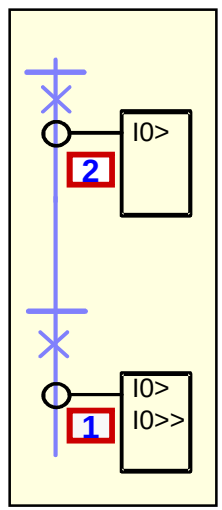
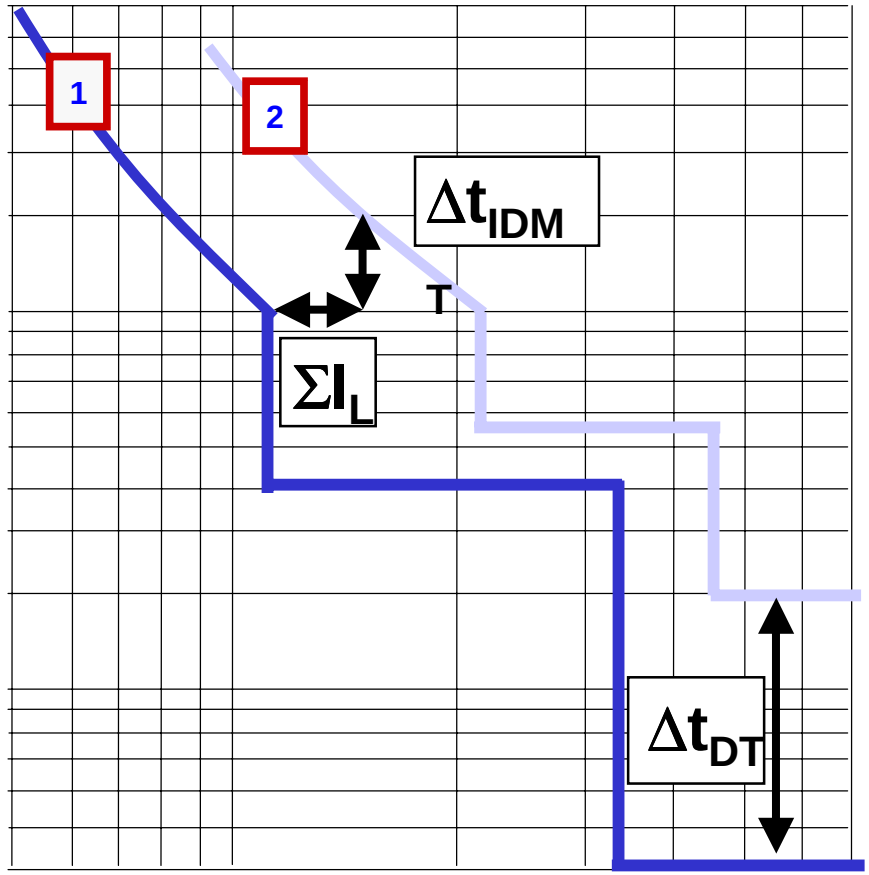
Time selective protection

- Discrimination of operation times

- Time grading = operation time difference between adjecent protection stages

- We have ΣI_L because the load currents at levels 1 and 2 are not same.





Time selective protection

- Time grading - definite time

$$\Delta t_{DT} = 2 \times t_E + t_R + t_{CB} + t_M$$

where t_E = tolerance of the relay op.time

t_R = retardation time of the relay

t_{CB} = operation time of CB

t_M = marginal time

t_R = Retardation time (Overshoot time) = time needed to cancel the trip.

t_M = Delay of an auxiliary relay (if used)
+ Possible delay of operation due saturation of CT. In theory this could be same as the time constant of DC-component. In practice 20 ms is enough because all protection stages will be delayed.

Time selective protection

- Time grading - definite time - example

$$\Delta t_{DT} = 2 \times t_E + t_R + t_{CB} + t_M$$

tolerance (2x25 ms)	50 ms
op.time of CB	50 ms
retardation time	30 ms
marginal	20 ms
	150 ms

Time selective protection

- Time grading - inverse time
- Rule of thumb for numerical relays
  - NI, VI, LI: $0.20 \times t_1 + 150\text{ms}$
  - EI: $0.35 \times t_1 + 150\text{ms}$

Time selective protection

- Time grading - inverse time

$$\Delta t_{IDMT} = t_1 \times \left(\frac{1 + \frac{E_1}{100}}{1 - \frac{E_2}{100}} - 1 \right) + t_R + t_{CB} + t_M$$

where $t_1 =$ op.time of the relay of the closest location

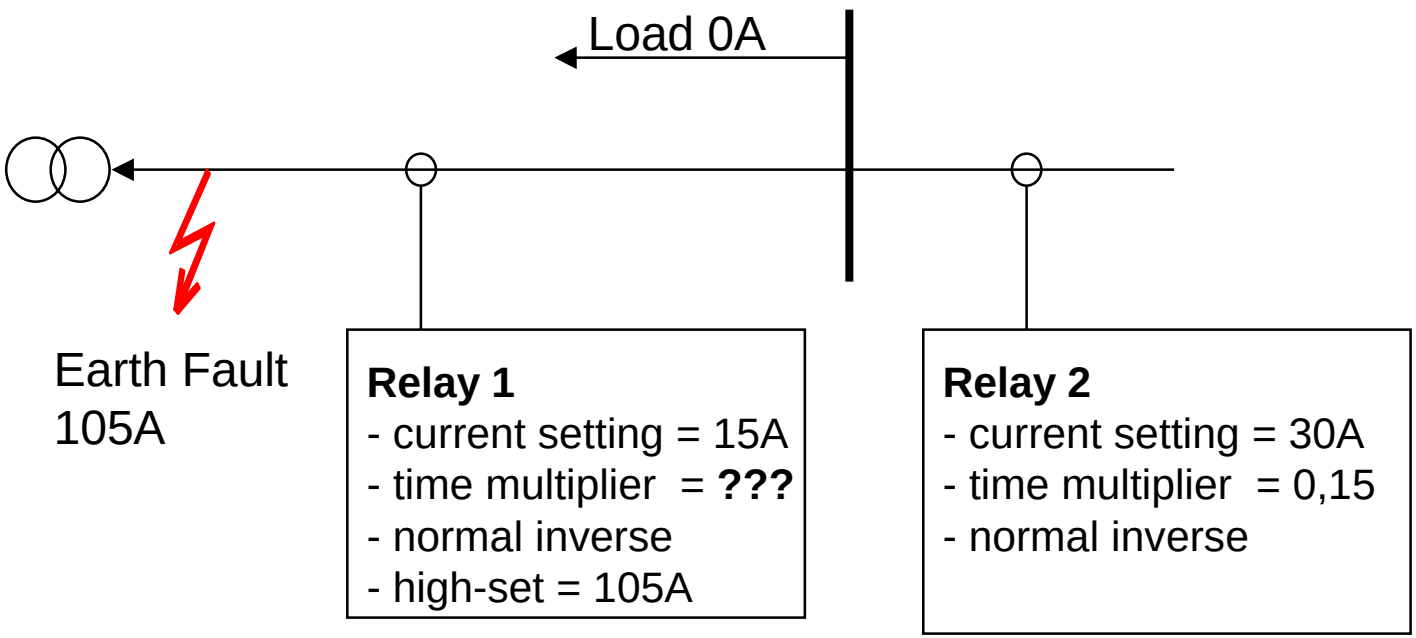
$E_1 =$ error of the relay of the closest location

$E_2 =$ error of the relay of the next location

Time selective protection

- Time grading - inverse time - example step by step

0. Data from the fault calculation

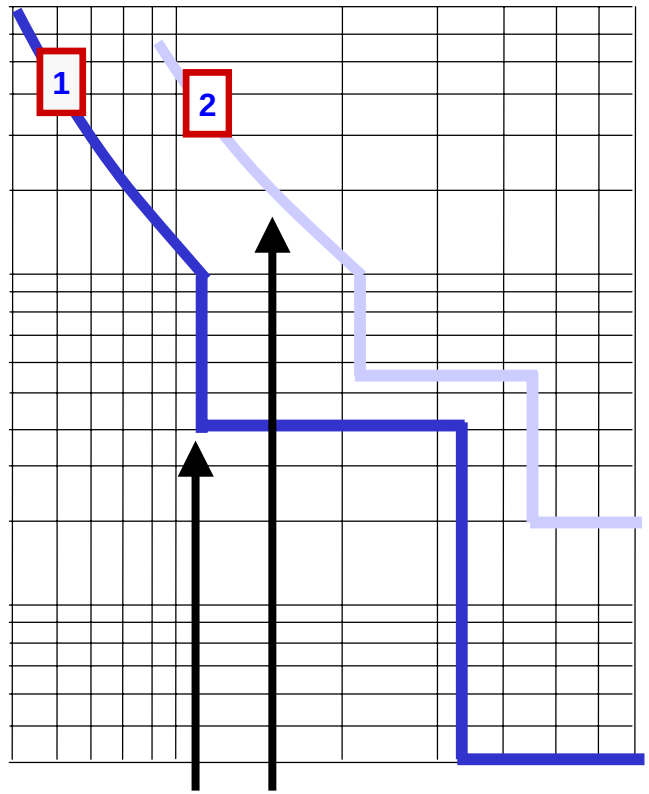


Time selective protection

- Time grading - inverse time - example step by step

1. Find the current values
   - Use the high-set of relay 1 for grading
   - When no high-set, use the fault current at location 1

I_1 = 105A ≈ 7.0 x setting (relay 1)
I_2 = 105A ≈ 3.5 x setting (relay 2)



Time selective protection

- Time grading - inverse time - example step by step

2. Look time-tolerances from the table

   Here we have Normal inverse,

E=5%

=> relay 1: 1.13xE ≈ 6%

=> relay 2: 2.22xE ≈ 11%

This information can be found in the relay manual

I/I>	Normal	Very	Extremely	Long time
2	2,22E	2,34E	2,44E	2,34E
5	1,13E	1,26E	1,48E	1,26E
7	-	-	-	1,00E
10	1,01E	1,01E	1,02E	-
20	1,00E	1,00E	1,00E	-

Time selective protection

- Time grading - inverse time - example

3. Calculate effect of measuring accuracy (+ CT errors)

   Here we use ±3%

   ⇒ Calculate the change in operating time when using -3% and +3%

   ⇒ Calculate the per cent errors. Take the highest value.

   Relay 1: 1.62%

   Relay 2: 2.52%

4. Sum erros 2) and 3) and we have E_1 and E_2

   E1 = 6% + 1.62 % = 7.62% (relay 1)

   E2 = 11% + 2.52 % = 13.52% (relay 2)

Time selective protection

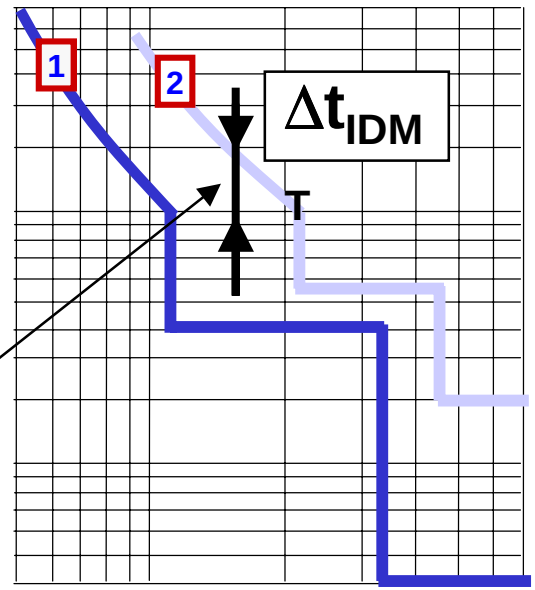
- Time grading - inverse time - example

5. Use equation

   t1 = time of relay 2 (at 105A) = 830 ms

$$\Delta t_{IDMT} = t_1 \times \left(\frac{1 + \frac{E_1}{100} - 1}{1 - \frac{E_2}{100}} \right) + t_R + t_{CB} + t_M$$

t1x(1-E1/100)/(1-E2/100)-1)	203 ms
op.time of CB	50 ms
retardation time	30 ms
marginal	20 ms
303 ms	



Time selective protection

- Time grading - inverse time - example

6. Find time multiplier *k* for relay 1

   time of relay 2 - grading = 830 ms - 303 ms = 527ms

   Using
   - Normal Inverse curve
   - current 7.0 x setting
   - operation time 0.527 s

   => the time multiplier *k* = 0.14