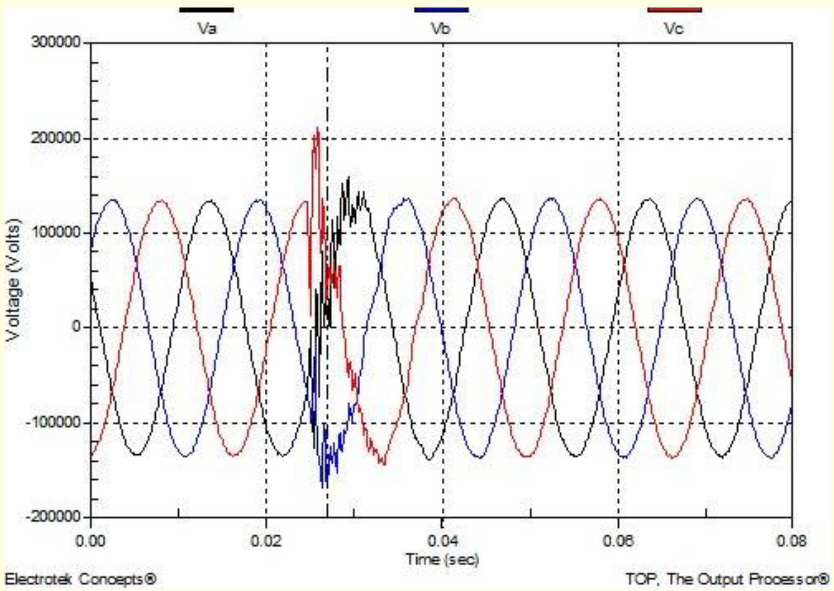
EE 741
Over-voltage and Over-current Protection

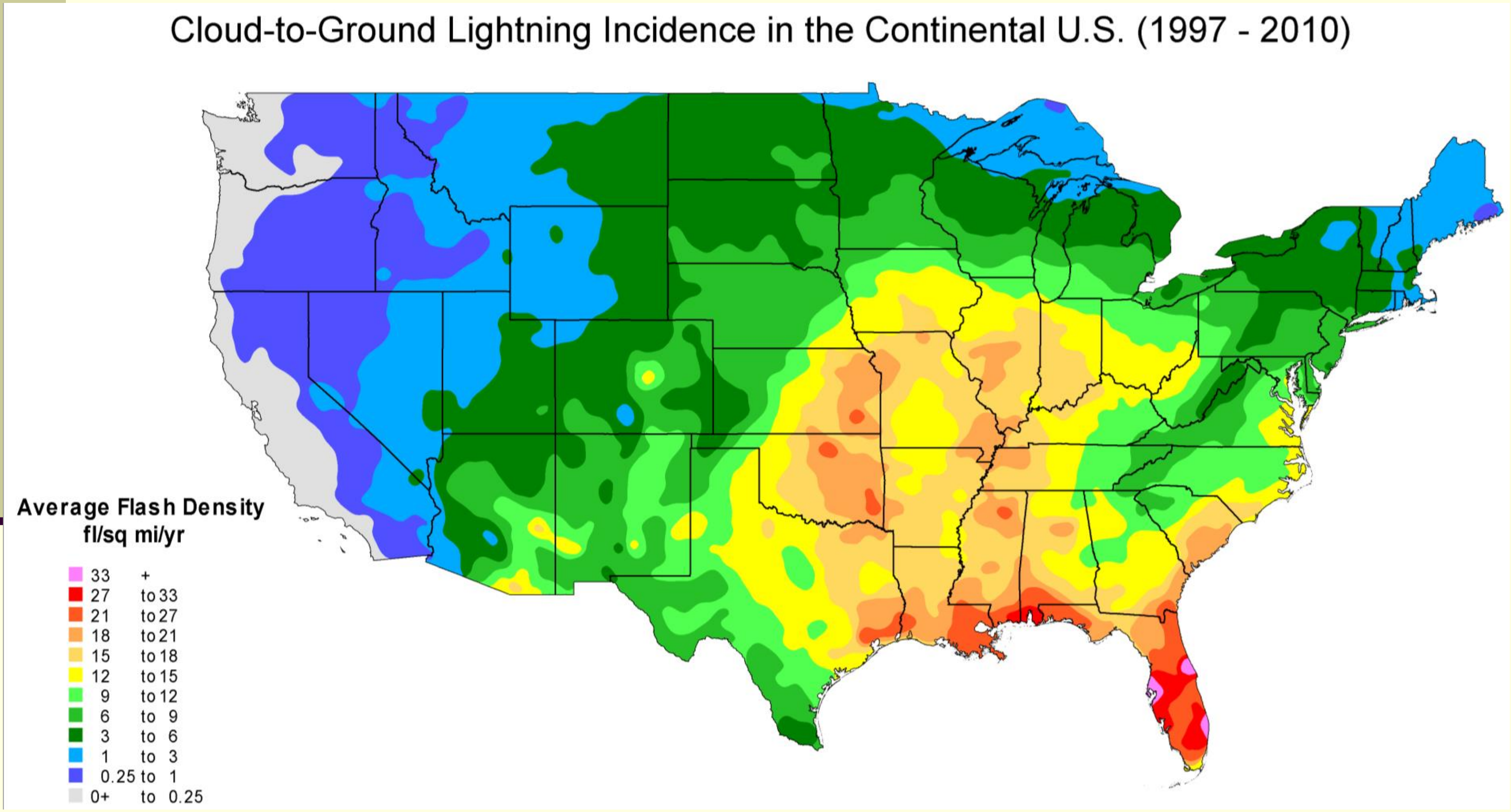
Spring 2014

Causes of Over-voltages

- Lightning
- Capacitor switching
- Faults (where interruption occurs prior to zero current crossing)
- Accidental contact with higher voltage systems



Ground Flash Density in US

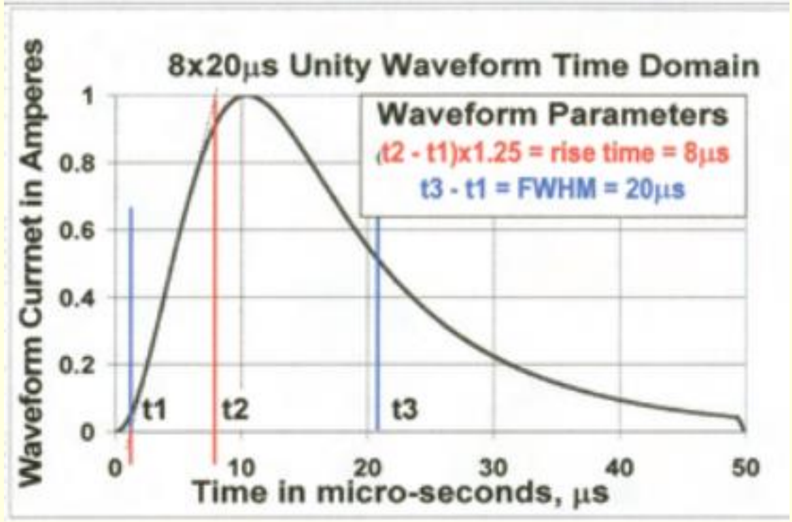


Lightening Time Duration

- Usually less that a couple of hundred micro-seconds.
- Statistical Distribution of stroke duration reported by the industry.

Single Stroke Duration (µs)	Percent
> 20	96
> 40	57
> 60	14
> 80	5
Average time = 43 microseconds	

- Reasonable approximation of lighting surge (8x20)



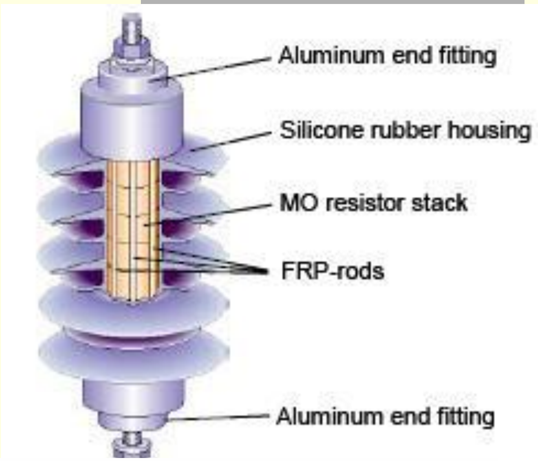
Current Magnitude, Rate of Rise, Polarity

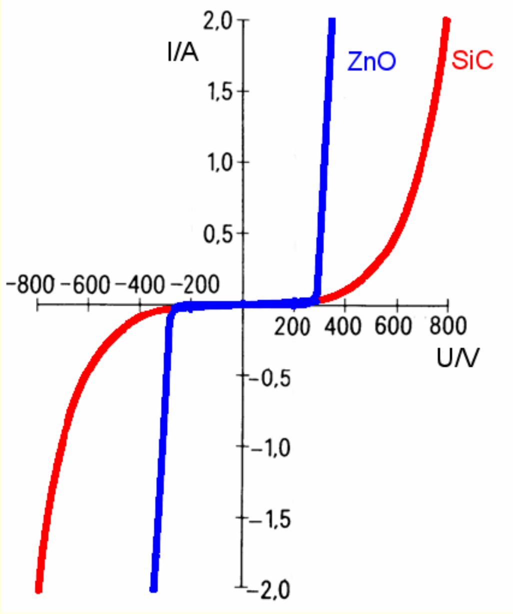
- Typical magnitudes of stroke currents fall into the following range: →
- Rate of rise: higher than 10 kA/μs over 50% of the time.
- Multiple strokes (from 2 to 40). 50% of direct strokes have at least 3 components.
- Cloud charge (-), earth's charge (+) in 90% of recorded measurements.

Range of Stroke Currents
5% exceeded 90,000 amperes
10% exceeded 75,000 amperes
20% exceeded 60,000 amperes
50% exceeded 45,000 amperes
70% exceeded 30,000 amperes

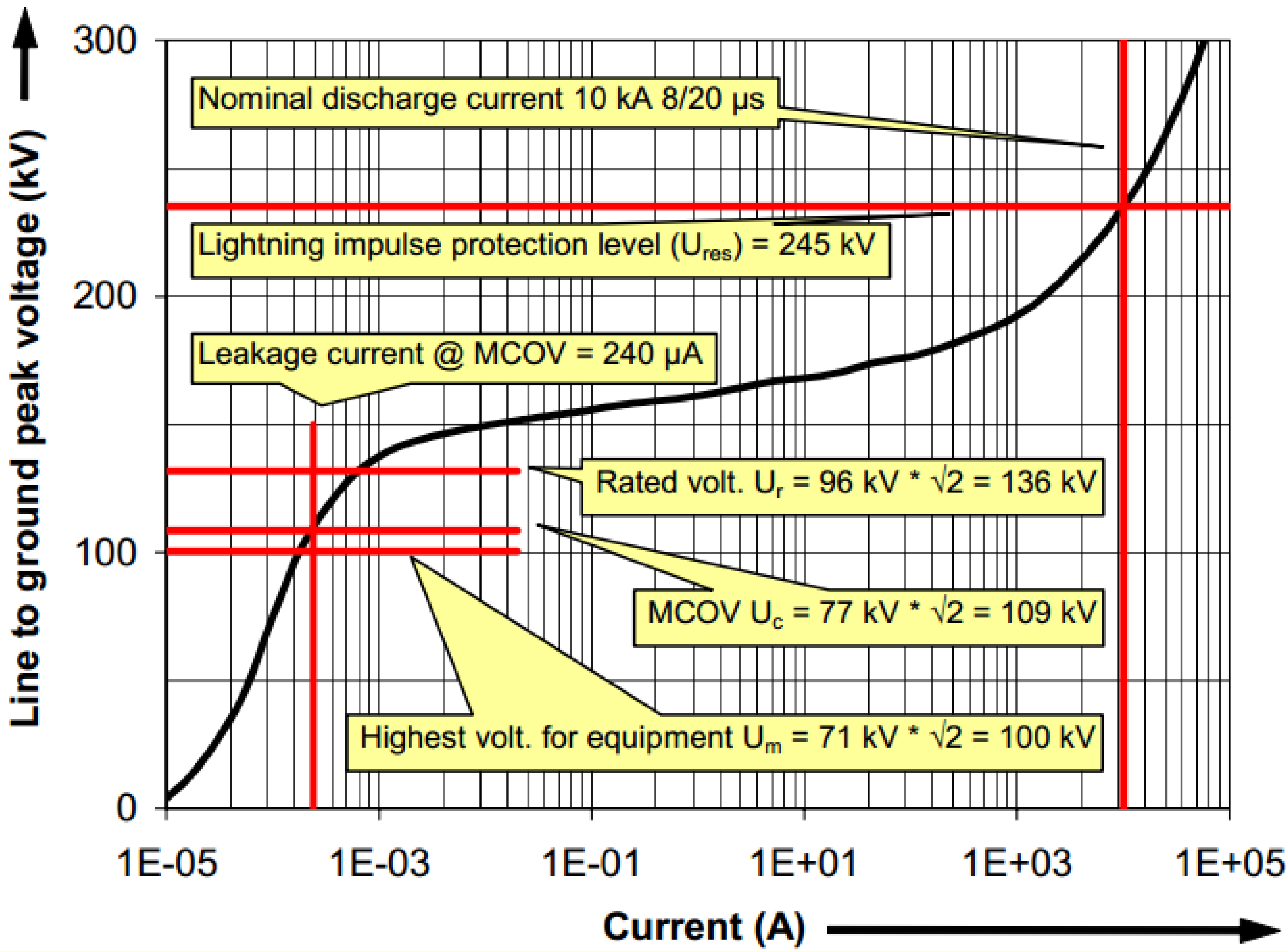
MOV Arrestors

- An MOV is a non-linear resistor whose function is to clamp the voltage (or divert the transient over-voltages) below the basic insulation level (BIL) of the apparatus it is protecting.
- The MOV contains a ceramic mass of zinc oxide grains, in a matrix of other metal oxides (such as small amounts of bismuth, cobalt, manganese) sandwiched between metal blocks.

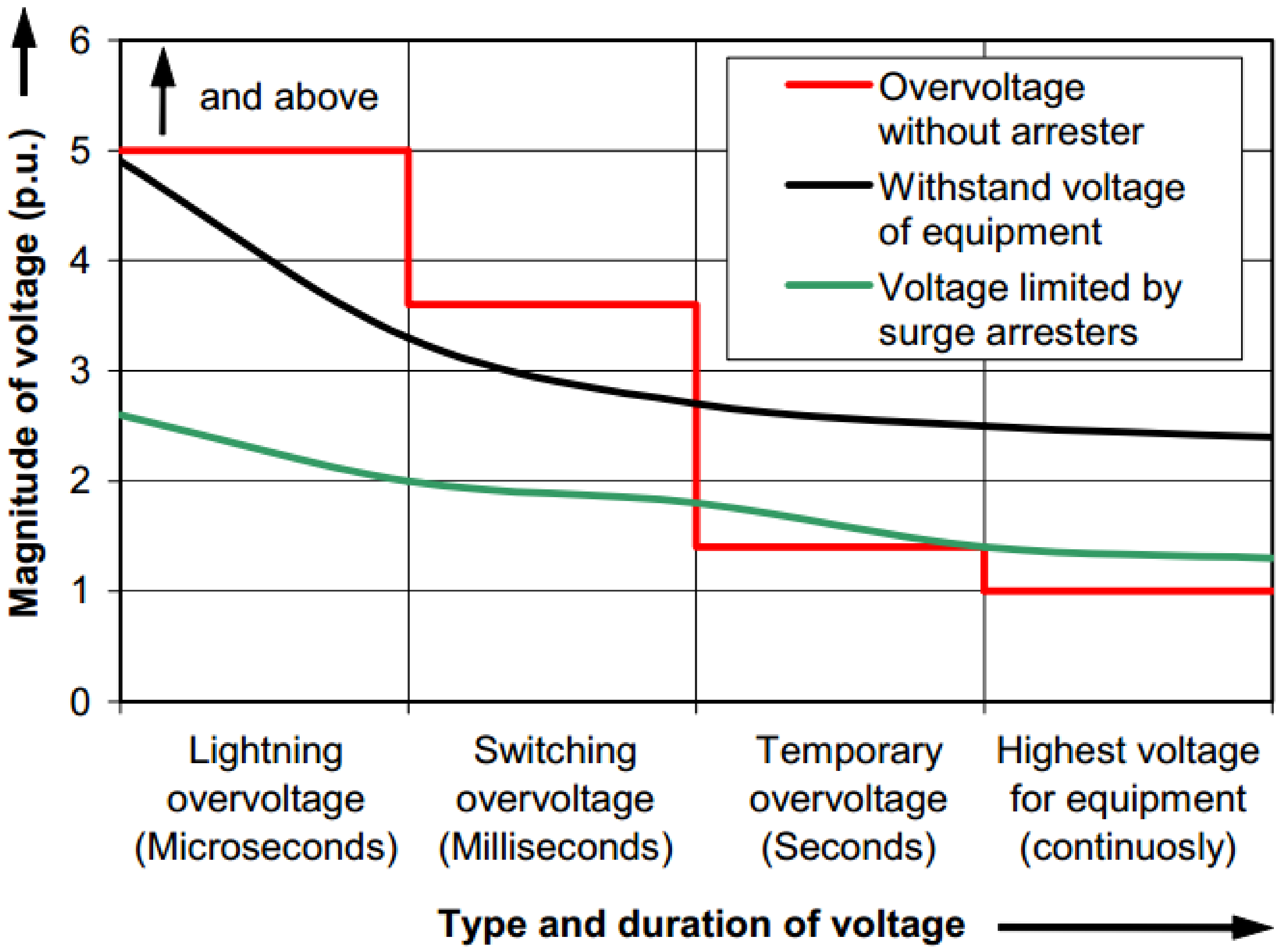




Nonlinear V-I characteristic of MO surge arrester
Rating for nominal system voltage 110 kV

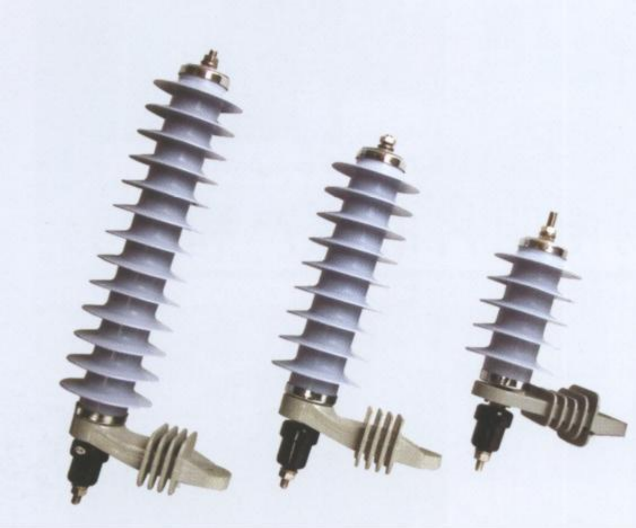


Voltages in Electric Power Systems
Voltage Limiting Effect of Surge Arresters



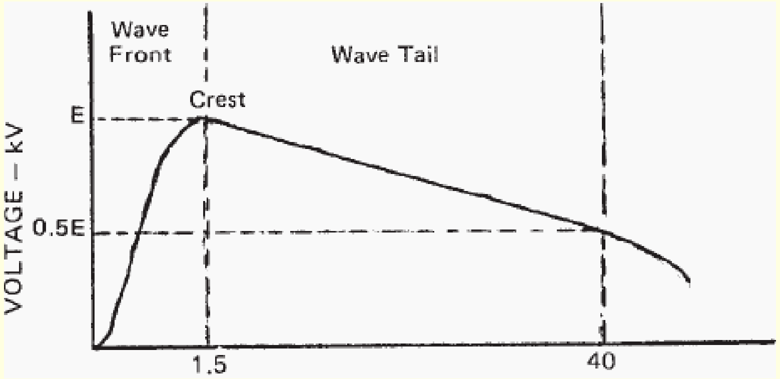
Arrestor Class and Selection

- There are 3 classes of arrestors: **distribution, intermediate, and station**. A larger block reduces the IR discharge voltage and greatly increases energy capability.
- Proper selection of an MOV requires knowledge of the system's Maximum Continuous Operating Voltage (MCOV), and the magnitude and duration of the Transient Over-Voltages (TOV) during abnormal operating conditions.
  - These are then compared to the arrestor MCOV and TOV capability.



Example

- A12 kV transformer has the following insulation characteristics: BIL (1.5x40 μs): 95 kV
- A 9 kV arrestor has an IR discharge at 20 kA of 36 kV.
- Insulation margin =100x(95-36)/95 = 62%.
- Recommended minimum protection margin: 20%



Arrester Placement

- Arrestors are place at the terminals of each piece of equipment, at riser poles, and along the feeder.
- Most surges in feeders are induced by nearby lightning strikes (induced voltages are usually less than 300 kV).
- Critical flashover of typical overhead distribution feeders is usually between 100-300 kV. Direct strikes will likely cause flashover.



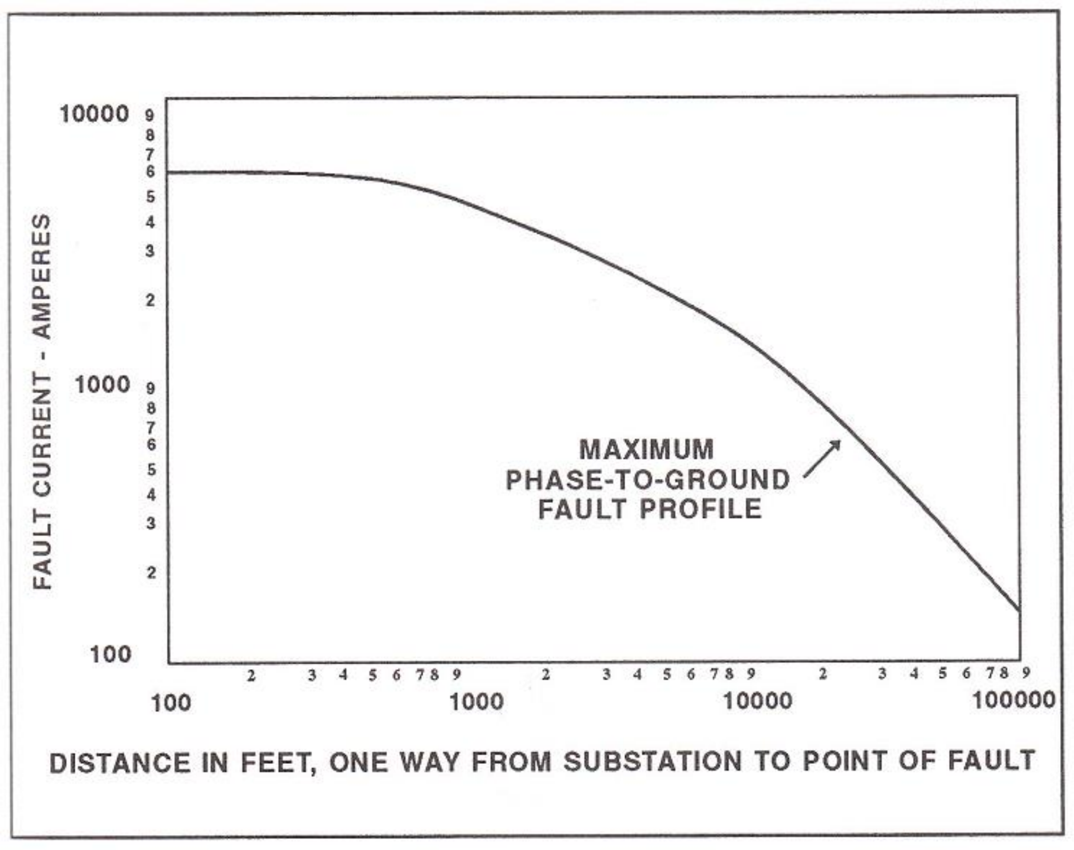

Wire Theft Caught on Camera!

Over-Current Protection

- Fuses
- Relay-controlled circuit breakers
- Automatic circuit reclosers
- Automatic line sectionalizers

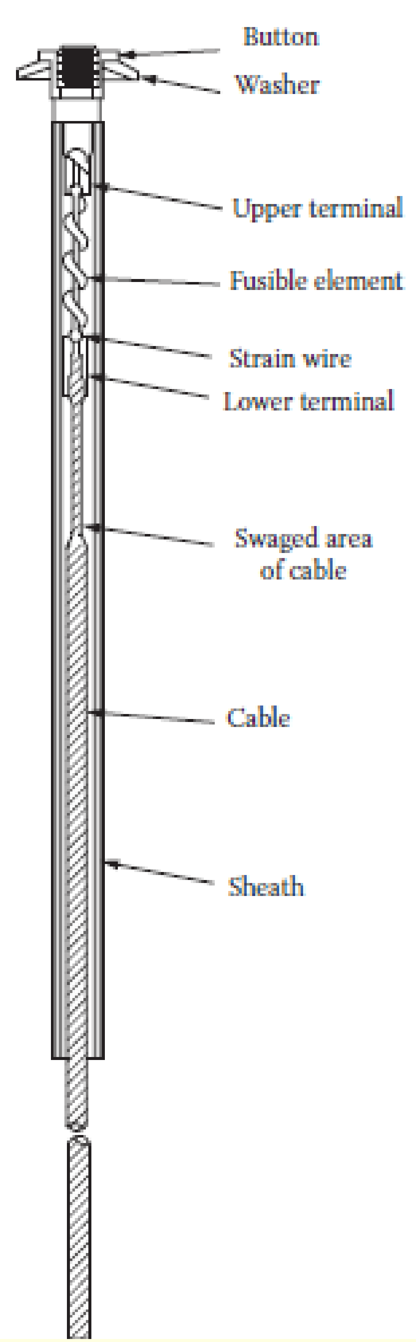
Fault Current on Radial Feeders

- Fault current decreases with distance from the substation.
- Protection of faults far out on the feeder cannot be protected at the substation.



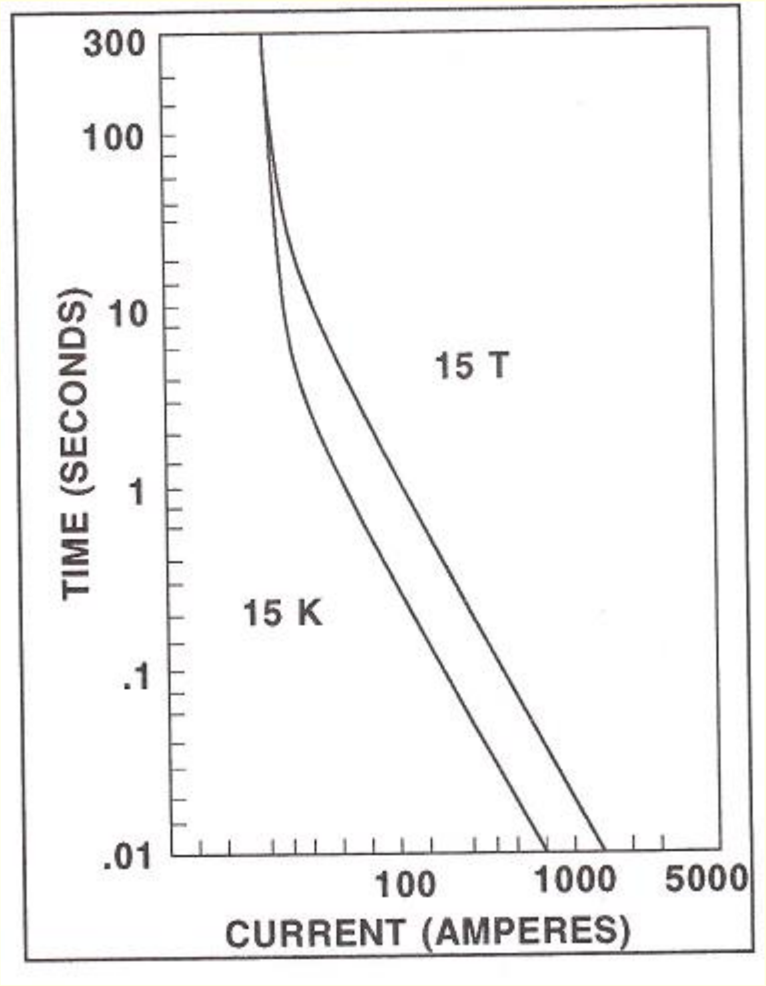
Characteristics of Fuses

- Although a fuse is deceptively simple in appearance, its function is complex.
- The fuse length and diameter are the main determinants of its characteristics.
- For a fuse to function properly, it must sense the condition it is trying to protect, interrupt the fault quickly, and coordinate with other protective devices.
- An expulsion fuse expulses gases during its operation to de-ionize the arc and allows a rapid buildup of dielectric strength to withstand the transient recovery voltage.



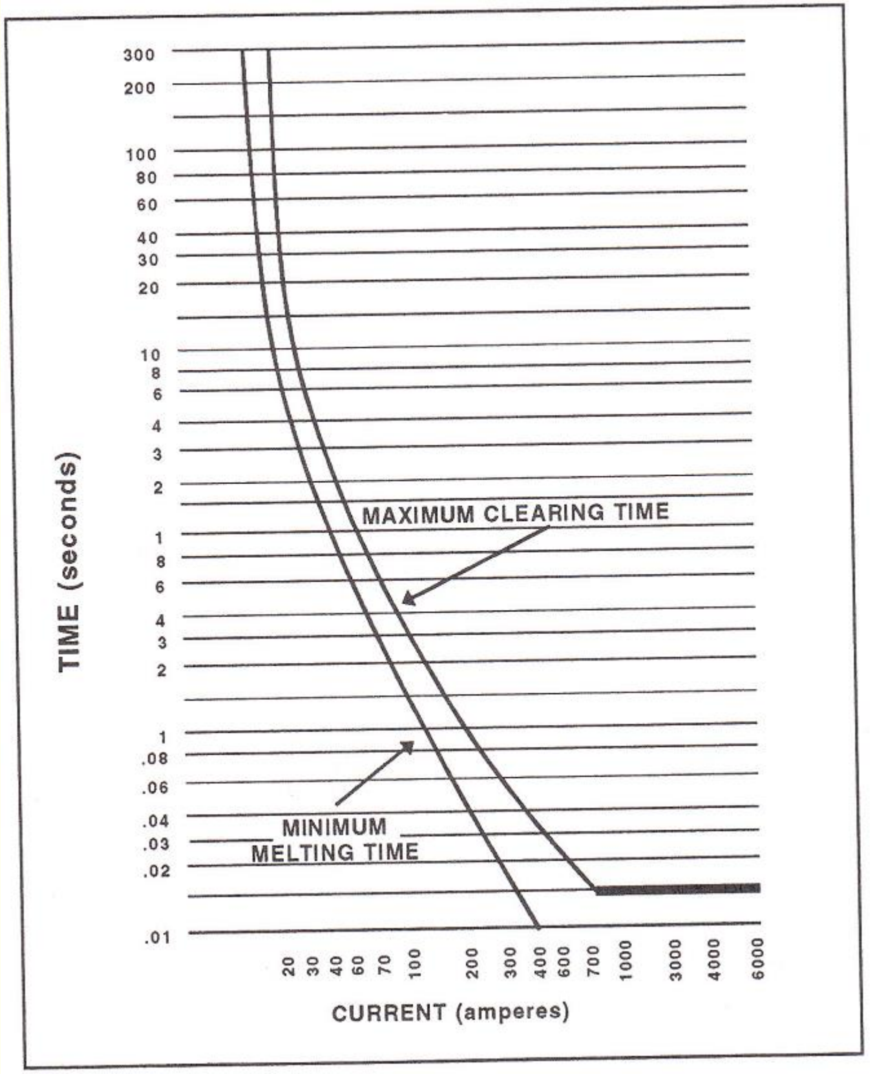
K-Type and T-Type Expulsion Fuses

- Same Time-Current-Curve (TCC) for low currents
- The T link reacts more slowly than the K link at high current.



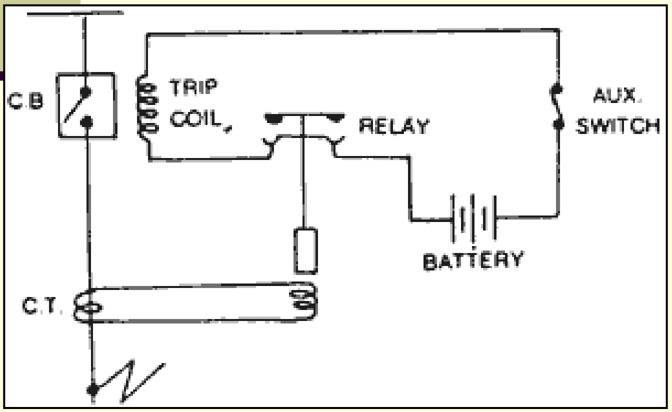
Fuse Characteristic: Minimum Melt Curve and Maximum Clearing Curve

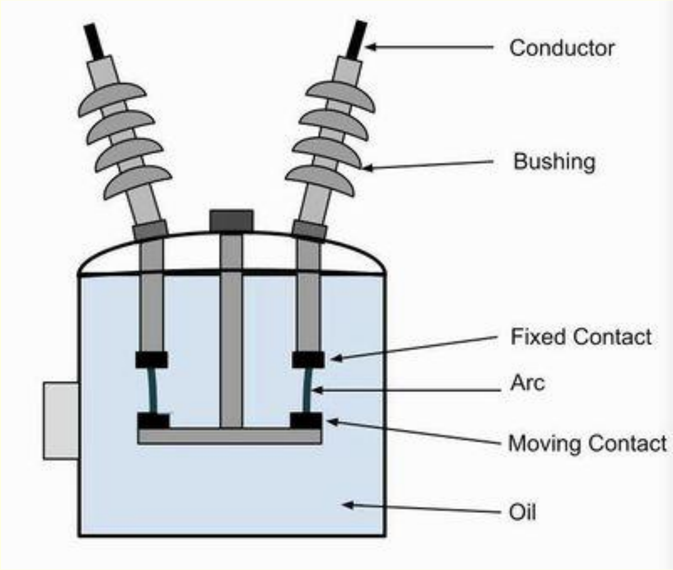
- 10% is subtracted from average melt time, and 10% is added to average clearing time from electrical tests



Over-Current Relay Characteristics

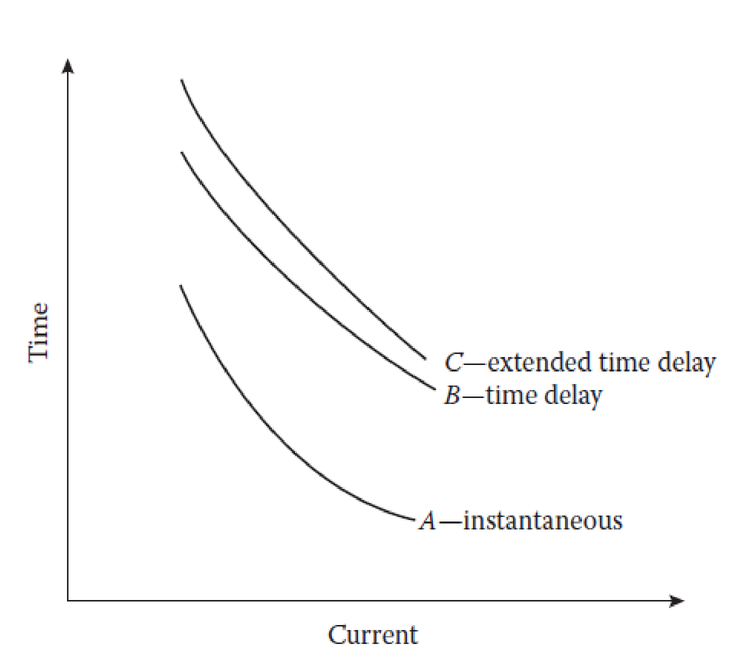
- **Sensitivity**: operate under minimum fault current condition expected,
- **Selectivity**: differentiate between conditions in which immediate action is required to those for which time-delayed action is required.
- **Speed:** ability to operate in the required time period.





Recloser

- Similar to a circuit breaker, the recloser is a self-contained device which can sense and interrupt fault currents as well as re-close automatically in an attempt to re-energize the line.
- A recloser has less current interrupting capability and costs considerably less.
- A recloser utilizes two inverse time curves:
  - Instantaneous curve (to save lateral fuses under temporary fault conditions)
  - Time delay curve (to delay recloser tripping and allow the fuse to blow under permanent fault conditions.

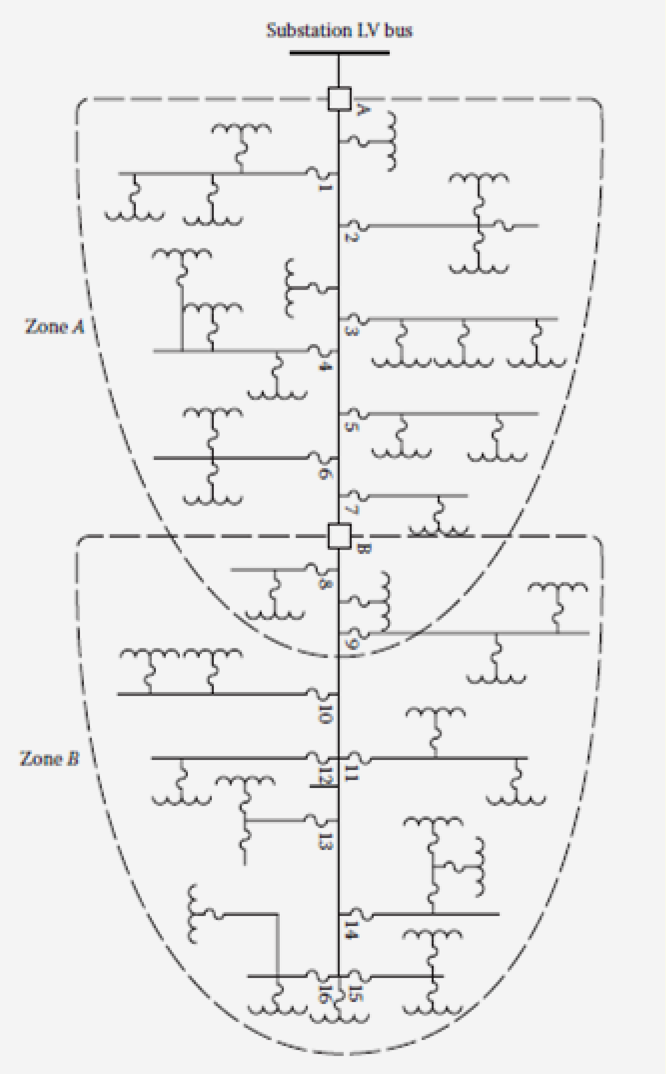


Sectionalizer

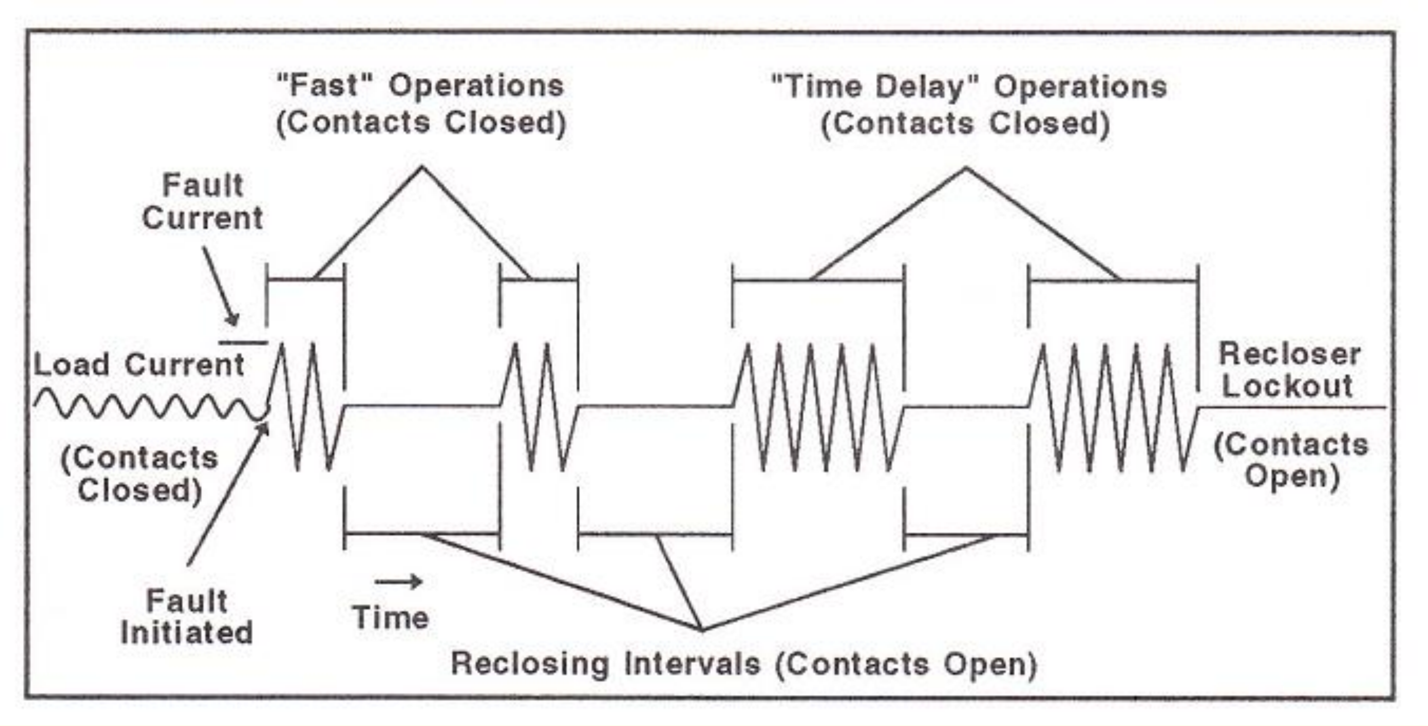
- A sectionalizer is used in juction with a recloser or breaker to isolate faulted sections of lines.
- A sectionalizer does not interrupt fault current. Instead, it counts the number of operations of the reclosing device, and opens when this backup device is open.
- After the sectionalizer opens, the backup device recloses to return power to the unfaulted sections of the line.
- If the fault is temporary, the sectionalizer will reset itself after a prescribed period of time.

Over-Current Protection Device Placement

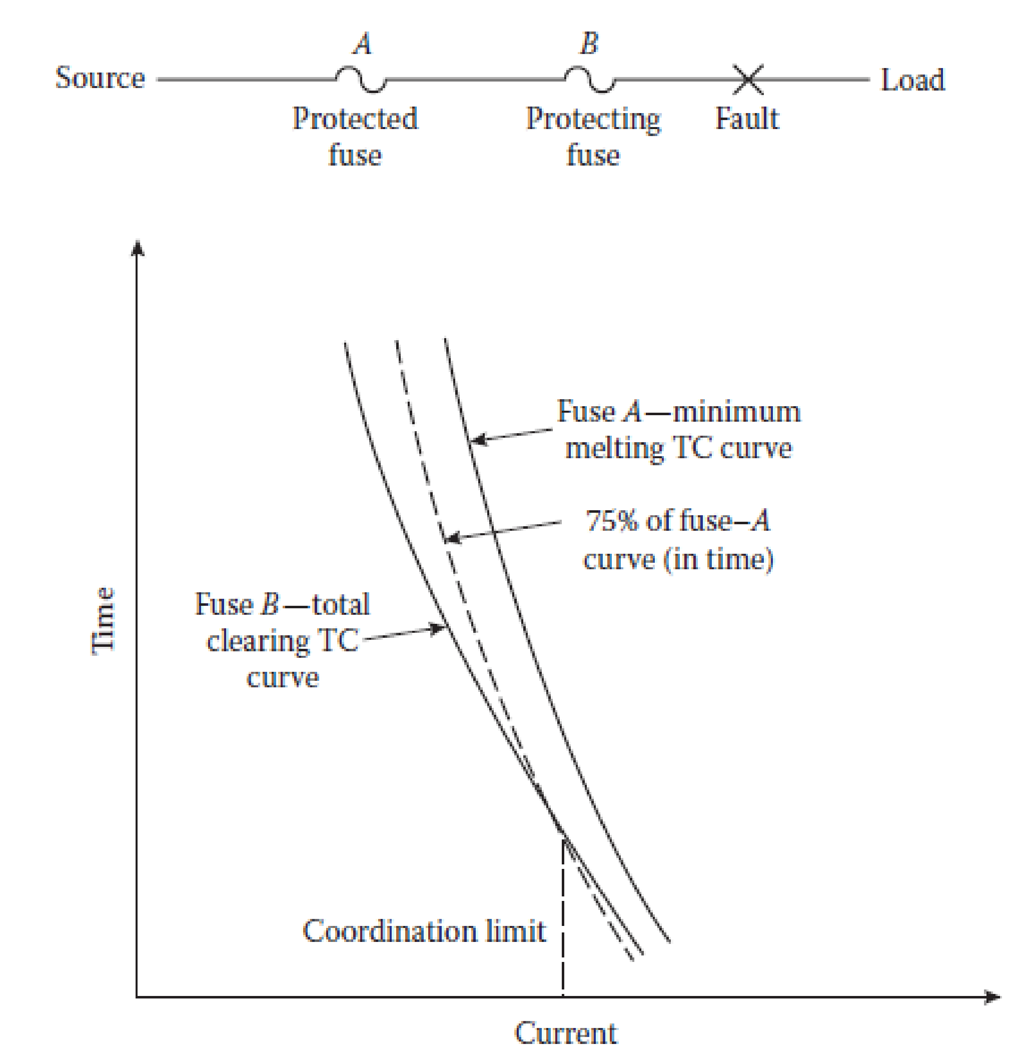
- Fuses and circuit breakers on customer side of meter.
- Fuses at each distribution transformer.
- Fuses at the head of each lateral.
- Circuit breaker at the substation.
- Recloser along the feeder (in case where the protection zone of the station circuit breaker is limited).



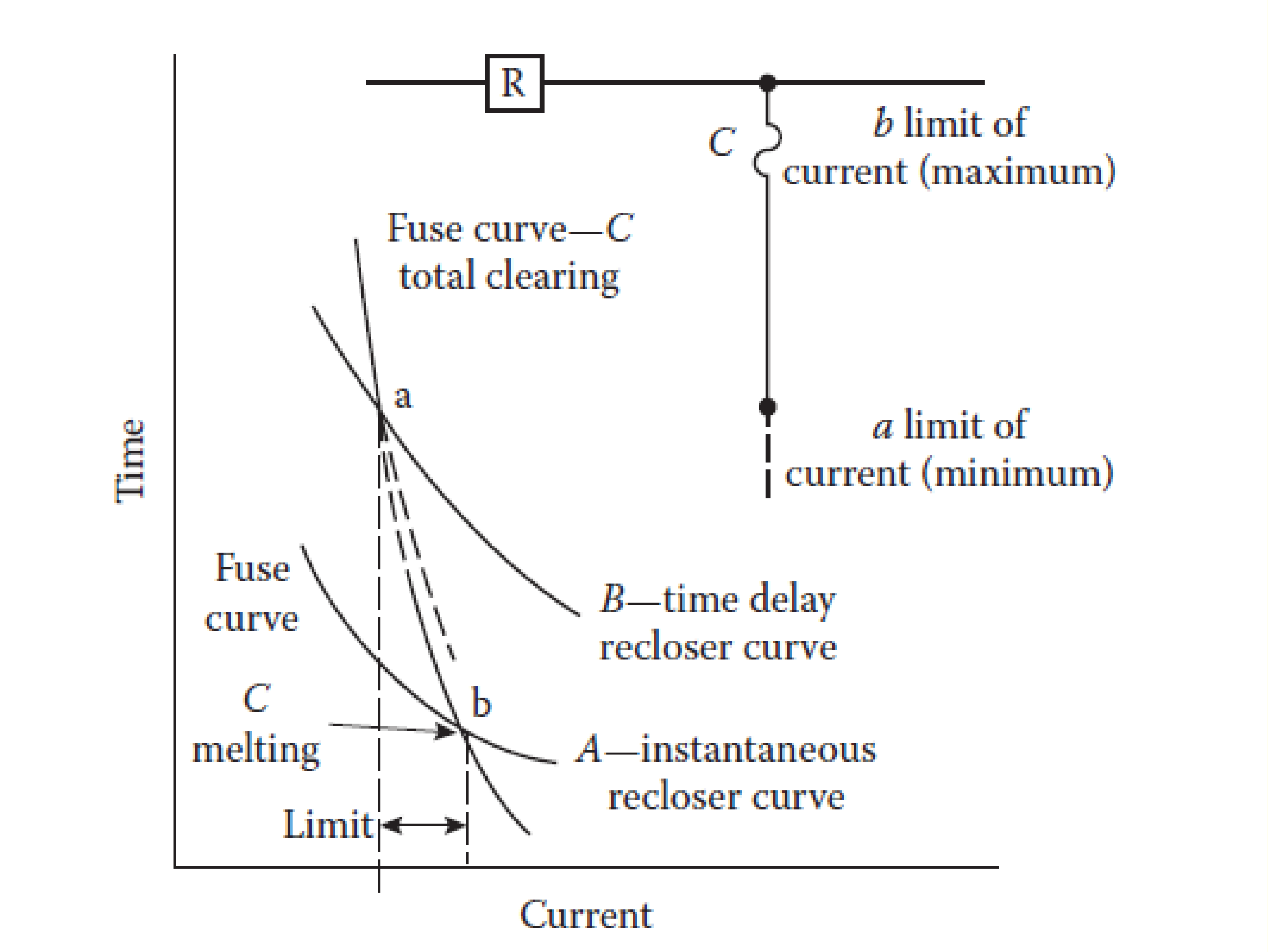
Typical Reclosing Sequence



Coordination: Fuse-to-Fuse



Coordination: Recloser-to-Fuse



Bushings

- a **bushing** is an insulated device that allows an electrical conductor to pass safely through a grounded conducting barrier such as the case of a transformer or circuit breaker.
- Bushings are typically made from porcelain.
- When an energized conductor is near a material at earth potential, it can form very high electric field strengths. The bushing controls the shape and strength of the field and reduces the electrical stresses in the insulating material.
- A typical bushing design has a conductor, surrounded by insulation, except for the terminal ends.

Can you differentiate between the phone/cable lines and power lines in the spider webs below?