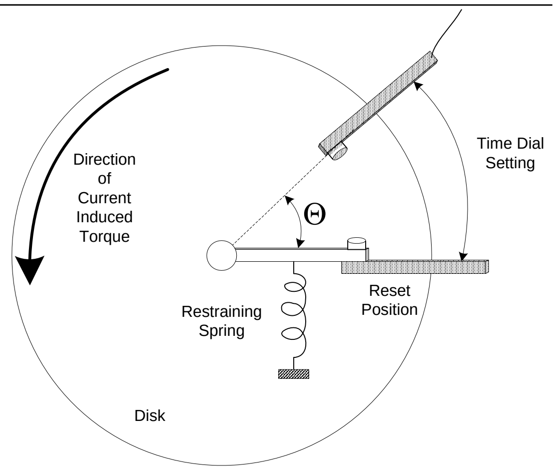
Time Overcurrent Relays

- More or less approximates thermal fuse
  - » Allow coordination with fuses



Basic equation

Operating torque *Restraining Torque*

$$T = \tau_s \left(\left(\frac{I}{I_p} \right)^2 - 1 \right) - K_d \left(\frac{\partial \theta}{\partial t} \right)$$

- τ_s = restraining spring torque
- I = applied current
- I_p = pick up current
- K_d = disk damping factor
- θ = angle of disk rotation (proportional to Time Dial Setting (TDS))

Relay Response

1. Operating torque = Restraining Torque

$$\tau_s\left(\left(\frac{I}{I_p}\right)^2-1\right)= K_d\left(\frac{\partial\theta}{\partial t}\right)$$

2. Integrate w.r.t. Time

$$\theta_2-\theta_1=\frac{\tau_s}{K_d}\left(\left(\frac{I}{I_p}\right)^2-1\right)(t_2-t_1)$$

3. TDS (setting angle), where triptime = t_2 -t_1

$$TDS=\frac{\tau_s}{K_d}\left(\left(\frac{I}{I_p}\right)^2-1\right)(trip\,time)$$

Relay Response

4. Finding trip time

$$(trip\,time)=TDS\frac{\frac{K_d}{\tau_s}}{\left(\left(\frac{I}{I_p}\right)^2-1\right)} = TDS\frac{A}{(M^2-1)}$$

Where: $M = I/I_p$

$A = K_d/t_s$

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Standard Curves -- standard formats

Reset Time (M < 1)

$$tr = TDS\left(\frac{C}{1-M^2}\right)$$

Trip time ($M \geq 1$)

$$tt = TDS\left(\frac{A}{M^p - 1} + B\right)$$

Some manufacturers include disk inertia in B

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US and IEC curve parameters

Curve	A	B	C	P
U.S. Moderately inverse (U1)	0.0104	0.2256	1.08	0.02
U.S. Inverse (U2)	5.95	0.180	5.95	2.00
U.S. Very inverse (U3)	3.88	0.0963	3.88	2.00
U.S. Extremely inverse (U4)	5.67	0352	5.67	2.00
U.S. Short-time inverse (U5)	0.00342	0.00262	0.323	0.02
I.E.C. Class A - Standard inverse (C1)	0.14	0.0	13.5	0.02
I.E.C. Class B – Very inverse (C2)	13.5	0.0	47.3	2.00
I.E.C. Class C – Extremely inverse (C3)	80.0	0.0	80.0	2.00
I.E.C Long-time inverse (C4)	120.0	0.0	120.0	2.00
I.E.C Short-time inverse (C5)	0.05	0.0	4.85	0.04

US Inverse (U2) Characteristic

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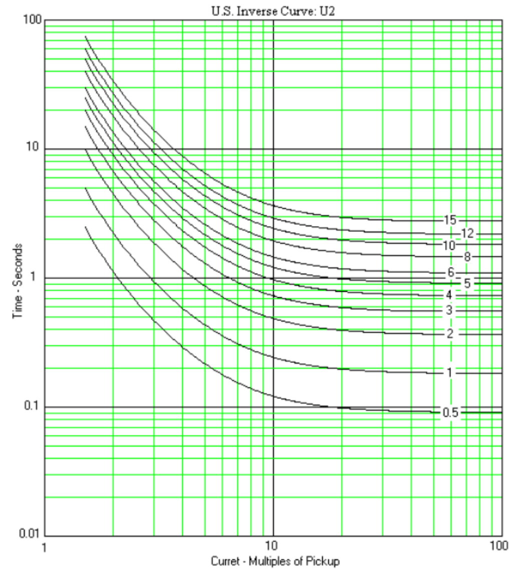

Comparison of curves

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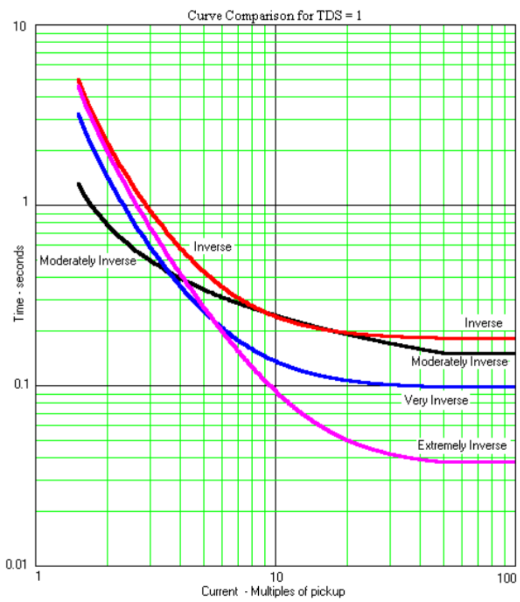
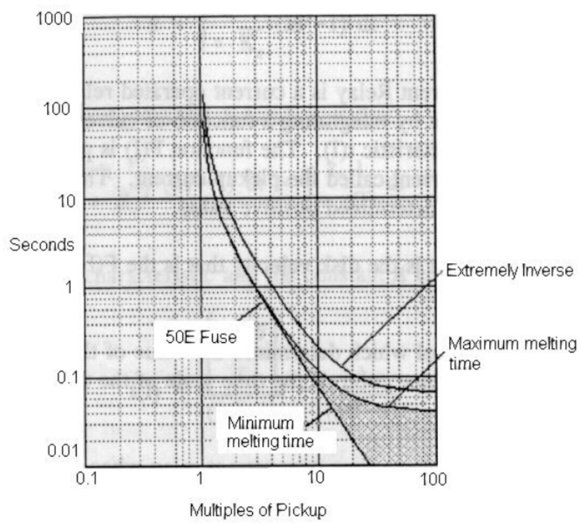
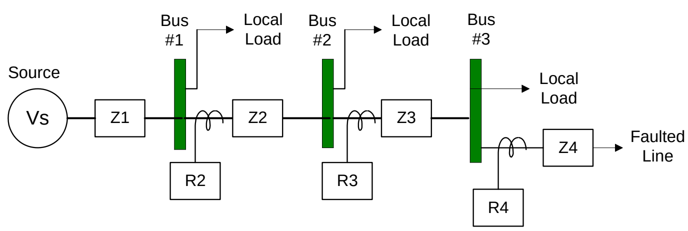


Extremely Inverse Curve and 50E fuse



Example



- Want the relay on the faulted line, R4, to be the only relay to trip
- Max and min fault current (based on ends of faulted line)

$$I_{f3phmax} = {V_s}/{Z1 + Z2 + Z3} \qquad I_{f3phmin} = {V_s}/{Z1 + Z2 + Z3 + Z4}$$

Example continued

- The desired coordination can be accomplished by: increasing the time dial settings as one proceeds toward the source.

» If relay R2 is expected to provide backup protection for relay R4,

  » Then R4, the relay with the greatest source impedance, would be set with the lowest time dial setting

Example continued

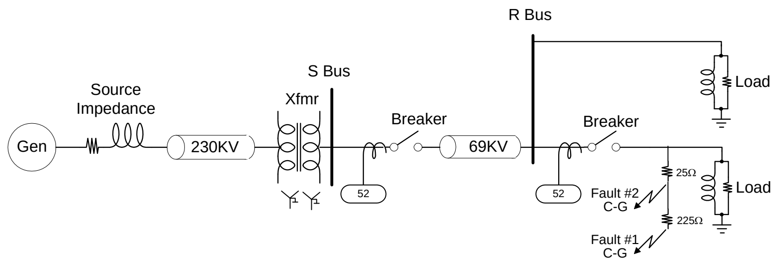
» If I_{MIN} is defined as the minimum fault current,

  » Then the pickup current must be set at or below this current but above maximum load current.

  » Usually with a margin around both

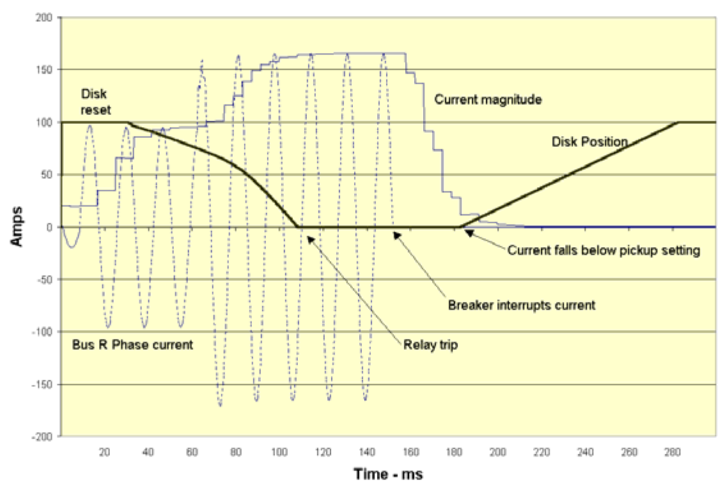
» For relays R2 and R3, the TDS must be set to trip no faster then the next downstream device when the fault current is maximum for an out of zone fault

EMTP relay simulation



250Ω resistive fault is initiated at 8.3 ms and progresses to a 25Ω fault at 62 ms as can occur by a tree branch coming in contact with the wire.

Example with a trip



Comparing relay coordination (light load)

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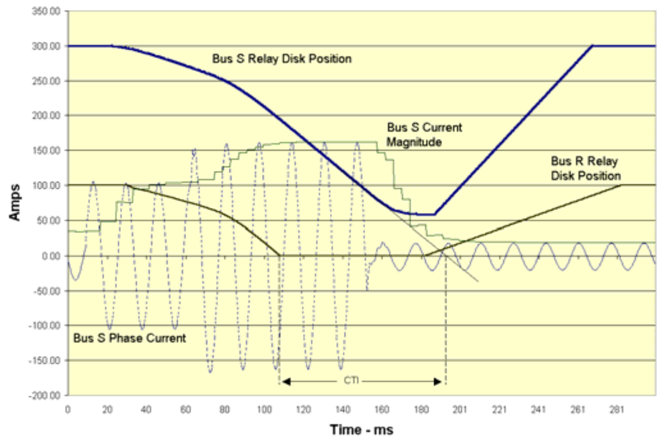

Comparing relay coordination (heavy load)

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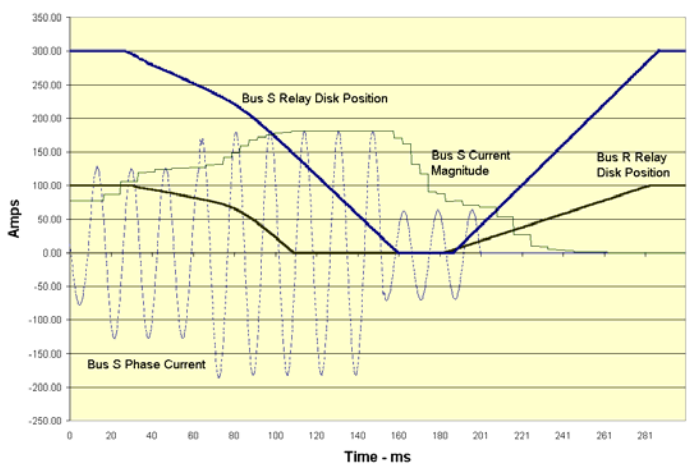

Directional Control vs Direction Supervision

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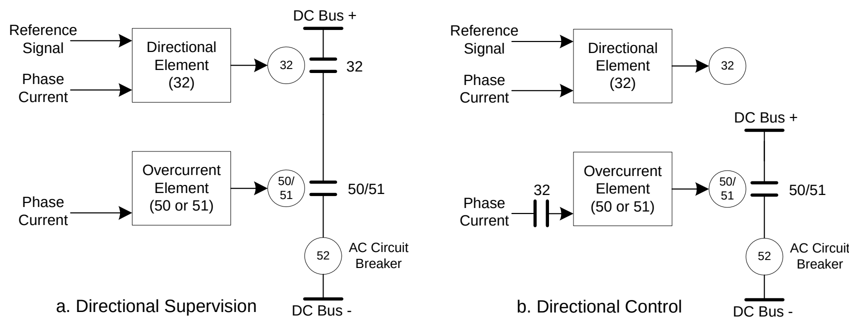

Directional Step-Time Overcurrent (ANSI 67)

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- The directional overcurrent relay can be perceived as a type 50 instantaneous element controlled by a type 32 directional element
- If the type 67 relay element is to provide backup protection, they use definite time delay for downstream coordination
- The 67 element requires more attention to detail for coordination than do type 51 relays
  - » The advantage that the stepped time has over the 51 is that the time steps are independently set**.**
  - » The disadvantage is that overreach errors have a more pronounced affect that often proves difficult to coordinate

Directional Step-Time Overcurrent (ANSI 67)

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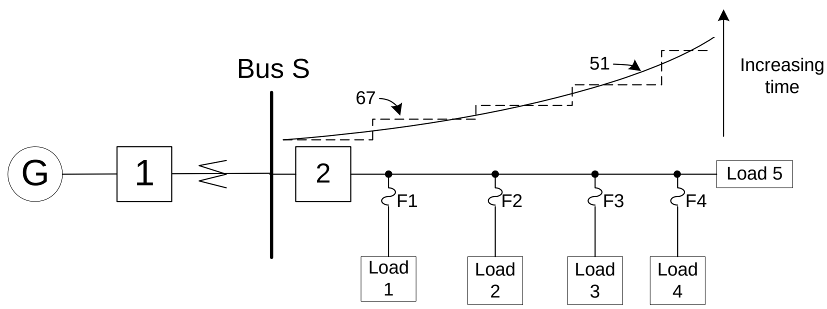

Overcurrent Elements in Microprocessor Relays

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- Expect the relay to be able to coordinate with fuses and electromechanical relays
- Implement relay function using the standard curve equations
- Use digital filters to compute RMS magnitude from measured currents
- Add directional supervision
- Take advantage of some calculations difficult to do without microprocessor