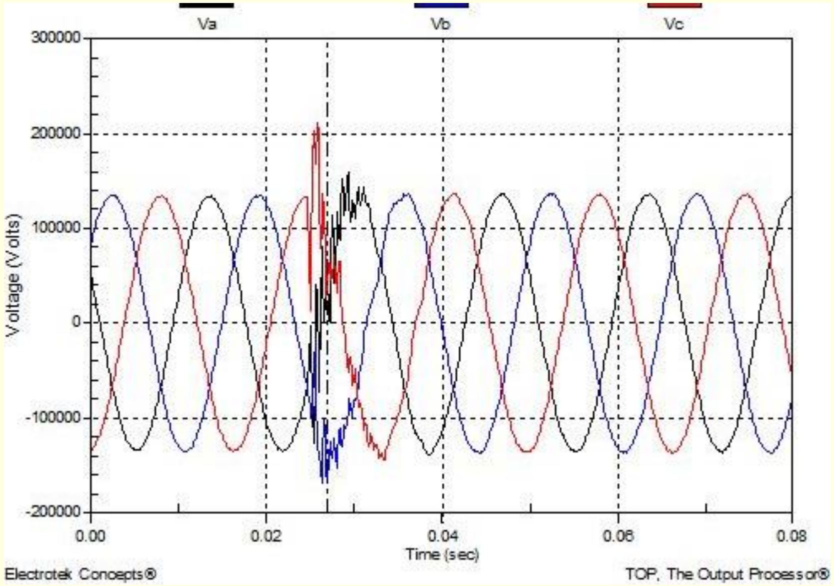
EE 741
Over-voltage and Over-current Protection

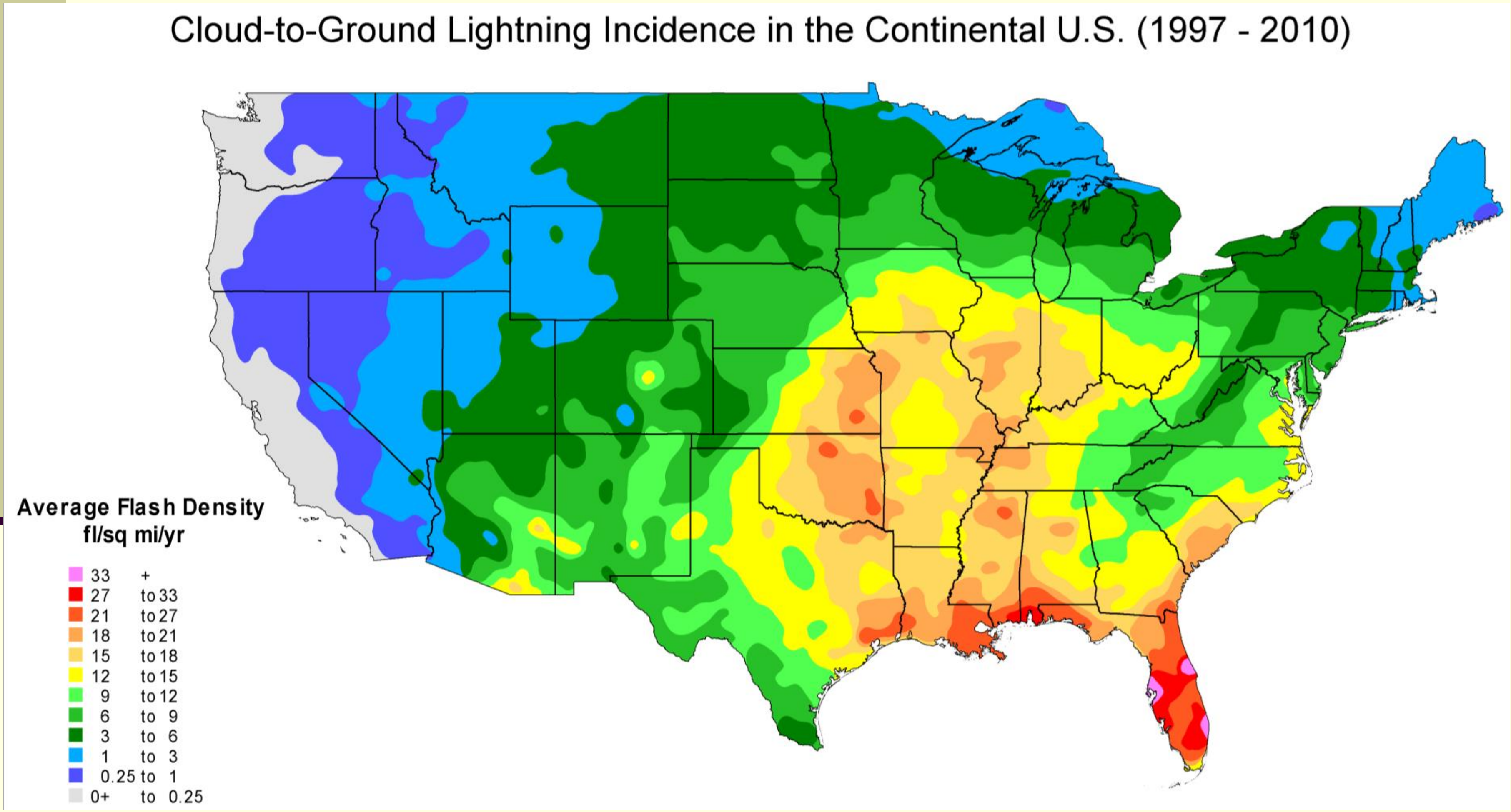
Spring 2014

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

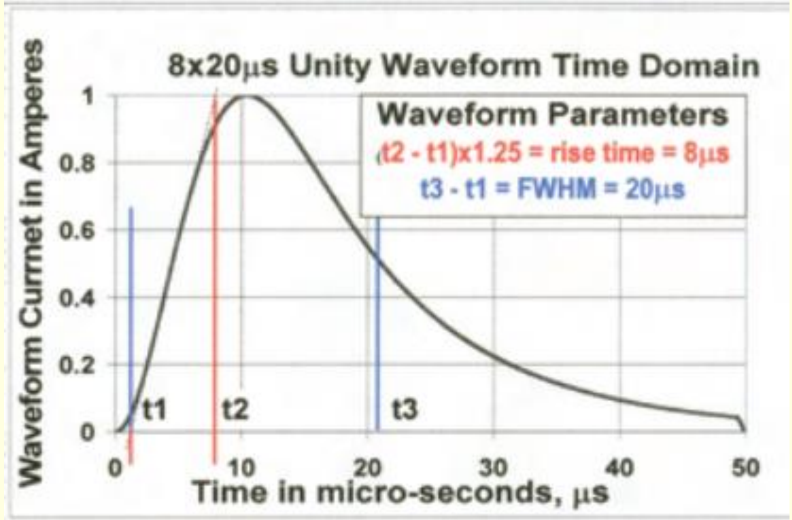


Lightening Time Duration

- 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)



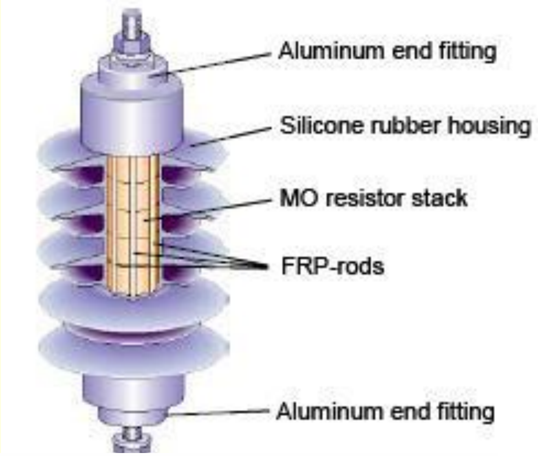
Current Magnitude, Rate of Rise, Polarity

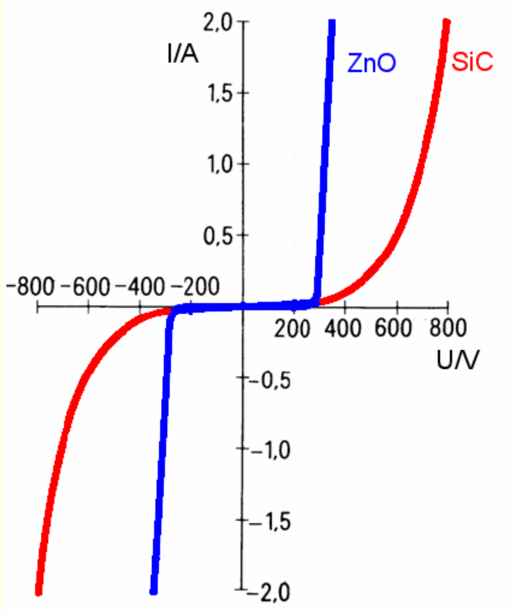
- Typical magnitudes of stroke currents fall into the following range: →
- Rate of rise: higher than 10 kA/µs over 50% of the time.
- Multiple strokes (from 2 to 40). 50% of direct strokes have at least 3 components.
- Cloud charge (-), earth's charge (+) in 90% of recorded measurements.

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

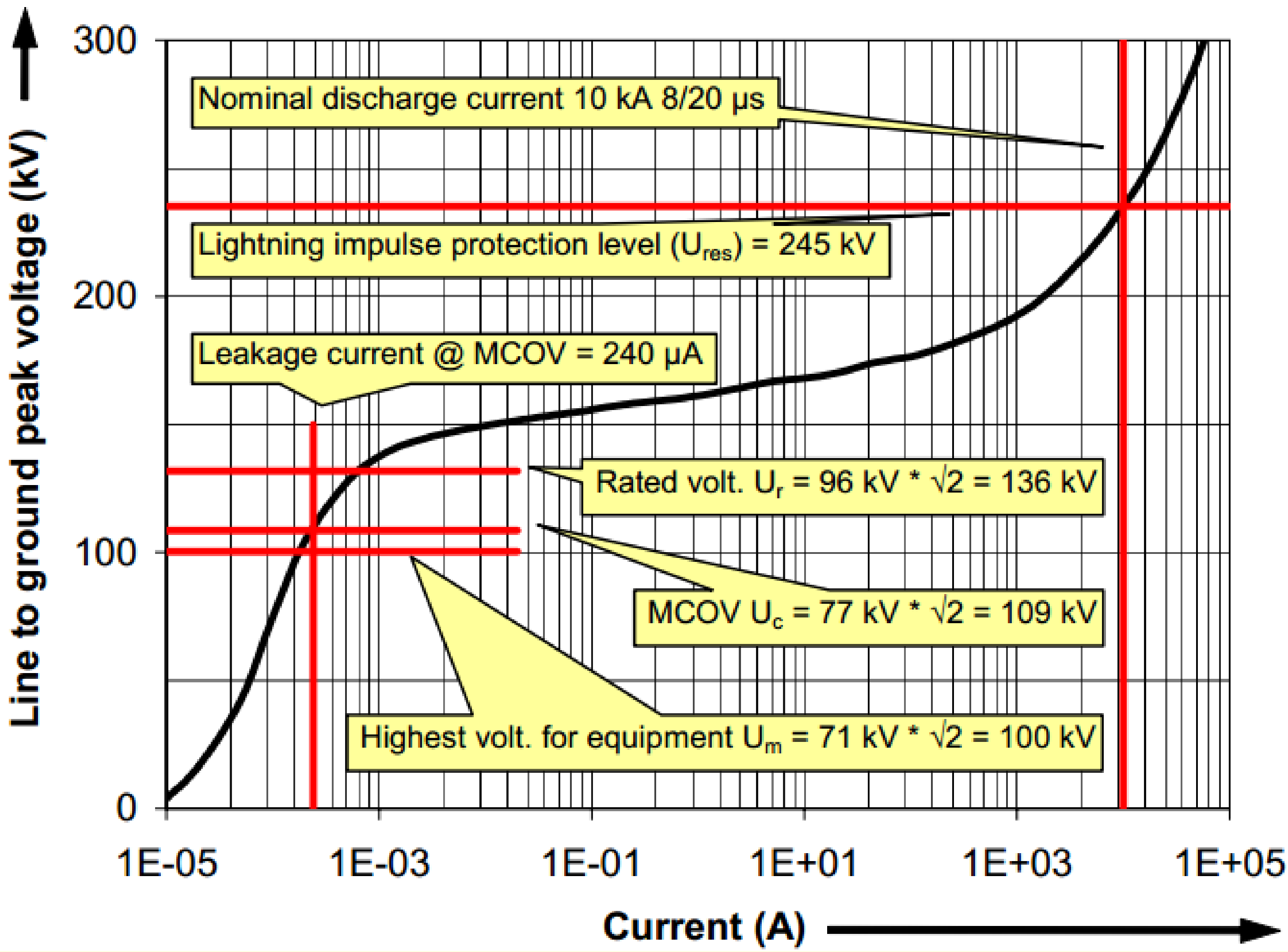
MOV Arrestors

- 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.

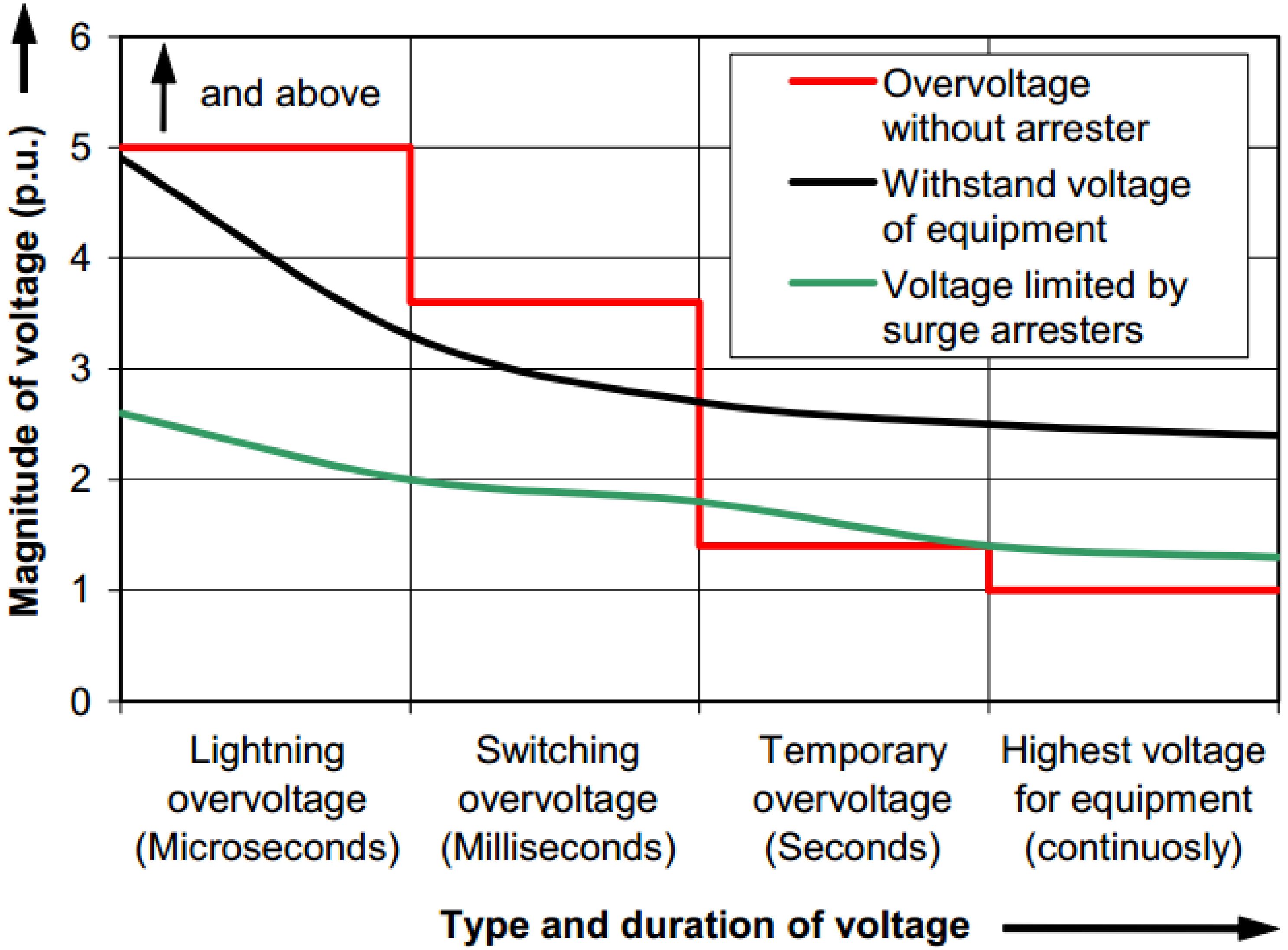




Nonlinear V-I characteristic of MO surge arrester Rating for nominal system voltage 110 kV

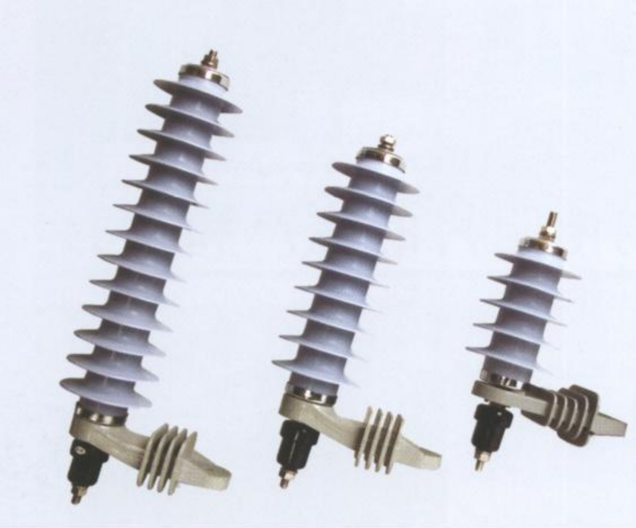


Voltages in Electric Power Systems
Voltage Limiting Effect of Surge Arresters



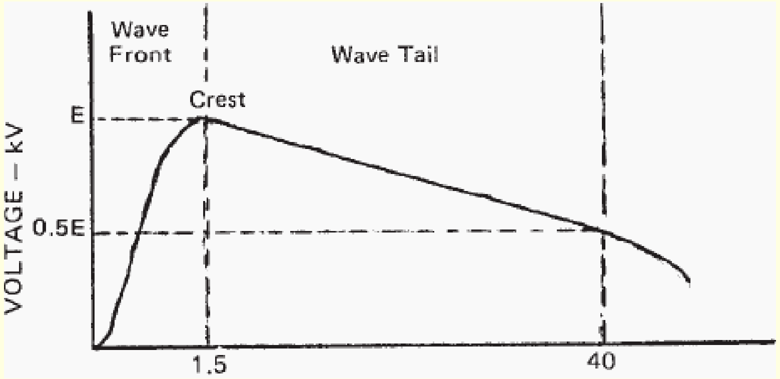
Arrestor Class and Selection

- 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.



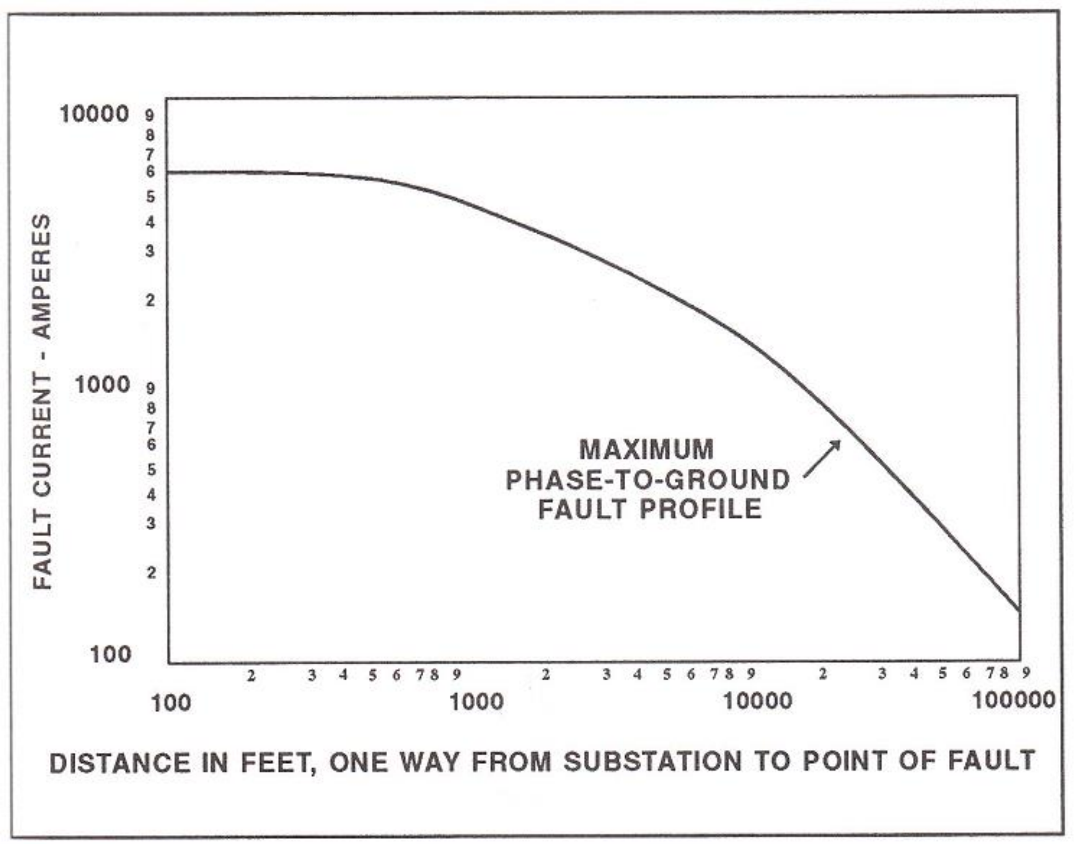

Wire Theft Caught on Camera!

Over-Current Protection

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

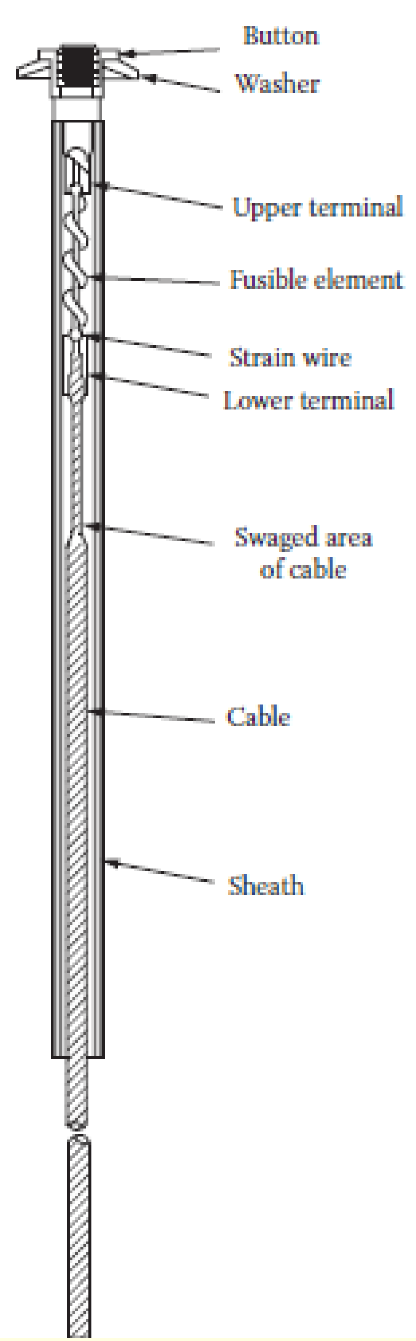
Fault Current on Radial Feeders

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



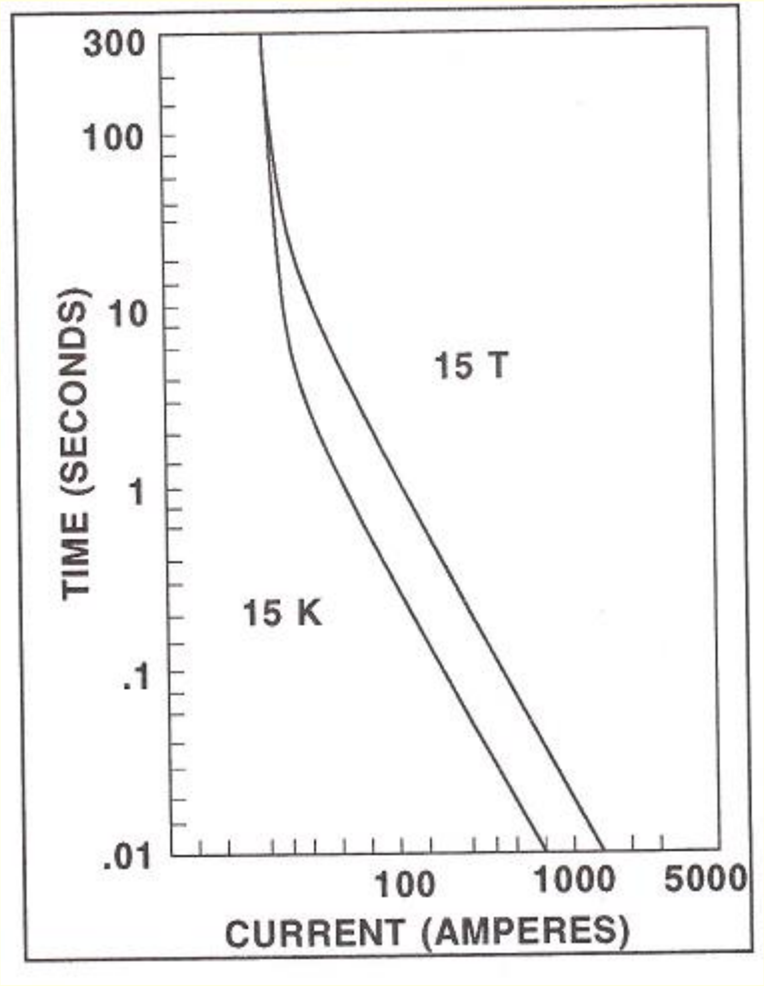
Characteristics of Fuses

- Although a fuse is deceptively simple in appearance, its function is complex.
- The fuse length and diameter are the main determinants of is 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 allow a rapid buildup of dielectric strength to withstand the transient recovery voltage.



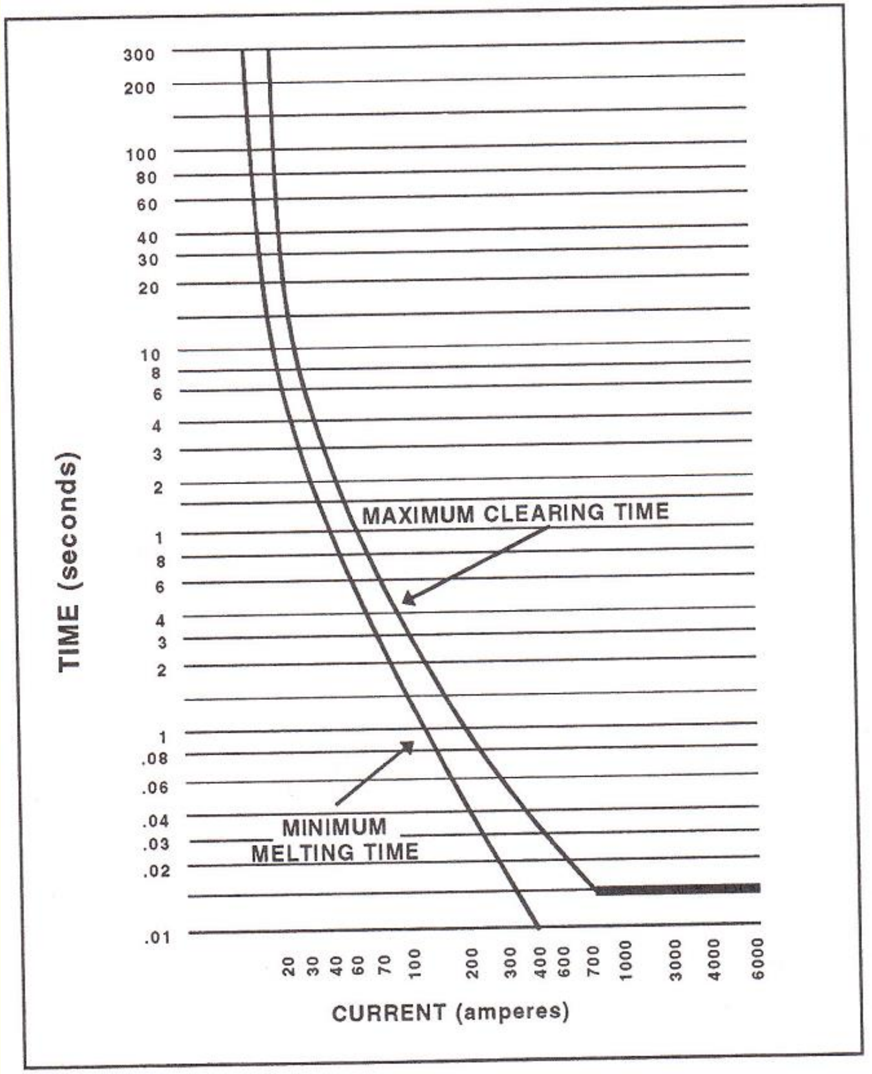
K-Type and T-Type Expulsion Fuses

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



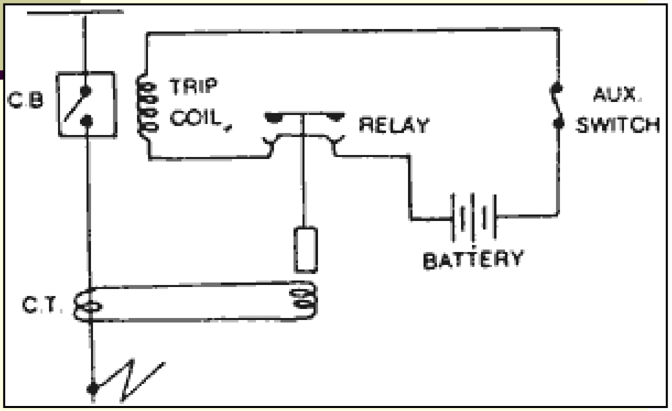
Fuse Characteristic: Minimum Melt Curve and Maximum Clearing Curve

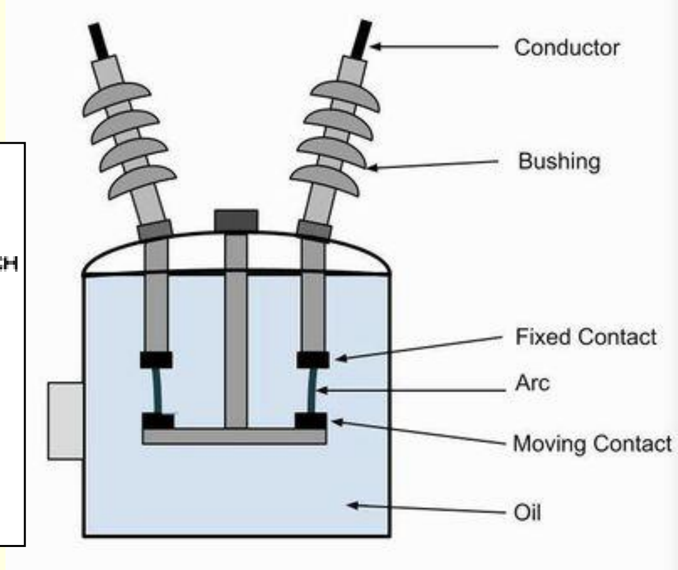
- 10% is subtracted from average melt time, and 10% is added to average clearing time from electrical tests



Over-Current Relay Characteristics

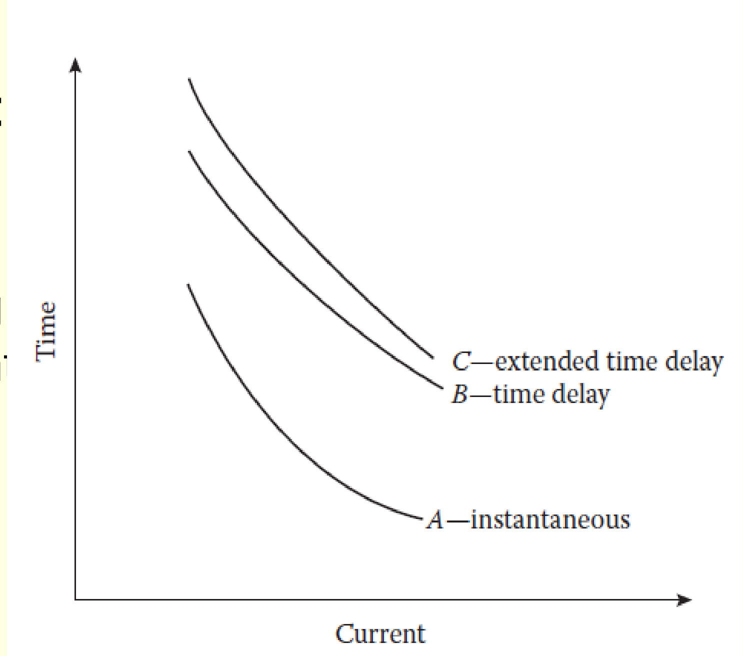
- **Sensitivity**: operate under minimum fault current condition expected,
- **Selectivity**: differentiate between conditions in which immediate action is required to those for which time-delayed action is required.
- **Speed:** ability to operate in the required time period.





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.

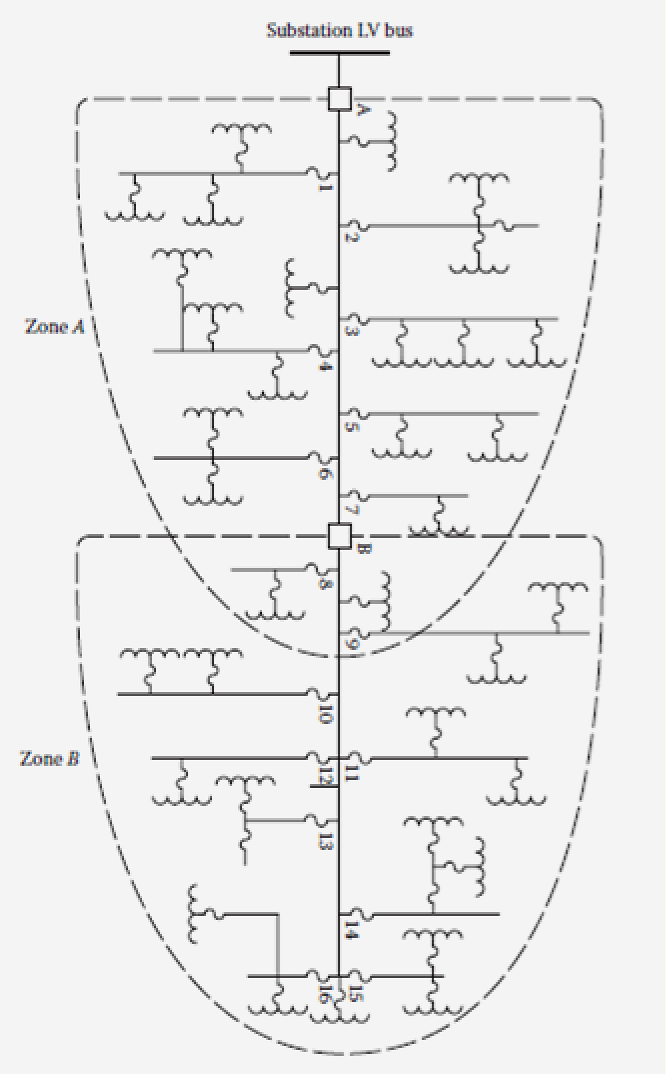


Sectionalizer

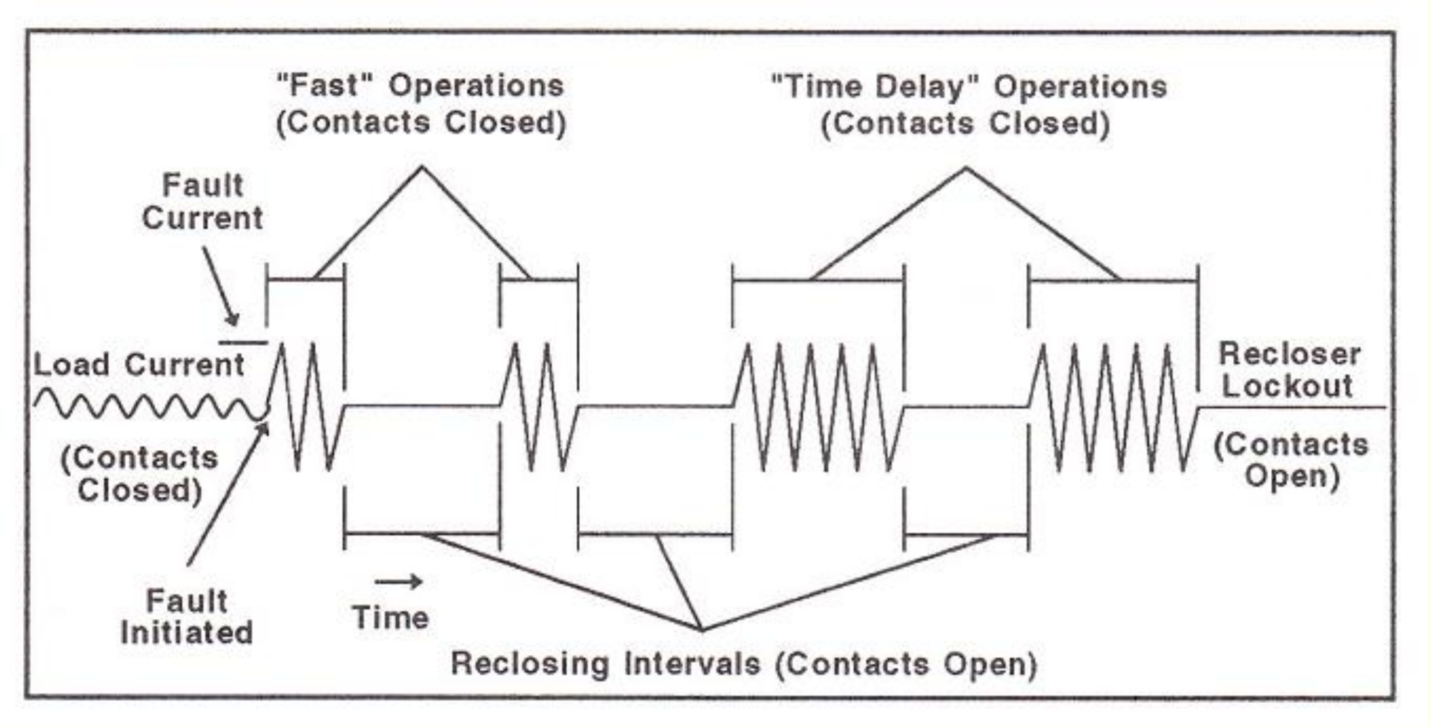
- A sectionalizer is used in juction with a recloser or breaker to isolate faulted sections of lines.
- A sectionalizer does not interrupt fault current. Instead, it counts the number of operations of the reclosing device, and opens when this backup device is open.
- After the sectionalizer opens, the 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

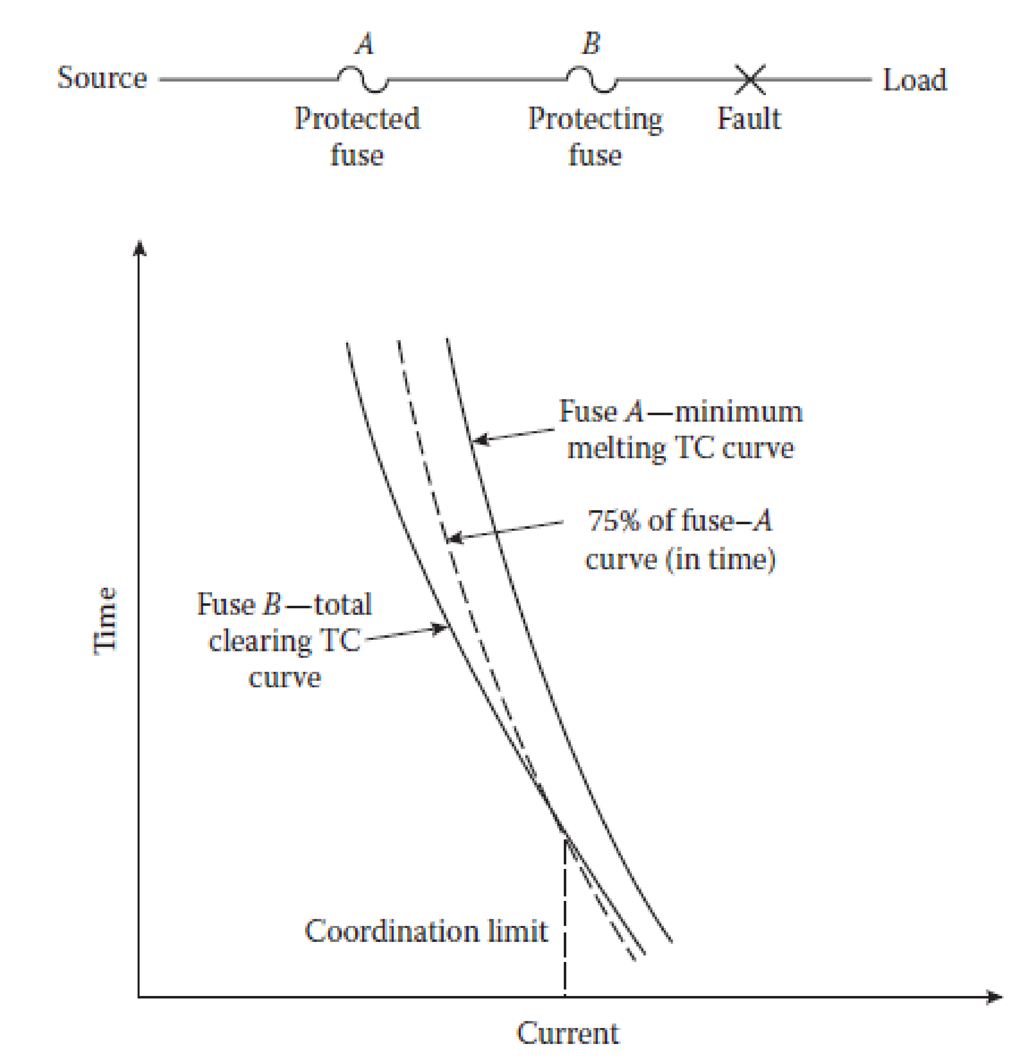
- Fuses and circuit breakers on customer side of meter.
- Fuses at each distribution transformer.
- Fuses at the head of each lateral.
- Circuit breaker at the substation.
- Recloser along the feeder (in case where the protection zone of the station circuit breaker is limited).



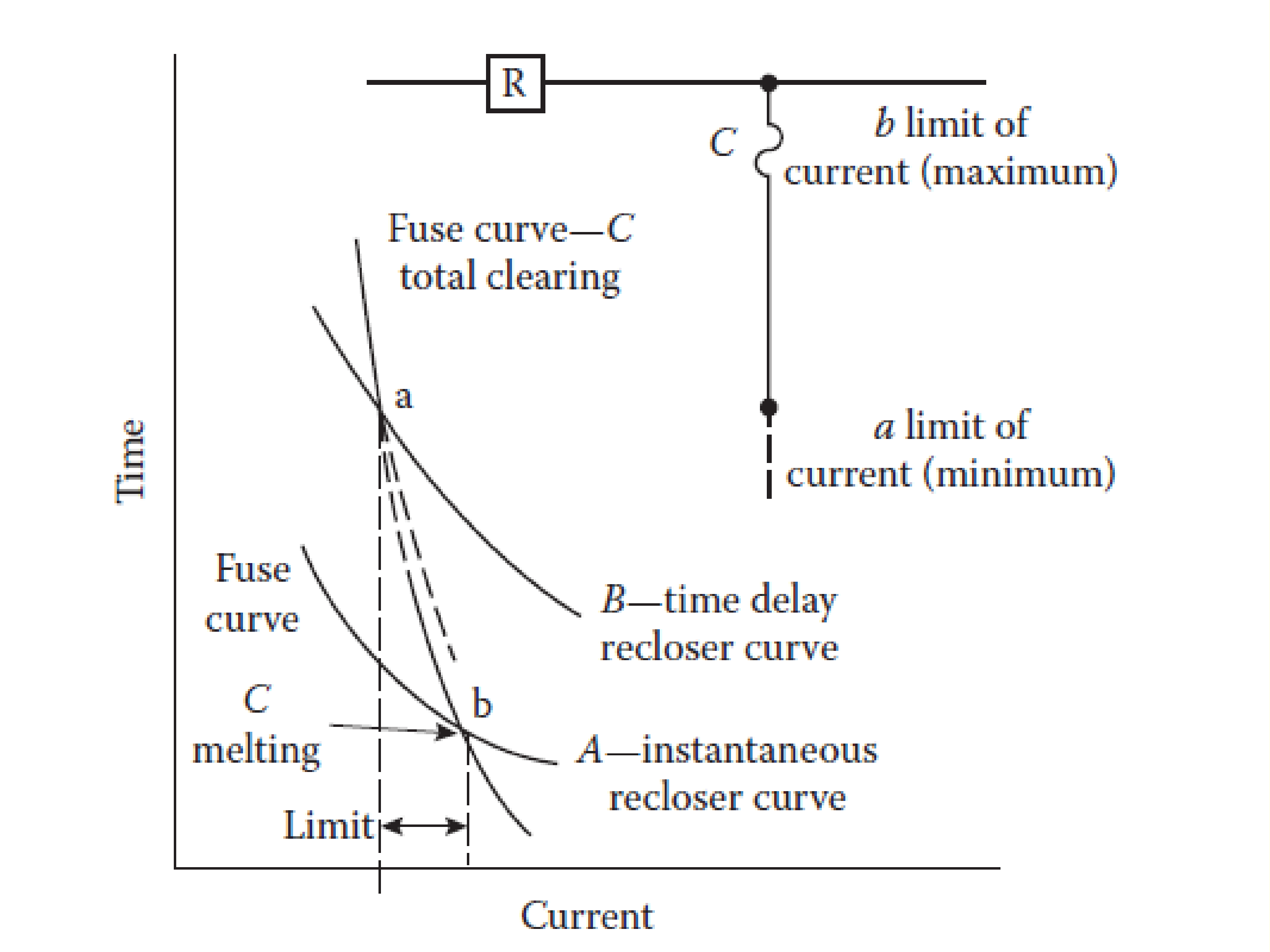
Typical Reclosing Sequence



Coordination: Fuse-to-Fuse



Coordination: Recloser-to-Fuse



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