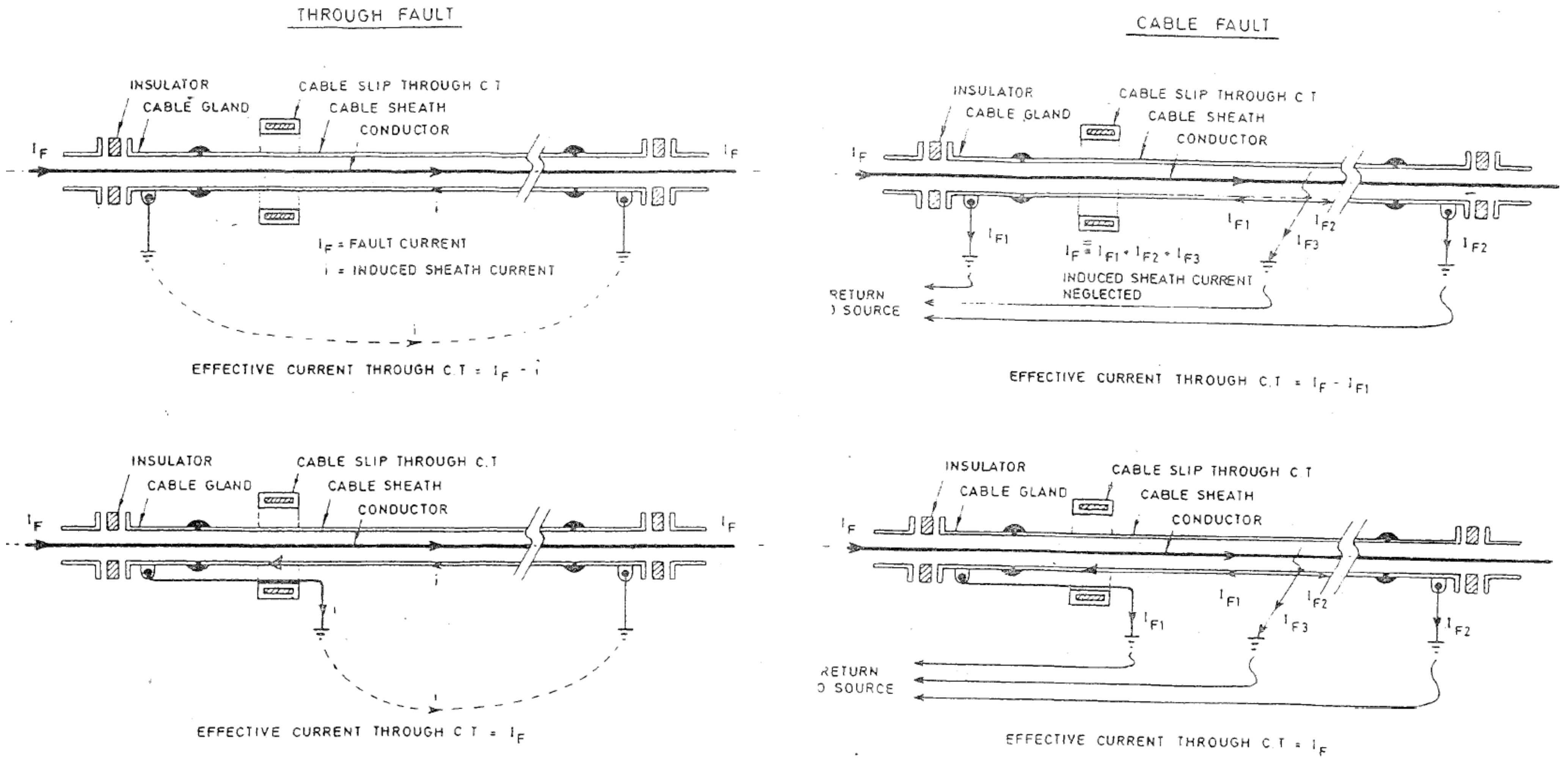






Earthing at Cable Sheath (PGG045)

- Under fault conditions, this induced voltage can become dangerously high. Therefore, it's a standard safety requirement to earth the cable sheath or armour at both ends. Earthing can provide a complete path for induced current to flow, which may lead to incorrect measurement of fault current for HZBBZ CTs if the lead is incorrectly applied.



Commissioning Requirement for HZBBZ and Spare Panel Energization (PGG080)

Tests to be performed for HZBBZ protection

- Basic CT tests for BBZ CT: Flick, Megger, Resistance, Magnetizing, Ratio
- Basic tests for auxiliary switch: fault recorder for contact timing

Main Contact	Open	Close
N.O. Aux Contact	Open	Close
N.C. Aux Contact	Close	Open

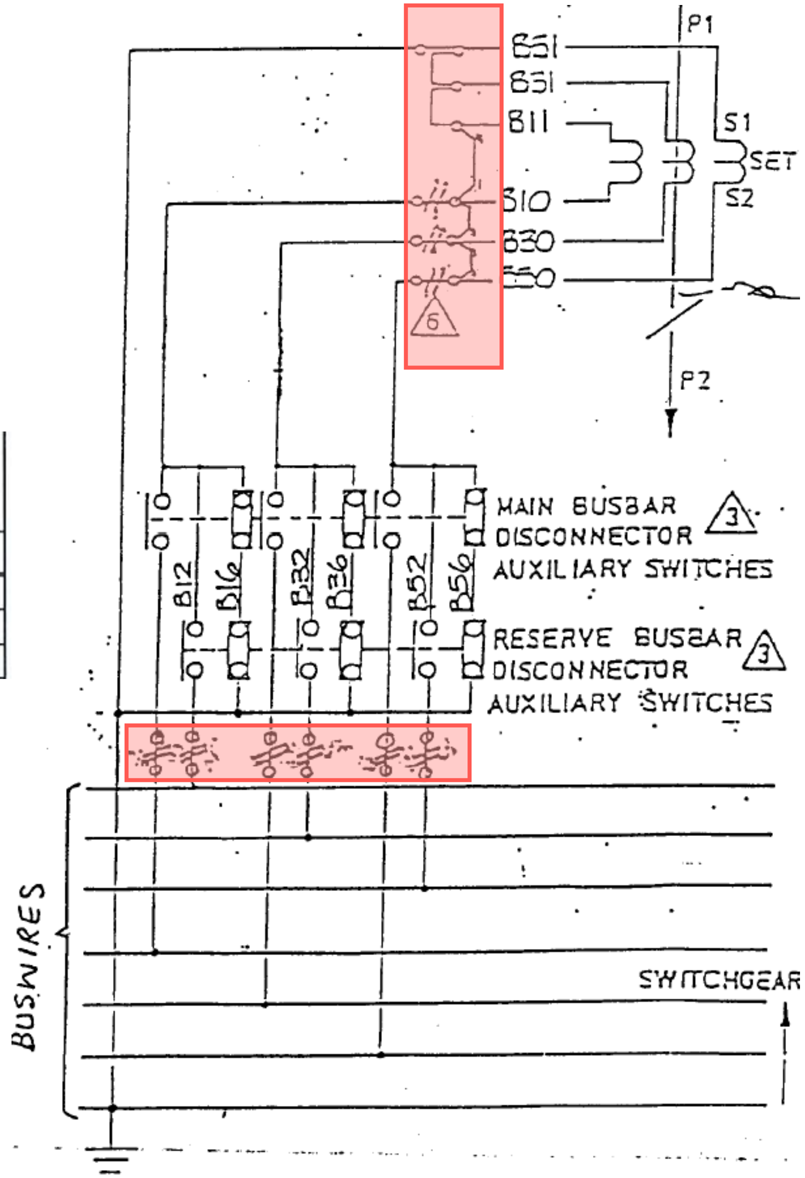
- Secondary Injection, Primary Injection (**Balance Test**)

TEST CONDITION			CURRENT IN TEST CIRCUIT (mA)			CURRENT IN STANDARD CCT (mA) P#1			CURRENT IN RELAY CIRCUIT (mA)		
PANEL UNDER TEST		STD PL CT									
NO.	CT		R	Y	B	R	Y	B	R	Y	B
2	S/C	NORMAL	–	–	–	200	200	201.3	50	51.5	51.3
	NORMAL	S/C	199	201.4	201.4	--	--	--	51.2	51.9	51.3
	NORMAL	NORMAL	199	201.6	201.5	201	200.7	200.5	T	T	T

- Function: 1. Correct Tripping at BB Position (Zone Selection Test),
  2. BFP Transfer Trip (Operate M1 > 0.4s → Trip R1)
  3. Breaker Failure Fail Timer (L71 – L73)
  4. Switch OUT and Sensitive Alarm OUT
- On Load Stability Test (Similar to CD).

Spare Panel Energization

- CT shorted and isolated (kind of unstabilizing the busbar zone to cover to cable lug)
- Busbar Auxiliary disconnected (not yet performed on load stability for the aux contact)



11kV HZBBZ Protection Maintenance (M075)

MAINTENANCE - HZBBZ PROTECTION TEST FORM M075 Ver.2.0

SUBSTATION: LON011

SYSTEM VOLTAGE: 11kV

1. Preparation

✓ IPACS ✓ BFP
✗ H60C2 ✗ P1BFP

1.1 ☑ Maintenance programme accepted by SOD informed of date & work.

1	LON011	HZBBZ Protection	Switch out HZBBZ Protection Remove all HZBBP trip and inter-trip isolation links Remove NAS Blocking Link
2	LON011	HZBBZ Protection	Carry out protection maintenance Check protection normal after protection maintenance
3	LON011	HZBBZ Protection	Check no HZBBP relay operated, Switch in HZBBZ protection, Check no HZBBP relay operated, Replace all HZBBP trip and inter-trip isolation links Replace NAS Blocking Link

BFP link out

1.2 ☑ Collect the appropriate HZ BBZ protection schematic for the S/S.

11kV HZBBZ Protection Maintenance

2. Protection and Tripping Isolation

2.1 ☑ Obtain consent of System Control Engineer, Mr. K K LEUNG to carry out maintenance

2.2 ☑ Switch out the BBZ protection and remove all trip and intertrip isolation links.
(Use ' Check List and Isolation Table ' to record and check the isolation links removed.)

2.3 ☑ Check BBZ out-of-commission indication and alarm.
☑ Local ☐ Remote

Remove alarm pin after remove all links

2.4 ☑ Measure the voltage across isolation link terminals to check continuity of trip circuit.

2.5 ☑ Short and isolate C. T.buswire from the protection .

If necessary, just isolate the C.T. Buswire
[Risk: under Fault, the CT circuit may have flashover!]

- Stability Test [OUT & IN] before test -
  Use CT clip meter to measure the current flowing into the zones at CT buswire (B12M1, B32M1 … B71R3).

- Perform CT Megger Test (500V > 2MΩ)
  Later pages on how to handle CT low insulation.
  Note 1: It is often as low as 3 – 50MΩ for all panels with insulation test in parallel. [50MΩ x (50 + 11 x 2 CTs) = 3600MΩ]
  Note 2: The buswire B71 should be ring looped at both switchgear side and also protection panel side. [often it is not the case]
  Note 3: The earth link is at the relay side. CT buswire isolation can separate relay insulation and CT circuit insulation.

11kV HZBBZ Protection Maintenance

Note 1: Voltage Supervision Timer to monitor if P1BFP is continuously energized at new scheme.
Note 2: MVTP is a timer AC relay. It requires DC injection at terminal 13 – 14.
Note 3: Busbar fault relay will be latched and flagged in case any one trip relay is not well reset.

3. Testing

3.1 Protection relay test.

USAGE	TYPE	MECH CHECK	INJECTION TEST Relay Op. at 70% V_R	TIMING TEST SETTING	TIMING TEST ACTUAL	FUNCTIONAL CHECK
M1 & R1 BB						
M1 HIGH IMP	KCGG142	✓	✓			✓
M1 SENSITIVE AL	MVTP31	✓	✓			✓
M1 PROT SW OUT	MVAJ53	✓				
R1 HIGH IMP	KCGG142	✓				
R1 SENSITIVE AL	MVTP31	✓				
R1 PROT SW OUT	MVAJ53	✓				
PROT DEF. TIMER	MVTT14	✓				
PROT DEF. TIMER RP	MVAA11	✓				

LEGEND :-

MECHANICAL CHECK

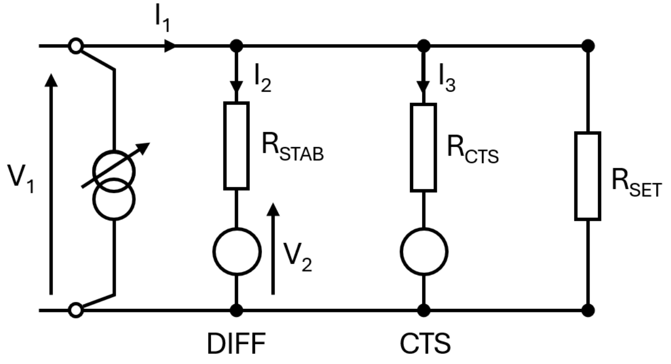
- RELAY GENERAL CLEANING & SEALING
- TIGHTNESS OF ALL CONNECTION
- SPRING LOADED CONTACT CHECKED
- CONTACT PRESSURE & ALIGNMENT
- OUTPUR CONTACT CONTINUITY
- FLAG FALL BEFORE CONTACT MADE

FUNCTIONAL CHECK

- TRIPPING
- INTERTRIPPING
- OPERATION OF MASTER TRIP RELAY
- INITIATION OF REPEAT RELAY
- INITIATION OF BFP / RTI
- INITIATION OF AUTO CLOSING
- LOCAL ALARM
- REMOTE ALARM

REMARK :-
* USE MAINTENANCE - RELAY TEST FORM 'B' FOR INJECTION TEST OF AC RELAYS
* USE 70% RATED VOLTAGE FOR DC RELAY FUNCTIONAL CHECK

11kV HZBBZ Protection Maintenance

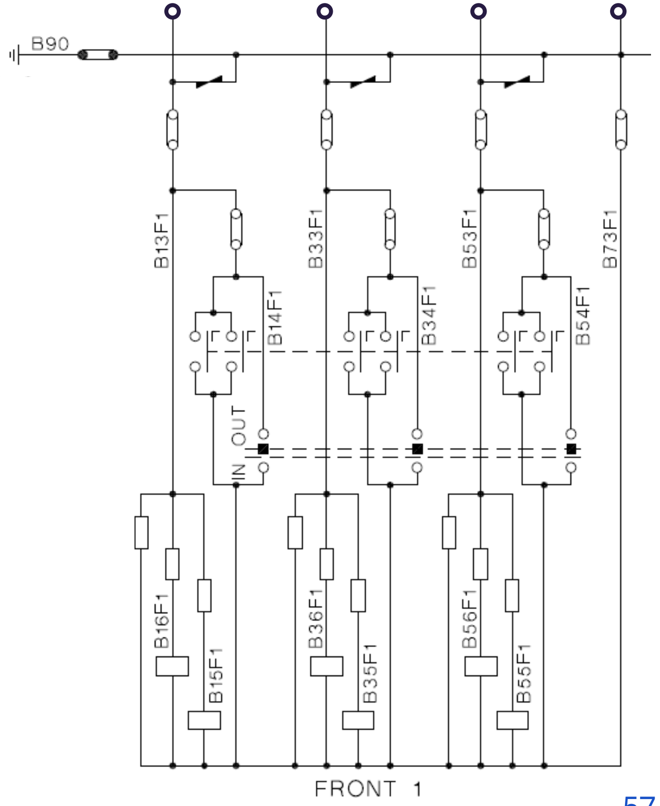


3.2 Setting Test

Relay	Type	Setting (* A / V)	
Differential	KCGG142	0.5A, 75V	POC=2100A
Sensitive Alarm	MVTP31	6V, 3sec	POC=200A

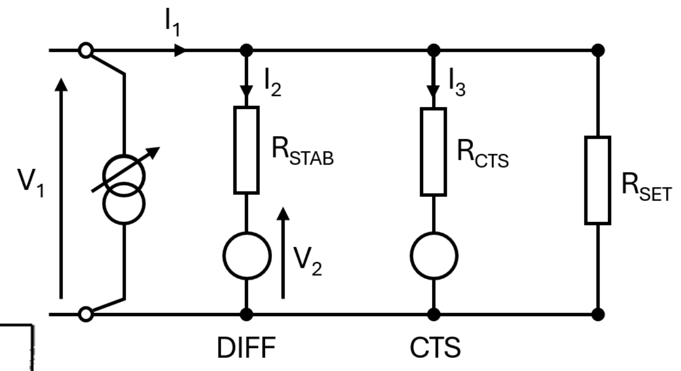
Protection Zone M2

Phase	Element Operated	Measurement					Operating Time
		V_1 (V)	I_1 (mA)	V_2 (V)	I_2 (mA)	I_3 (mA)	
R	Differential	78.17	2010	16.10	498	1.023	N.A.
	Sensitive Alarm	5.963	147	-	36	0.078	3.026 sec.
Y	Differential	77.62	1990	17.60	498	1.034	N.A.
	Sensitive Alarm	6.081	138	-	34	0.081	3.011 sec.
B	Differential	77.08	1971	18.10	498	1.032	N.A.
	Sensitive Alarm	6.196	144	-	36	0.083	3.012 sec.



1. Draw out CT Supervision Relay to perform setting test and timing test to CTS relay (in case R_{CTS} = 0).
2. Inject back V_1 to the network at observe I_1 from injection set, I_2 at BBZ relay (KCGG / DADN). [Sensitive Alarm at TB: 2 – 4, Trip at TB: 26 – 28]

11kV HZBBZ Protection Maintenance



3.2 Setting Test

Phase	Element Operated	Measurement					Operating Time
		V_1 (V)	I_1 (mA)	V_2 (V)	I_2 (mA)	I_3 (mA)	
R	Differential	38.17	2010	16.10	498	1.023	N.A.
	Sensitive Alarm	5.963	147	-	36	0.078	3.026 sec.
Y	Differential	37.02	1990	17.60	498	1.034	N.A.
	Sensitive Alarm	6.081	138	-	34	0.081	3.011 sec.
B	Differential	37.08	1971	18.10	498	1.032	N.A.
	Sensitive Alarm	6.196	144	-	36	0.083	3.012 sec.

Before Test – Short and Isolate CT (in theory CT should have high impedance so that no significant current will flow through CTs)

1. Inject at CT terminal block B12M1 – B71 …
   Observe the voltage V_1 and current I_1 at injection set.
2. Measure V_2 at the back of BBZ relay (KCGG / DADN)
3. Observe the current I_2 at BBZ relay display
4. See if I_3 can be measured at the back of Sensitive Alarm Relay, or measure the current flowing through R_{SET} (in case the connection is not double wired). Or else, deduce the current with calculated internal resistance of CTS relay (MVTP) from Sensitive Alarm Test (V_1 / I_3), assume no back EMF and linear resistance.

11kV HZBBZ Protection Maintenance

4. Scheme Functional Check

Note: BBZ DEF/OOC is activated once you switch out the protection.

It is more important to check if the CT buswire is shorted under switch out condition.

4.1 Switch out the protection and operate main relay for t > 2 s.
Check that ' Protection Defective Alarm ' comes out with no operation of BBZ trip relay.

Protection Zone	Main 1/~~Fornt 1~~			Reserve 1/~~Rear 1~~			Main 2/~~Fornt 2~~			Reserve 2/~~Rear 2~~			Main 3/~~Fornt 3~~			Reserve 3/~~Rear 3~~		
Phase	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B
Checked	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

4.2 Switch in the protection and operate sensitive alarm relay for t > 2 s.
Check that switch out relay operates and ' Protection Defective Alarm ' & ' Protection Out of Commissioning Alarm ' come out with no operation of BBZ trip relay.

Protection Zone	Main 1/~~Fornt 1~~			Reserve 1/~~Rear 1~~			Main 2/~~Fornt 2~~			Reserve 2/~~Rear 2~~			Main 3/~~Fornt 3~~			Reserve 3/~~Rear 3~~		
Phase	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B
Checked	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Provide > 8V injection at CT terminal block to activate **Sensitive Alarm relay** (MVTP 6V, 3 sec), **Protection Switch OUT relay** (MVAJ53, latched) and **defective alarm timer** (MVTT, 1 sec)

11kV HZBBZ Protection Maintenance

4. **Scheme Functional Check** (Cont'd)

Inject a voltage above setting ~80V to operate the BBZ relay, BBZ fault relay and Trip relay at corresponding panel.

4.4 Operate main relay for t < 0.4 s. Check tripping of corresponding protection zone by monitoring the operation of BBZ trip relay.

BBZ Trip Relay Operation Check

Trip Relay Circuit Name		Circuit Position	Main 1/Front 1			Reserve 1/Rear 1			Main 2/Front 2			Reserve 2/Rear 2		
			R	Y	B	R	Y	B	R	Y	B	R	Y	B
Cap Bank No.1	P1					✓	✓	✓						
	P2		✓	✓	✓									
	P3					✓	✓	✓						
SPARE	P4	-												
	P5					✓	✓	✓						

SPARE panel is not operative as both MBBI and RBBI open (and Aux Contact not yet proven by Stability Test)

In case not operated correctly, check the status of MBBI and RBBI aux contact.

11kV HZBBZ Protection Maintenance (TLR: D12554)

Incorrect Racking Switch Status at KTN011 (2021-06)

Fault Description : During protection maintenance of KTN011-HZBBZ, the scheme functional check of F1 zone. The trip relays of all circuits connected to F1 zone are operated, but those relays of all circuits connected to R1 are operated too.
Cause : It was found that F1 buswire-P9F1 and R1 buswire-P9R1 are connected wrongly. Further investigation revealed that panel 9 CB racked in R1 circuit position, but these racking switch contacts are closed for F1 and R1.
Action Taken : Working with Region staff, panel 9 was switched out to rectify the racking switch problem. Both racking switches were re-conditioned and function satisfactorily. HZBBZ scheme functional check and HZBBZ on-load test of panel 9 were performed with satisfactorily results attained.

11kV HZBBZ Protection Maintenance

5. Restoration

5.1 ☑ Restore C.T. circuit.

5.2 ☑ BBZ stability test.

Spill Current Measurement

Protection IN / OUT Switch	Phase	Zone of Protection					
		Main 1/~~Front 1~~	Reserve 1/~~Rear~~ 1	Main 2/~~Front 2~~	Reserve 2/~~Rear 2~~	Main 3/~~Front 3~~	Reserve 3/~~Rear 3~~
OUT	R	0.124	0.095	0.098	0.121	0.123	0.065
	Y	0.081	0.090	0.104	0.080	0.122	0.087
	B	0.132	0.104	0.094	0.076	0.145	0.079
	N	1.264	0.176	0.224	0.197	0.180	0.103
IN	R	0.117	0.092	0.083	0.110	0.121	0.065
	Y	0.081	0.081	0.090	0.079	0.114	0.087
	B	0.108	0.097	0.084	0.070	0.140	0.097
	N	1.212	0.187	0.161	0.187	0.105	0.100

5.3 ☑ Ensure all relay contacts have been fully reset and no flag indication.

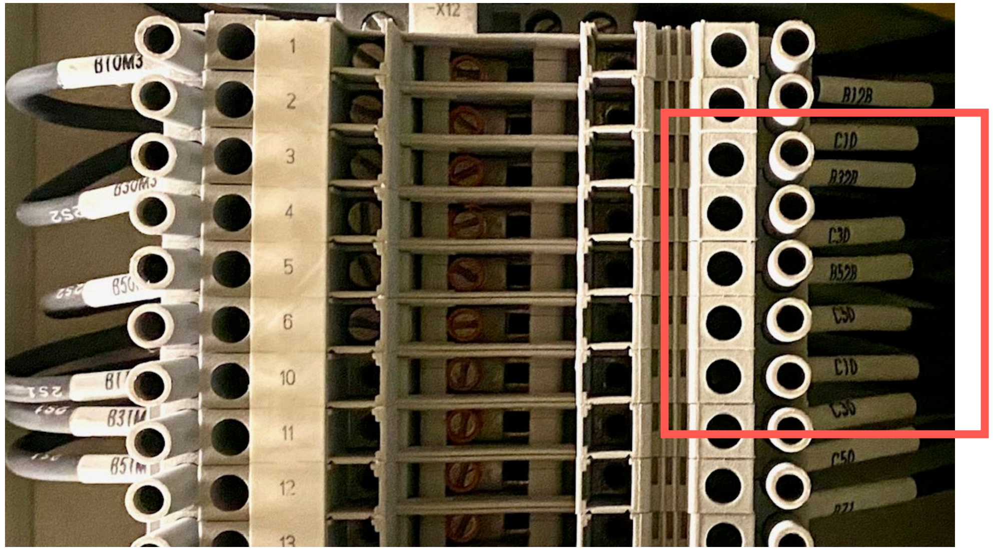
5.4 ☑ Switch the BBP IN / OUT selector switch to ' IN ' position.

5.5 ☑ Replace all BBP trip and intertrip isolation links for all circuits.

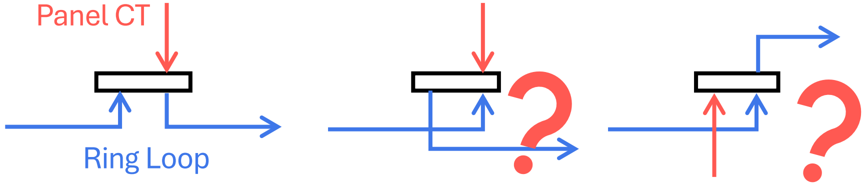
Measure DC voltage at upper jaw of trip link.

CT Low Insulation Discovered during 11kV HZBBZ Mtc

- It was often found 11kV HZBBZ CT circuit (number of CT parallel connected through B71 + Auxiliary Contact + Ring Loop + Multicore to Protection panel) during protection maintenance due to damaged wires at internal wires of switchboard.
- Solved: LNK011 HZBBZ on 2020-11-26 by active injection location (with small enough fault resistance)
- Remain Unsolved: TMU011 HZBBZ, LON011 HZBBZ
- It is hard to locate the fault point as the primary circuit is on load, and the internal wires in 11kV switchboard is quite messy.



Group C CT wires at Group B CT Terminal Block?

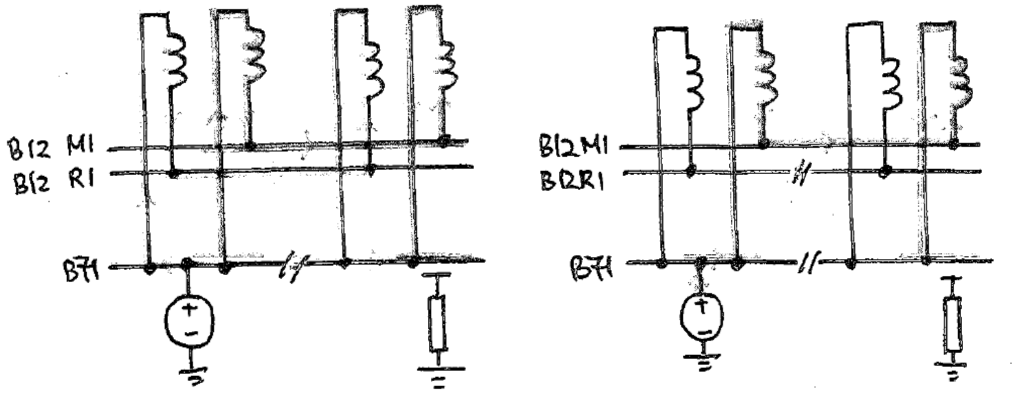


Uncertain connection with Non-indicative Ferrule

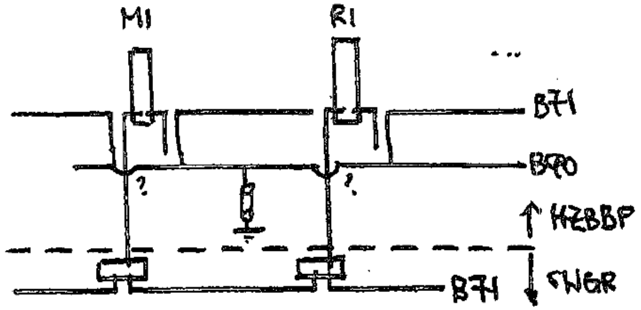
CT Low Insulation Discovered during 11kV HZBBZ Mtc

Problem

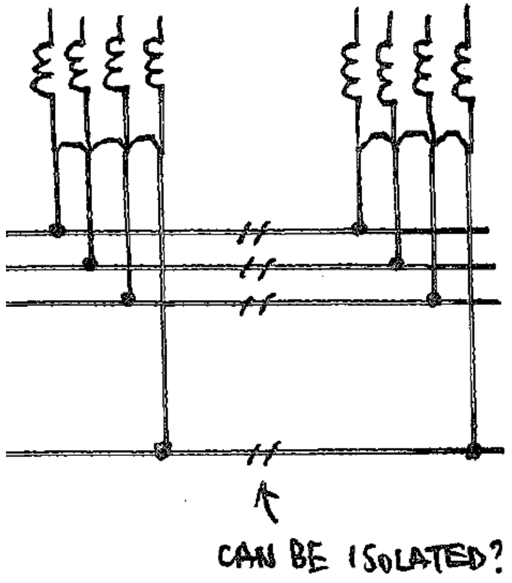
1. All CTs are connected through B71 bus at switchgear side and protection side. Breaking any two buses does not help isolating the CTs in section.



2. It was discovered that the B71 was shorted inside the switchgear panel for main bus loop and reserve bus loop, creating difficulties on isolation.



3. Even the CT bus wire was shorted at both side (output missing, input flowing into HZBBZ panel), the bus still have current (circulating current principle). It is danger to break the current without isolation links at terminal block.

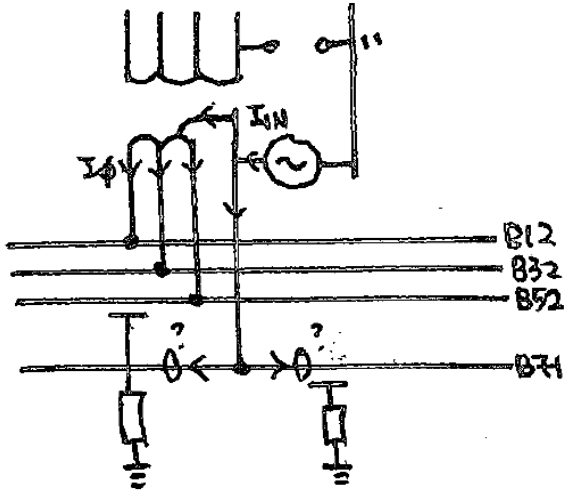


CT Low Insulation Discovered during 11kV HZBBZ Mtc

Solution (May not be Feasible)

1. **Active Injection**
   Inject a voltage (B71 – B90 with earth link removed)
   Measure the current flow and distribution.

   Problem –
   - Low enough resistance to have high enough current
   - B71 is easier to trace (each panel 0.33mA loss)
   - B12M1 – B52M1 are harder with large current flow from BC / BS and Tx to feeder panels.



$I_N = 100mA$

$I_R = 35mA$

$I_W = 34mA$

$I_B = 30mA$

2. **Bisection Method with Insulation Test**
   Separate the bus into several parts to identify which section has the lowest megger value.

   Problem –
   - Require shorting all Group B CTs. → Time Constraint
   - Breaking ring loop with current is hard at high load with unidentifiable connection (to be identified only with large enough load or injection)