# Power Protection System

## Overcurrent Relay Coordination

Ir. Saiful Zuhaimi Bin Ahmad
CKE, JKR Melaka

# Objective

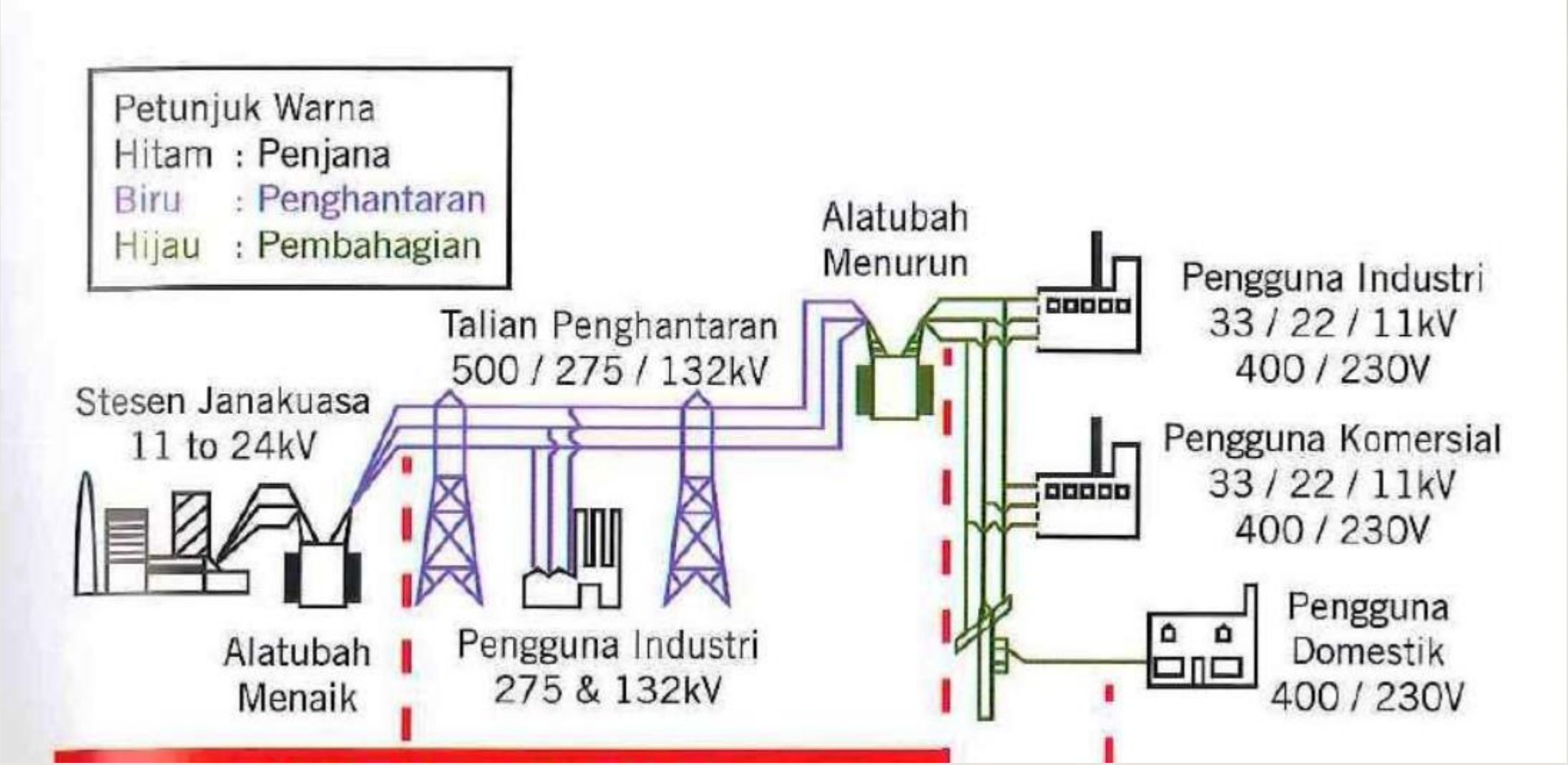
Able to understand & explain :-

- 1. Electrical Power Network & Distribution.
- 2. Requirement from ST
- 3. What is Protection Relay
- 4. How does the Relay Work.
- 5. Why must have Protection Scheme.
- 6. How does OCR Operate.
- 7. Primary & Backup Relay.
- 8. How to carry out OCR Coordination.
- 9. Able to verified result.  (Relay operating time)

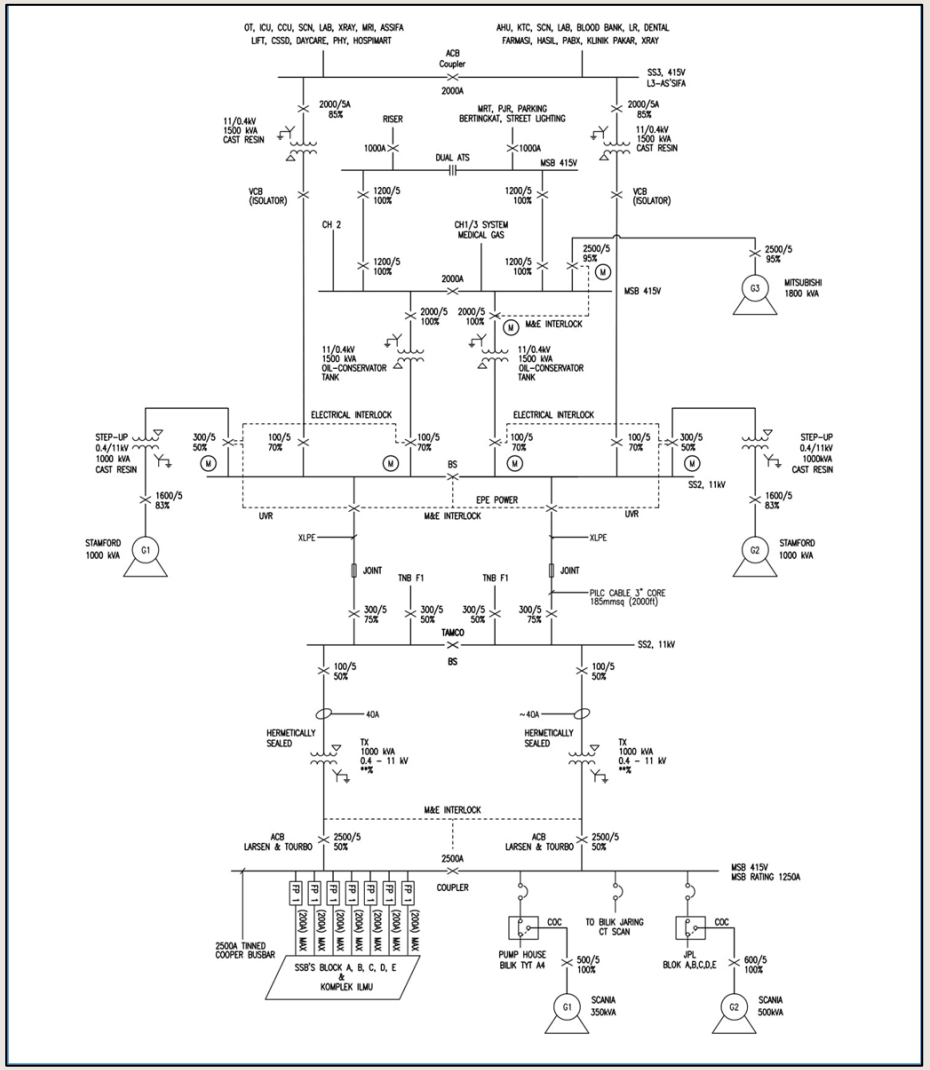
# Content

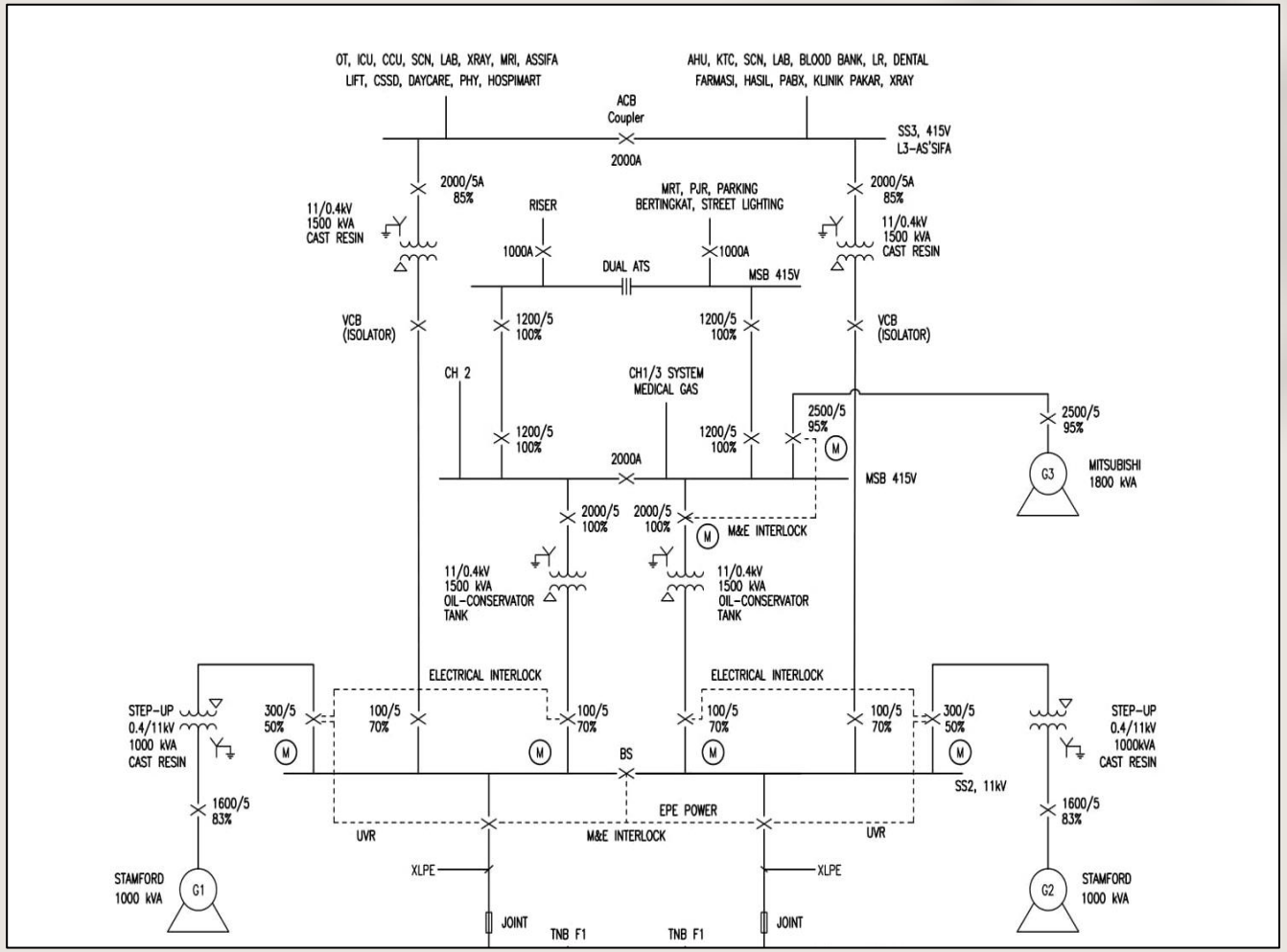
- 1. Electrical Power Network (Quick View).
- 2. Introduction to Protection Relay.
- 3. The 2 major faults in electrical network.
- 4. Power Protection Scheme.
- 5. OCR Basic Operation.
- 6. OCR Coordination.
- 7. Case Study.
- 8. Protection Scheme Test & Result.
- 9. The result verifications.
- 10. Q & A

# Electrical Power Network – Quick View

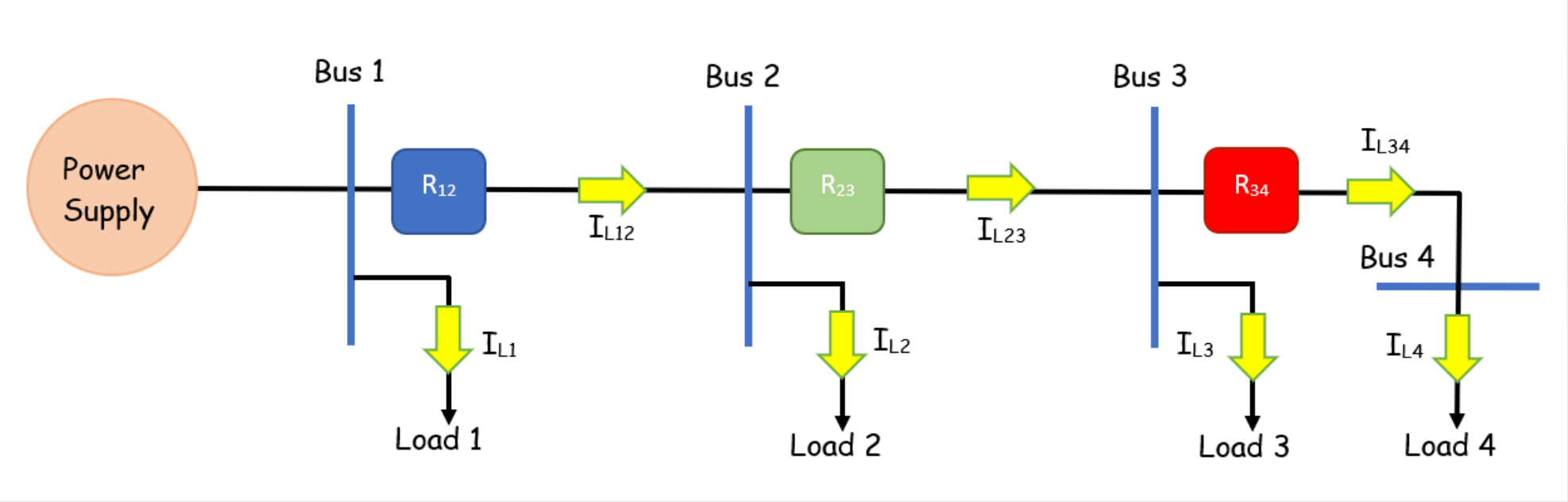


# Electrical Power Network – Distribution



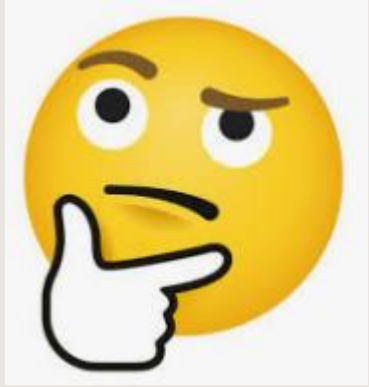



# Electrical Power Network – Equivalent Circuit



# Quiz #1

- From the Equivalent Circuit : Related Law (Electrical)?



# Akta 447 – ABE 1990

- Akta Bekalan Elektrik 1990 (Akta 447)

  - Seksyen 23 (1) : Tiada pepasangan atau loji atau kelengkapan elektrik selain daripada yang dipunyai atau diuruskan olehpihak berkuasa bekalan boleh dikerjakan atau dikendalikan kecuali oleh atau di bawah kawalan orang-orang yang meliliki apa-apa kelayakan dan memegang apa-apa perakuan sebaimana yang ditetapkan dan tiada seorang pun yang tidak memiliki kelayakan atau memegangn perakuan seperti yang disebut terdahulu boleh menjaga apa-apa pepasangan atau boleh mengawal pengendalian apa-apa loji atau kelengkapan elektrik.

  - Seksyen 23 (2) : Mana-mana orang yang melanggar seksyen ini adalah melakukan sesuatu kesalahan dan apabila disabikan boleh dikenakan denda tidak melebihi RM10,000.00 dan jika pelanggaran ini diteruskan dikenakan denda tidak melebihai RM1,000.00 bagi tiap-tiap hari atau sebahagian daripada sehari selama pelanggaran itu diteruskan selepas disabit.

# Orang Kompeten – ST

- Orang Kompeten : Orang yang memegang sesuatu perakuan kekompetenan yang dikeluarkan oleh Suruhanjaya Tenaga (ST) untuk melaksanakan kerja mengikut sekatan-sekatan, jika ada, yang dinyatakan dalam perakuan itu.

# Penyelenggaraan Pepasangan – ST

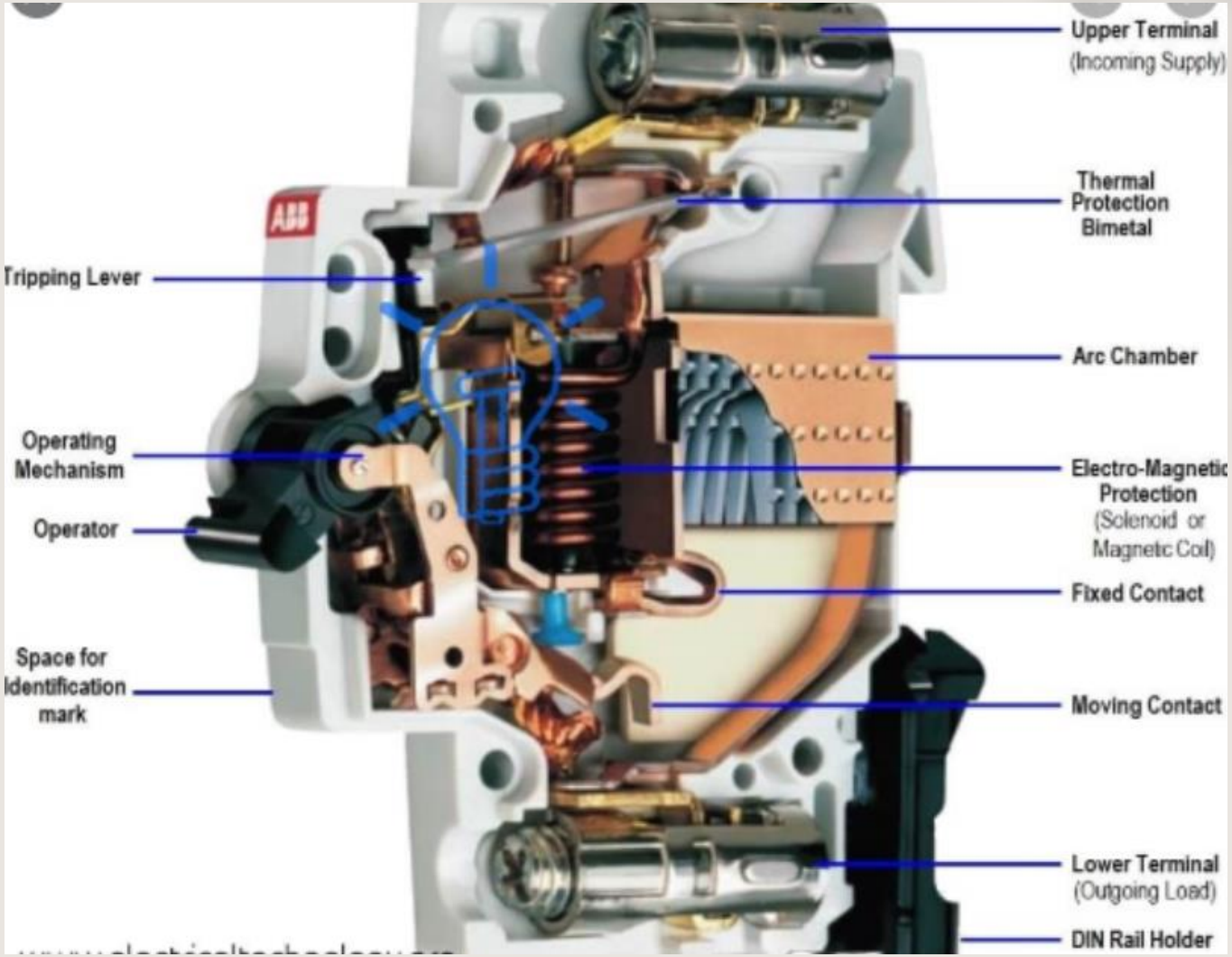
- Peraturan-Peraturan Elektrik 1994
  - PPE 1994 (110) : (1) – (5)
  - 110 (1) : Pepasangan hendaklah diselenggarakan.
  - 110 (2) :Tanggungjawab untuk menyelenggara terletak pada pemunya pengurusan/pemegang lesen/penghuni pepasangan.
  - 110 (3) : Selain pepasangan domestik, pepasangan hendaklah diperiksa diuji dan ditentukur oleh orang kompeten setiap 5 tahun sekali atau bila-bila masa yang diarahkan oleh ST.
  - 110 (4) : Mana-mana geganti dan peranti perlindungan hendaklah diperiksa, diuji dan ditentukur oleh Orang Kompeten sekurang-kurangnya setiap 2 kali setahun atau pada bila-bila masa yand diarahkan oleh ST.
  - 110 (5) : Pemeriksaan oleh ST.

# The 2 Major Electrical Faults – Quiz #2

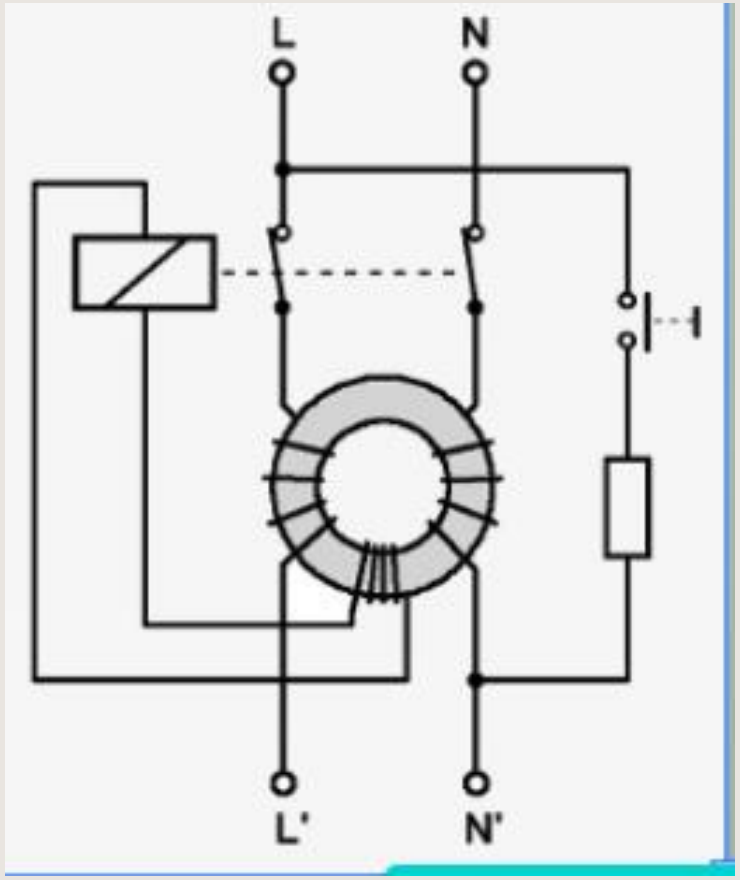
- 1. Short Circuit :
  - i. What Cause SC ?
  - ii. Protective Devices?
  - iii. How does it operate & Protect?

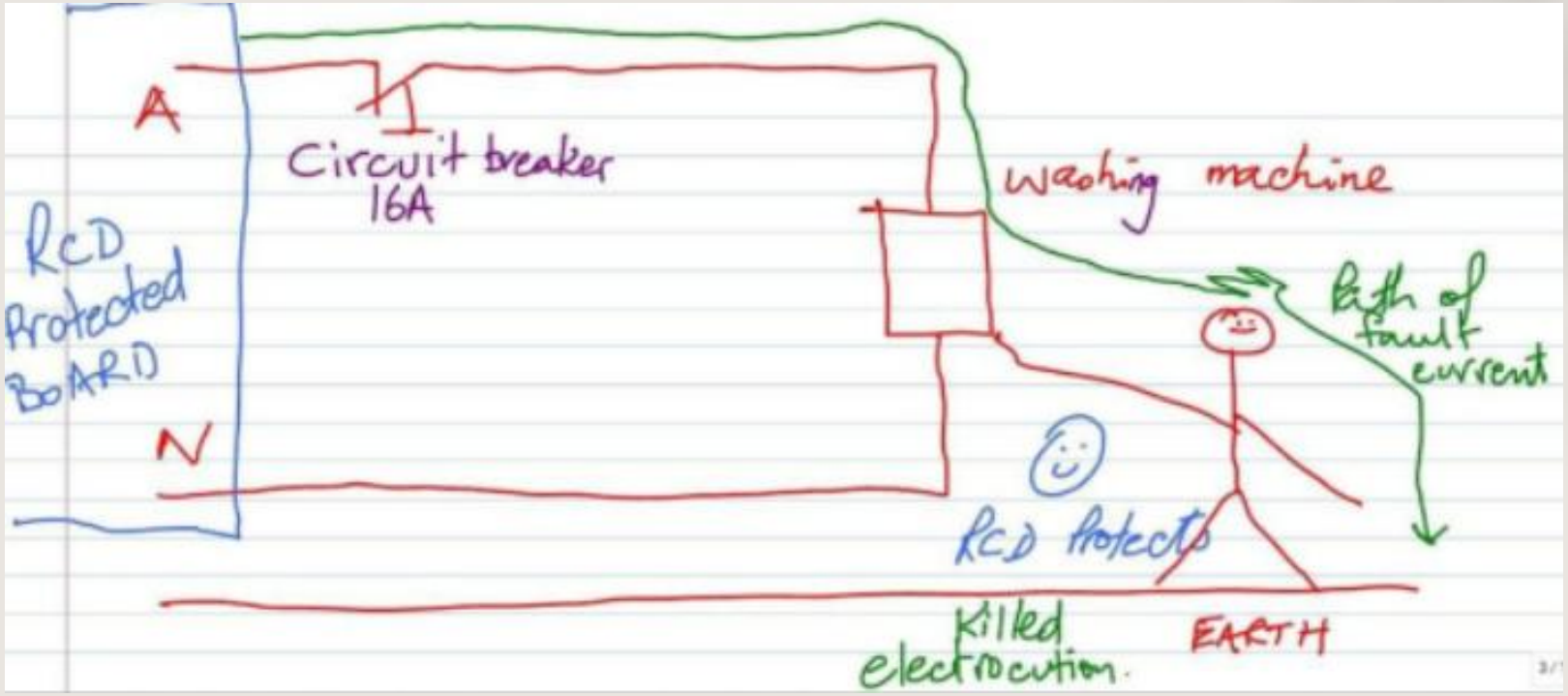
- 2. Earth Fault :
  - i. What Cause EF ?
  - ii. Protective Devices?
  - iii. How does it operate & Protect?

# Basic Protective Device Operation - SC

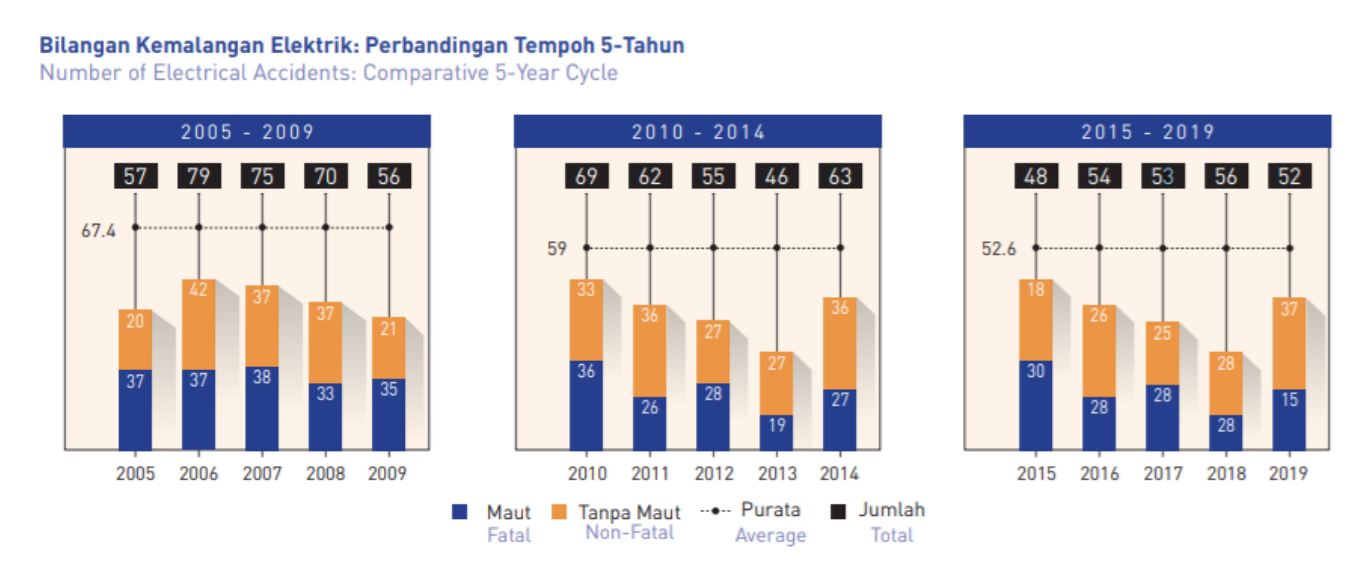



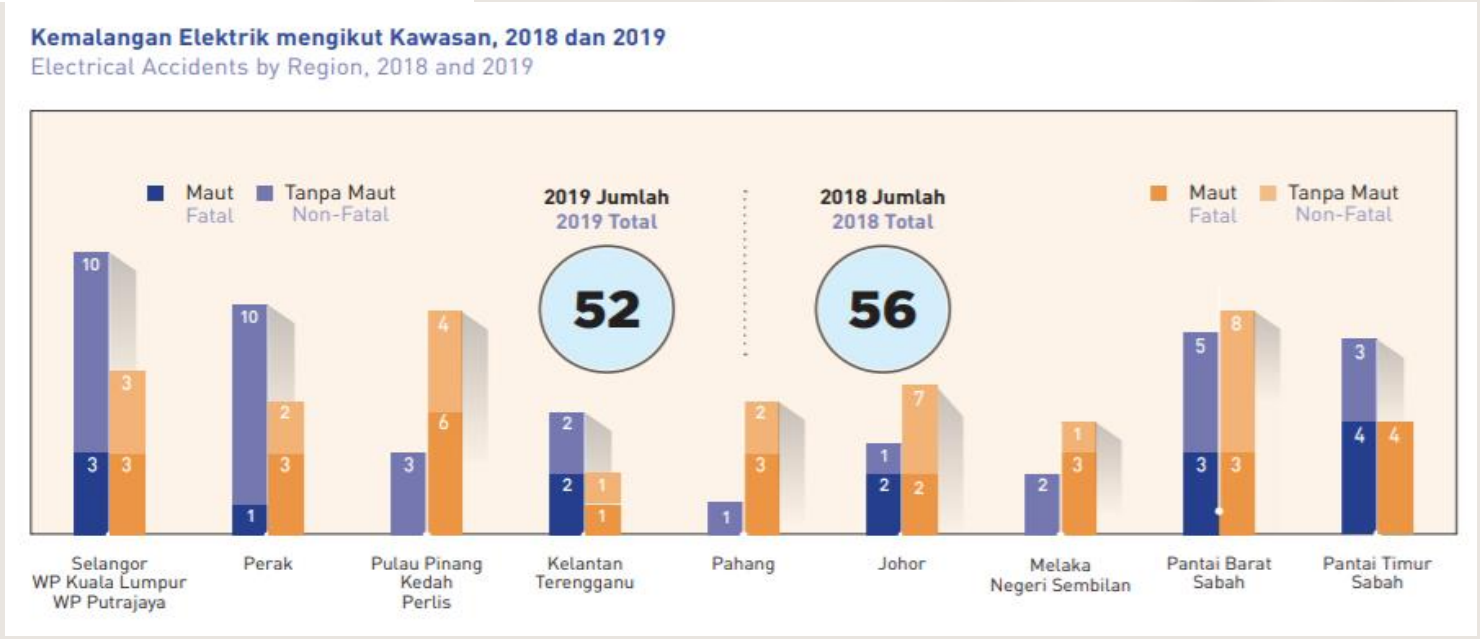
# Protective Device – EF



# Electrical Accident Data - ST



# Power Protection System & Requirement

- **Protection** systems, the most important – to clear faults and limit any damage to transmission/distribution equipment.
- Basic principles of protection arrangements for any power system:
  1. **Reliability**: the ability of the protection to operate correctly.
     i. **Dependability** – the certainty of a **correct operation** on the occurrence of a fault.
     ii. **Security –** the ability to avoid **incorrect operation** during faults.
  2. **Speed**: min. operating time to clear a fault in order to avoid damage to equipment.
  3. **Selectivity**: maintaining continuity of supply by disconnecting the min. section of the network necessary to isolate the fault.
  4. **Cost**: max. protection at the lowest cost possible.

# Protection Zones

- General **philosophy** for the use of relays –
  - Divide the system into separate zones, which can be individually protected and
  - Disconnected on the occurrence of a fault, in order to permit the rest of the system to continue in service wherever possible.

- Power system can be divided into **protection zones**:
  - Generators,
  - Transformers,
  - Groups of generator transformers,
  - Motors,
  - Busbars and
  - Lines.

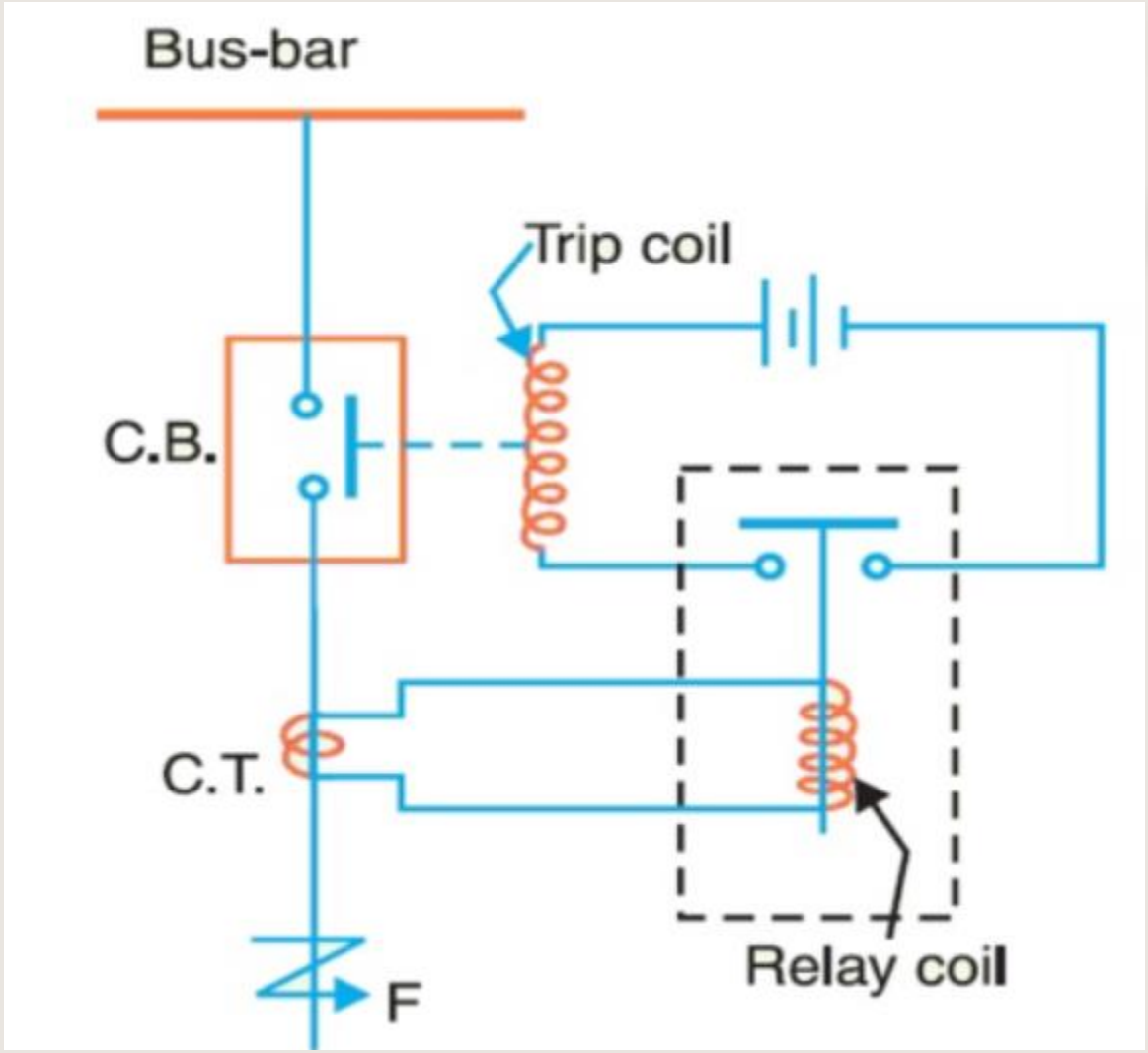
# Overcurrent Relay Coordination System

- **Co-ordinated OCR protection :**
  - Vital to ensure that an electricity transmission/distribution network can operate within preset requirements for safety for individual items of equipment, public, and the network overall.
  - Automatic operation – isolate faults on the networks as quickly as possible in order to minimise damage.

# Primary & Backup Protection Relay

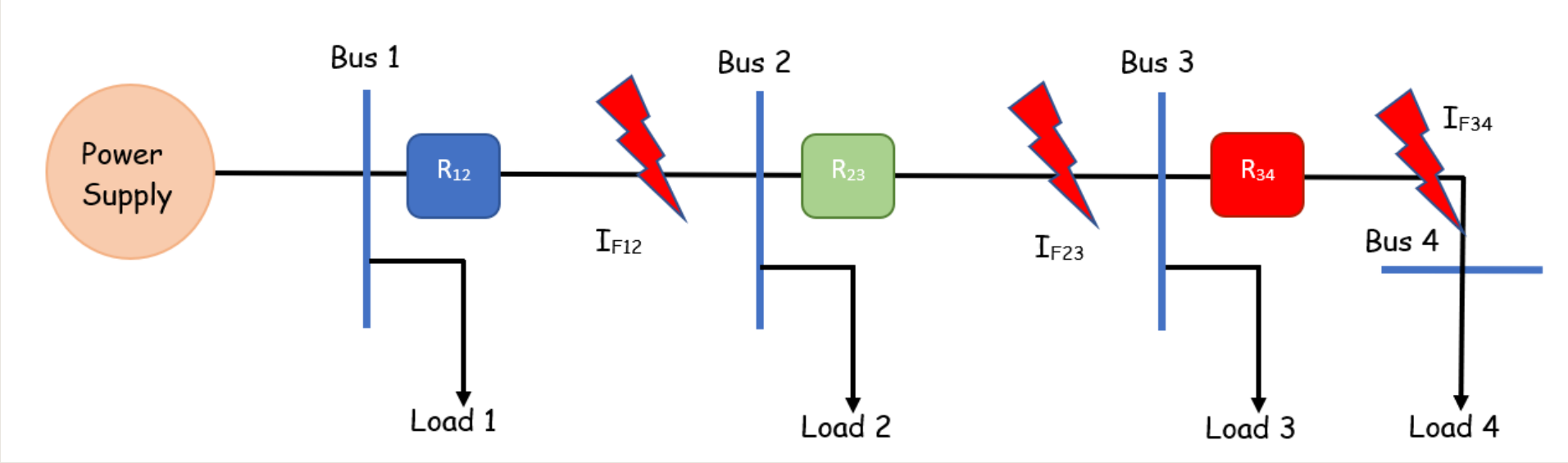
- All the elements of the power system must be correctly protected so that the relays only operate on the occurrence of a fault.
  - **Unit protection**, operate only for faults within their protection zone.
  - **Non-unit protection**, detect faults both within a particular zone and also outside (adjacent) it – back up the primary protection as a second line of defence.
- Any fault is isolated, even if the associated main protection does not operate.
  - Wherever possible, every element in the power system should be protected by both **primary** and **back-up** relays.

# Relay Operation



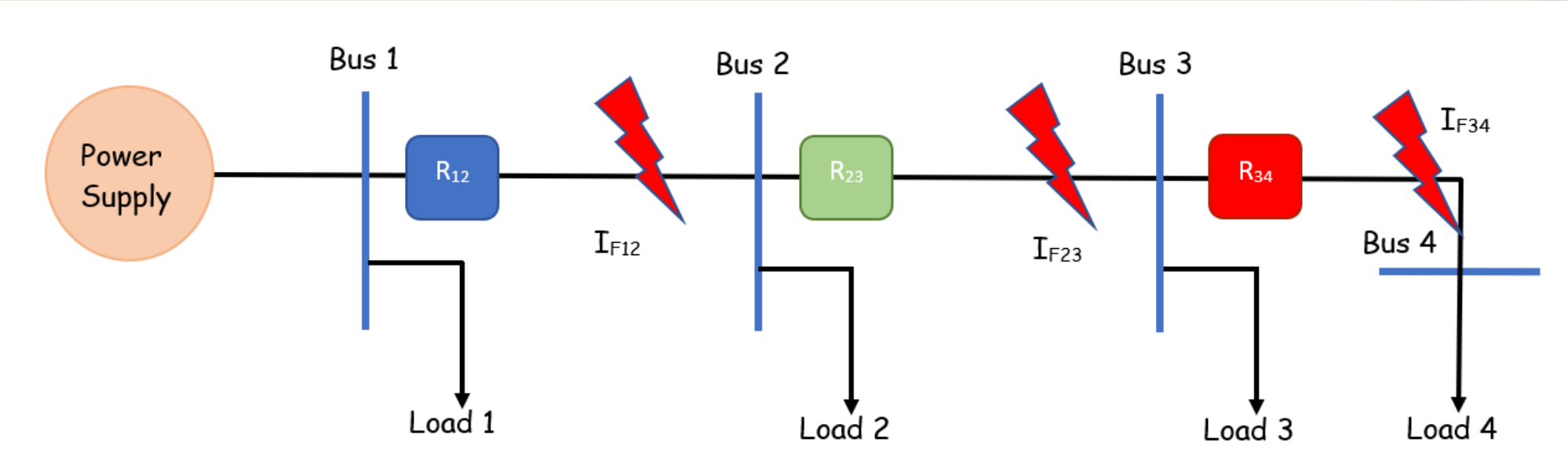
# Power Protection Scheme

- The reliability of a protection system is critical and necessary (D. K. Singh & Gupta, 2012; Dy et al., 2012; Masselot et al., 2016)



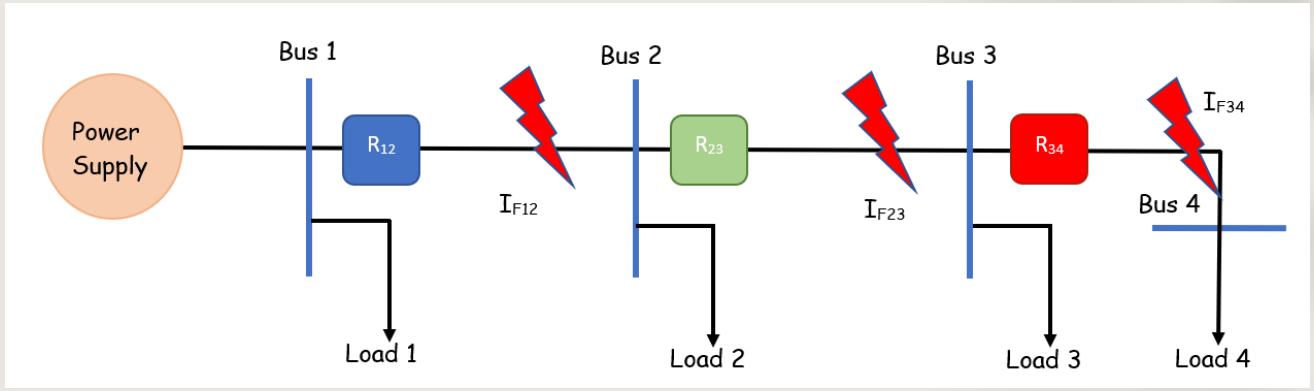
# Primary & Backup Relay

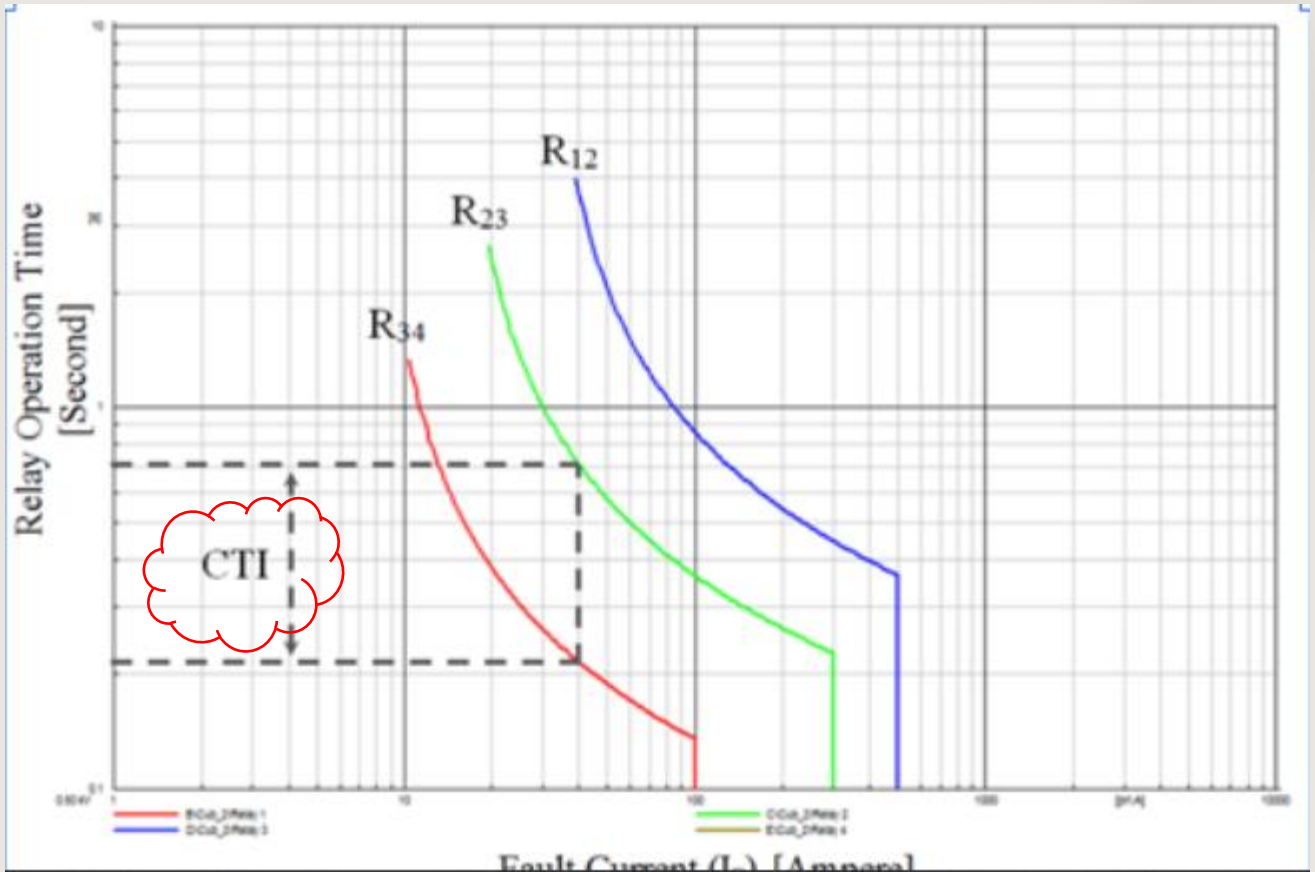
| Fault Location | Fault Current | Relay Pair Selection | |
|---|---|---|---|
| | | Primary Relay | Backup Relay |
| Bus 3-4 | $I_{F34}$ | $R_{34}$ | $R_{23}$ |
| Bus 2-3 | $I_{F23}$ | $R_{23}$ | $R_{12}$ |
| Bus 1-2 | $I_{F12}$ | $R_{12}$ | - |



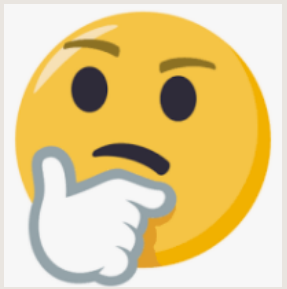

For each fault location, in the event that any of these devices were to fail, each should be backed up by another protective device (Zellagui et al., 2015).

# OCR Coordination

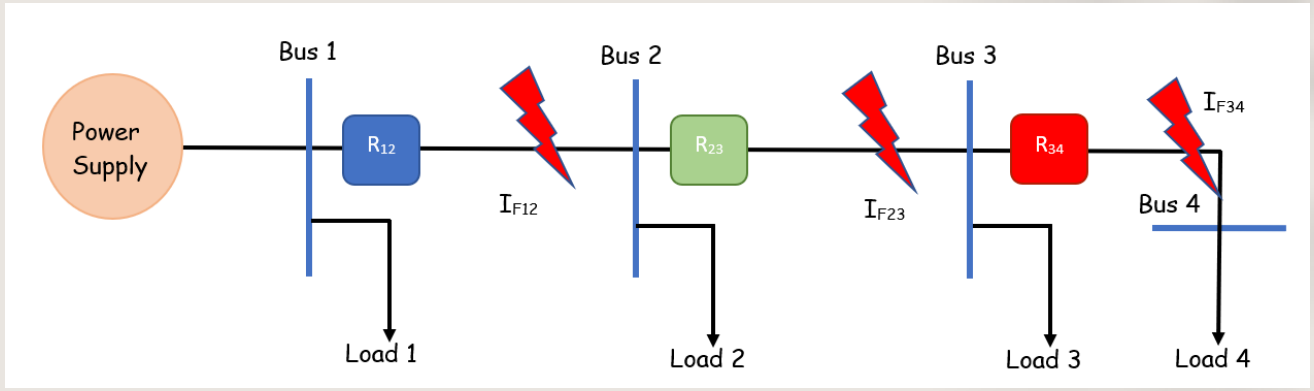


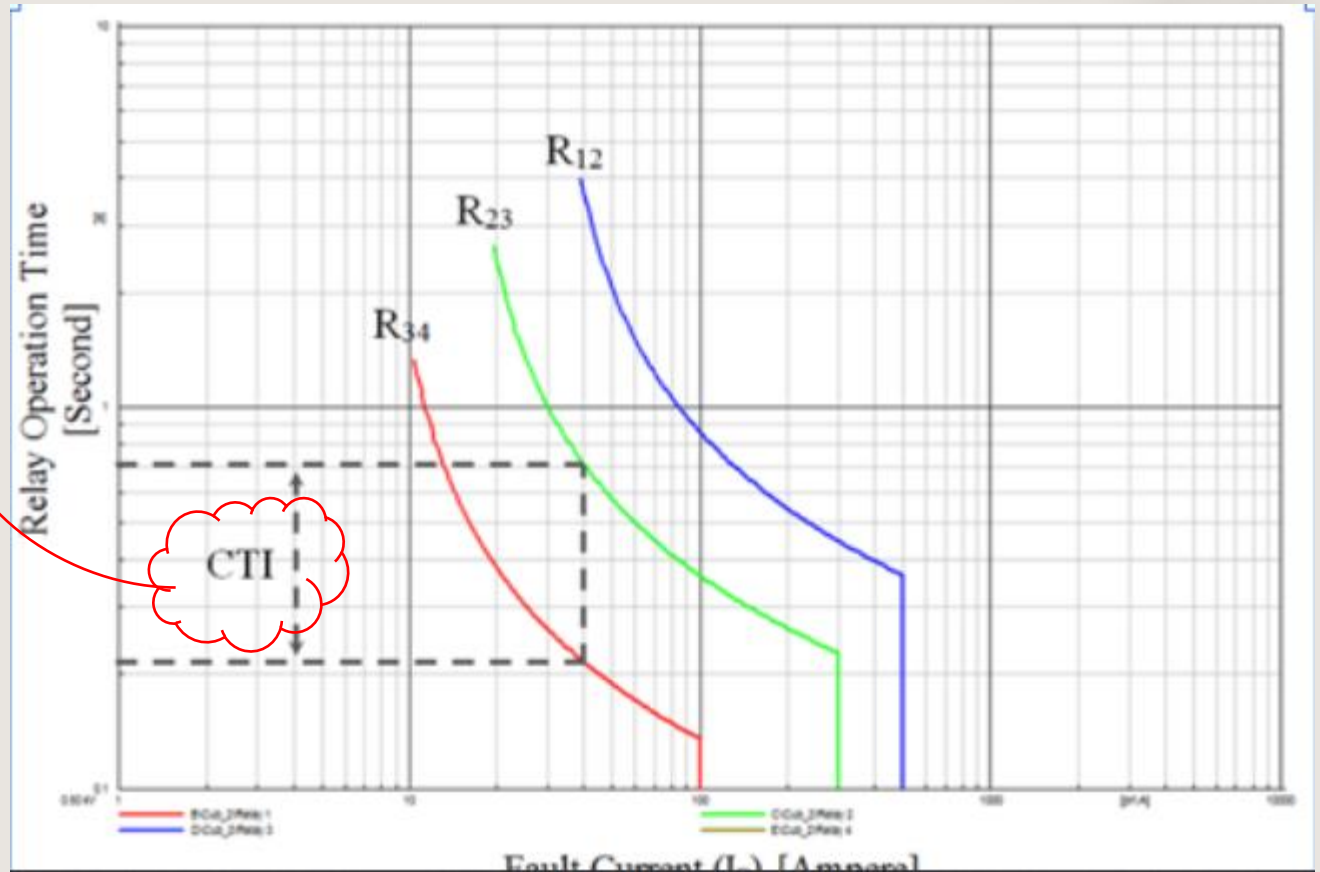



# Quiz #3



CTI : ?


Bus 1
Bus 2
Bus 3
Bus 4
Power Supply
R12
R23
R34
IF12
IF23
IF34
Load 1
Load 2
Load 3
Load 4


R12
R23
R34
CTI
Relay Operation Time [Second]
Fault Current (I) [Ampere]

# IDMT Characteristic

| Curve Description | Standard | α | β | L |
|---|---|---|---|---|
| Moderately inverse | IEEE | 0.02 | 0.0515 | 0.114 |
| Very inverse | IEEE | 2.0 | 19.61 | 0.491 |
| Extremely inverse | IEEE | 2.0 | 28.2 | 0.1217 |
| Inverse | CO8 | 2.0 | 5.95 | 0.18 |
| Short-time inverse | CO2 | 0.02 | 0.0239 | 0.0169 |
| Standard inverse | IEC | 0.02 | 0.14 | 0 |
| Very inverse | IEC | 1.0 | 13.5 | 0 |
| Extremely inverse | IEC | 2.0 | 80.0 | 0 |
| Long-time inverse | UK | 1.0 | 120 | 0 |

$$T = \frac{\beta \times TDS}{\left(\left(\frac{I_{SC}}{I_{Pickup}}\right)^{\alpha} - 1\right)}$$

# OCR Parameter Setting

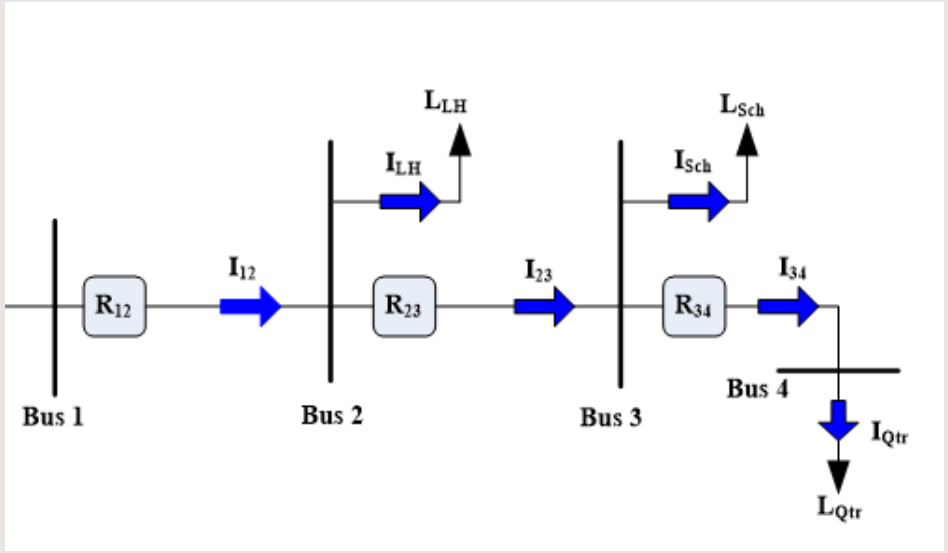
- 1. Plug Setting (PS)The PS is varied in the range of 50% to 200% and in steps of 25%.

- 2. Time Dial Setting (TDS)/Time Multiplier Setting (TMS) The Normal Inverse Curve (IEC-60255) has been chosen and the first TDS/TMS value is always set as 0.05 for the first relay, continuously in step of 0.05.

- LS-1 [May 11’ (Rev 2) -  Section 5.0]

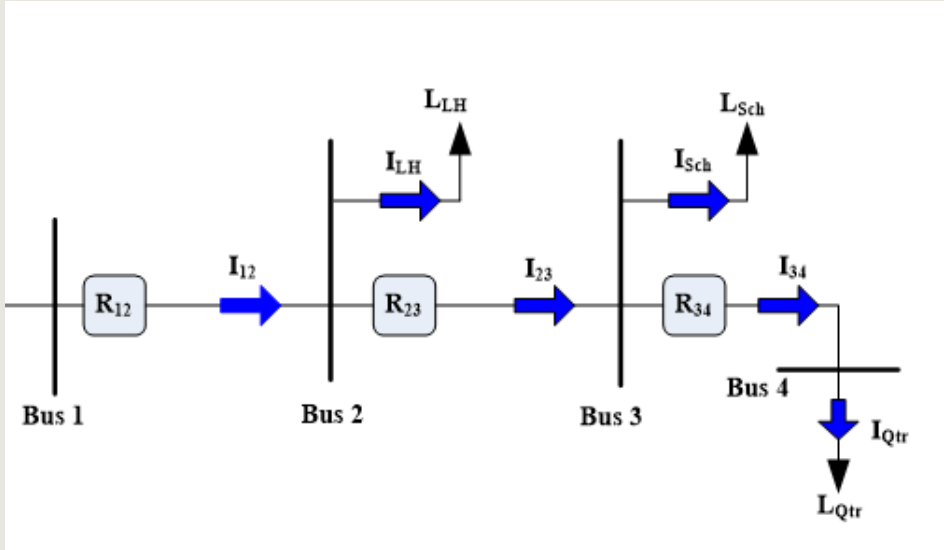
# Test Network – Load & Data

| No. | Description | Load [kW] |
|---|---|---|
| 1. | Load LH | 120.00 |
| 2. | Load Sch | 28.00 |
| 3. | Load Qtr | 75.00 |
| 4. | Total | 223.00 |



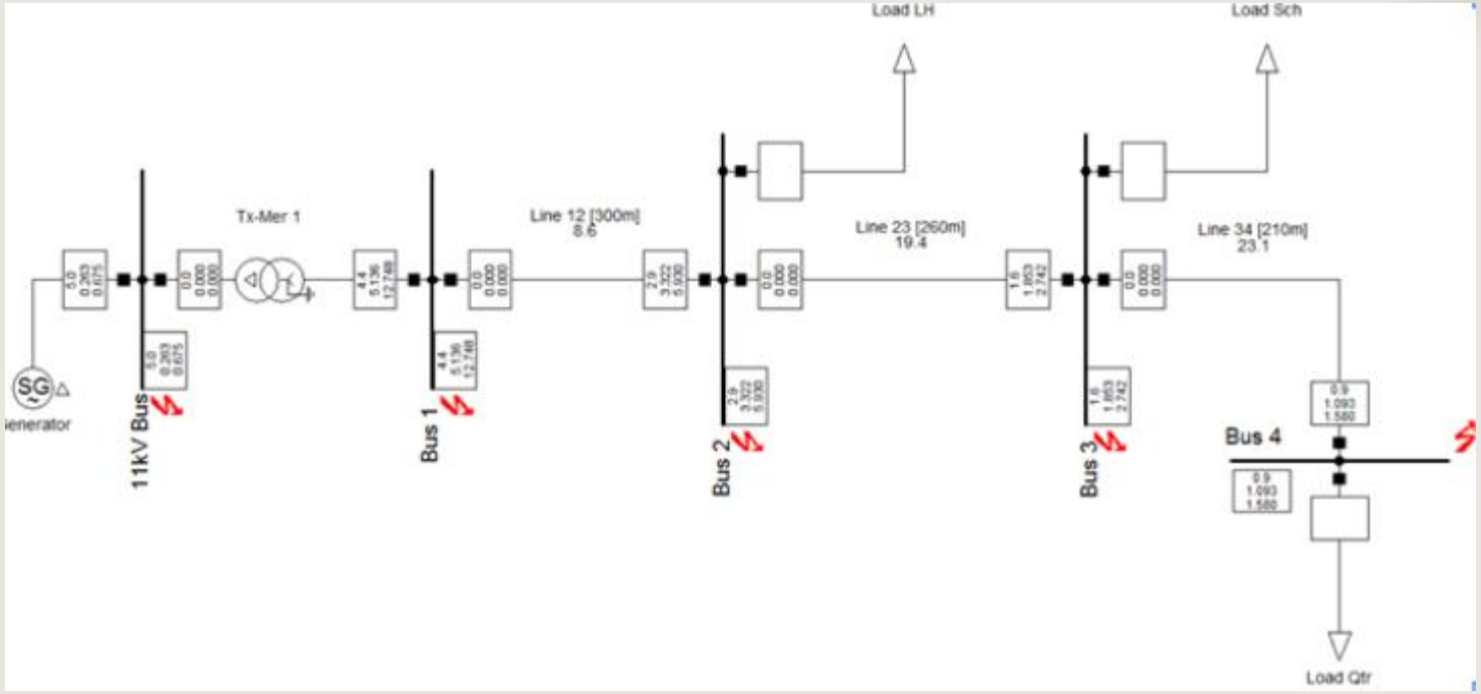
# Test Network – Load Flow Analysis

| No. | Description | Current [A] | Voltage [V] | Load [kW] | Cos θ |
|---|---|---|---|---|---|
| 1. | $I_{12}$ | 356.228 | $V_{B1}$ = 455 | 280.737 | 0.85 |
| 2. | $I_{LH}$ | 186.092 | $V_{B2}$ = 438 | 120.000 | 0.85 |
| 3. | $I_{23}$ | 170.068 | $V_{B2}$ = 438 | 28.000 | 0.85 |
| 4. | $I_{Sch}$ | 120.721 | $V_{B3}$ = 422 | 75.000 | 0.85 |
| 5. | $I_{Qtr}$ | 125.170 | $V_{B4}$ = 407 | 75.000 | 0.85 |



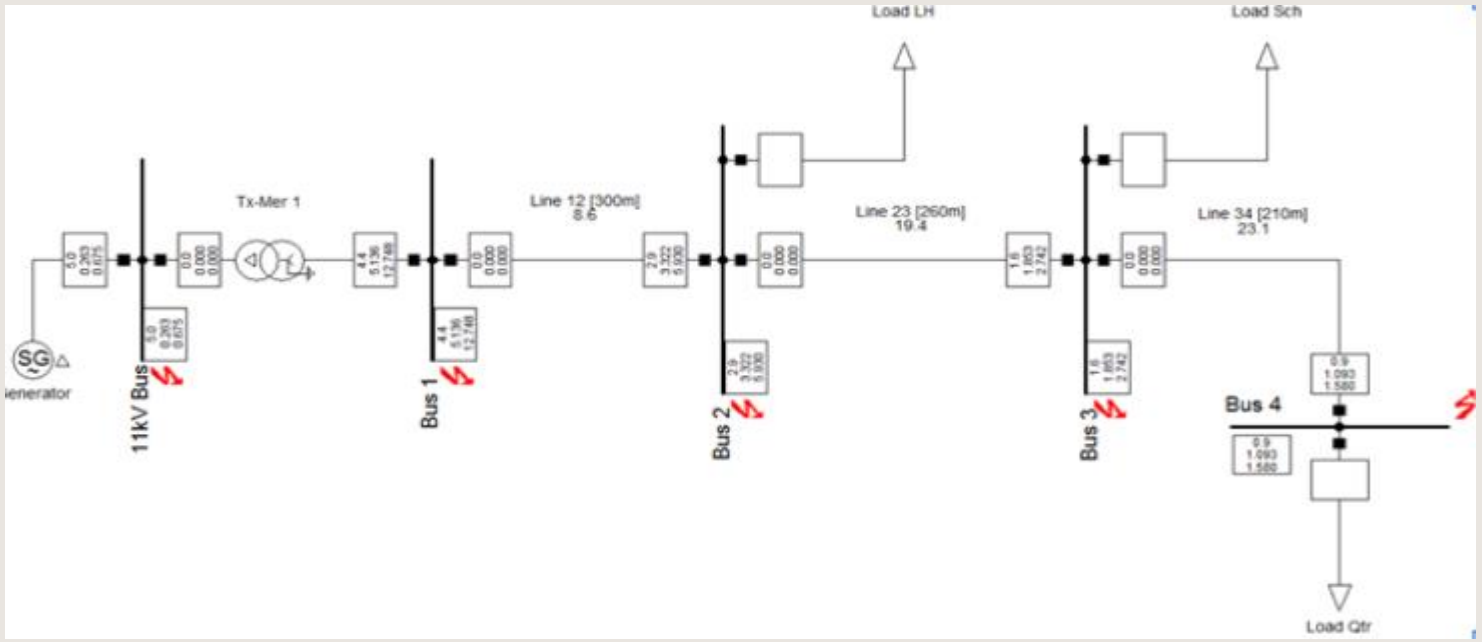
# Test Network – Load Flow Analysis

| Fault Location | Fault Current | Relay Pair Selection | | Current Seen By Relay | |
|---|---|---|---|---|---|
| | | Primary Relay | Backup Relay | Nominal (A) | SC (A) |
| Bus 4 | $I_{F34}$ | $R_{34}$ | $R_{23}$ | 125.00 | 1,093 |
| Bus 3 | $I_{F23}$ | $R_{23}$ | $R_{12}$ | 170.00 | 1,853 |
| Bus 2 | $I_{F12}$ | $R_{12}$ | - | 356.00 | 3,322 |



# Quiz #4

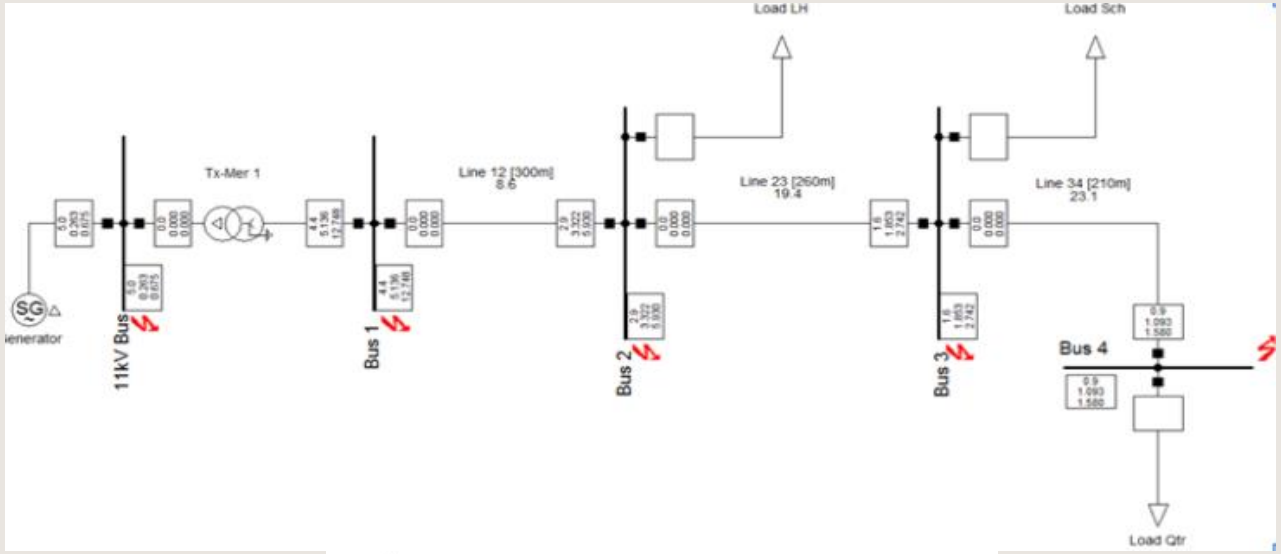
| Fault Location | Fault Current | Relay Pair Selection | | Current Seen By Relay | |
|---|---|---|---|---|---|
| | | Primary Relay | Backup Relay | Nominal (A) | SC (A) |
| Bus 4 | $I_{F34}$ | $R_{34}$ | $R_{23}$ | 125.00 | 1,093 |
| Bus 3 | $I_{F23}$ | $R_{23}$ | $R_{12}$ | 170.00 | 1,853 |
| Bus 2 | $I_{F12}$ | $R_{12}$ | - | 356.00 | 3,322 |

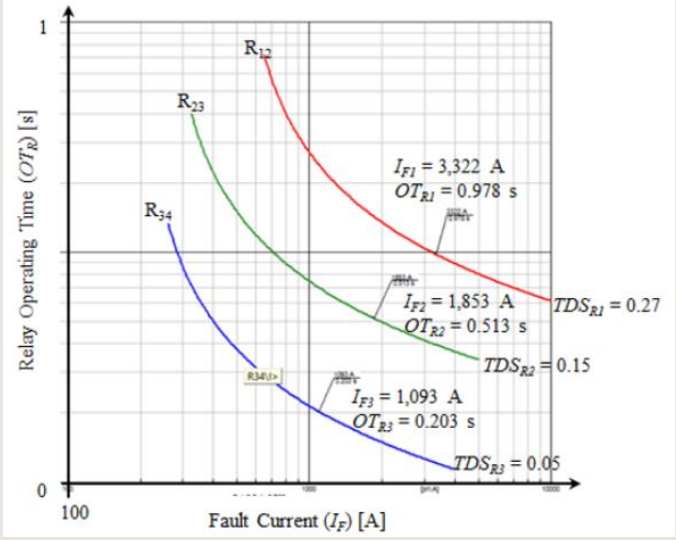



Why ???

$I_{F34} < I_{F23} < I_{F12}$

# Test Network – Relay Operating Time

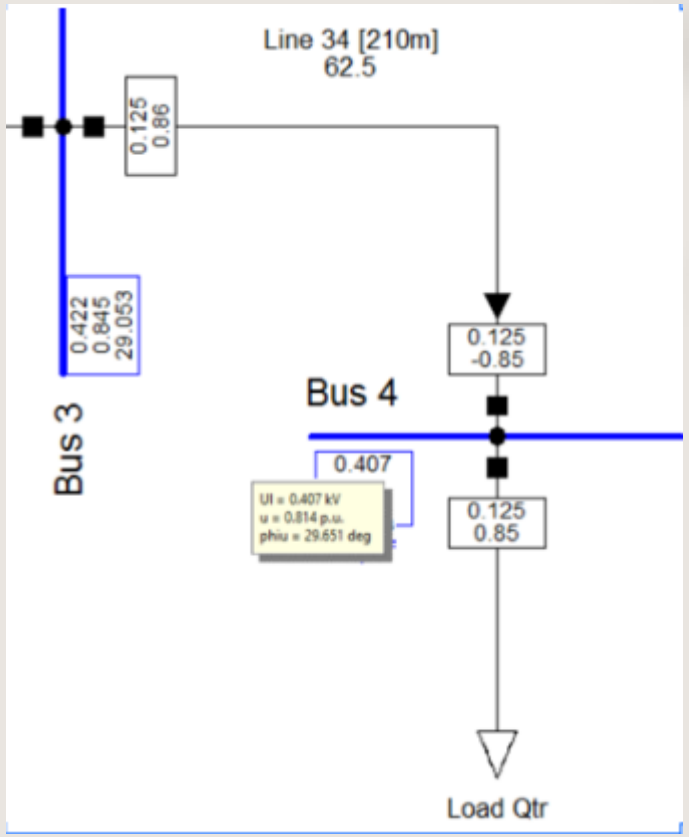


# Test Network – Result Verification ($I_{B4}$)

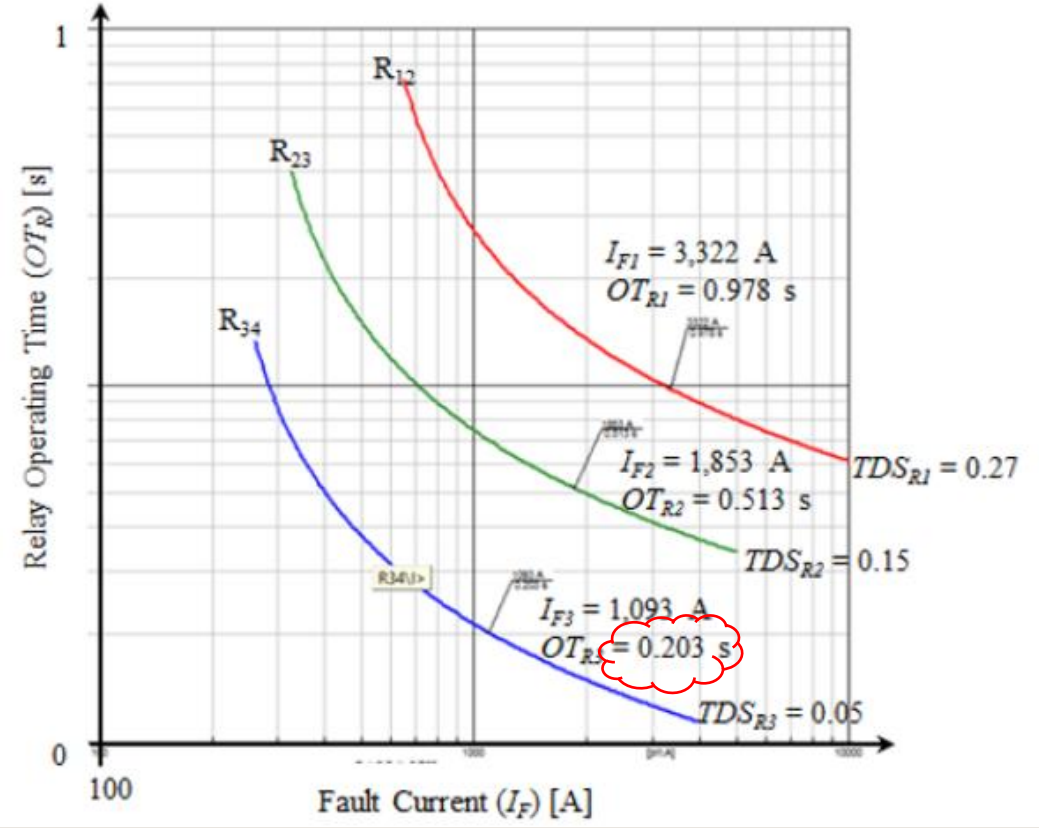
## Verify the current flow to Load Qtr?

Hint :
Load at Bus 4 : 75.00 kW
Voltage at Bus 4 : 407 V
Cos θ = 0.85



# Test Network – Result Verification ($R_{OT34}$)

- Relay Operating Time = 0.203 Sec




$$OT_{R34} = \frac{\beta \times TDS_{R34}}{\left(\frac{I_{SC}}{I_{Pickup}}\right)^{\alpha} - 1} = \frac{0.14 \times 0.05}{\left(\frac{1,093}{200}\right)^{0.02} - 1} = 0.2026\,s$$

The CT Ratio for Line 34 which CT Ratio for Relay 34 ($CT_{R34}$) is 200:5 has been selected. Thus,

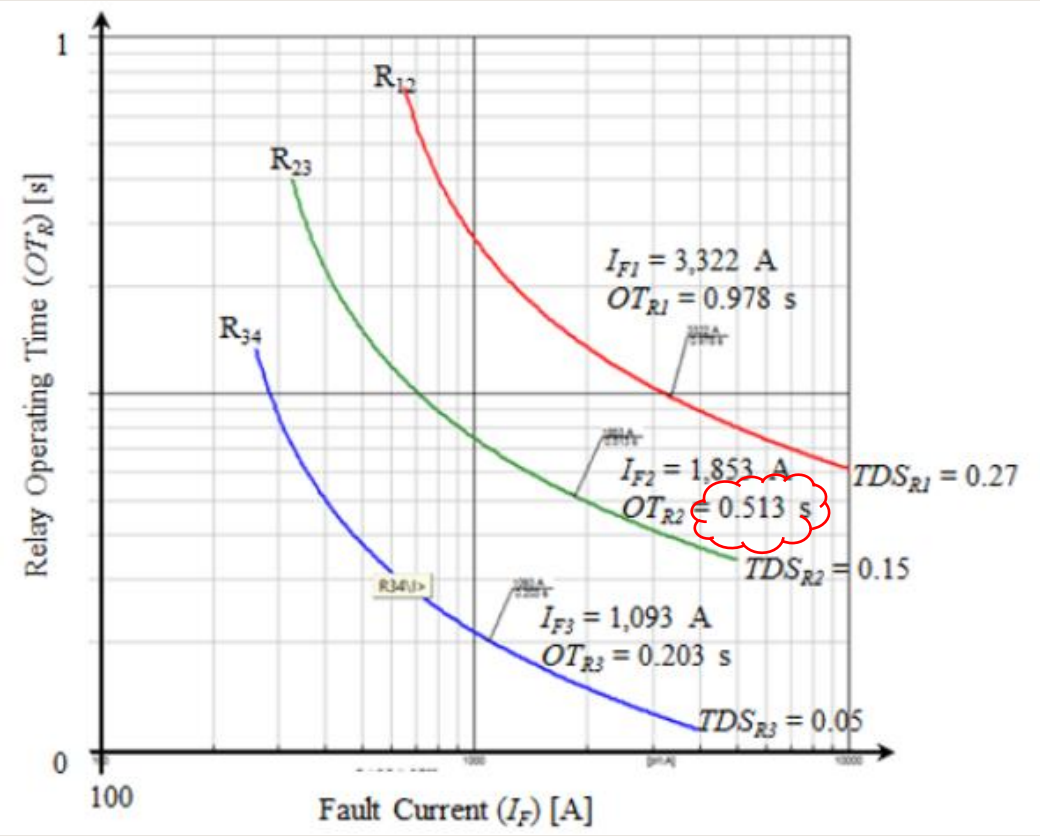
Percentage Plug Setting of the Relay = $\%PSR_{34}$

$$\%PS_{R34} = \frac{Overload\ Current}{CT\ Primary\ Current} \times 100 = \frac{187.50}{200} \times 100 = 93.75\,\% \approx 100\%$$

$$I_{Overload} = \frac{PS_{R34} \times CT_{R34}}{100} = \frac{100 \times 200}{100} \rightarrow PS_{R34} = 200A$$

# Test Network – Result Verification ($R_{OT23}$)

- Relay Operating Time = 0.513 Sec




$$T = \frac{\beta \times TDS}{\left(\left(\frac{I_{SC}}{I_{Pickup}}\right)^{\alpha} - 1\right)}$$

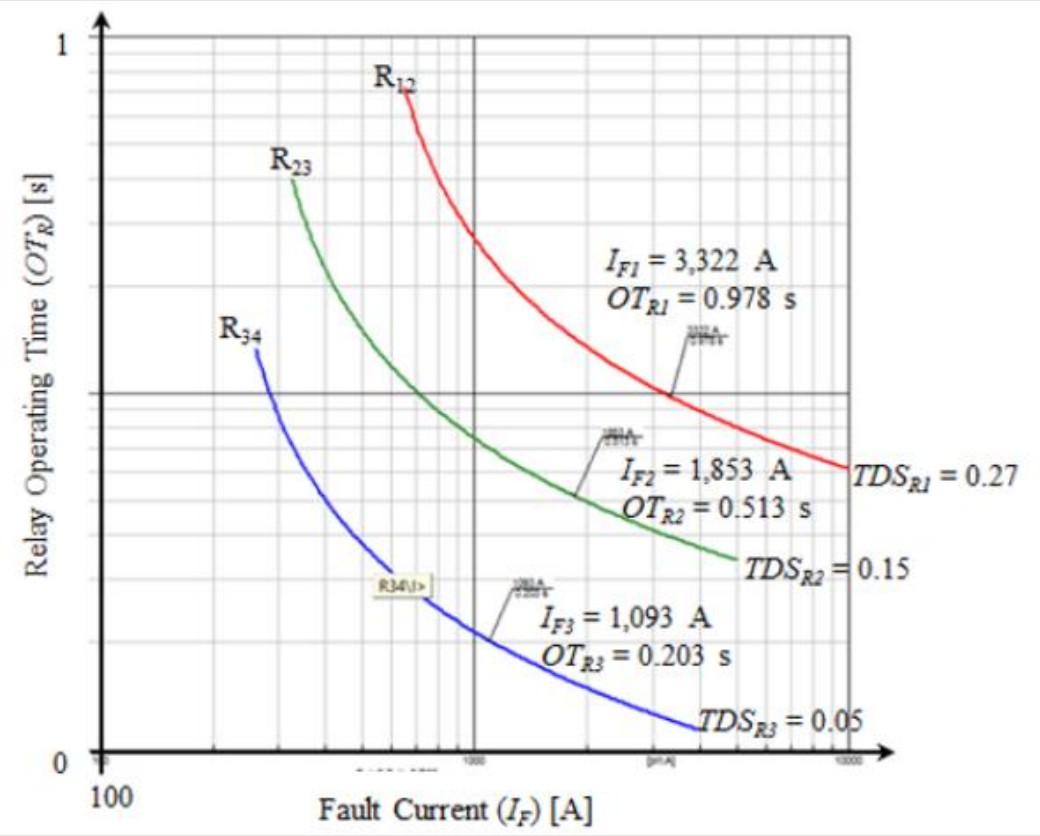
Hint :

Fault Current = 1,853 A
I pickup = 250 A
TDS = 0.15

*Normal Inverse

# Quiz #5

- What happen to Protection Relay if any of the Graph ($R_{12}$, $R_{23}$ & $R_{34}$) Overlapping?




# 고맙습니다

# Terima Kasih

# References


[1] Ger J. M., & Holmes, E. J. (2004). Protection of Electricity Distribution – principles and application (2nd. Edi). U.K : The Institute of Engineering and Technology, Michael Faraday House. Six Hill Way, Stevenage. Herts, SG1 2AY, U,K

[2] Haron, A. R., Mohamed, A., & Shareef, H. (2013). Coordination of Overcurrent, Directional and Differential Relays for the Protection of Microgrid System. *Procedia Technology*, *11*(Iceei), 366–373.

[3] Laporan Prestasi dan Keselamatan Elektrik, "Suruhanjaya Tenaga 2018 & 2019".

[4] Hussain, M.,Singh, M. K., & Reddy, P. N. (2013). A Fast Adaptive Protection Scheme for Distributed Generation Connected Networks with Necessary Relay Coordination. In *In Engineering and Systems (SCES), 2013 Students Conference . IEEE.* (pp. 1–5).

[5] Ratnadeep, K. S., Bhosale, Y. N., & Kurkani, S. (2013). Fault level analysis of power distribution system . 2013 International Conference on Energy Efficient Technologies for Sustainability, 1001 – 1005.

[6] Specification for Low Voltage Internal Electrical Installation (L-S1) [Rev 2, May 2011]