GENERATOR DIFFERENTIAL PROTECTION RELAY STABILITY VIS-A VIS SELECTION OF CTS

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AT

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GENERATOR DIFFERENTIAL PROTECTION RELAY STABILITY VIS-À-VIS SELECTION OF CTS

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- **GENERATOR DIFFERENTIAL PROTECTION (87G)**
  - **SIMPLEST BALANCE CURRENT DIFFERENTIAL PROTECTION :**

    UNTIL IT IS MESSED UP BY EXPERTS
  - **SIMPLE SYSTEM :**
    - **GENERALLY, HIGH IMPEDANCE SCHEME.**
    - **INSTANTANEOUS OVER CURRENT RELAY WITH STABILIZING RESISTOR**
    - **CT'S WITH CLASS-PS SPECIFICATIONS.**
    - **SCHEME PROVIDES HIGH SENSITIVITY AND SECURITY.**

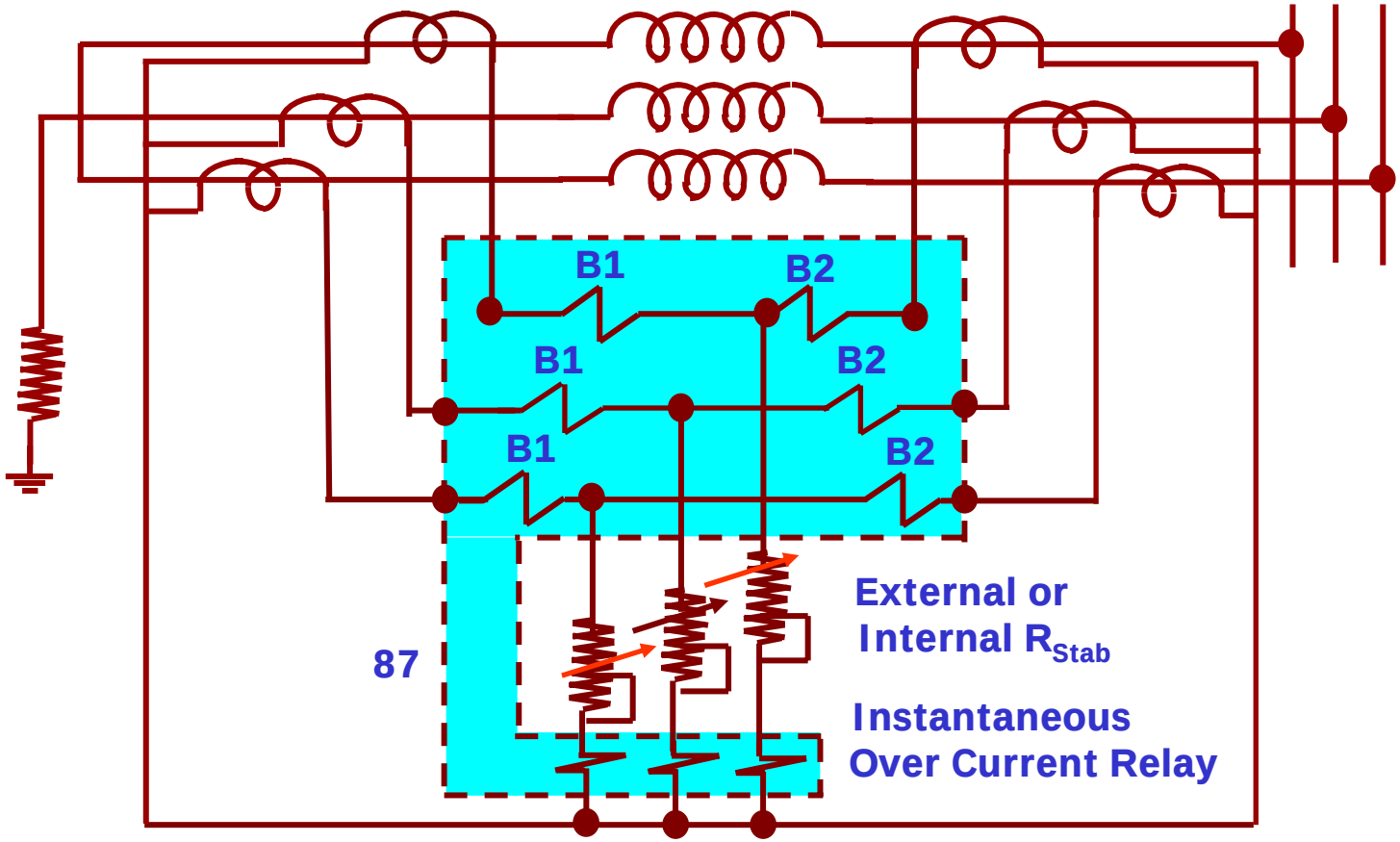

FIG : TYPICAL HIGH IMPEDANCE GENERATOR DIFFERENTIAL PROTECTION SCHEME

- **PRESENT SCENARIO, & CASE STUDY**

  SIMPLE, RELIABLE, SENSITIVE AND SECURED PROTECTION MADE COMPLEX AND UNRELIABLE, BY USING :

  - GENERAL PROTECTION CLASS CT'S
  - LOW IMPEDANCE TYPE BIASED DIFFERENTIAL PROTECTION SCHEME.
  - TRANSFORMER DIFFERENTIAL PROTECTION RELAY IN PLACE OF GENERATOR DIFFERENTIAL PROTECTION RELAY.
  - RESULT : SCHEME LESS SECURED AND LESS SENSITIVE.

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THEN WHY DO WE USE

- LOW IMPEDANCE PROTECTION SCHEME
- GENERAL PROTECTION CLASS CTS.

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- **CASE STUDY : CHEMICAL PLANT**

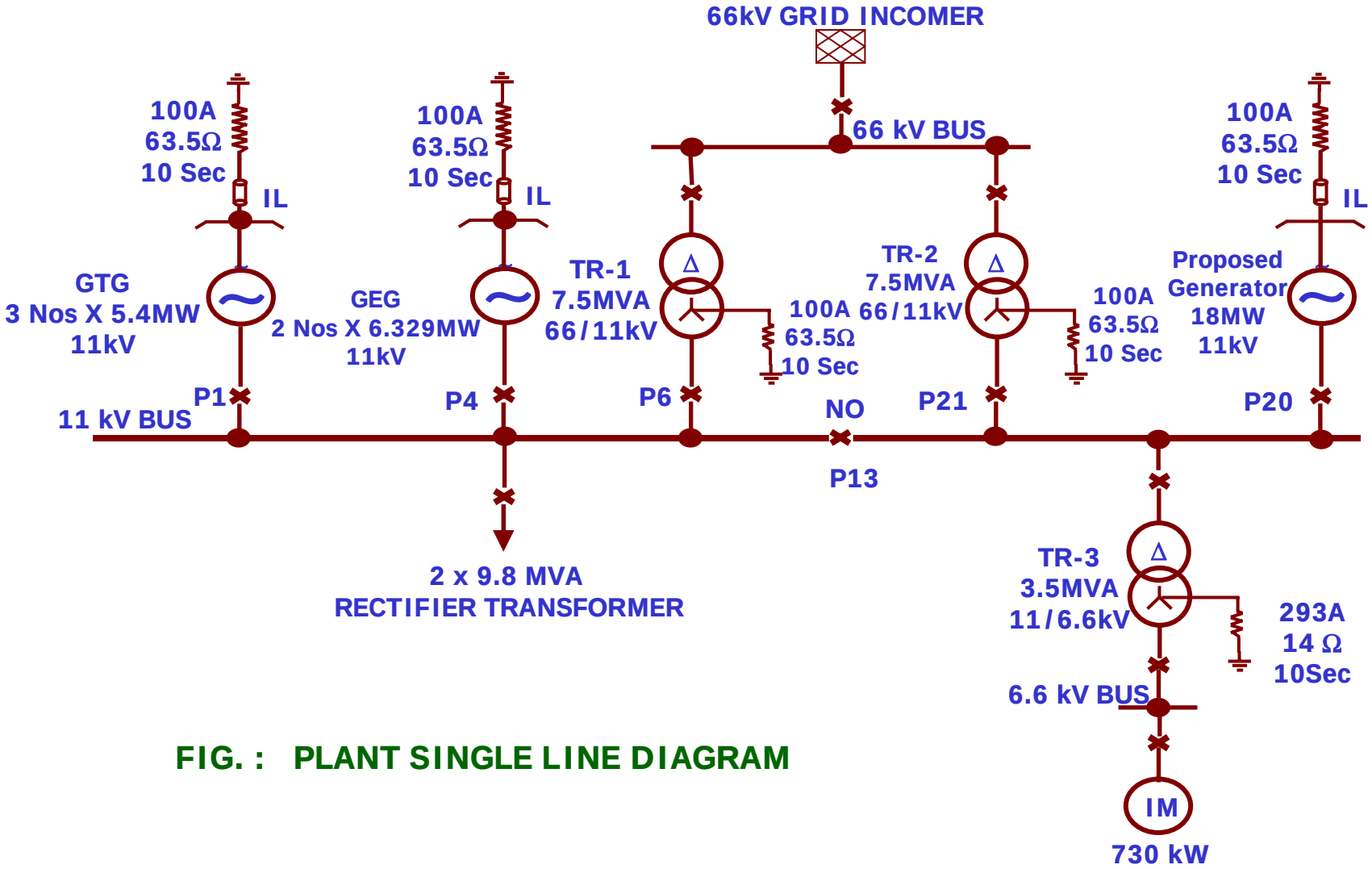

FIG. : PLANT SINGLE LINE DIAGRAM

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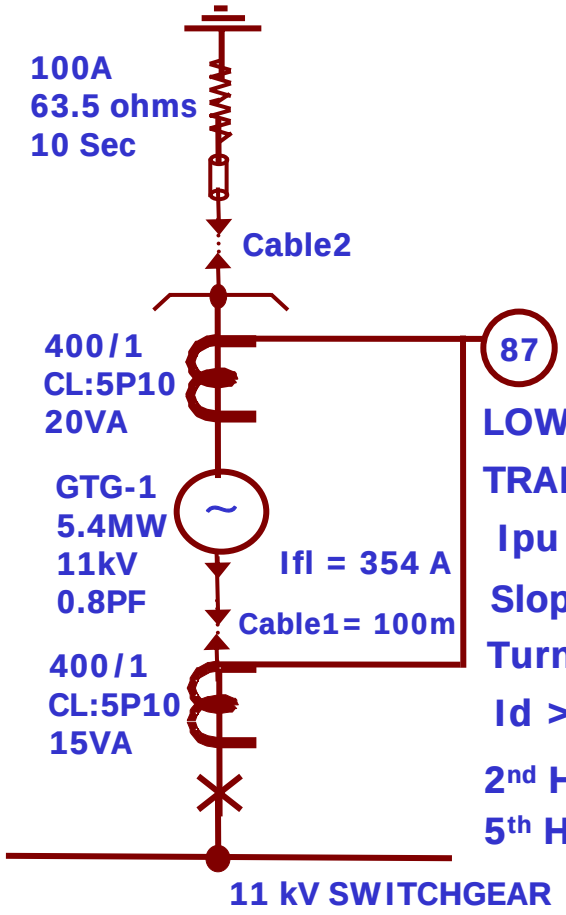
Vendor : A
Design : Vk = 200 V app
Tested Values
Vk = 275 V; Iex = 10 mA
Iex at Vk/2 = 4.5 mA
at Vk/4 = 2.5 mA

Vendor : B
Design : Vk = 150 V App
Tested Values
Vk = 181.5 V; Iex = 75 mA
Iex at Vk/2 = 14 mA
at Vk/4 = 5.5 mA



LOW IMPEDANCE TYPE
TRANSFORMER DIFFERENTIAL PROTECTION

Ipu = Id>= 0.15 To 2.0 In
Slope1 = 0 – 50 %, Slope2 = 0 – 100 %
Turn Point1 = 0 – 20 In (Break Point)
Id >> = 0.5 – 20 In

2nd Harmonic Blocking = 10 to 80 % Id
5th Harmonic Blocking = 10 to 80 % Id

FIG. : GENERATOR DIFFERENTIAL PROTECTION SCHEME

CT SPECIFICATION & SETTING RANGE

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- **DEFICIENCY IN ENGINEERED SCHEME**
  - **DIFFERENT VENDOR HAVE SUPPLIED CTS FOR TWO ENDS OF DIFFERENTIAL PROTECTION.**
    - **BOTH CT'S HAVE GOT DIFFERENT CHARACTERISTIC.**
  - **CT SPECIFICATION ARE INADEQUATE**
  - **RELAY CONNECTED IS LOW IMPEDANCE TYPE, TRANSFORMER DIFFERENTIAL PROTECTION**

INSTEAD OF

GENERATOR DIFFERENTIAL PROTECTION.

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- **DIFFERENTIAL PROTECTION SCHEME OPERATION :**
  - **SCHEME IS STABLE FOR STEADY STATE CONDITION AND GENERATORS EVACUATE 100% POWER.**
  - **SCHEME MAL – OPERATES DURING**
    - **SUDDEN LOAD THROW IN**
    - **SUDDEN LOAD THROW OFF**
    - **SWITCHING IN OF A LARGE MOTOR**
  - **MAL – OPERATIONS ARE IN CONSISTENT.**

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- **SCHEME TESTING :**
  - **SIMULATED SCHEME TESTING WAS CARRIED OUT FOR,**
    - **EXTERNAL FAULT STABILITY AND**
    - **INTERNAL FAULT SENSITIVITY**
  - **TEST RESULTS WERE FOUND SATISFACTORY.**

- **GENERATOR DIFFERENTIAL PROTECTION RELAY CHARACTERISTICS & SETTING RANGE :**
  - **RELAY INSTALLED AND COMMISSIONED**
    - **MULTIFUNCTION DIGITAL PERCENTAGE BIASED DIFFERENTIAL PROTECTION RELAY FOR *TRANSFORMER OR GENERATOR TRANSFORMER UNIT* ? ? ?**

WRONG APPLICATION FOR GENERATOR DIFFERENTIAL PROTECTION.

? ? ?

- **SETTINGS FOR USER SELECTION :**
  - **ABSOLUTE VALUE DIFFERENTIAL UNIT $I_{b.}$**
  - **PERCENTAGE BIASED DIFFERENTIAL UNIT WITH TWO SLOPES P1 AND P2.**
  - **OVERCURRENT PROTECTION UNIT $I_d >>$.**
  - **TIME DELAY OF 20 m SEC TO 99.99 SEC PROVIDED FOR ALL THRESHOLD VALUES ???**
    - **RELAY MANUAL INDICATES THAT THIS TIME DELAY IS PROVIDED TO AVOID TRIPPING COMMAND TO SWITCHGEAR IF CT SATURATES ???**

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DELAYING TRIP COMMAND

TO PREVENT MALOPERATION

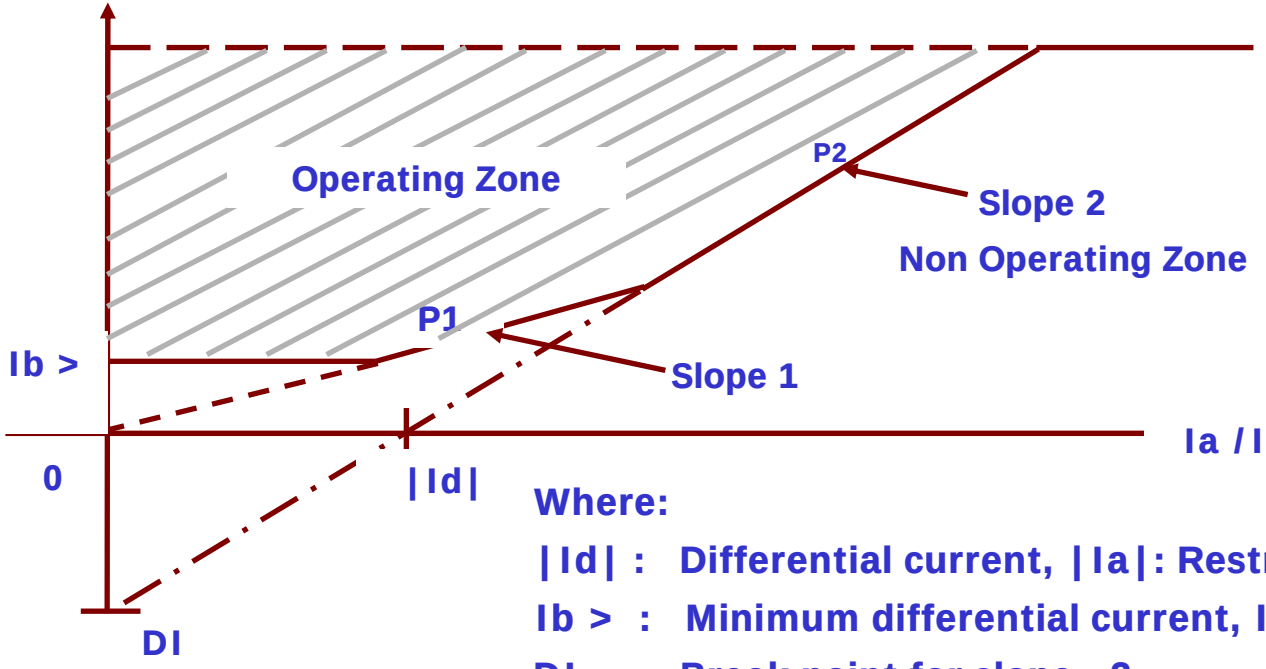
DUE TO

CT SATURATION

IS IT CORRECT CONCEPT

? ? ?

- **DIFFERENTIAL PROTECTION RELAY TRIPPING CHARACTERISTICS**



Where:

|Id| : Differential current, |Ia|: Restraining current

Ib > : Minimum differential current, In : Relay rated current

DI : Break point for slope : 2

(Intersection of P2 straight line with Id/In axis)

Relay Operates : when,

Threshold : $|Id| \geq Id>>$

Threshold Id > - Any of the following equations,

$|Id| \geq Ib$, $|Id| \geq (P1 . |Ia|)$, $|Id| \geq (P2 . |Ia| - DI)$

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- **MAL-OPERATION OF SCHEME EXPERIENCED DURING**
  - **SWITCHING IN OR OFF**

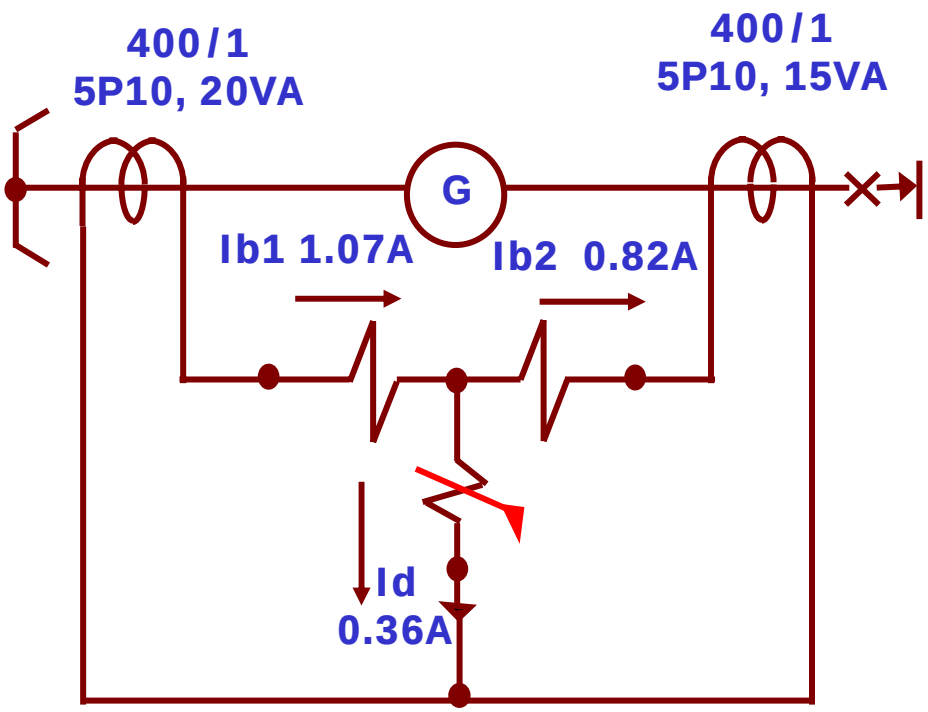
    9.8 MVA RECTIFIER TRANSFORMER.
  - **SWITCHING IN OF**

    730 KW INDUCTION MOTOR.
- **TYPICAL EVENT RECORDING :**
  - **MAL – OPERATION OF THIS DIFFERENTIAL PROTECTION WAS RECORDED FOR A TYPICAL CASE**

CASE : SWITCHING IN OF 9.8 MVA RECTIFIER TRANSFORMER

FIG : GTG-1 87G RELAY MAL-OPERATION

R-PHASE :



RELAY OPERATES.

% Slope (P1) set at 20 %

$|Id| = 0.2\ In$, $|Id| \geq P1 \times |Ia|$

$$|Id| \geq \frac{0.2 \times (1.07 + 0.82)}{2}\ ,\ |Id| \geq 0.2 \times 0.945$$

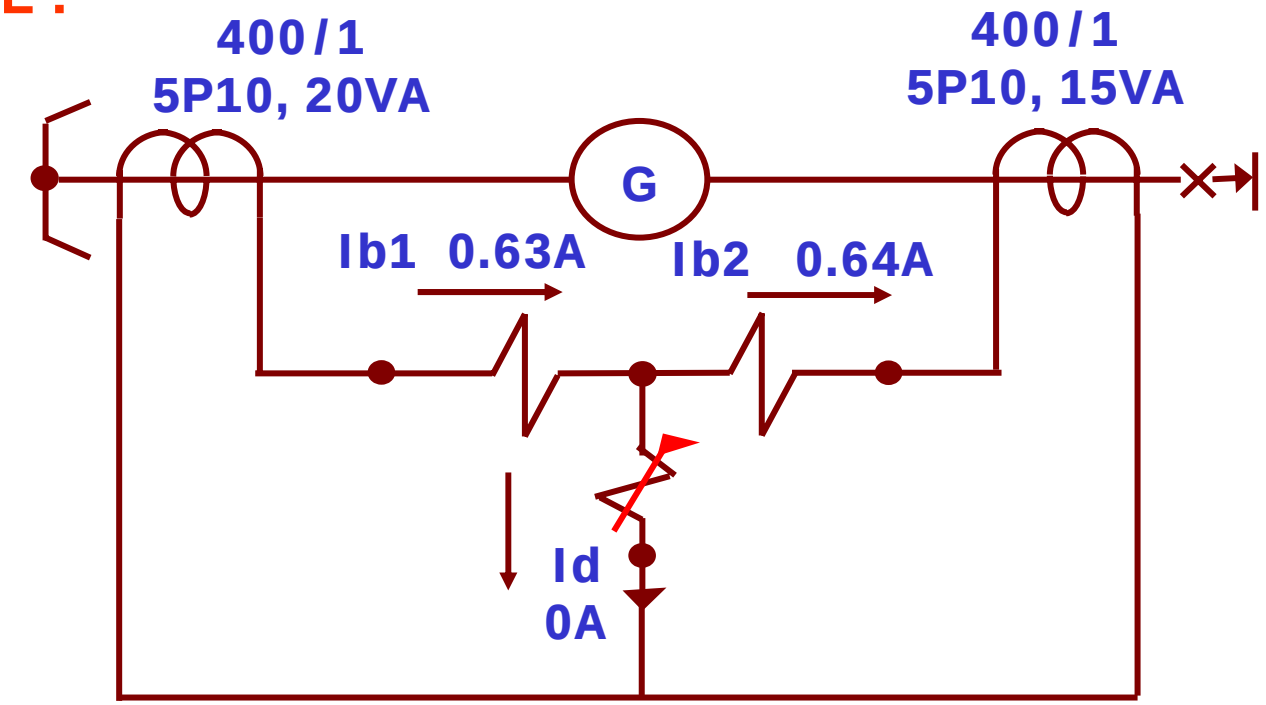
$|Id| \geq 0.189$,

Since, Id actual (0.36) ≥ 0.189

CASE : SWITCHING IN OF 9.8 MVA RECTIFIER TRANSFORMER

FIG : GTG-1 87G RELAY MAL-OPERATION

Y-PHASE :

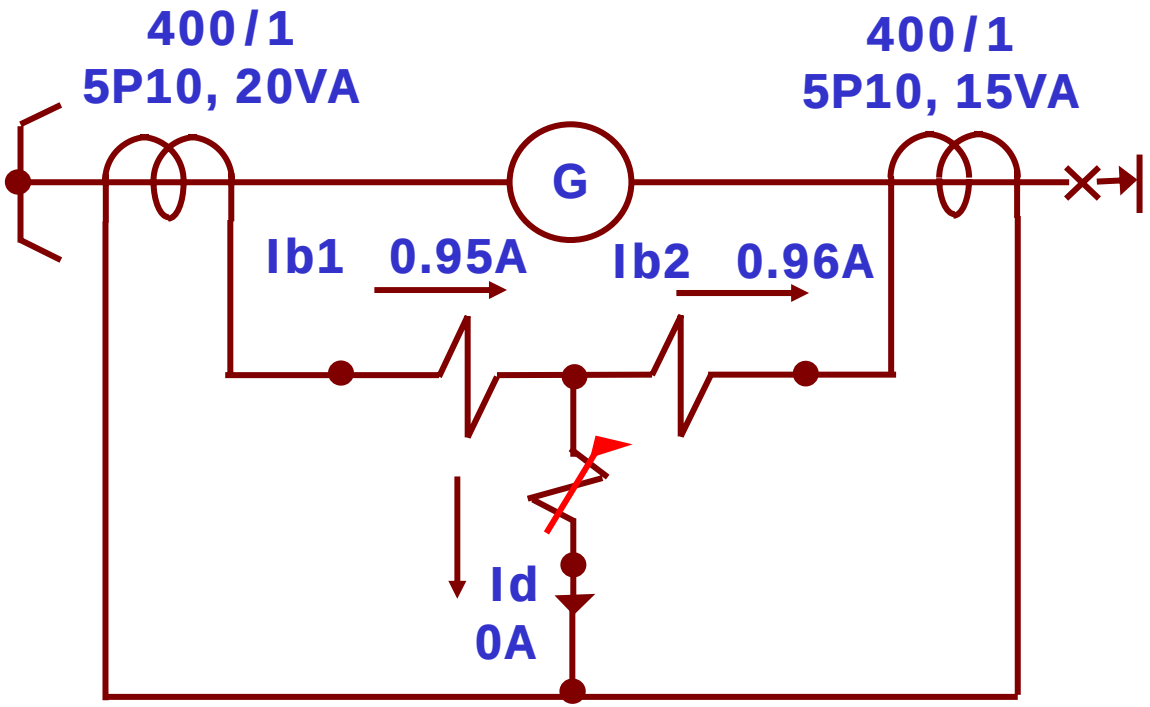


Y PHASE RELAY IS STABLE BECAUSE NO SPILL CURRENT FLOWS.

CASE : SWITCHING IN OF 9.8 MVA RECTIFIER TRANSFORMER

FIG : GTG-1 87G RELAY MAL-OPERATION

B-PHASE :



B PHASE RELAY IS STABLE BECAUSE NO SPILL CURRENT FLOWS.

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- **ANALYSIS**
  - **SEQUENCE OF EVENT RECORDING INDICATES :**
    - **UNDER TRANSIENT CONDITION CURRENT TRANSFORMERS ARE SATURATING.**
    - **RESULTING INTO,**
      - **UNBALANCE CURRENT IN THE DIFFERENTIAL RELAY OPERATING COIL.**
      - **CAUSING RELAY MAL-OPERATION.**
  - **THIS REQUIRES CHECKING DEFICIENCY IN CT RATING SPECIFICATION.**

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- **SPECIFICATION OF CURRENT TRANSFORMER INSTALLED AND COMMISSIONED:**

o **VENDOR A : NEUTRAL END**

DESIGN VALUE	FIELD TEST VALUES
CTR: 400/1	Vk = 275 V, Iex = 10 mA
CL: 5P10, 20VA	Iex at Vk/2 = 4.5 mA
Design Vk = 200V App.	Iex at Vk/4 = 2.5 mA

o **VENDOR B : PHASE END**

DESIGN VALUE	FIELD TEST VALUES
CTR: 400/1	Vk = 181.5 V, Iex = 75 mA
CL: 5P10, 15VA	Iex at Vk/2 = 14 mA
Design Vk = 150V App.	Iex at Vk/4 = 5.5 mA

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- **REVIEW OF SPECIFICATION OF CTS & FIELD TEST RESULTS**
  - **DESIGNED CT SECONDARY VOLTAGES ARE WIDELY DIFFERENT**

    200 & 150 V FOR EITHER END CTS.
  - **TESTED VALUE OF KNEE POINT VOLTAGE FOR EITHER END CT'S HAVE HIGH DIFFERENCE.**

    275 V AND 181 V FOR EITHER END CTS.
  - **EXCITATION CURRENT ALSO HAS LARGE DIFFERENCE**

    AT VK/2 – 4.5 mA & 14 mA

    AT VK/4 – 2.5 mA & 5.5 mA

- **LARGE DIFFERENCE IN SATURATION**
  - **VOLTAGE (KPV)**
  - **EXCITATION CURRENT I_{EX} , AT THE SATURATION VOLTAGE IS THE REASON FOR,**
    - **DIFFERENTIAL CURRENT THROUGH OPERATING COIL, THUS MAL-OPERATION OF RELAY.**

- **DESIRED CT SPECIFICATION :**

SPECIFIC REQUIREMENT OF CURRENT TRANSFORMER SECONDARY VOLTAGE

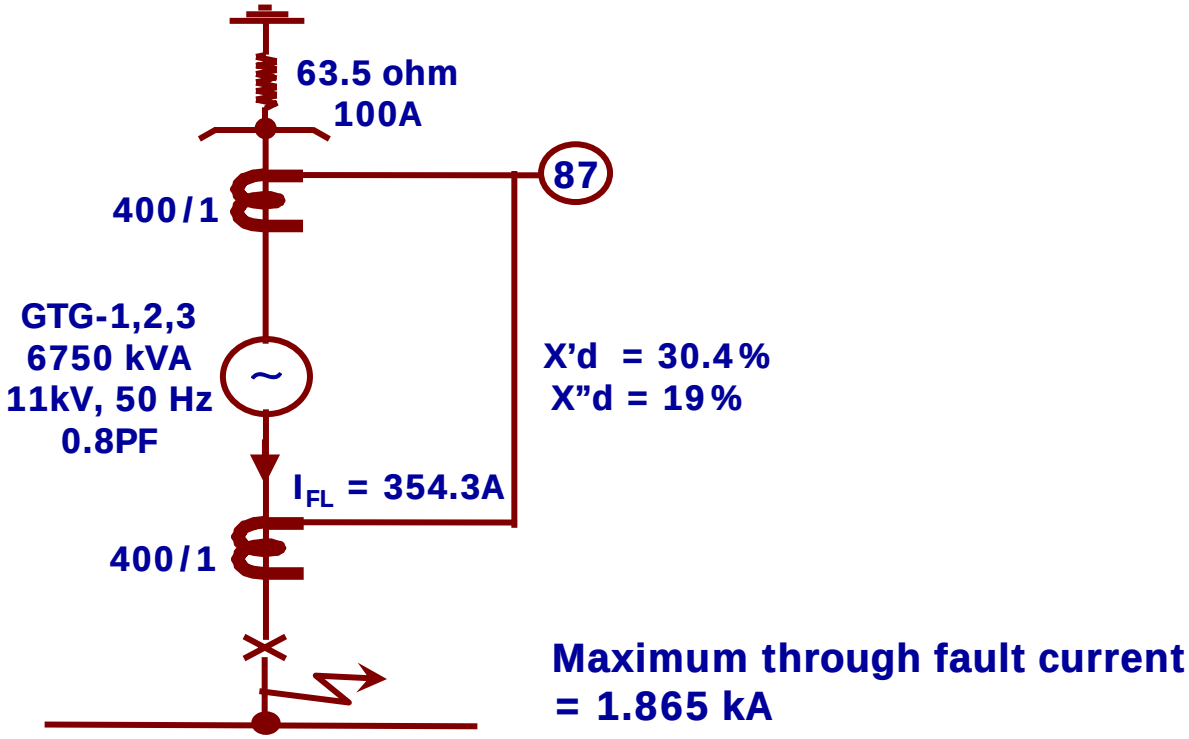

FIG : ACTUAL REQUIREMENT OF C.T. SPECIFICATION

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- **CT SPECIFICATIONS FOR 87 RELAY**

$$\text{FAULT MVA} = \frac{100 \times 6.75}{19}$$

$$= 35.52 \text{ MVA}$$

FAULT CURRENT = 1865 AMPS

@ 11 kV BASE

- **CRITERIA I :**

  CONSIDERING EXTERNAL THROUGH FAULT CURRENT

R_{LEAD} = 0.8 Ω FOR 100 MTRS. (8Ω/KM)

$$VK \geq \frac{2\ IF\ (R_{CT} + 2R_L + R_R)}{CTR}$$

$$\geq \frac{2 \times 1865\ (R_{CT} + 2 \times 0.8 + 0)}{400}$$

$$\geq (9.325\ R_{CT} + 15\ V)$$

OR

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- **CRITERIA II :**

CHARGING CURRENT OF RECTIFIER TRANSFORMER

$$\text{FULL LOAD CURRENT} = \frac{9800\ \text{KVA}}{\sqrt{3} \times 11 \times 10^3} = 514.4\ \text{A}$$

CHARGING CURRENT, SAY MAX 12 X FULL LOAD = 6180 A

$$V_k \geq \frac{2 \times 6180 (R_{CT} + 2 \times 0.8 + 0)}{400}$$

$$\geq 30.9\, R_{CT} + 49.44$$

Select

$$V_k \geq (31\, R_{CT} + 50)\text{V},$$

$$I_{ex} @ V_K / 4 = \frac{0.15 \text{ Min Pickup} \times 0.8}{2}$$

$$= 60 \text{ m Amp} \geq 60 \text{ m Amp.}$$

- **RECOMMENDED SPECIFICATION :**

  $VK \geq (31\ R_{CT} + 50)V$,

  I_{EX} @ V_K / 4 = 60 m AMP.

  - **ESTABLISHED THAT DUE TO INADEQUACY OF CURRENT TRANSFORMER RATING SPECIFICATION THE CTS WERE SATURATING.**
  - **RESULTING INTO MAL-OPERATION OF THE SCHEME.**

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- **DEFICIENCY IN RELAY SELECTION AND RELAY PROGRAMMING :**
  - **PERCENTAGE BIASED TRANSFORMER DIFFERENTIAL (MIN BIAS 20%) PROTECTION RELAY IS UTILIZED.**
  - **CHARACTERISTICS IS LOW IMPEDANCE TYPE.**
  - **RELAY IS LESS SECURED, RELAY OPERATES FOR SPILL CURRENT FLOWING THROUGH OPERATING COIL UNDER TRANSIENT CONDITION DUE TO CT SATURATION.**
  - **RELAY IS LESS SENSITIVE.**

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- **CONCLUSION :**
  - **SCHEME WAS MALOPERATING DUE TO**
    - **GENERAL PROTECTION CLASS CT'S.**
    - **LOW IMPEDANCE SCHEME PROTECTION RELAY NOT PREFERRED FOR GENERATOR DIFFERENTIAL PROTECTION TO ENSURE,**
      - **HIGHER SENSITIVITY &**
      - **HIGHER SECURITY AGAINST EXTERNAL FAULT.**

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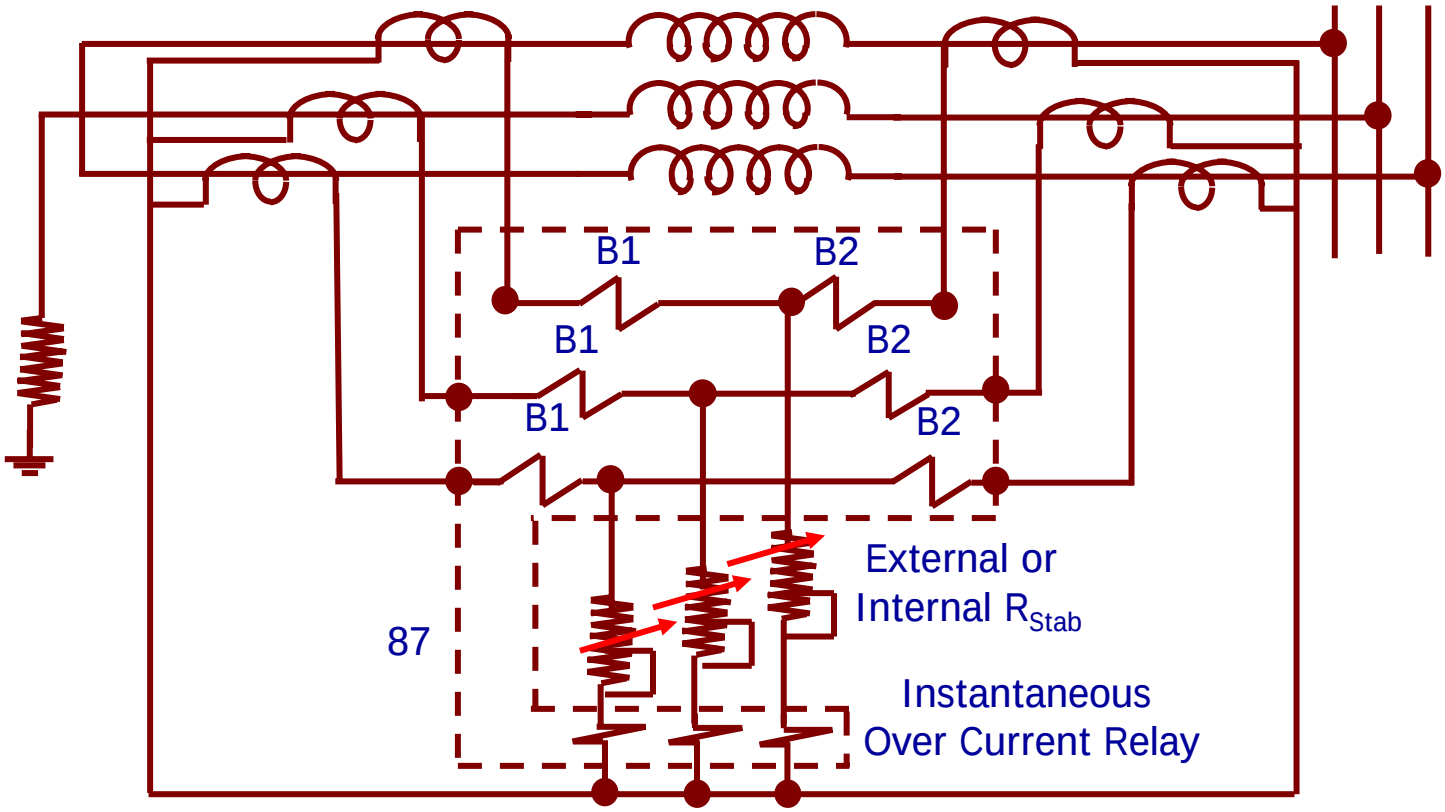
- **RECOMMENDATIONS :**

TO ENSURE STABILITY AND RELIABILITY

- **CTS WITH CLASS PS SPECIFICATIONS FOR GENERATOR DIFFERENTIAL AND/OR FOR ANY DIFFERENTIAL (BALANCE CURENT PROTECTION) TO BE USED.**
- **EVEN IF RELAYS ARE PROVIDED WITH FEATURE TO DETECT CURRENT TRANSFORMER SATURATION AND BLOCK THE RELAY,**

  SELECT CT'S OF CLASS PS SPECIFICATIONS
- **CONSIDER HIGH IMPEDANCE DIFFERENTIAL PROTECTION SCHEME TO ENSURE**
  - **HIGH SENSITIVITY OF PROTECTION**
  - **HIGH SECURITY FOR EXTERNAL FAULT AND TRANSIENT DISTURBANCES**

GOOD OLD SECURED, RELIABLE HIGH IMPEDANCE DIFFERENTIAL PROTECTION SCHEME



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THANK YOU

QUESTIONS ARE WELCOME NOW

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