

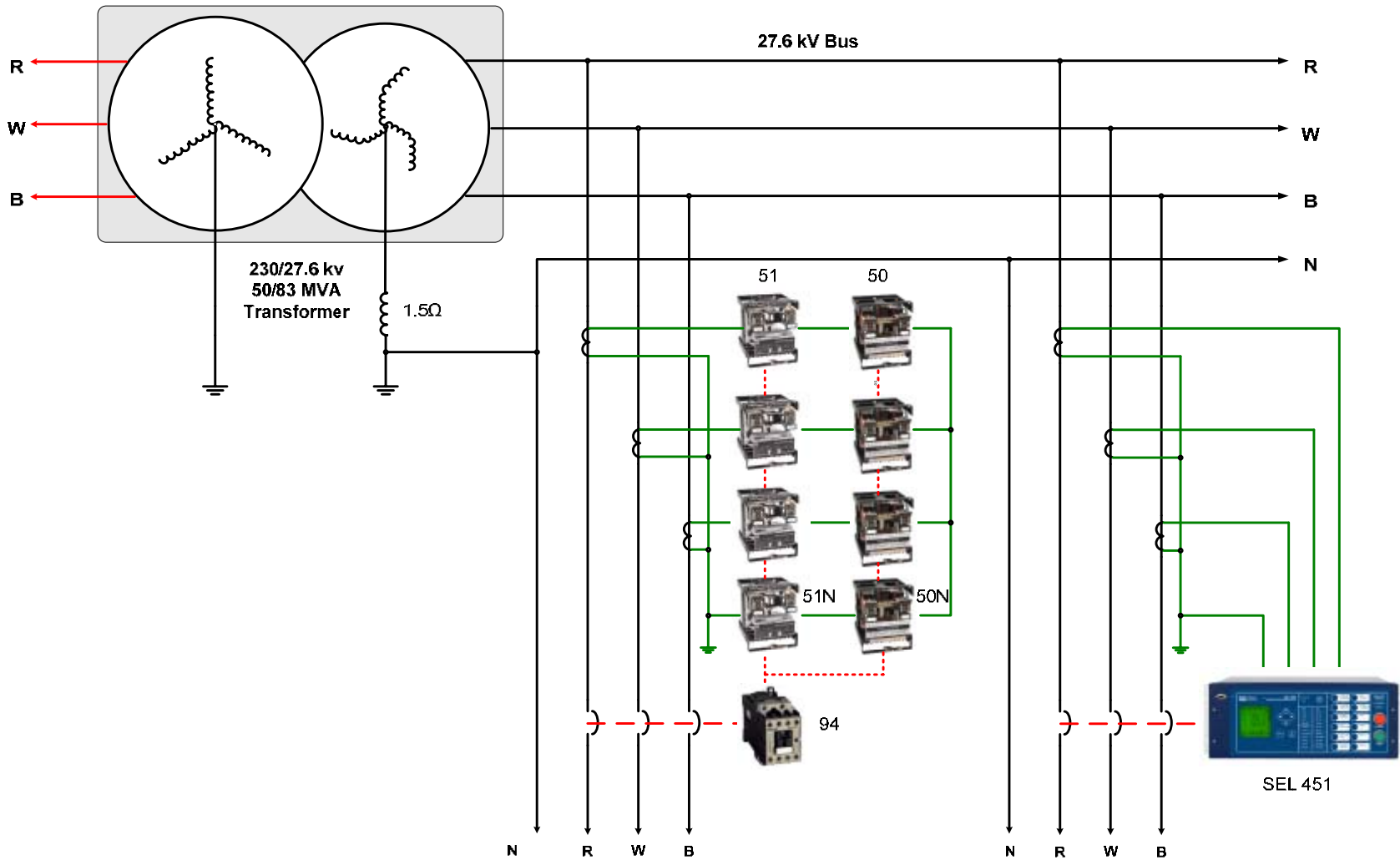
4 Wire Distribution Feeder Protection

Trip Saving Vs Fuse Saving

Presentation Topics

- 4 Wire Feeder design
- Feeder Protection hardware
- Feeder Protection elements
- Feeder Fault Types
- Feeder Protection strategy
 - Trip Saving
 - Fuse Saving
- Feeder Protection settings Criteria
- Developing Protection Settings

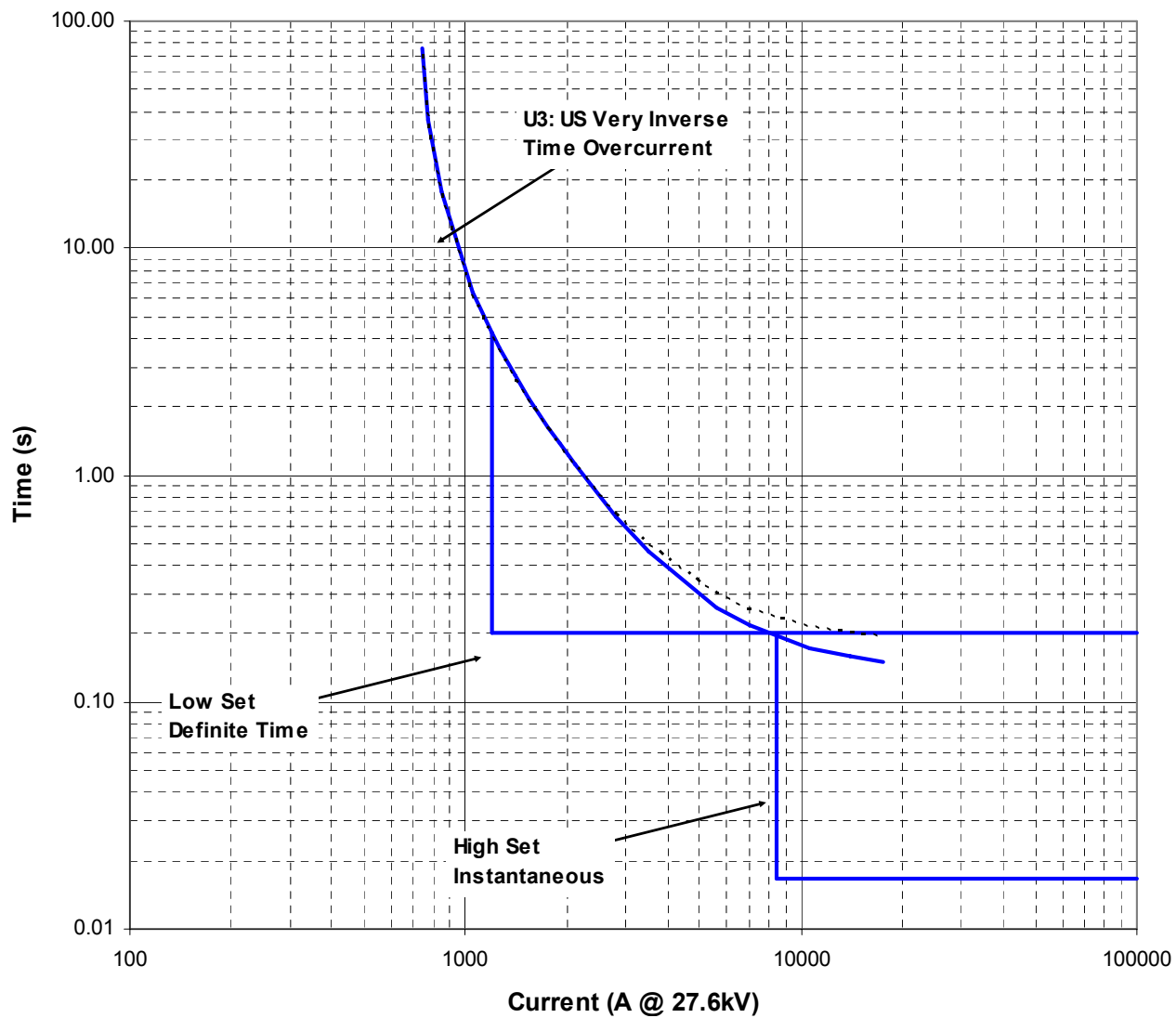
4 Wire Feeder Protection Design



9/27/2010



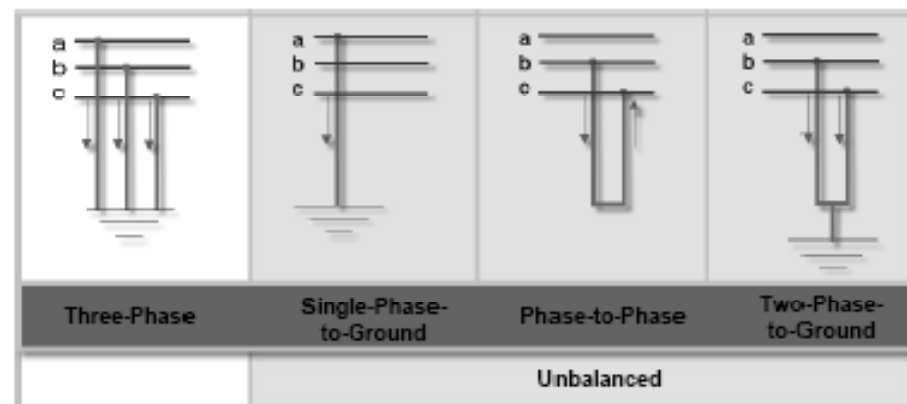
Typical Feeder Phase Protection



Feeder Fault Types

- Fault Duration:
 - Permanent
 - Transient
- Fault Location:
 - Load side lateral fuse
 - Feeder:
 - Before 1st lateral fuse
 - After 1st lateral fuse
- Fault Type:
 - \emptyset to \emptyset
 - \emptyset to \emptyset to \emptyset
 - \emptyset to G

Basic Fault Types



Trip Saving Feeder Protection Strategy

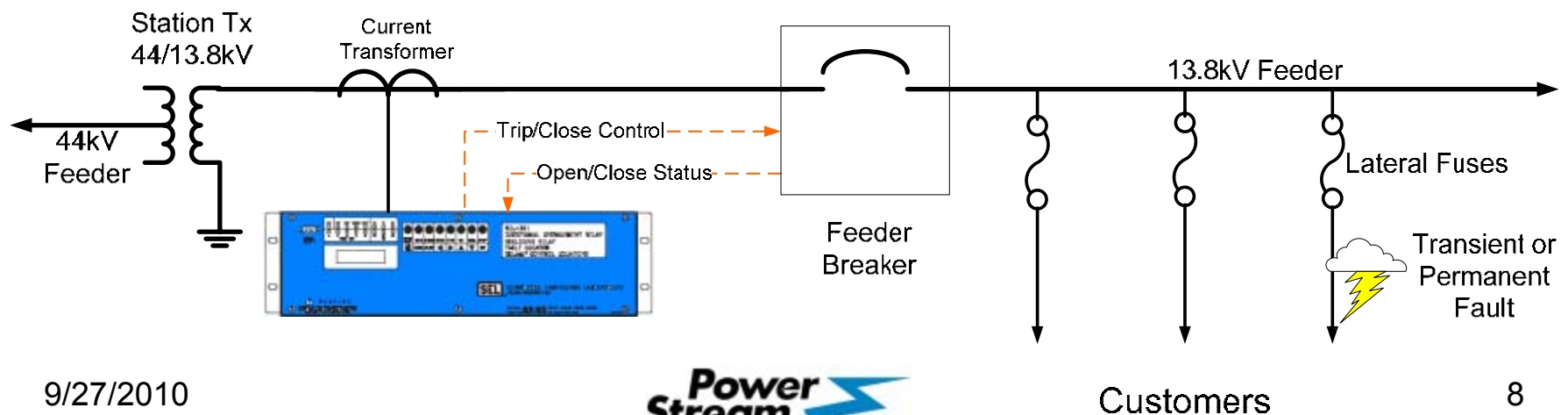
- For 3 locations of *transient* faults, the feeder protection will:
 - Fault on the feeder, upstream of the first lateral fuse - The feeder will trip on high set instantaneous (50a) and lockout.
 - Fault on the feeder, downstream of the first lateral fuse - The feeder will trip on low set instantaneous (50b) and reclose.
 - *Fault on the load side of a lateral fuse – The feeder will not trip, The fuse will blow and clear the fault.*
- For 3 locations *permanent* faults, the feeder protection will:
 - Fault on the feeder, upstream of the first lateral fuse - The feeder will trip on high set instantaneous (50a) and lockout.
 - Fault on the feeder, downstream of the first lateral fuse - The feeder protection will trip on low set instantaneous (50b) and reclose, then trip on timed overcurrent (51) and lockout.
 - *Fault on the load side of a lateral fuse - The feeder will not trip, the fuse will blow and clear the fault.*

Fuse Saving Feeder Protection Strategy

- For 3 locations of *transient* faults, the feeder protection will:
 - On the feeder, upstream of the first lateral fuse - The feeder will trip on 50a and lockout.
 - On the feeder, downstream of the first lateral fuse - The feeder will trip on 50b and reclose.
 - *On the load side of a lateral fuse - The feeder will trip on 50b and reclose. The fuse will not blow.*
- For 3 locations of *permanent* faults, the feeder protection will:
 - On the feeder, upstream of the first lateral fuse - The feeder will trip on 50a and lockout.
 - On the feeder downstream of the first lateral fuse - The feeder protection will trip on 50b, reclose, then trip on 51 and lockout.
 - *On the load side of a lateral fuse - The feeder protection will trip on 50b, reclose, then the fuse will clear the fault.*

Trip Saving / Fuse Saving Strategy Differences

- a) Transient Fault on the load side of a lateral Fuse:
- Trip Saving – Feeder will not trip; fuse will blow
 - Fuse Saving – Feeder will trip & reclose, fuse will not blow
- a) Permanent Fault on the load side of a lateral Fuse:
- Trip Saving – Feeder will not trip; fuse will blow
 - Fuse Saving – Feeder will trip, reclose, fuse will blow



Trip Saving / Fuse Saving Operations Comparison

- **Trip Saving:**

- Pros:

- Only the customer(s) fed from the fuse that blows are affected.

- Cons:

- For a transient fault on the load side of a lateral fuse; a crew must be dispatched to replace the fuse.
- For a transient fault on the load side of a lateral fuse; an outage will occur.

- **Fuse Saving:**

- Pros:

- For a transient fault on the load side of a lateral fuse; the fuse does not blow.

- Cons:

- For a transient or permanent fault on the load side of a lateral fuse; all customers on the feeder experience a trip & reclosure.

Phase Elements - Protection Setting Criteria

- High Set Instantaneous Overcurrent (50a)
 - Pick up setting $> \emptyset\text{-}\emptyset$ fault current available at closest tapped fuse
- Low Set Instantaneous Overcurrent (50b)
 - Pick up setting:
 - Equal or greater than 2 times maximum load
 - Less than 0.5 feeder end $\emptyset\text{-}\emptyset$ fault level
 - Trip Saving Delay Setting – sufficient to permit tapped fuses to clear first for $\emptyset\text{-}\emptyset$ fault (No delay for Fuse Saving)
- Timed Overcurrent (51)
 - Pick-up Setting:
 - Equal or greater than 2 times maximum load
 - Less than 0.5 feeder end $\emptyset\text{-}\emptyset$ fault level
 - Less than 0.8 bus backup pick-up
 - Time Setting:
 - 0.3 Seconds slower than slowest tapped fuses on feeder
 - Clear minimum feeder end fault within 1.5 seconds

Ground Elements - Protection Setting Criteria

- High Set Instantaneous Overcurrent (50Na)
 - Pick up setting $> \emptyset$ -G fault current available at closest tapped fuse
- Low Set Instantaneous Overcurrent (50Nb)
 - Pick up setting:
 - Equal or greater than 2 times maximum load unbalance current
 - Less than 0.5 feeder end \emptyset -G fault level
 - Trip Saving Delay Setting – sufficient to permit tapped fuses to clear first for \emptyset -G fault (No delay for Fuse Saving)
- Timed Overcurrent (51N)
 - Pick-up Setting:
 - Equal or greater than 2 times maximum load unbalance current
 - Less than 0.5 feeder end \emptyset -G fault level
 - Less than 0.8 ground bus backup pick-up
 - Time Setting:
 - 0.3 Seconds slower than slowest tapped fuses on feeder
 - Clear minimum feeder end fault within 1.5 seconds

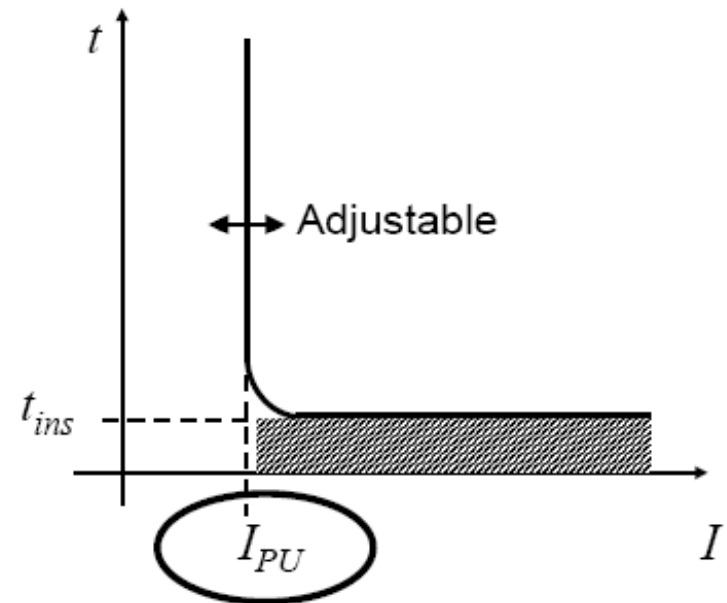
Developing Instantaneous Overcurrent Settings

Overcurrent Settings

50 Element Settings

- Pick-up Current
- Time Delay

50 Element Setting



Time, t_{ins} , is less than 1.5 cycles

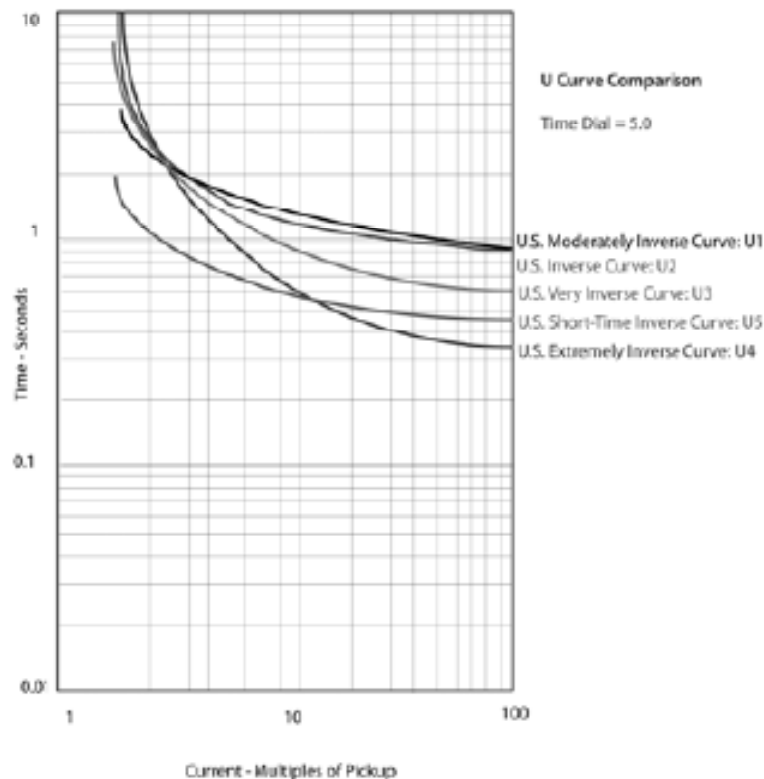
Developing Timed Overcurrent Settings

51 Element Settings

- Pickup current
- Curve shape
- Time dial

Inverse Timed Overcurrent Curve Shapes

51 Element



- Inverse curve allows coordination among multiple protective devices
- Defined by standard equations (US and IEC)
 - Moderately Inverse
 - Inverse
 - Very Inverse
 - Short-Time Inverse
 - Extremely Inverse

Defining Curve Shapes

Curve Type	Operating Time
U1 (Moderately Inverse)	$T_p = TD \cdot \left(0.0226 + \frac{0.0104}{(M^{0.02} - 1)} \right)$
U2 (Inverse)	$T_p = TD \cdot \left(0.180 + \frac{5.95}{(M^2 - 1)} \right)$
U3 (Very Inverse)	$T_p = TD \cdot \left(0.0963 + \frac{3.88}{(M^2 - 1)} \right)$
U4 (Extremely Inverse)	$T_p = TD \cdot \left(0.0352 + \frac{5.67}{(M^2 - 1)} \right)$
U5 (Short-Time Inverse)	$T_p = TD \cdot \left(0.00262 + \frac{0.00342}{(M^{0.02} - 1)} \right)$

Definitions:

T_p - Operating time

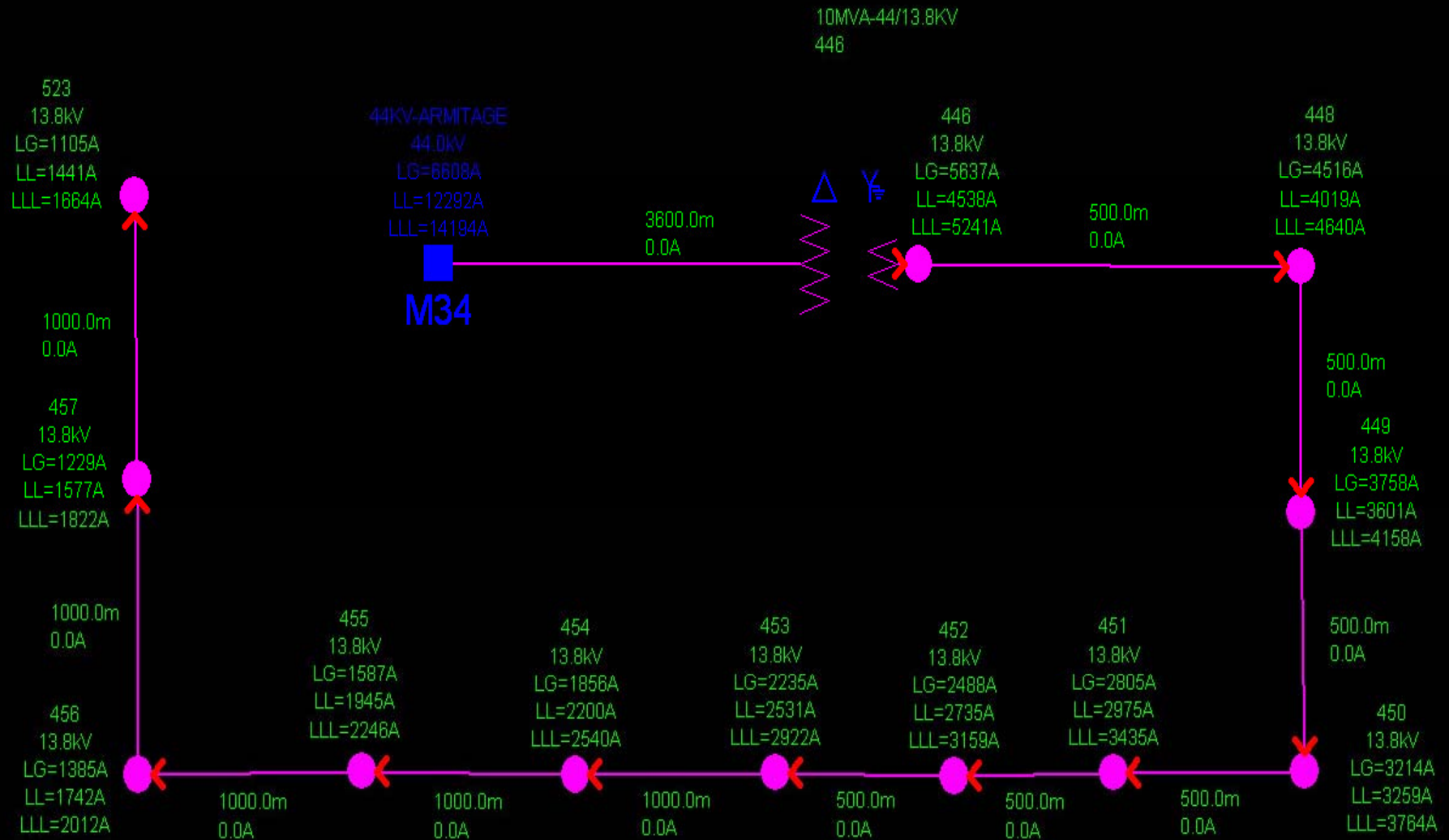
T_r - Reset time

TD - Time dial settings

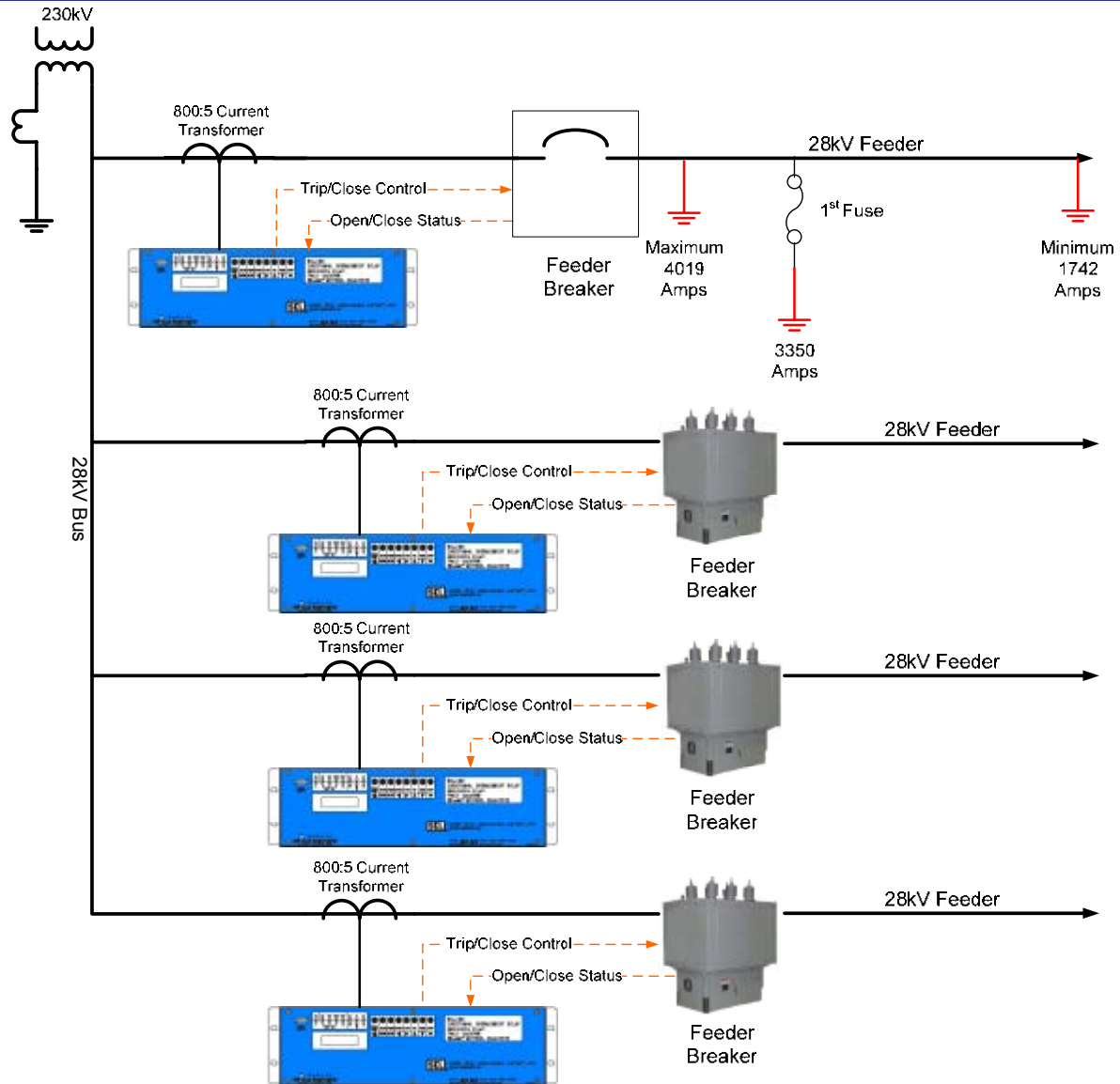
$M = I_f / I_{pu}$ - Ratio of fault current (secondary) to the relay pickup

where M = applied multiples of pickup current [for operating time (T_p), $M > 1$; for reset time (T_r), $M \leq 1$]

Feeder Fault Levels



Typical Feeder Fault Levels

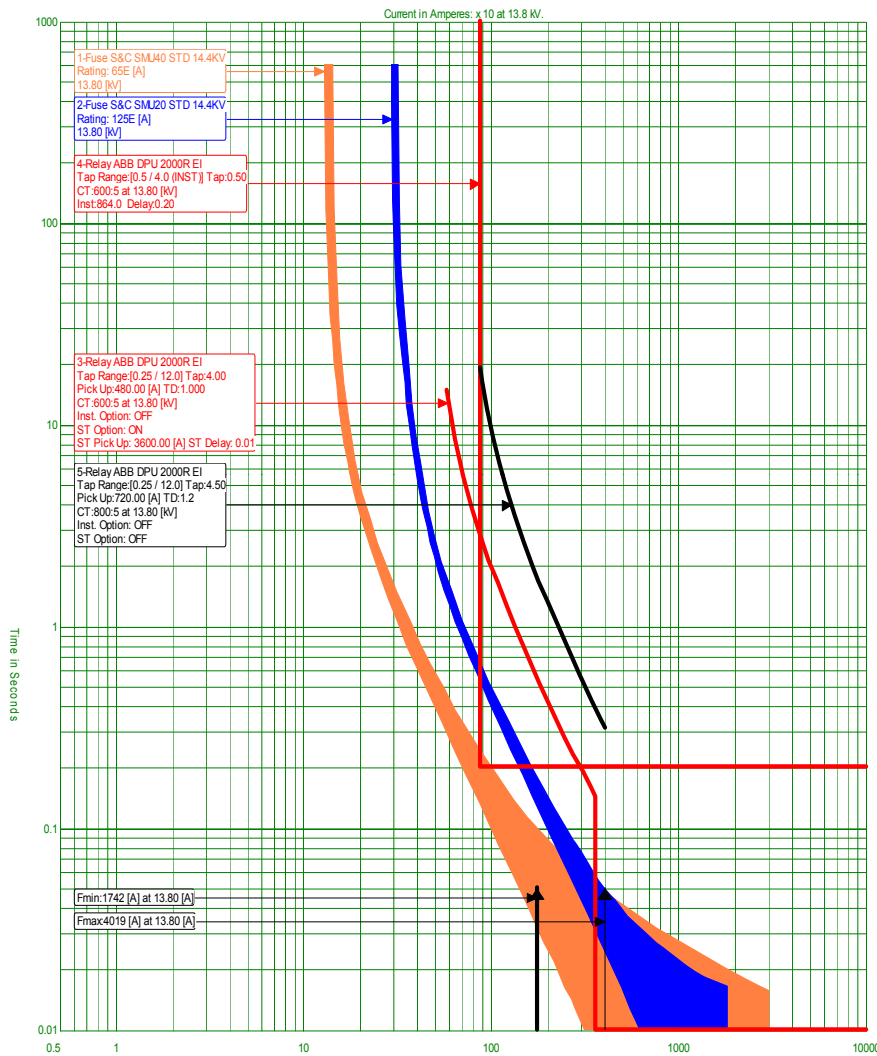


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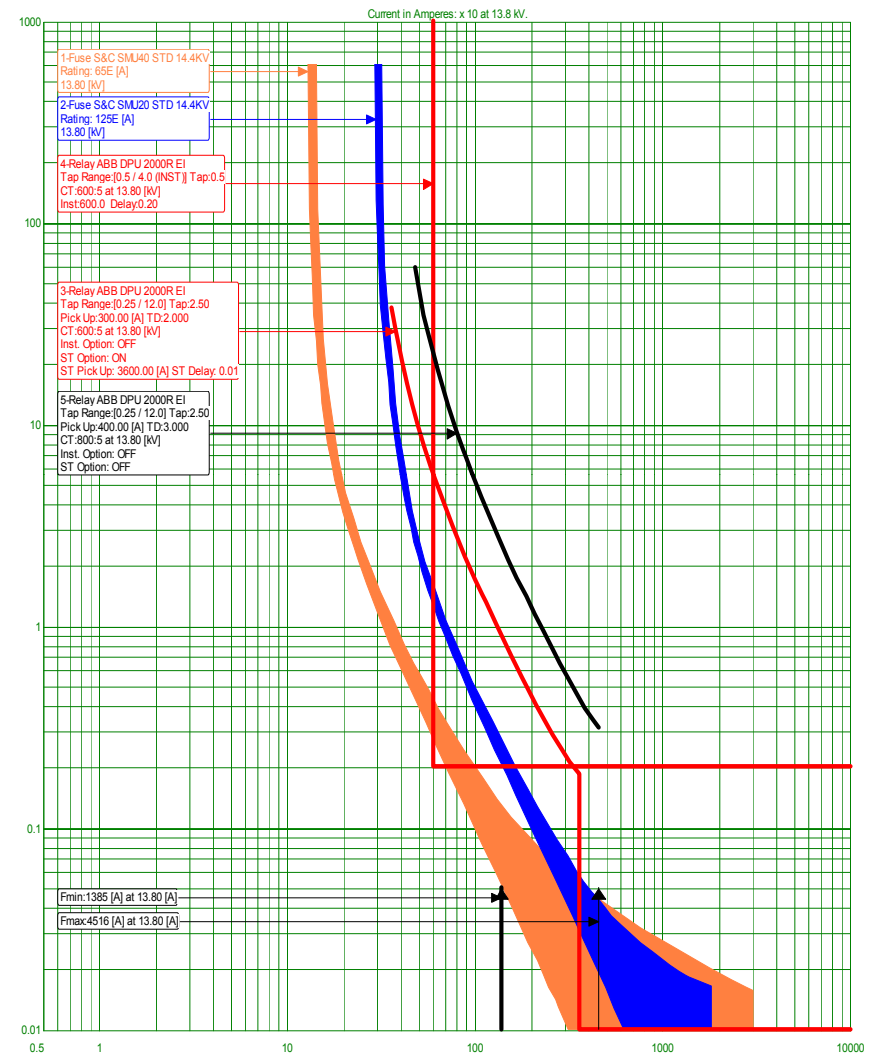
Feeder Phase & Ground Protection Curves



Aurora MS5 - Feeder Phase Protection-Revised TIME CURRENT CHARACTERISTIC CURVES
BY: BB

PLOTTING VOLTAGE: 13.8 kV **Phase**

NO: _____
DATE: 10/20/2008



Aurora MS5 - Feeder Ground Protection-Revised TIME CURRENT CHARACTERISTIC CURVES
BY: BB

PLOTTING VOLTAGE: 13.8 kV **Ground**

NO: _____
DATE: 10/20/2008

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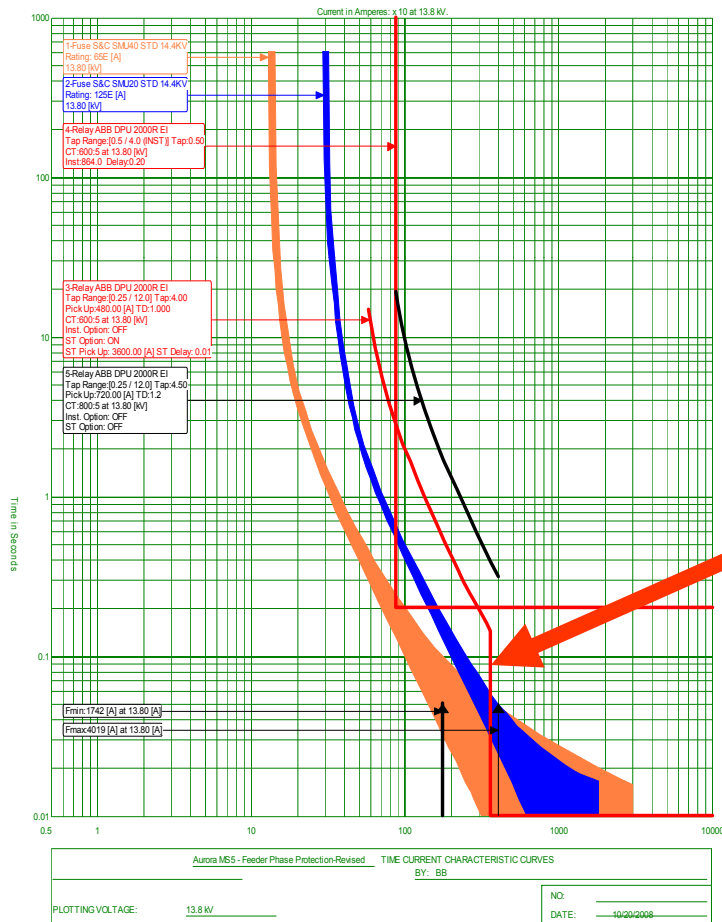


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Calculate Feeder Protection Settings

- 50a
 - Pickup
- 50b
 - Pickup
 - Delay
- 51
 - Pickup
 - Curve Shape
 - Time Dial

High Set Instantaneous (50a) Phase Pick-up



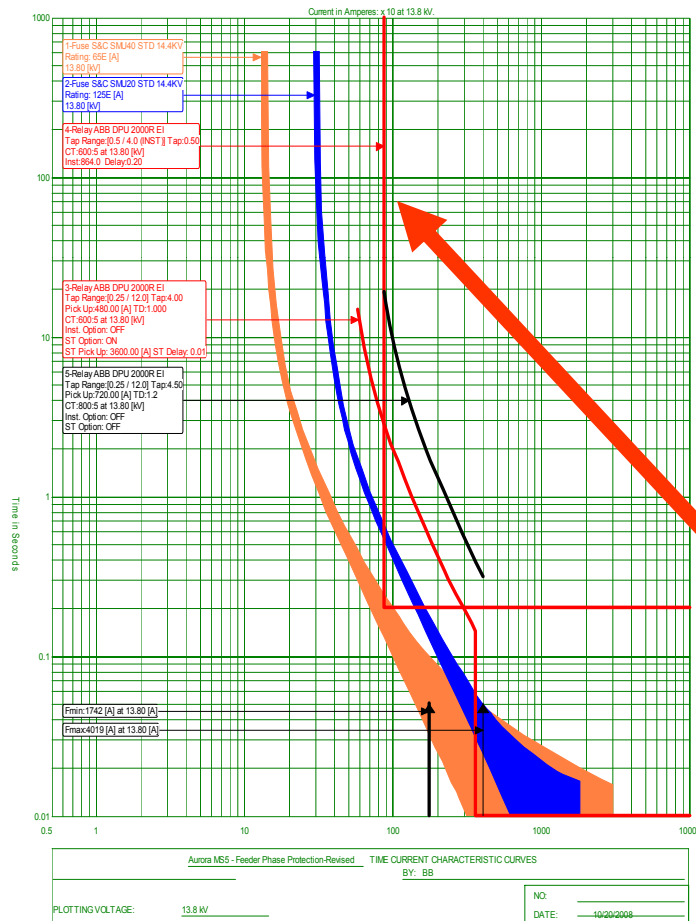
- Pick-up setting > \emptyset - \emptyset fault current available at closest tapped fuse
- Fault current available at 1st fuse = 3350 Amps
- Set 50a pick-up = 3600 Amps

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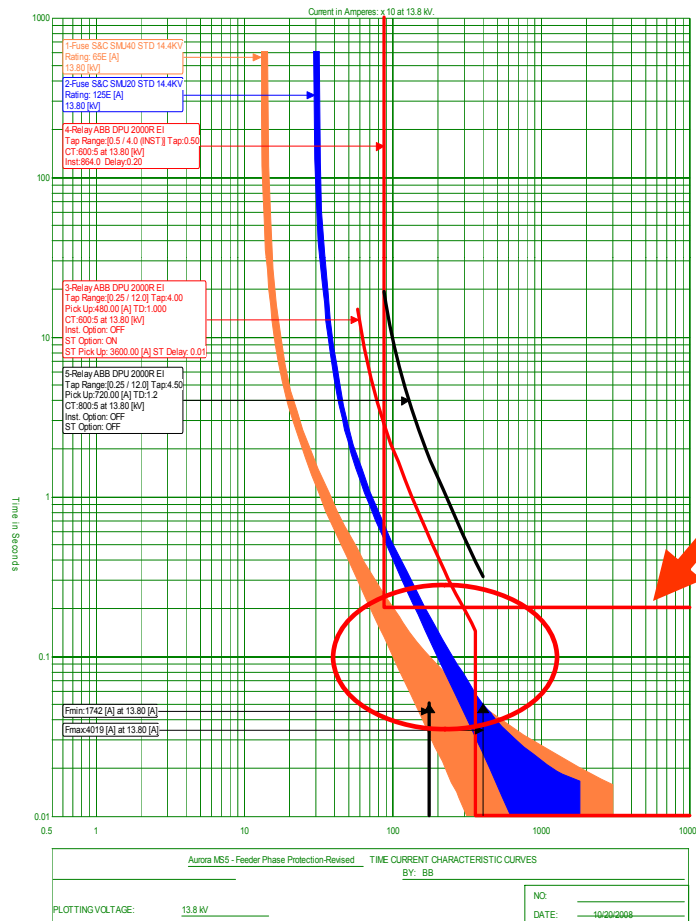
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Low Set Instantaneous (50b) Phase Pick-up



- Equal or greater than 2 times maximum load
 - Max load = 400A
- Less than 0.5 feeder end \emptyset - \emptyset fault level
 - Feeder end fault level = 1742A.
- Set 50b pick-up = 864A

Low Set Instantaneous (50b) Phase Delay



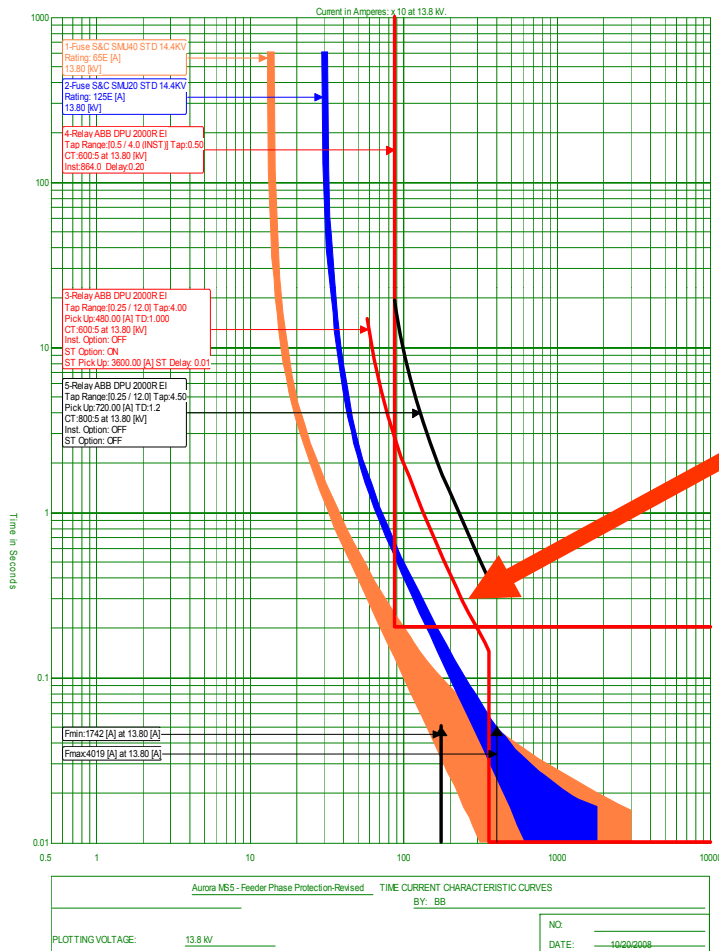
- Setting to permit tapped fuses to clear first for \emptyset - \emptyset fault
- Set 50b delay = 200ms

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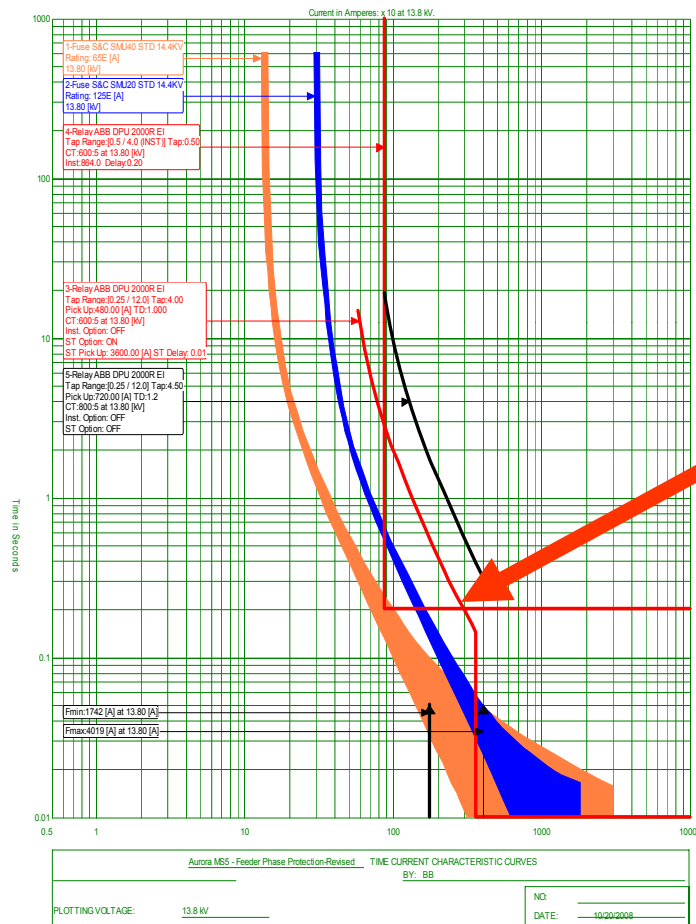
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Timed Overcurrent (51) Phase Pick-up & Curve Shape

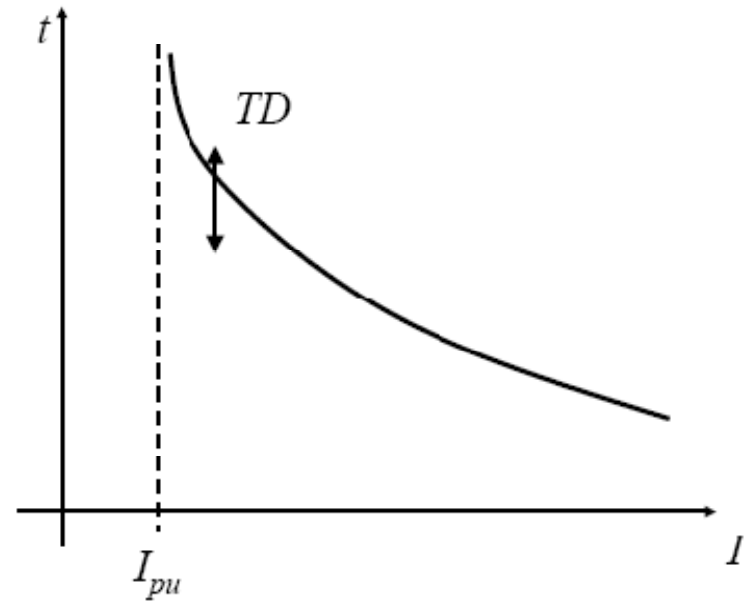


- Pick-up:
 - $\leq 0.5 \times 1742\text{A}$ (min \emptyset - \emptyset fault)
 - $\leq 0.8 \times 720\text{A}$ (Bus bu pu)
 - $\geq 2.0 \times \approx 200\text{A}$ (max load)
 - = 480 Amps
- Curve Shape
 - Match fuse curve
 - Select Extremely Inverse (EI)

Phase Time Dial Setting



Time Dial Setting



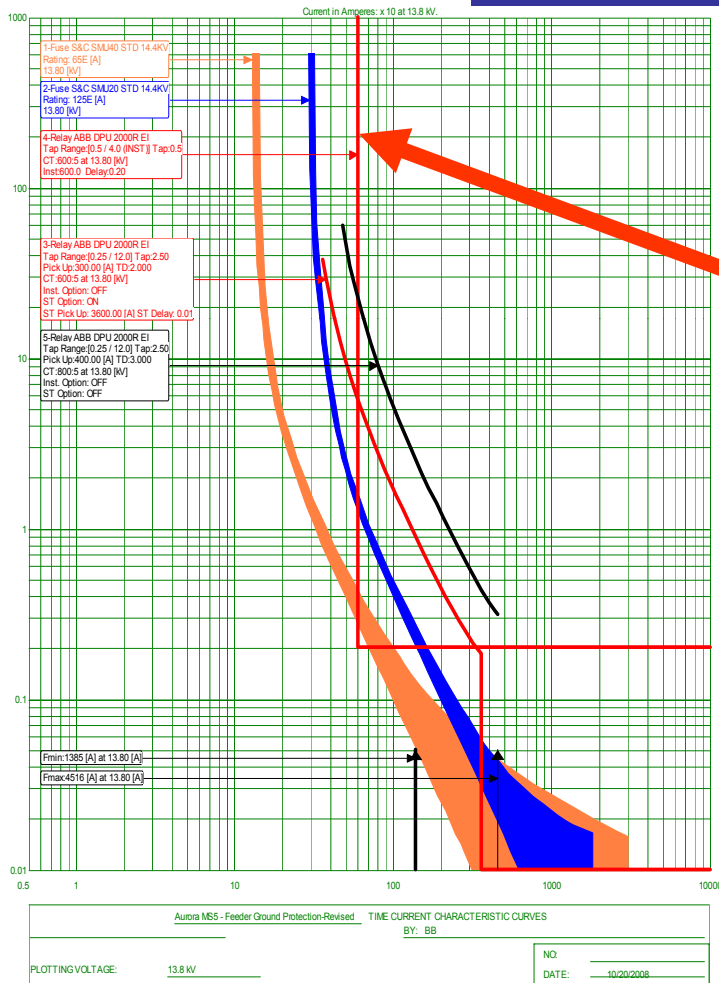
$$T_p = TD \cdot \left(0.0352 + \frac{5.67}{(M^2 - 1)} \right)$$

Time Dial Setting Calculation

- $I_{\text{Fault}} = 2000 \text{ Amp}$
- $I_{\text{Pick up}} = 480 \text{ Amp}$
- $M^2 = (2000/480)^2$
 $= 17.36$
- $T_{\text{Pick up}} = 0.4 \text{ Sec.}$
- $TD = 1.04$

$$T_p = TD \cdot \left(0.0352 + \frac{5.67}{(M^2 - 1)} \right)$$

Low Set Instantaneous (50Nb) Ground Pick-up



- Equal or greater than 2 times maximum load unbalance current
 - Max unbalance current = 400A
- Less than 0.5 feeder end \emptyset -G fault level
 - Feeder end fault value = 1385A
- Set 50Nb pick-up = 600A

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