

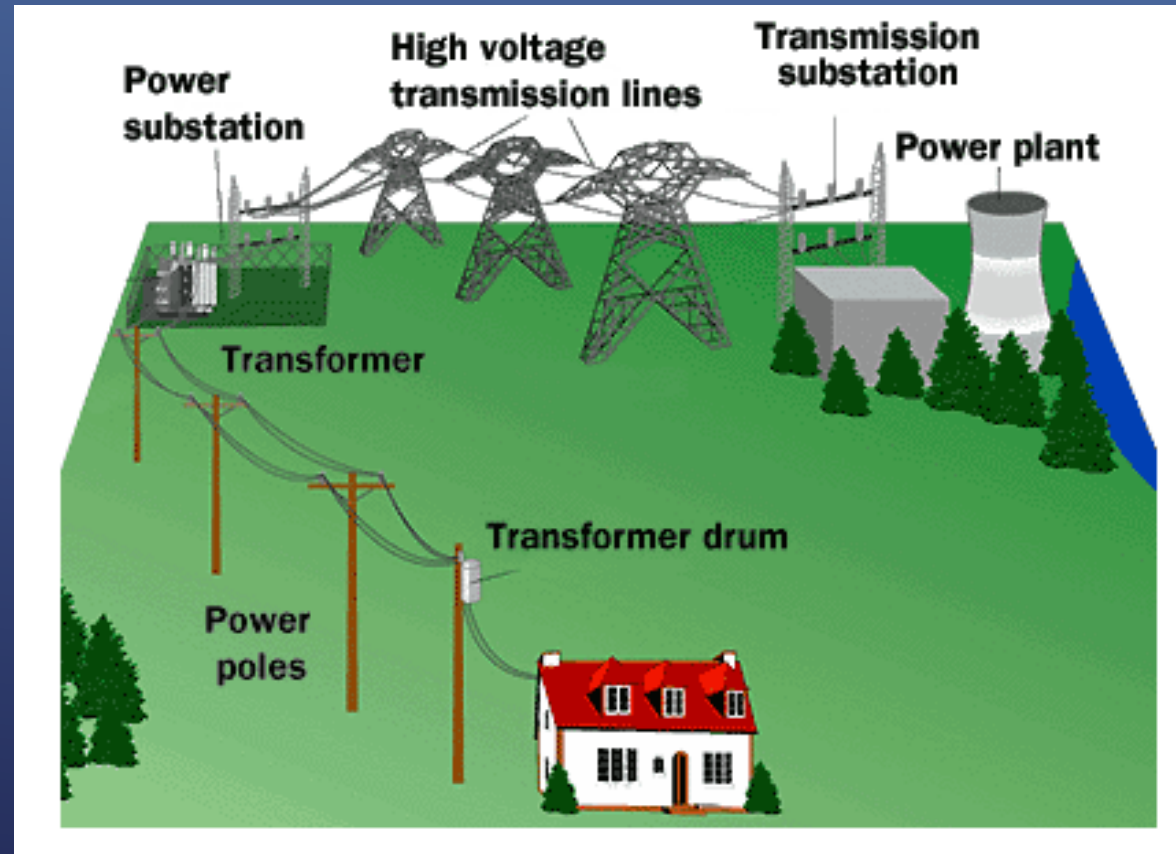


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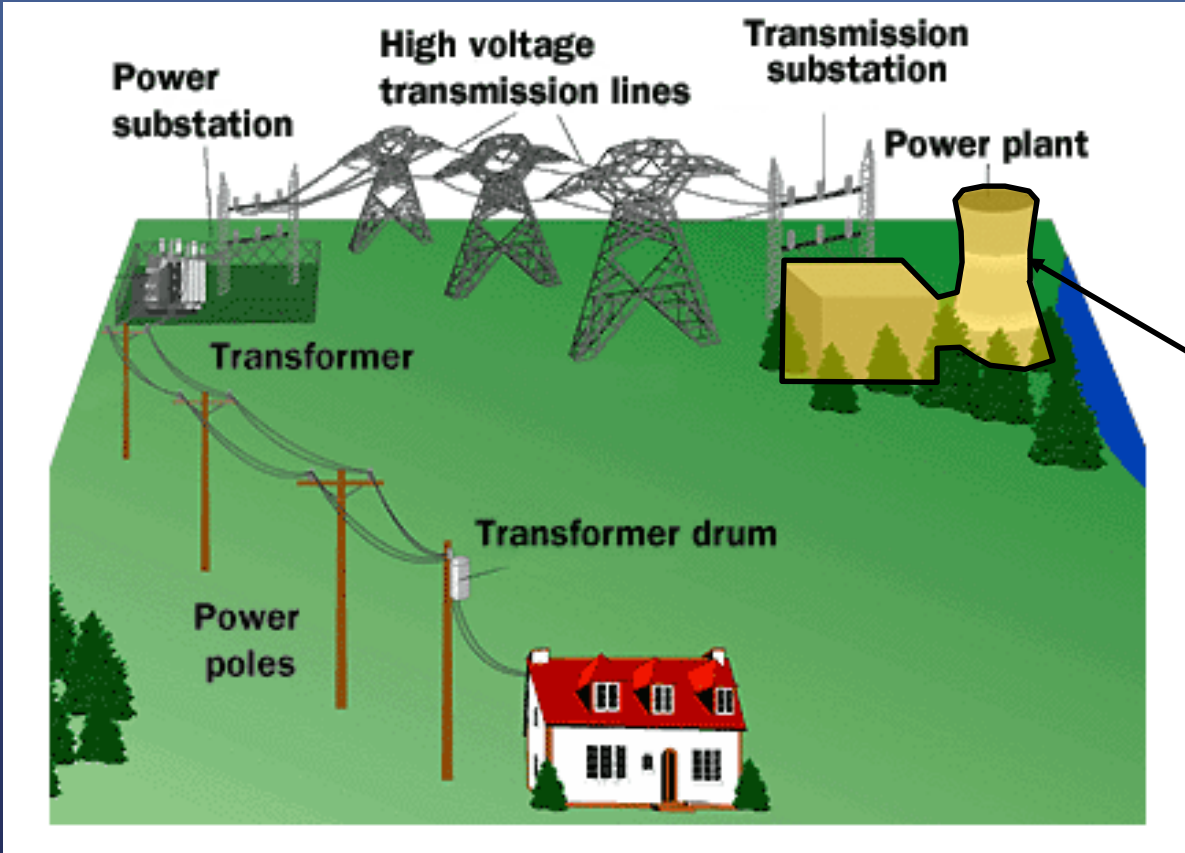
# Simplified Electric Operating System



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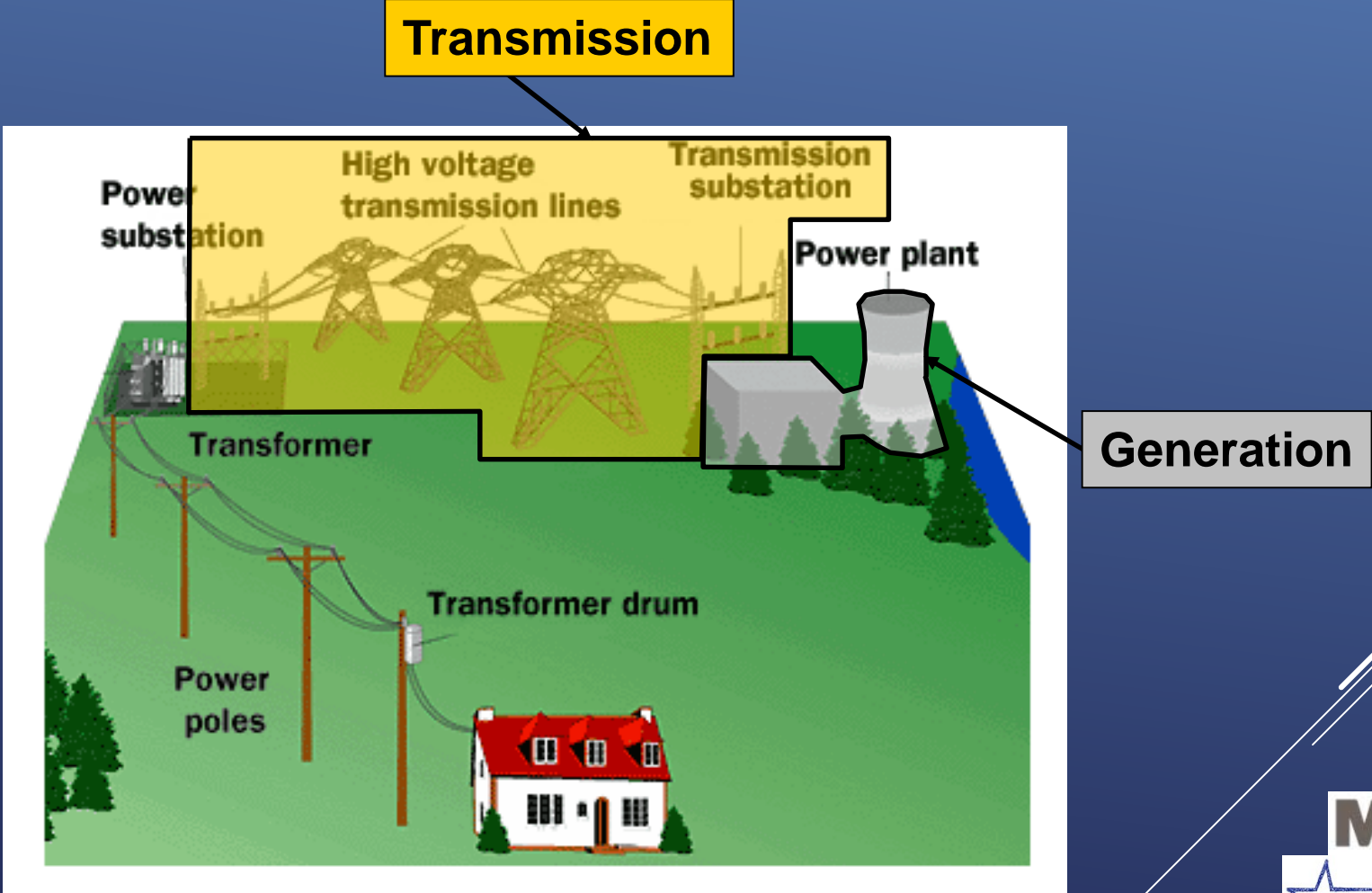
*Westar Energy*<sup>™</sup>

# Simplified Electric Operating System

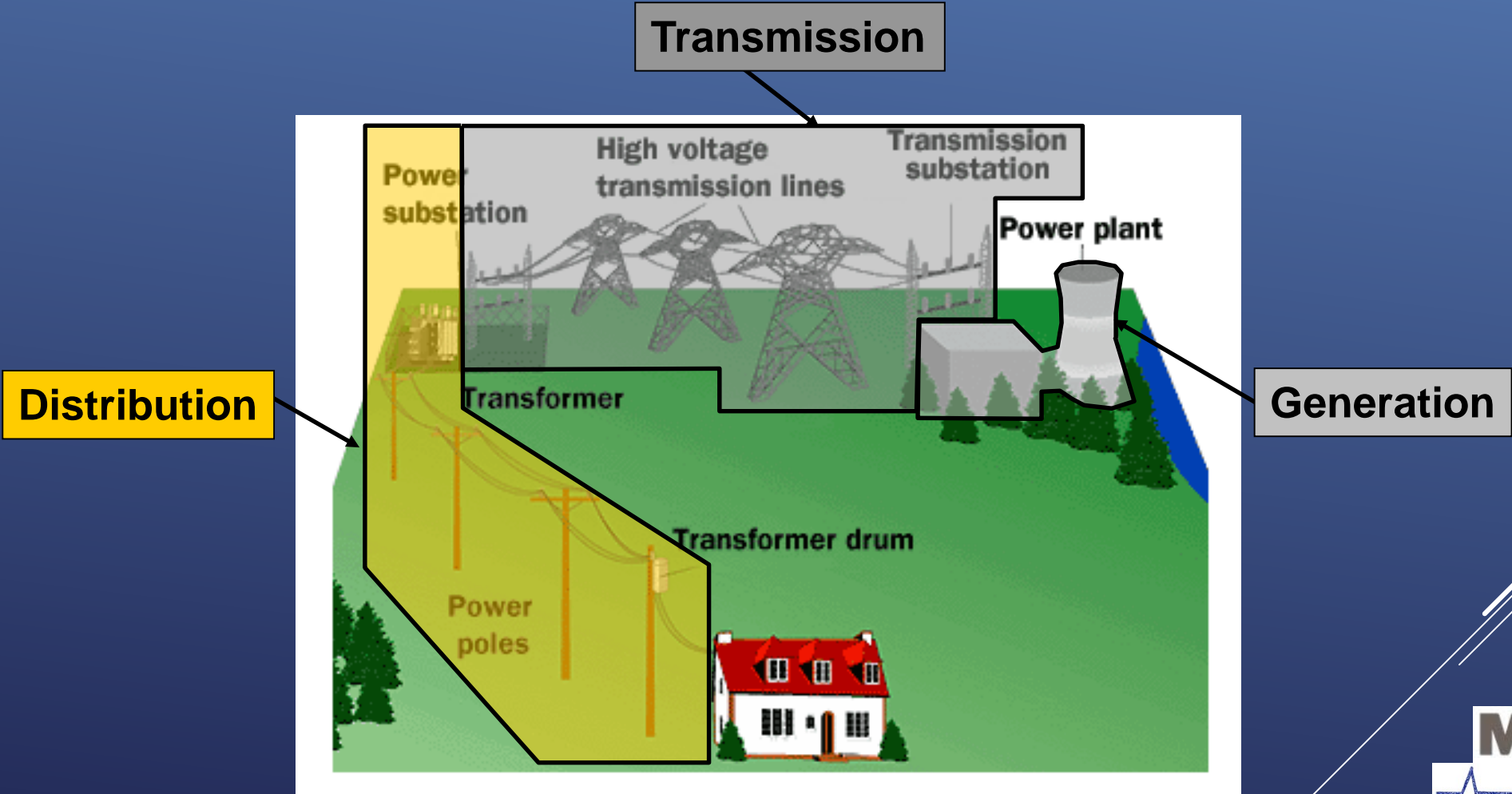


**Generation**

# Simplified Electric Operating System



# Simplified Electric Operating System





# Substations



# Substations

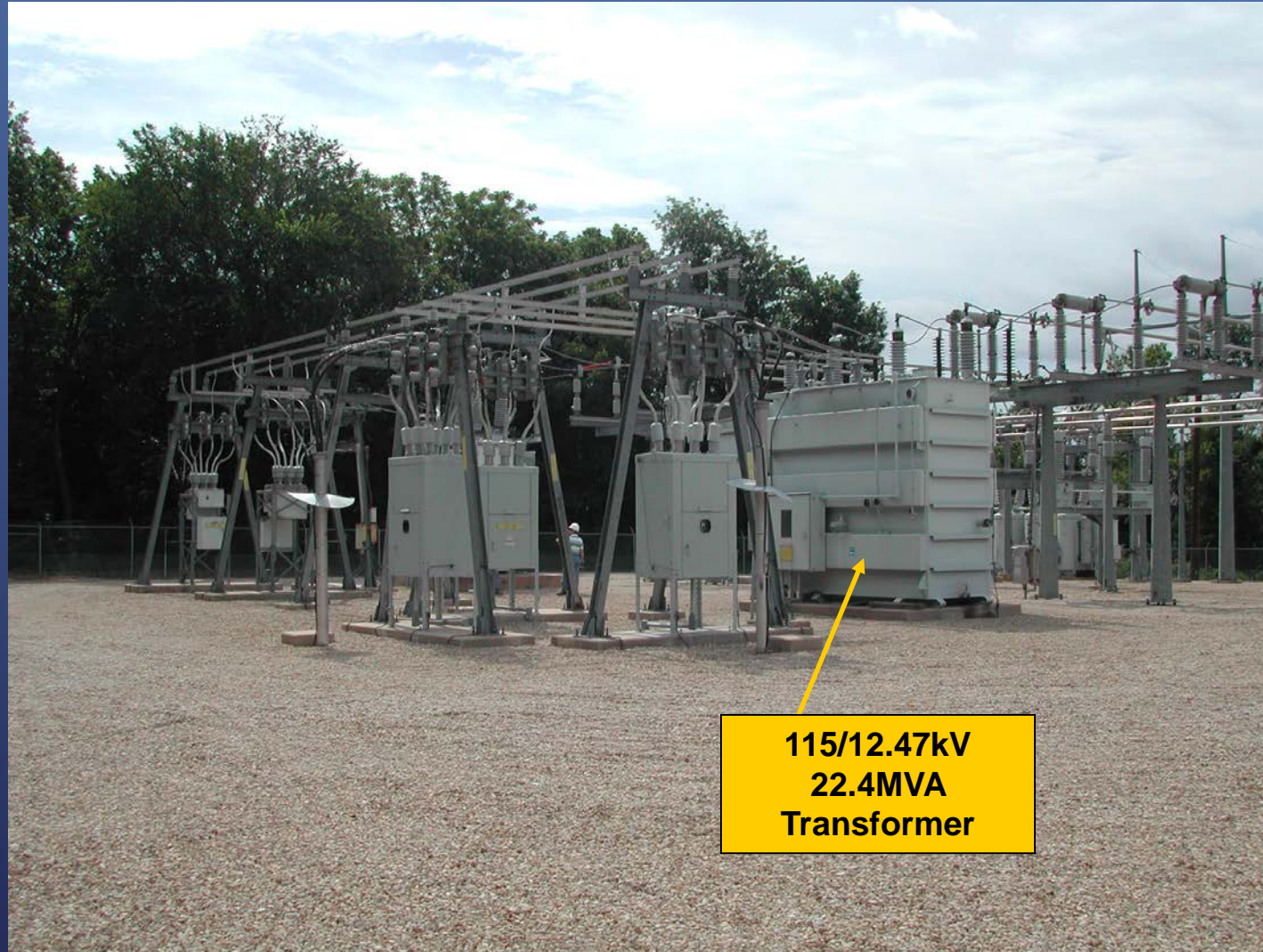


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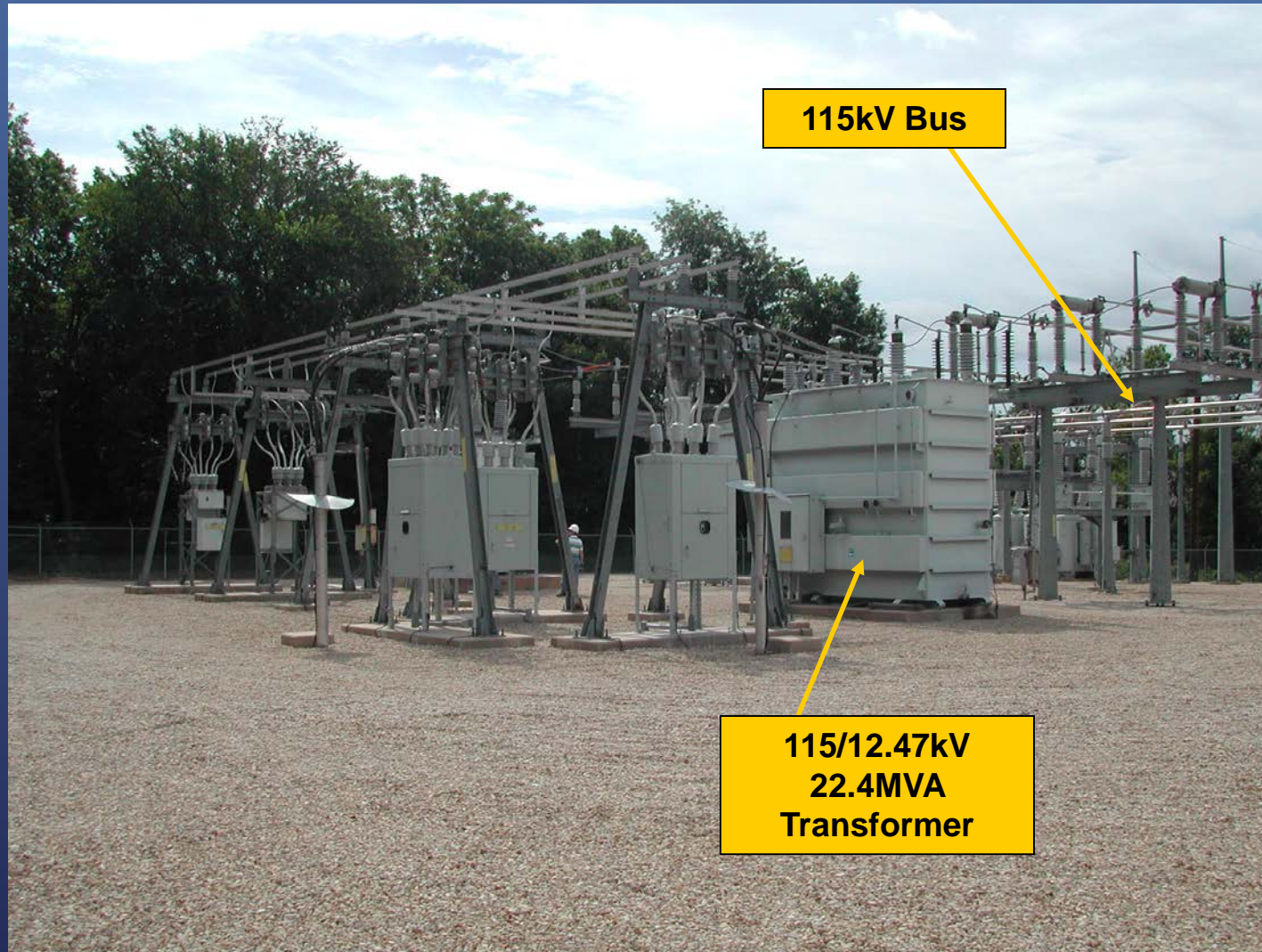
# Substations



**115/12.47kV  
22.4MVA  
Transformer**



# Substations



115kV Bus

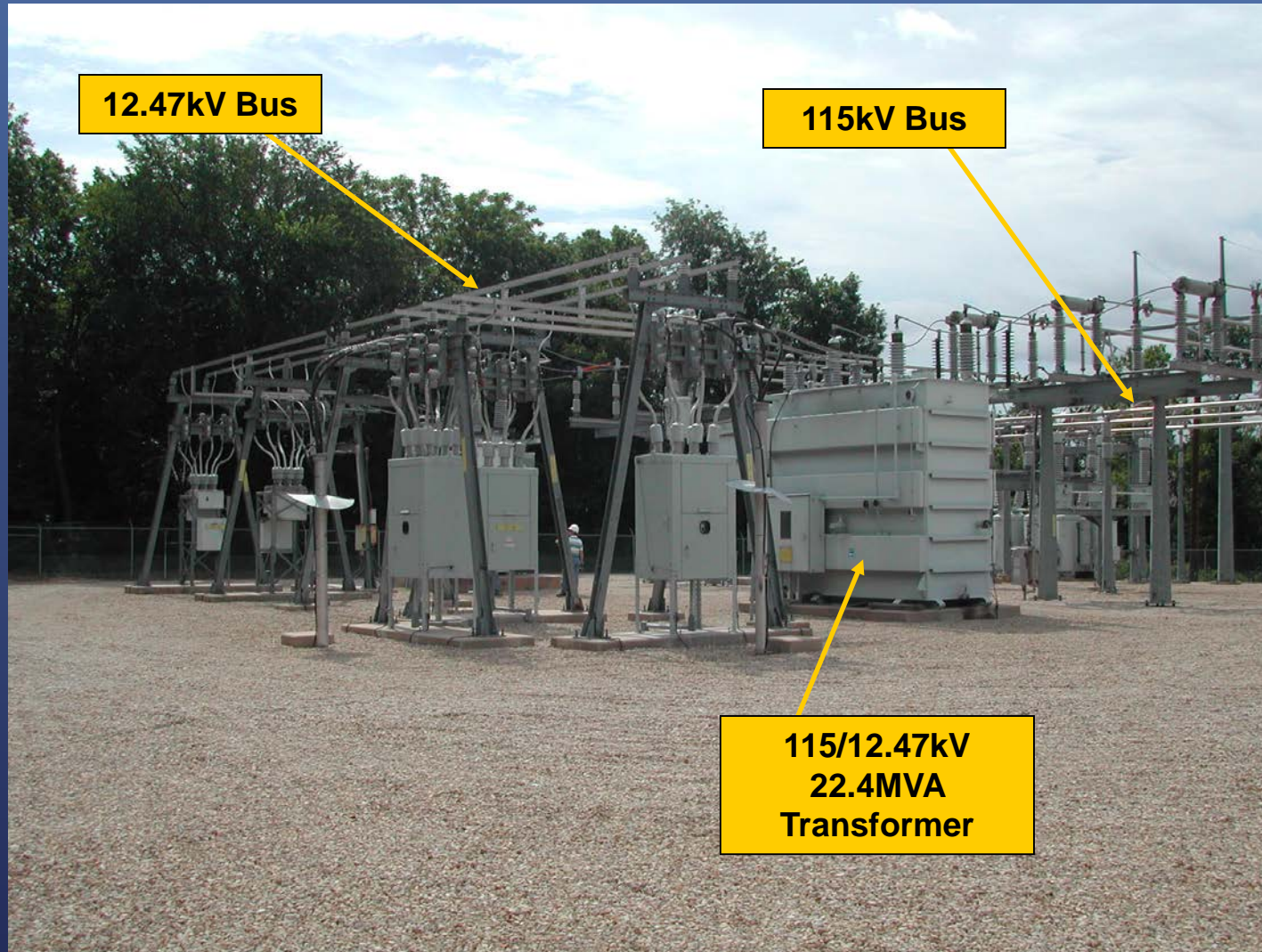
115/12.47kV  
22.4MVA  
Transformer

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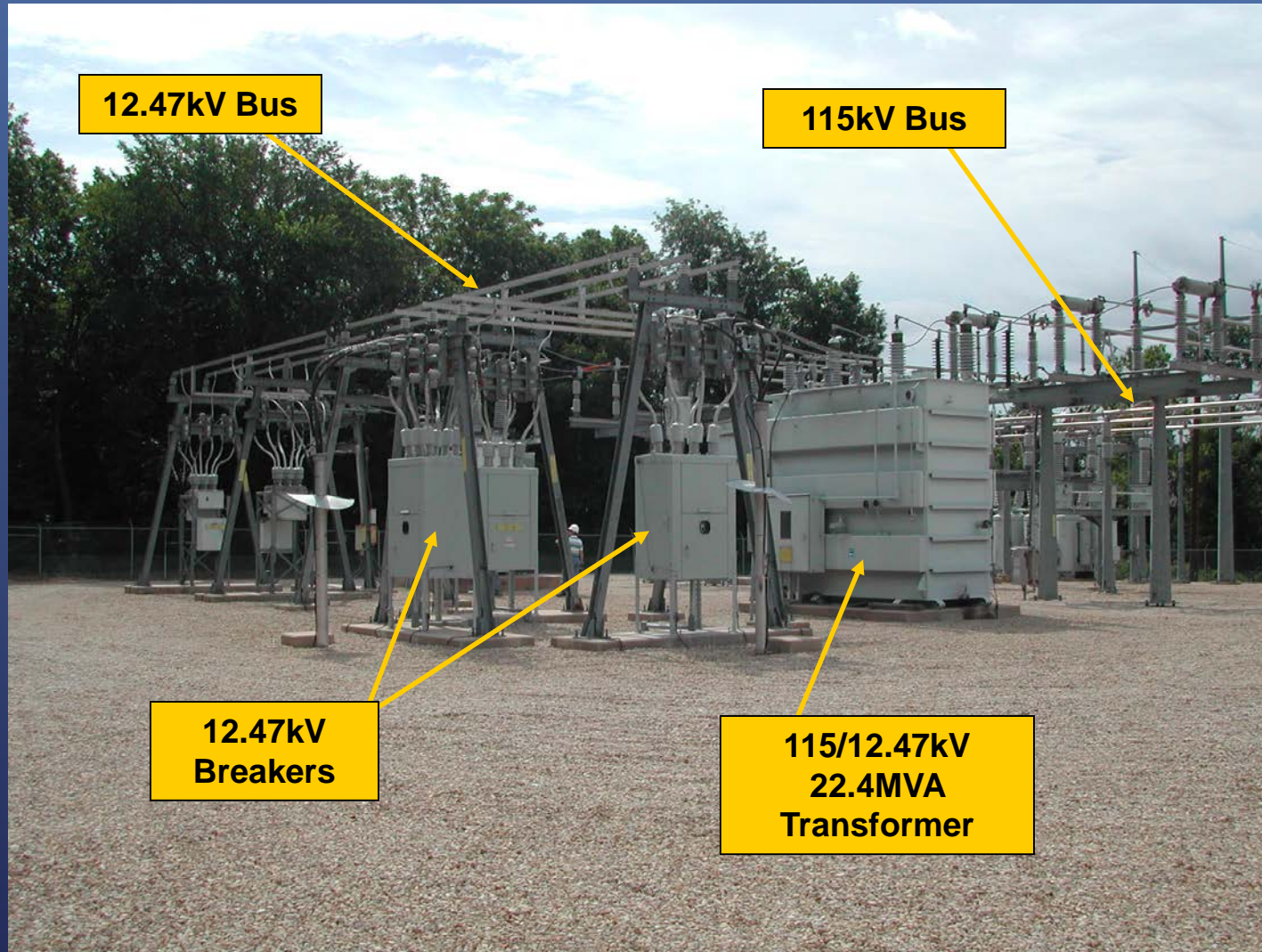


# Substations





# Substations





# Substations 12.47kV Breakers



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Substations  
115kV Bus and 115/12.47kV 10.5MVA Xfmr



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# Substations

## 115kV Bus and 115/12.47kV 10.5MVA Xfmr



115kV Fuses

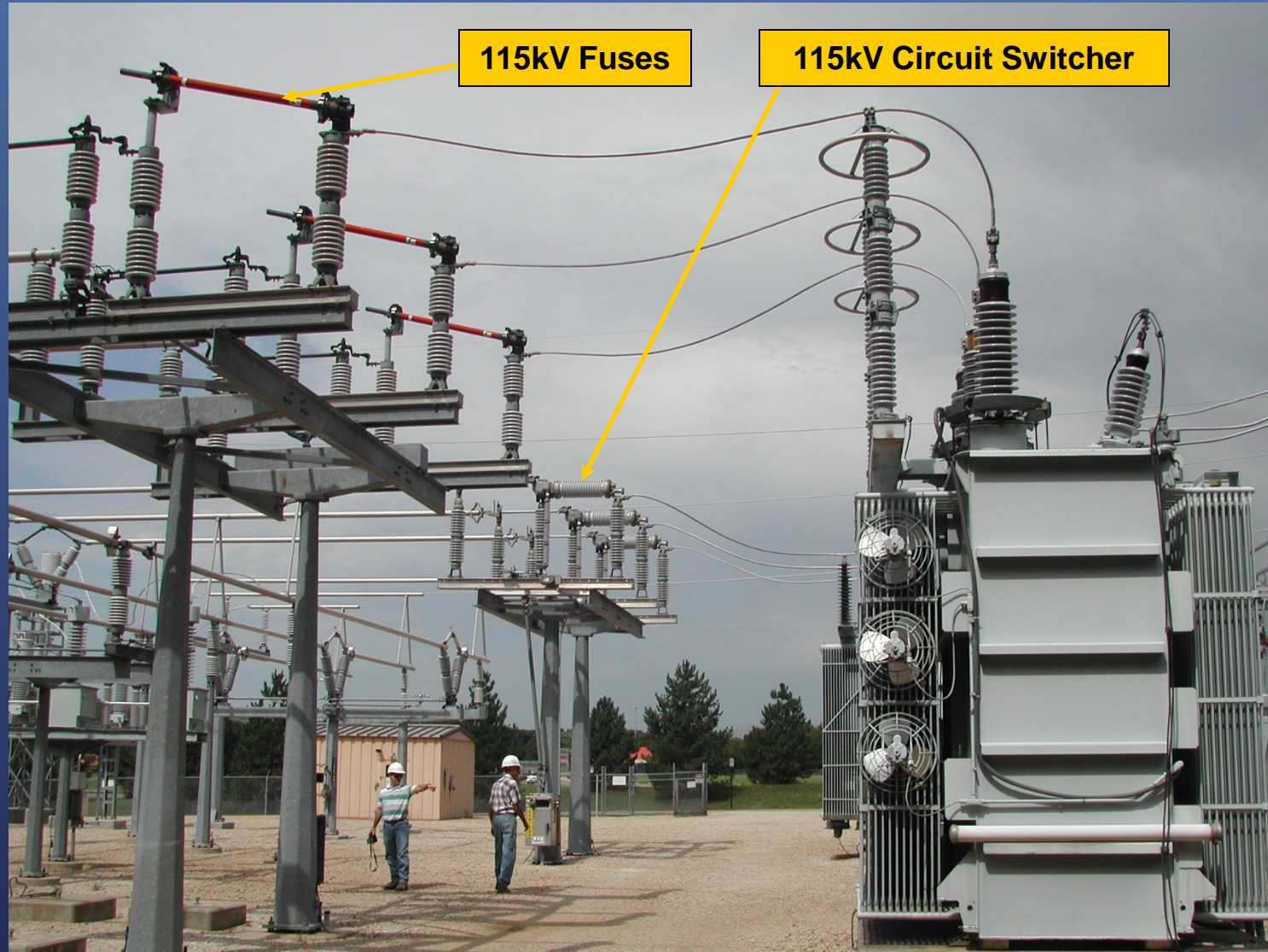
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# Substations

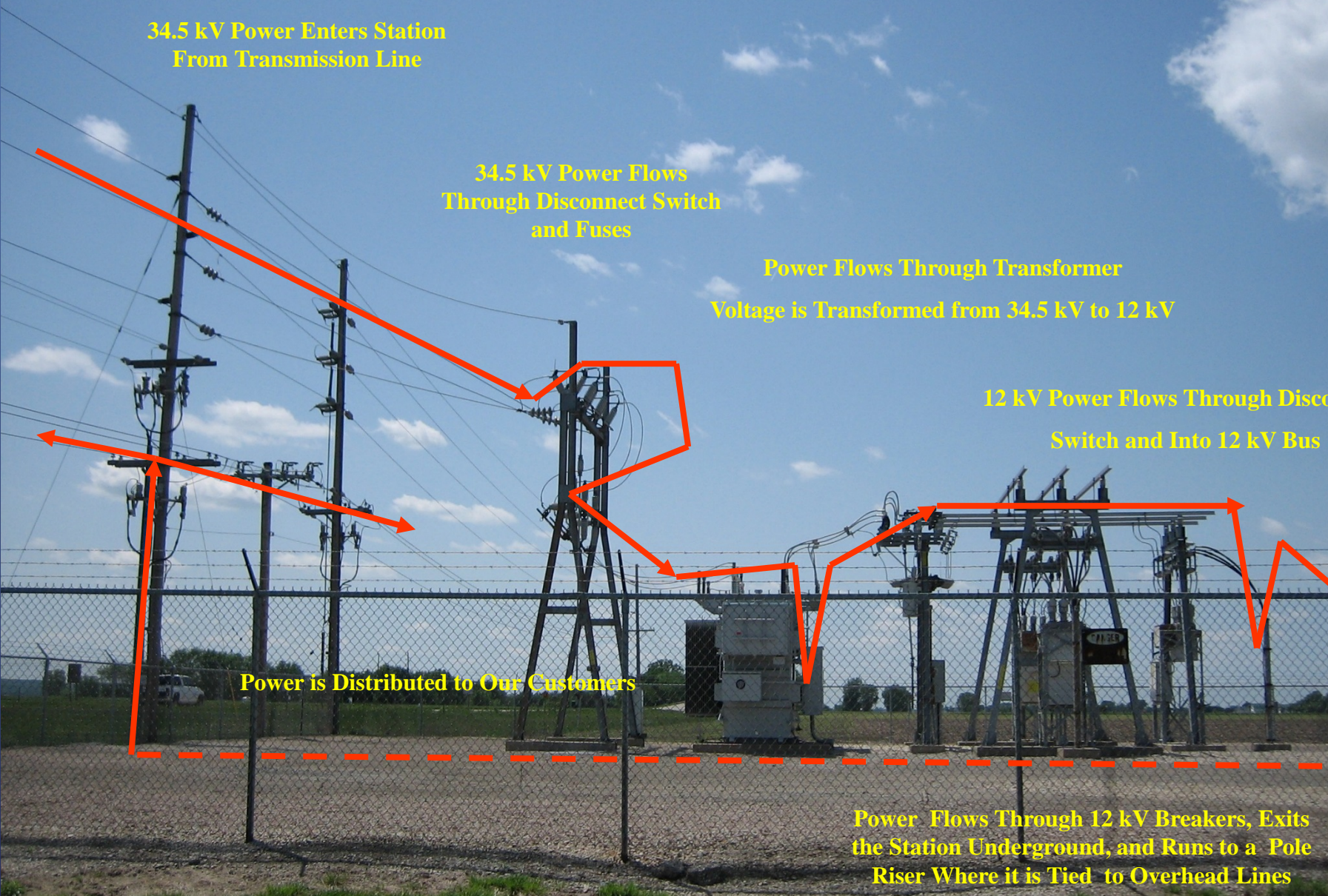
## 115kV Bus and 115/12.47kV 10.5MVA Xfmr



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34.5 kV Power Enters Station  
From Transmission Line

34.5 kV Power Flows  
Through Disconnect Switch  
and Fuses

Power Flows Through Transformer  
Voltage is Transformed from 34.5 kV to 12 kV

12 kV Power Flows Through Disconnect  
Switch and Into 12 kV Bus

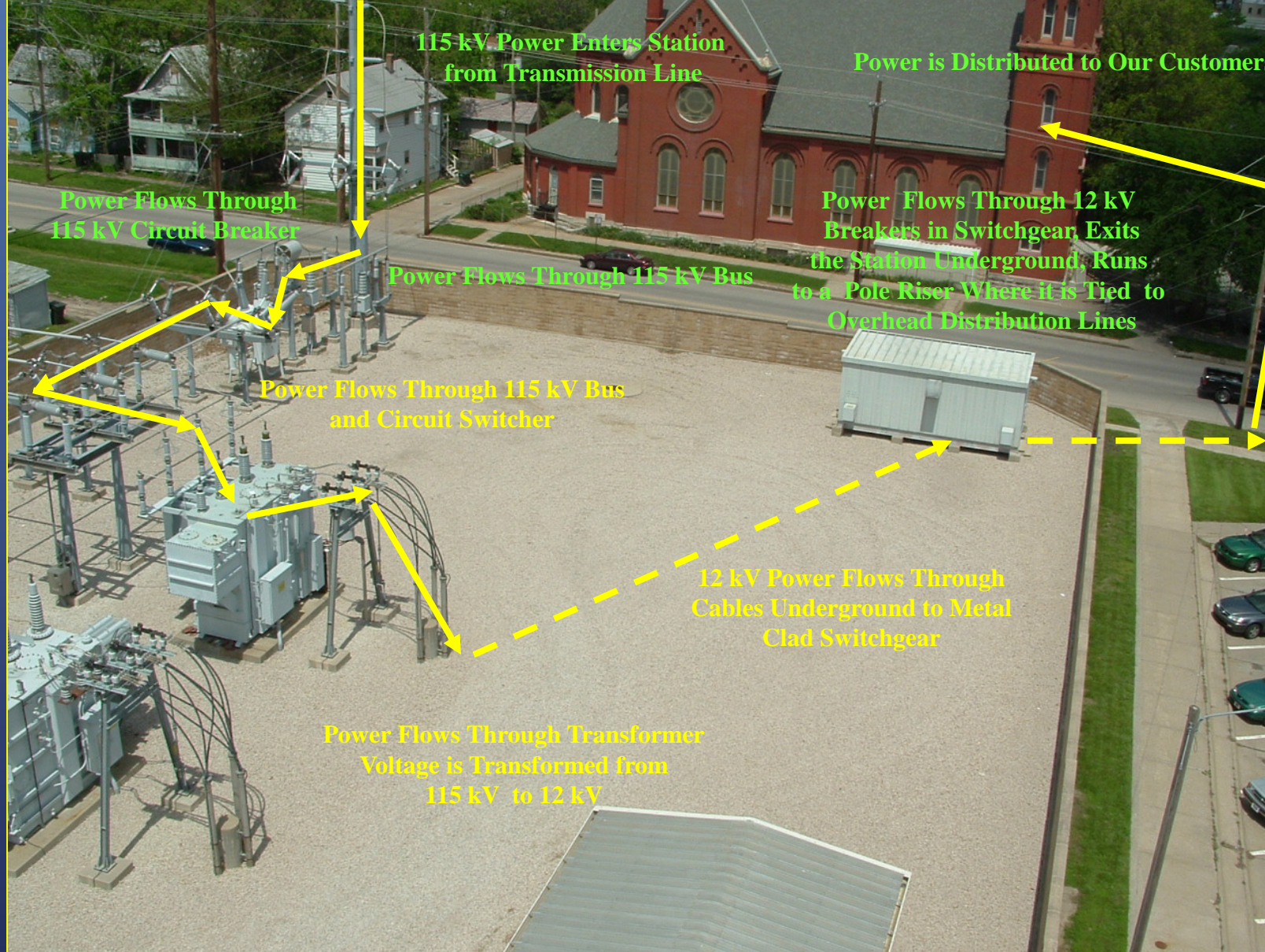
Power is Distributed to Our Customers

Power Flows Through 12 kV Breakers, Exits  
the Station Underground, and Runs to a Pole  
Riser Where it is Tied to Overhead Lines

# Power Flow Through Westgate Substation







**Power Flow Through 4<sup>th</sup> and Van Buren Substation**



# Distribution System

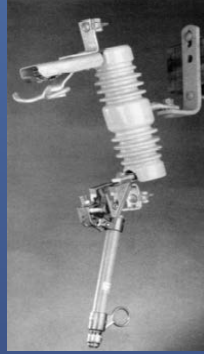


# Distribution System

- The purpose of the Distribution System is to reduce Transmission System voltages to lower usable levels and to locally transport power from the substations to each individual customer.
- Lower voltages allow for a more cost effective means of locally transporting electrical power to individual customers  
(ie lower voltage=smaller equipment=lower installed costs)
- Typical Distribution primary operating levels include:
  - 34.5kV (sub-transmission)
  - 12.47kV
  - 7.2kV
  - 4.16kV
  - 2.4kV
- Westar operates and maintains approximately 27,000 miles of distribution lines serving approximately 659,000 customers.



# Typical Distribution Line Equipment





# Distribution Equipment- Transformers

Overhead (Pole-Mount)



Underground (Pad-Mount)



## Distribution Equipment- Transformers

- Transformers are used to reduce primary line voltage levels (typically 12.47kV-3ph, 7.2kV 1ph) down to a usable level by the customer (480V, 240V, 208V, 120V)
- Transformers consist of “primary” windings (high voltage) and “secondary” windings (low voltage) wound around a common core that are linked by electromagnetic fields. The amount of voltage reduction is directly related to the “turns ratio” between the windings.
- Transformers are rated to handle a certain amount of power expressed in “KVA”. The power limitation insures transformer thermal limits are not exceeded which could otherwise create a reduction in life.
- Single phase transformers consist of one primary and one secondary winding.
- Three phase transformers consist of three primary and three secondary windings.
- Single phase overhead transformers are routinely wired together to form three phase transformer banks. In general, summation of the three individual transformer sizes yields the equivalent 3 phase rating (excluding open-wye/open-delta banks).



# Distribution Equipment

## Typical Overhead Transformer Installations



← Single Phase  
25KVA Xfmr

Three Phase →  
500KVA Xfmr



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# Distribution Equipment- Fused Cut-Outs

**Closed**



**Open**





# Distribution Equipment- Cut-Outs

- “Cut-Outs” are actually fuse holders which function normally as passive devices in that they simply conduct electricity to the load.
- On the event of a short-circuit condition downstream of the cut-out, a high amount of current instantaneously flows through the fuse element which in turn generates heat. After a given amount of time the fuse element melts out allowing the “barrel” to drop out of the cut-out thus interrupting power to the faulted section of line.
- This disruption of power to the faulted line segment is called sectionalizing and allows customers upstream of the cut-out to retain their electricity once the cut-out has opened.
- Fuses are sized to coordinate with the next upstream protective device to insure the proper sequence of sectionalizing occurs on the occurrence of a fault.
- Fuse elements are a one-time device and once they have melted, the fuse elements must be replaced.
- Cut-outs are used to protect the main feeders by installing them at each “tap” to increase reliability to other customers on the circuit. Cut-outs are also used on capacitor banks and transformers to isolate faulted equipment.

# Distribution Equipment

## Open Cut-Outs on Three Phase Capacitor Station



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# Distribution Equipment- Hydraulic Reclosers

Single Phase



Three Phase



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## Distribution Equipment- Hydraulic Reclosers

- Reclosers are similar to a circuit breaker in that they open under unusually high amounts of electrical current (i.e. faulted condition).
- Reclosers normally act as passive devices in that they simply conduct electricity to the load.
- On the event of a short-circuit condition downstream of the recloser, a high amount of current instantaneously flows through the recloser. After a predefined amount of time the recloser will open and then, as the name implies, reclose thus momentarily interrupting power to the faulted section of line. This “reclosing” action allows for temporary faults to clear and then reestablishes power flow to the momentarily disrupted customers thus reducing/eliminating sustained outages.
- For permanent faults, the recloser will go through a series of open-close cycles before finally opening permanently. This is termed “going to a lock-out condition”. The faulted section of line must then be cleared and the recloser must be manually reset/closed.
- Reclosers are sized to coordinate with downstream fuses and upstream protective devices to insure the proper sequence of sectionalizing occurs on the occurrence of a fault.
- Timing is achieved through a mechanical “hydraulic” action of oil flowing through orifices, thus the term “Hydraulic Reclosers”.

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# Distribution Equipment- Hydraulic Reclosers Typical Field Installation



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# Distribution Equipment- Electronic Reclosers

Three Phase Vacuum Recloser



Electronic Recloser Control

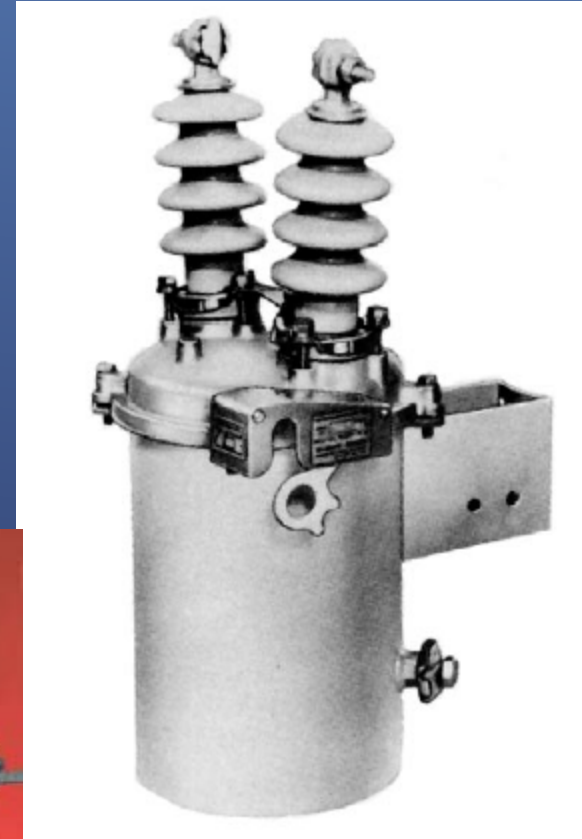
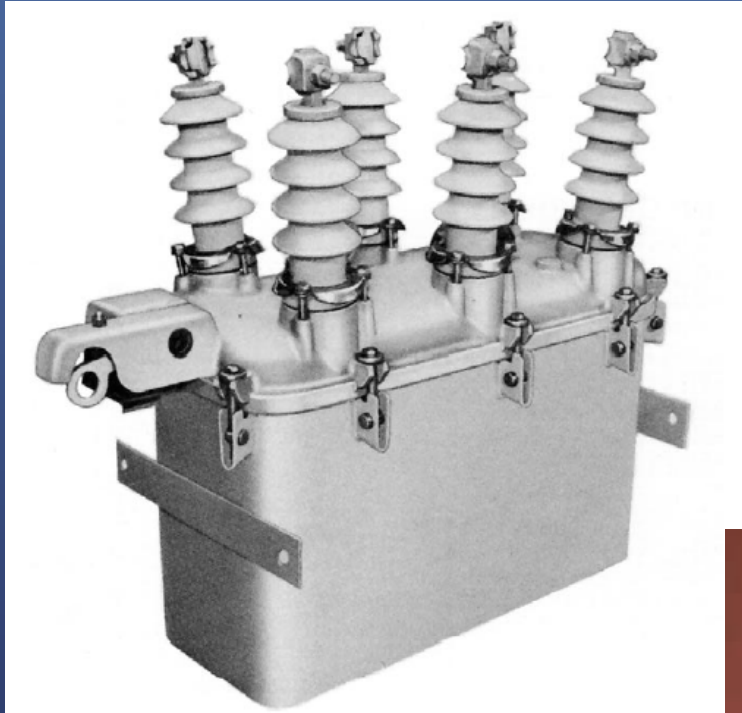




## Distribution Equipment- Electronic Reclosers

- Electronic Reclosers operate similar to hydraulic reclosers except they utilize an electronic control for current/voltage measurement and open/close timing sequences.
- Electronic Reclosers may have communication devices interfaced to them which allow for bringing back measured data (ie currents, voltages, power factor, etc) as well as status and control (ie open, close, lock-out, hot-line tagging).
- Can be remotely operated if the proper communications are installed. This will also allow for notifying the DSO's of outages on the occurrence of a lock-out condition.

# Distribution Equipment- Sectionalizers





## Distribution Equipment- Sectionalizers

- Available in both three phase and single phase models.
- Act to isolate faulted sections of line automatically.
- Operate by “counting” the number of times a fault has occurred downstream and open after upstream protective device has interrupted the flow of fault current.
- Sized to next upstream protective device.
- Resettable in the field.
- Don’t require down-sizing downstream fuses.
- Allows for carrying more load on a tap while still providing sectionalizing capabilities.
- Electronic types mount in standard cut-out frame.



# Distribution Equipment- Sectionalizers

## Typical Field Installation



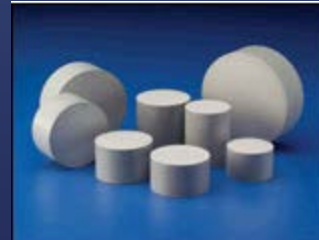
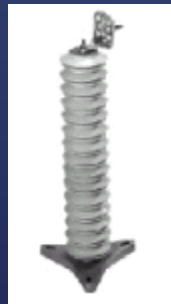
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## Distribution Equipment- Arresters

- Utilized to reduce voltage surges on primary lines due to switching surges, faults and lightning strikes.
- Minimizes voltage stresses to distribution equipment.
- Normally are connected phase to ground and do not conduct.
- Newer styles utilize stacks of MOV (Metal Oxide Varistor) disks. Older styles utilized Silicon Carbide and/or spark gaps (similar to a spark-plug).



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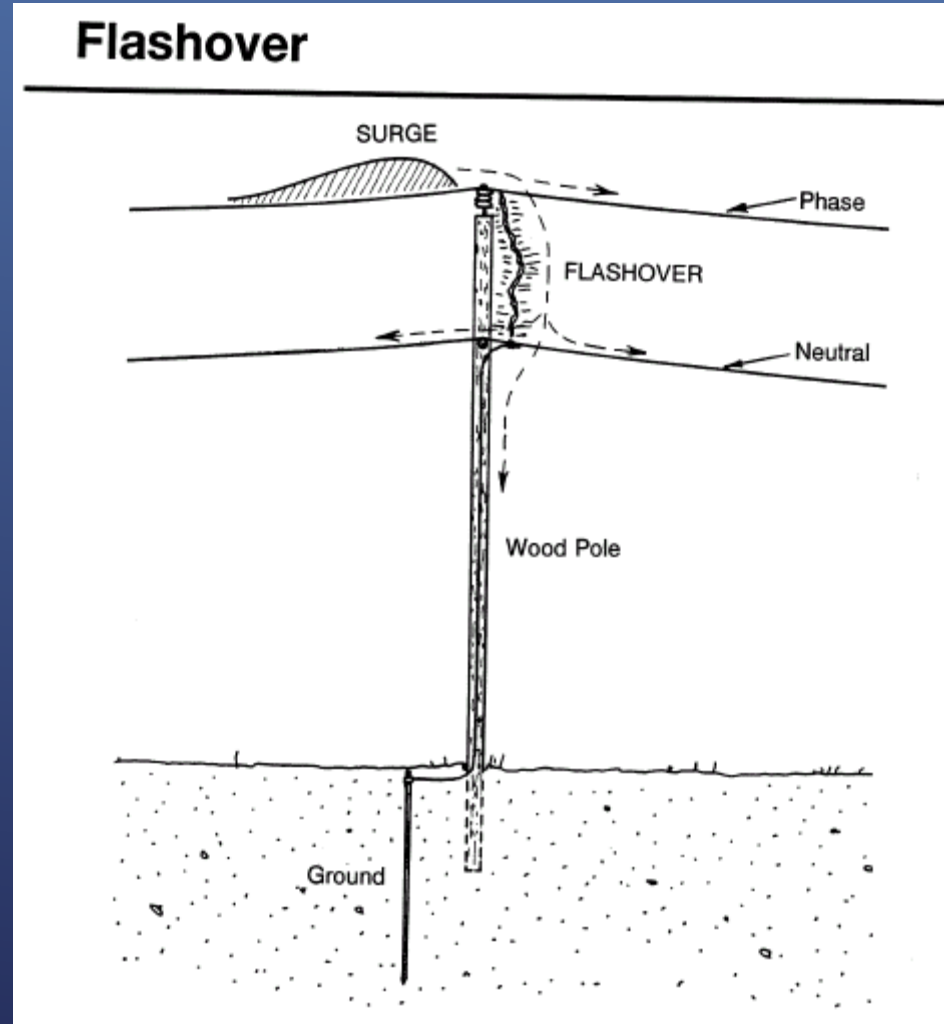
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# Lightning/Surge Protection





# Distribution Equipment- Arresters



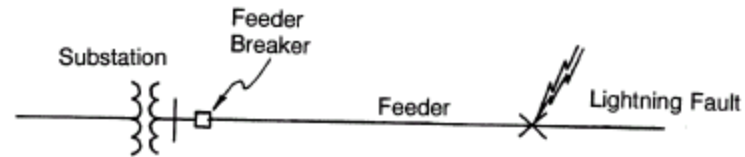
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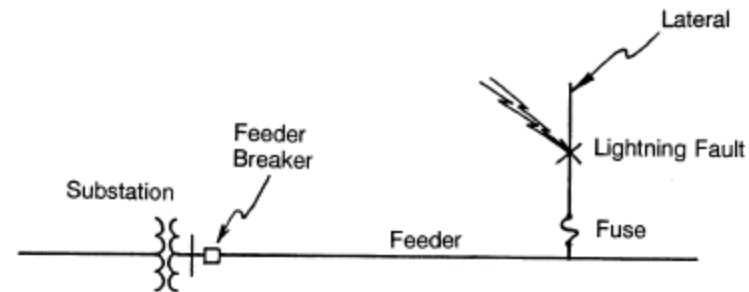
# Distribution Equipment- Arresters

## Two Types of Flashovers

Flashover on the Main 3Ø Feeder



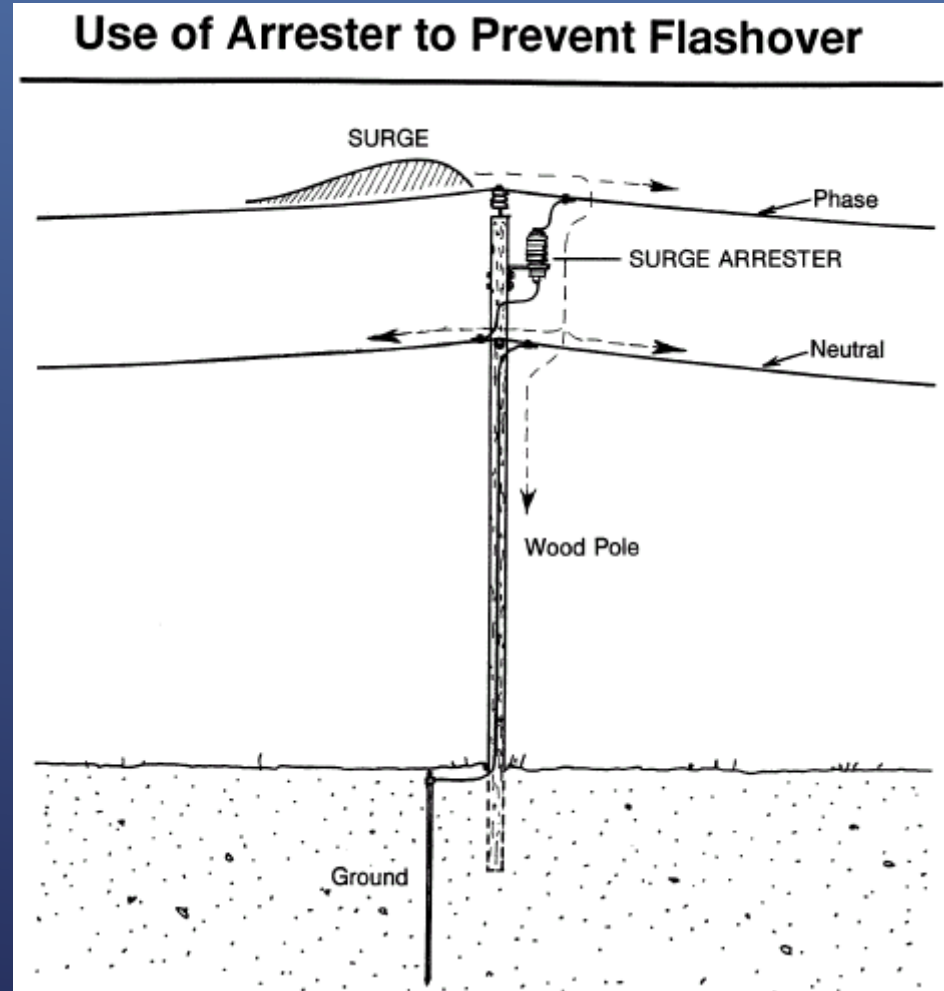
Flashover on 1Ø Lateral Protected by Fuse



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# Distribution Equipment- Arresters



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# Protective Device Coordination



# Coordination of Protective Devices

## What does Coordination mean?

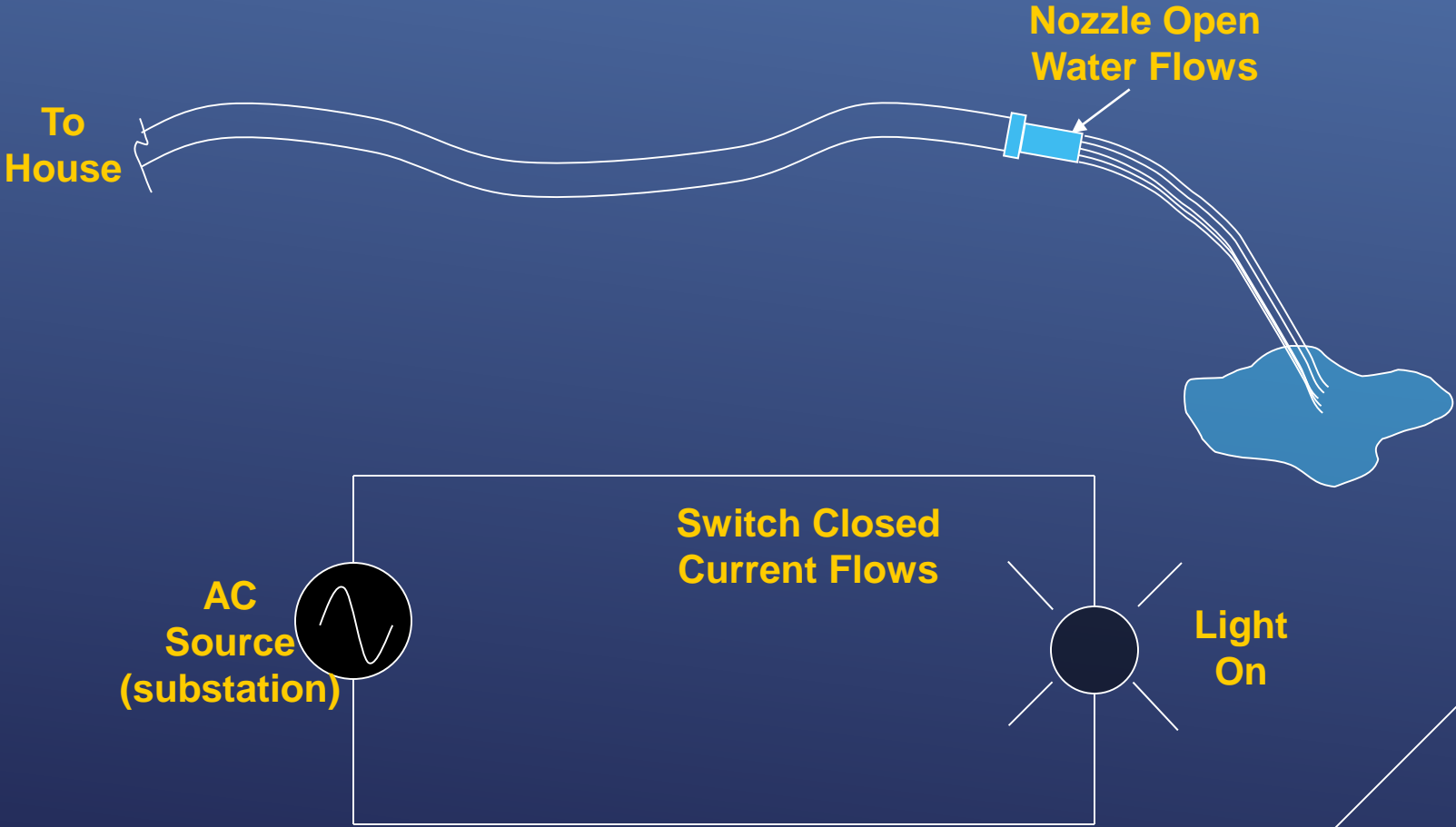
- **Distribution Circuit Coordination is a means of automatically and systematically minimizing sustained outages to customers.**
- **Properly coordinated systems will minimize the number of customers that are subjected to temporary outages.**
- **Proper circuit coordination also aids in locating permanent faults on the system.**
- **Properly coordinated systems also insure equipment is not damaged due to faults and will also help minimize equipment damage.**
- **Coordination helps to protect personnel by limiting fault energy.**





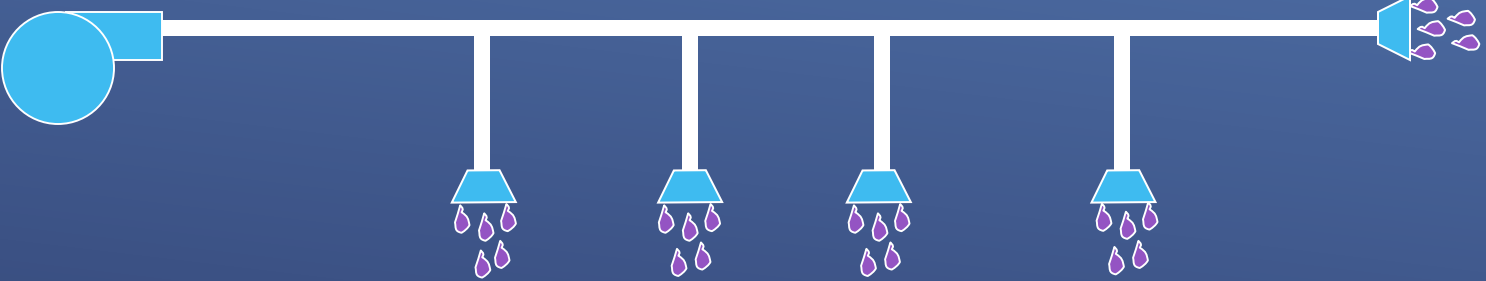
# How Do Fault Currents Flow?

Electricity behaves similar to water flow in a garden hose

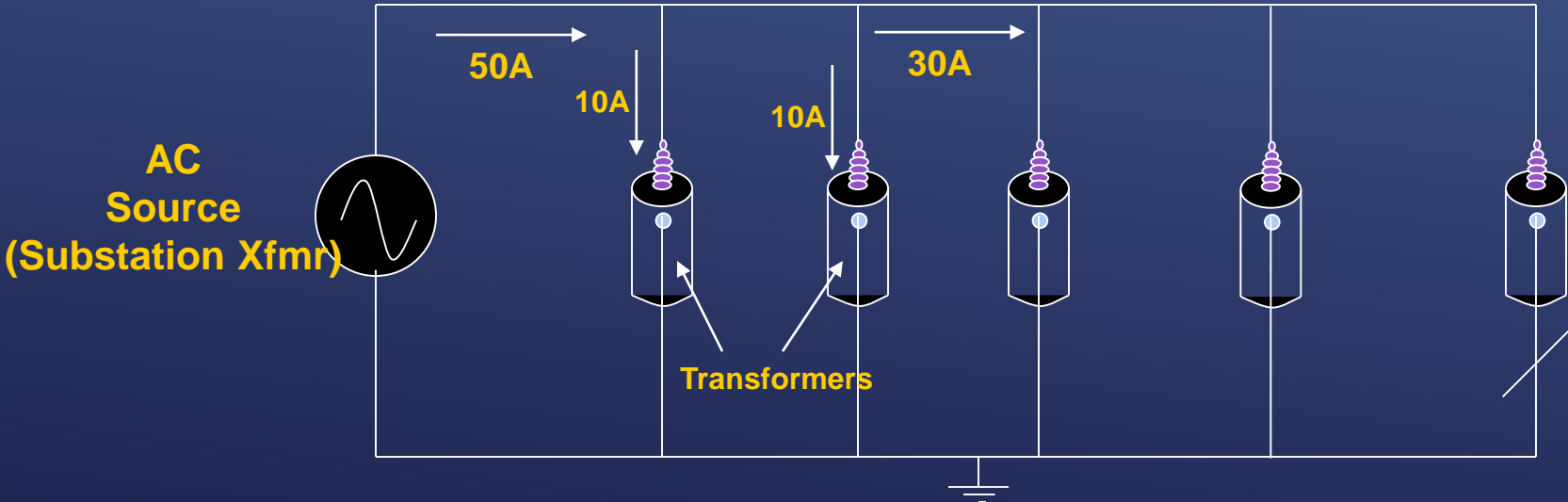


# How Do Fault Currents Flow?

Water distributed to multiple nozzles (loads) keeps system flow to relatively low levels

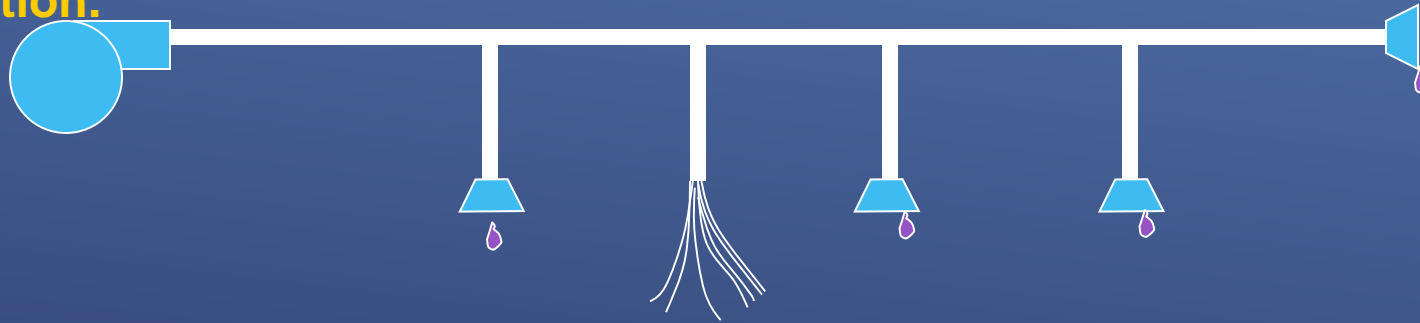


Similarly, electricity distributed to multiple loads keeps system current flow to relatively low levels

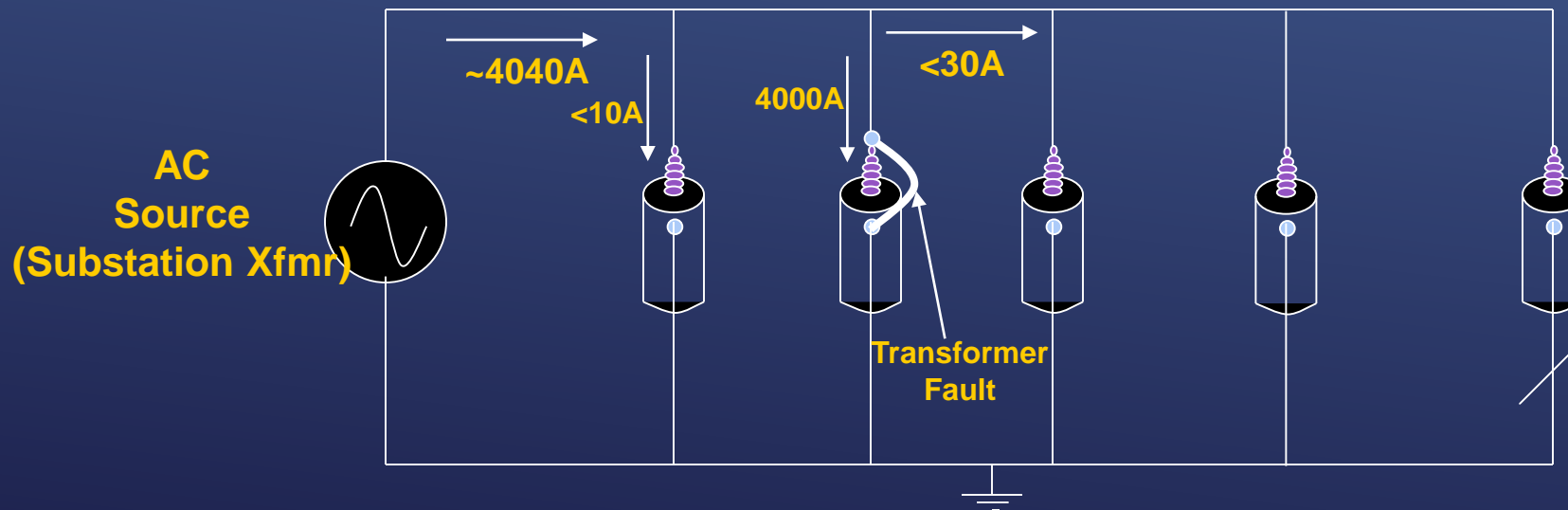


# How Do Fault Currents Flow?

A water line break at one nozzle causes system flow to vastly increase up to point of break. Downstream flow is substantially reduced due to pressure reduction.



Similarly, an electrical short circuit causes current flow to vastly increase up to point of fault. Downstream current flow is reduced due to voltage reduction.

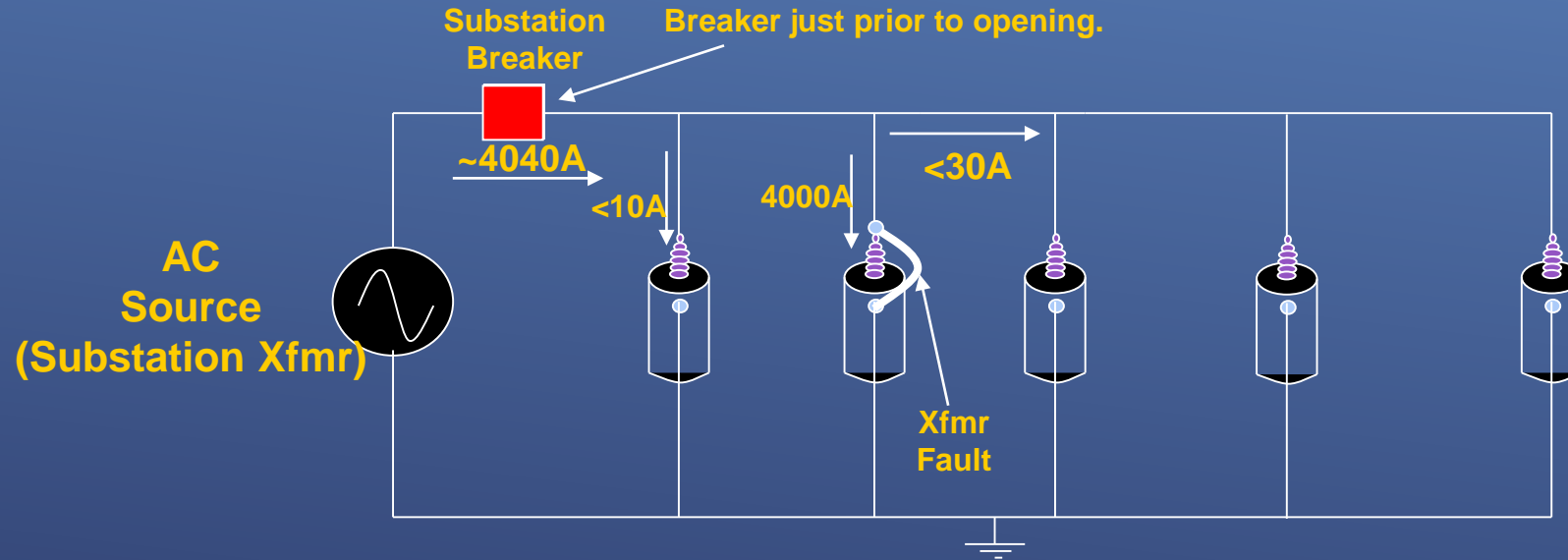




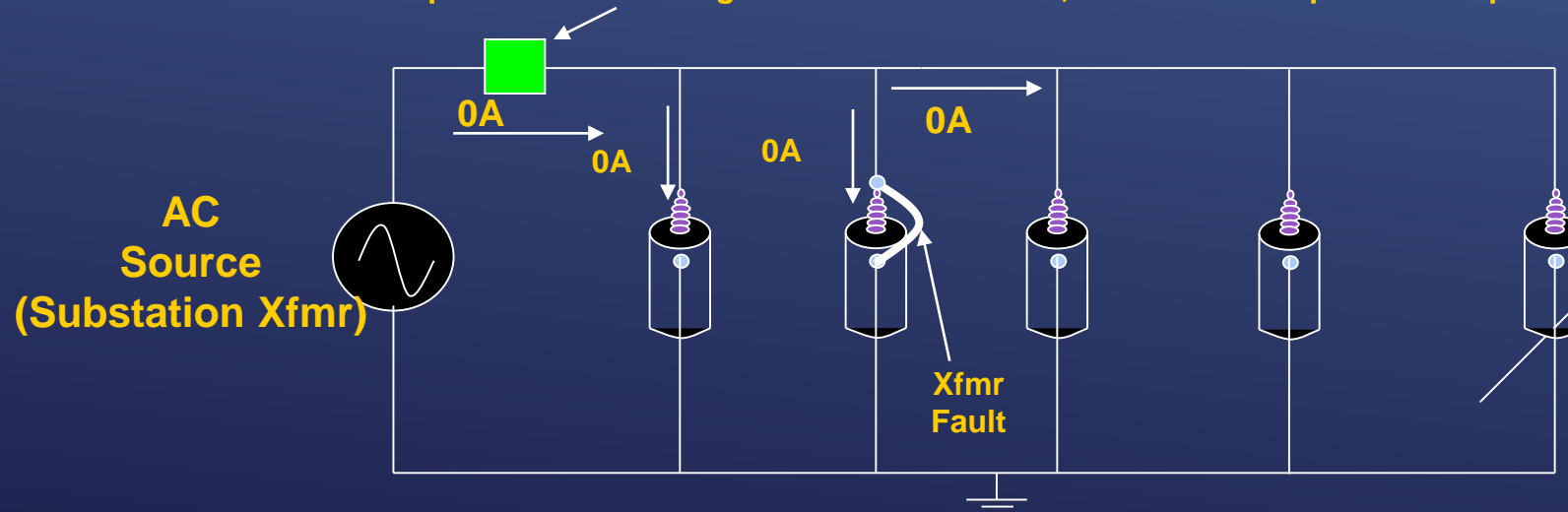
# Common Overcurrent Protective Devices

- **Circuit Breakers (w/relaying)**
- **Fuses**
- **Reclosers**
- **Sectionalizers**

# Circuit Protection (Ckt Brkr)



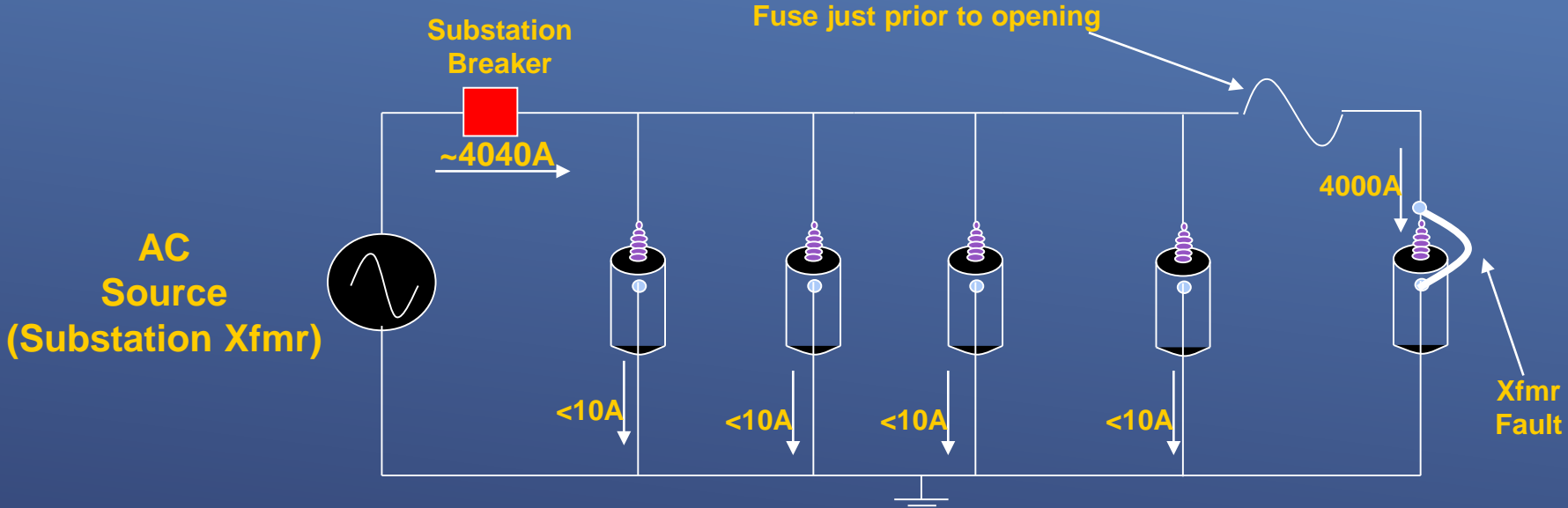
Breaker opens and then recloses thus allowing the downstream fault time to clear, assuming temporary fault. Breakers typically operate a maximum of three times before “locking-out” the fault. If the previous 2 reclosings didn’t clear the fault, breaker locks open on 3<sup>rd</sup> operation.



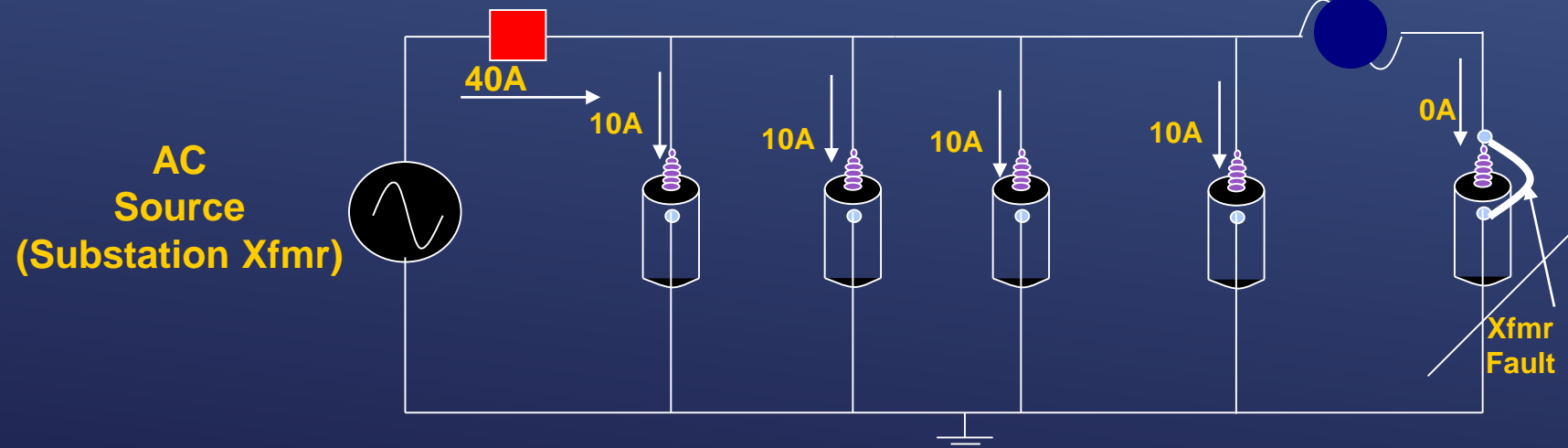
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# Circuit Protection (Ckt Brkr & Fuse)

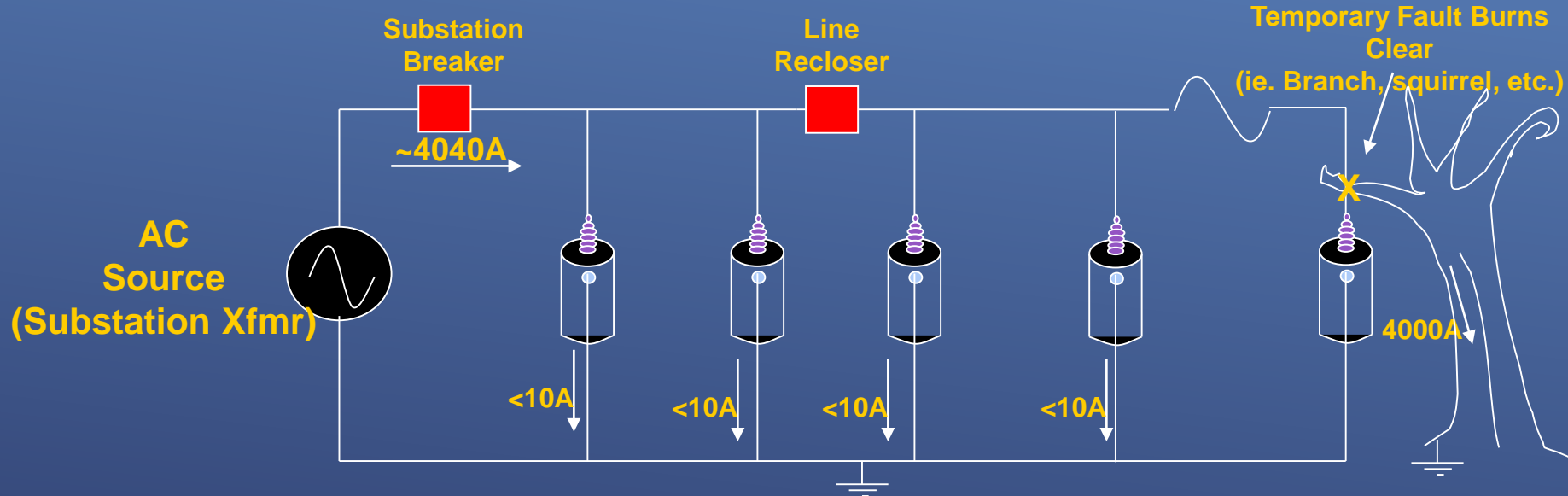


Fuse opens thus clearing the fault while upstream customers retain power.

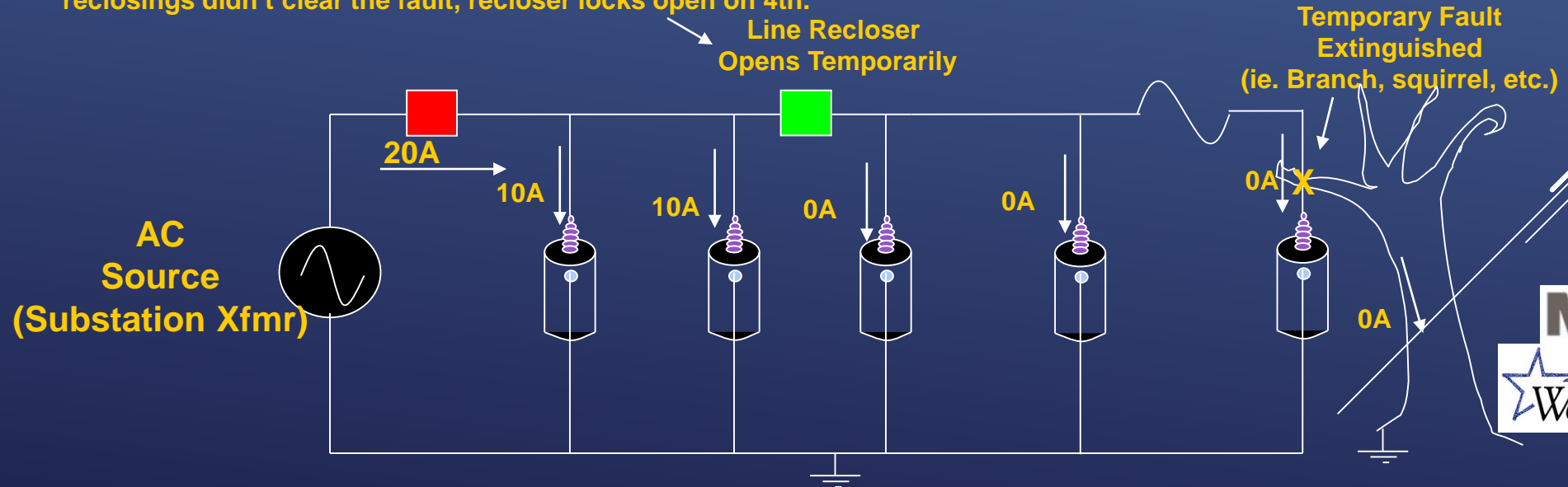




# Circuit Protection (Ckt Brkr, Recloser, Fuse)



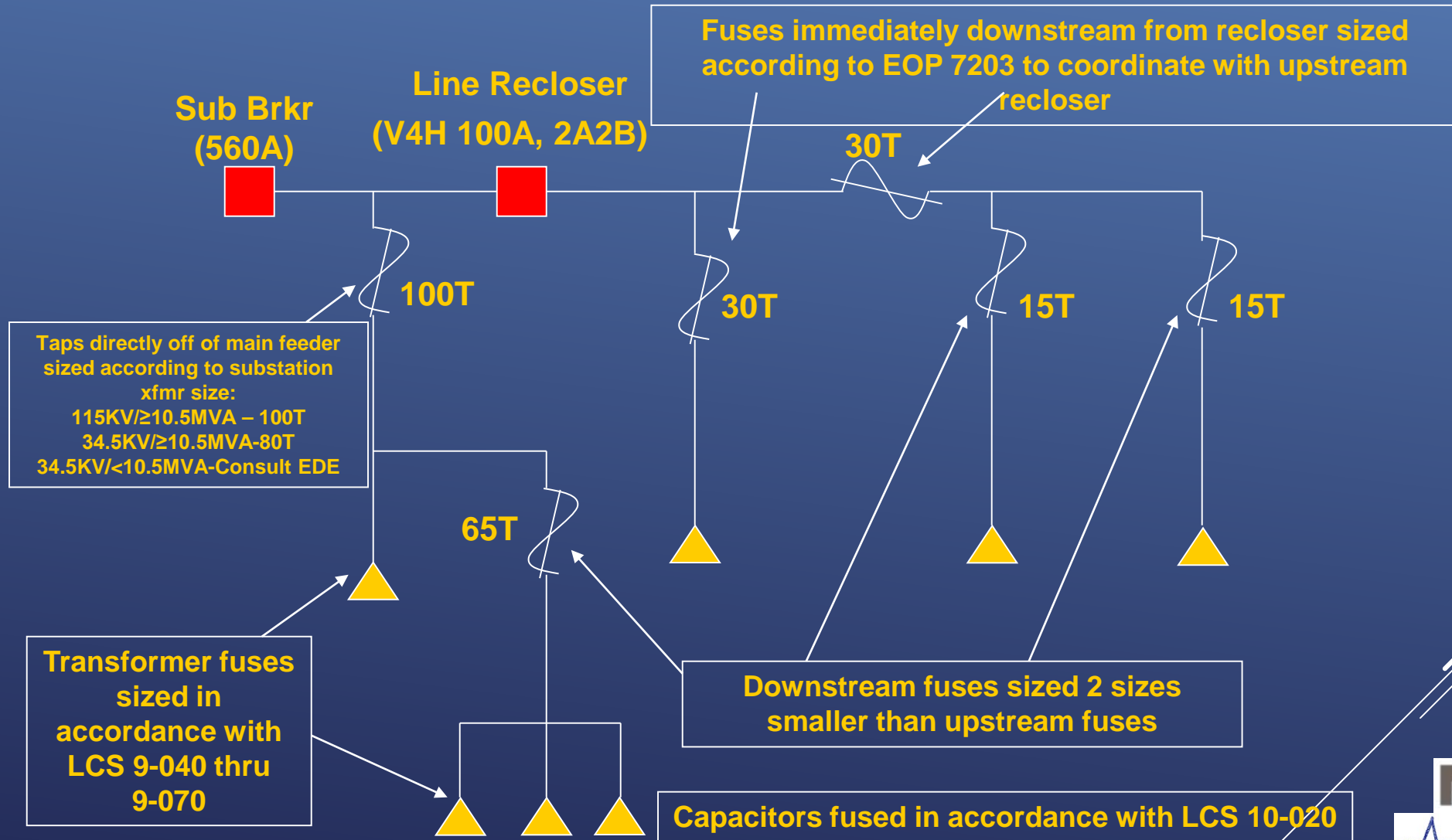
Recloser opens and then recloses thus allowing the downstream fault time to clear. Fuse doesn't open if fault clears. Reclosers typically operate a maximum of twice before fuse clears the fault. If fault is upstream of fuse, and previous 3 reclosings didn't clear the fault, recloser locks open on 4th.



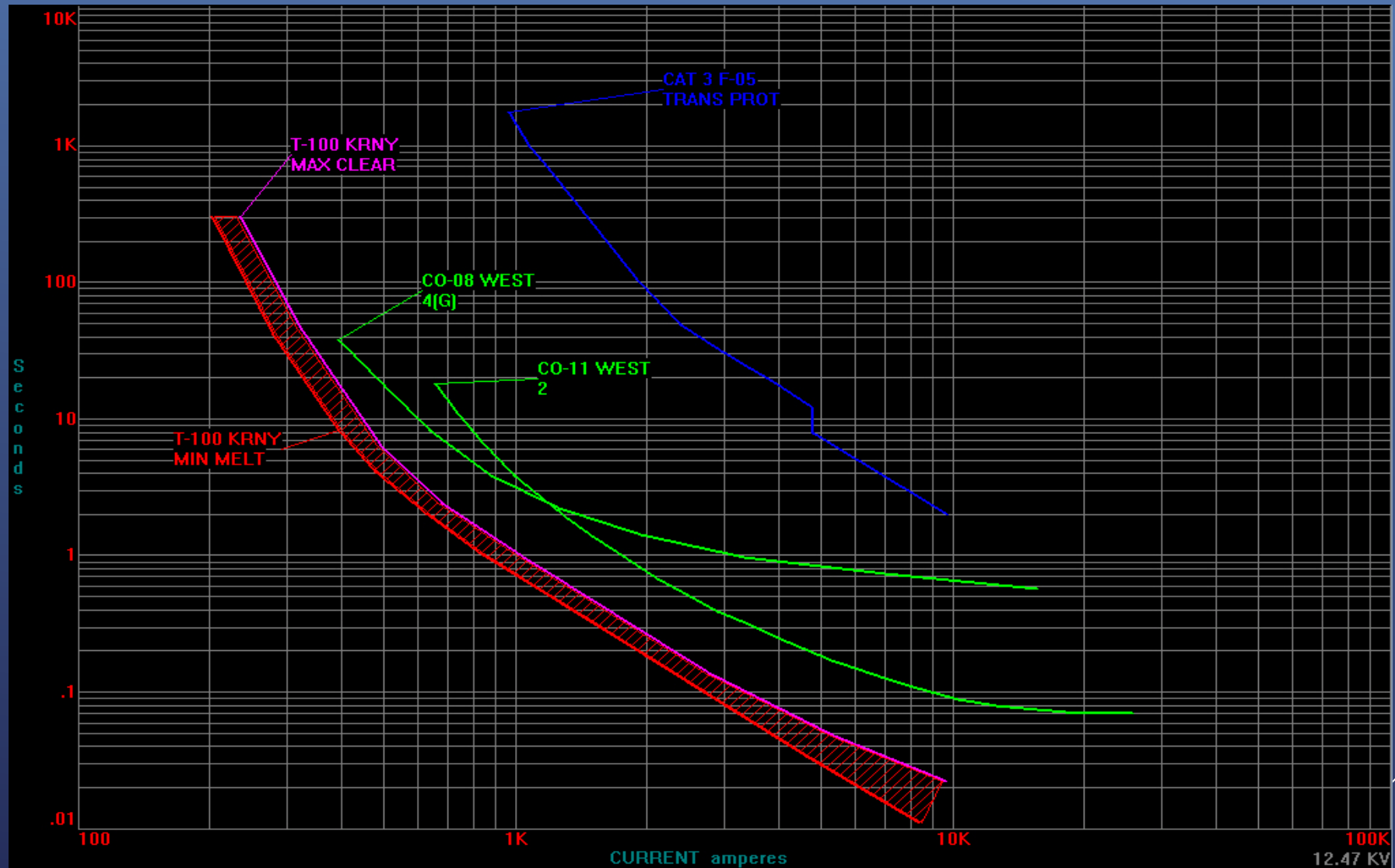
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# Practical Overcurrent Device Application

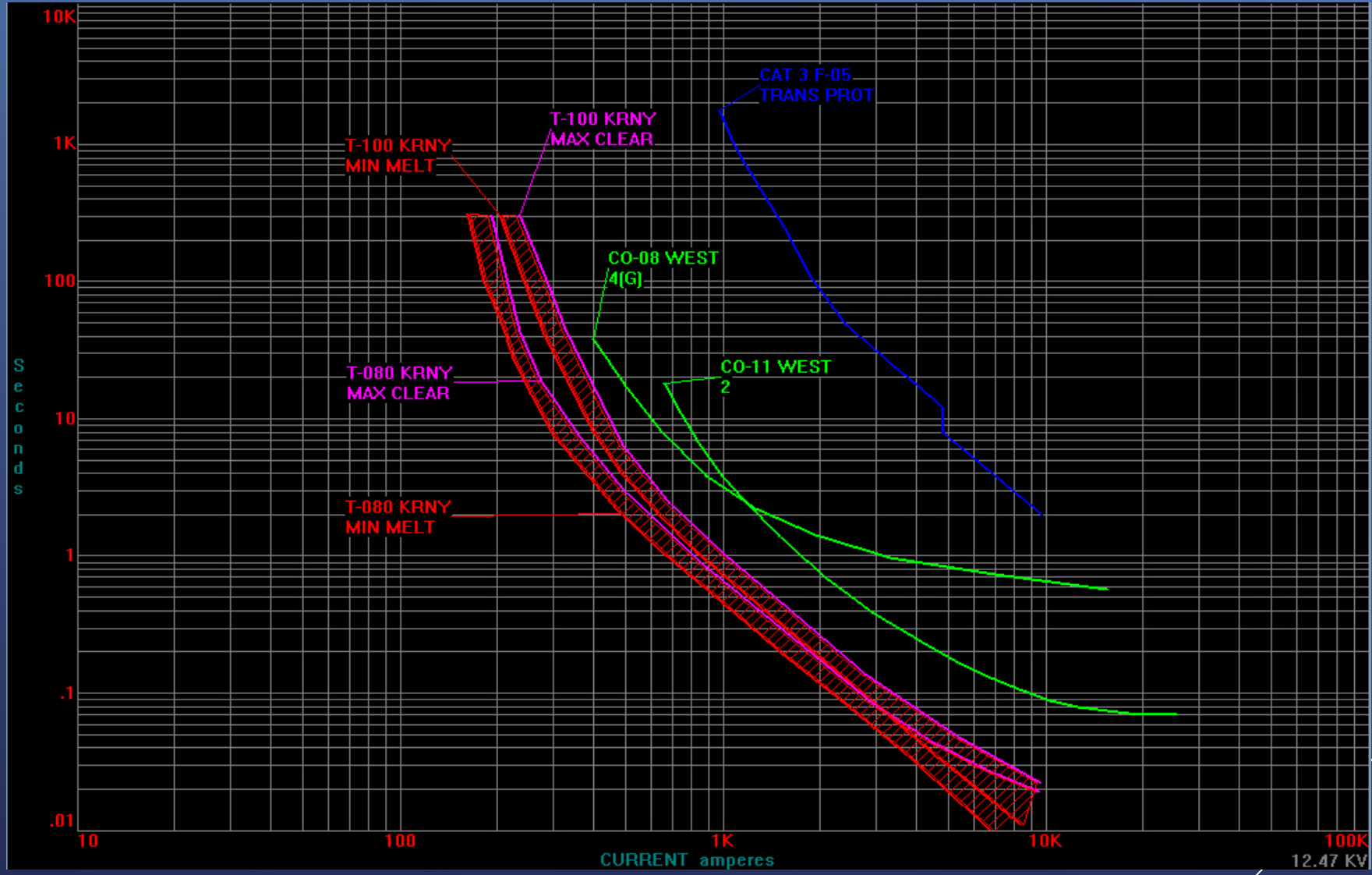


# Substation Breaker – Fuse Coordination





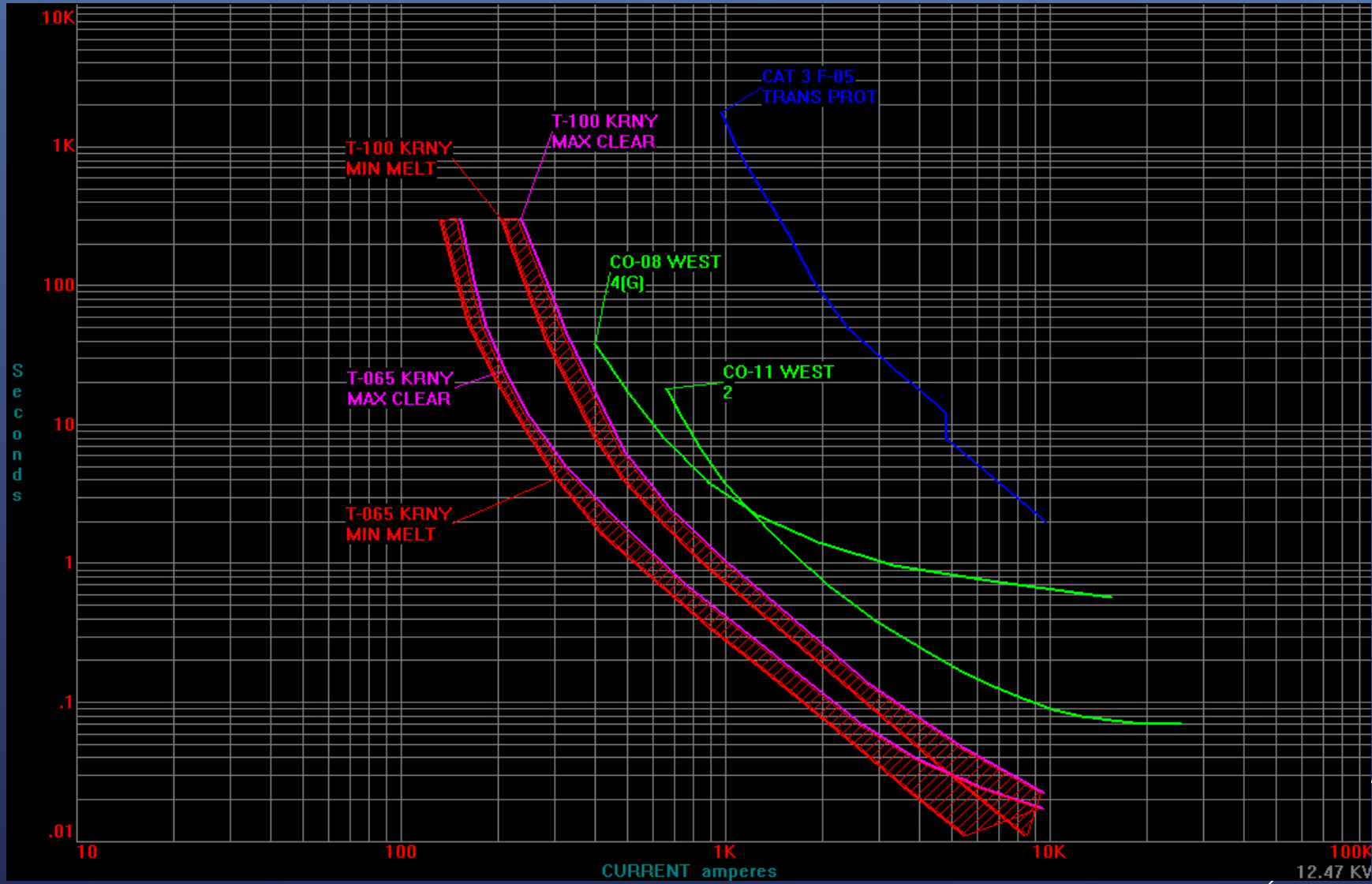
# Fuse – Fuse Incorrect Coordination



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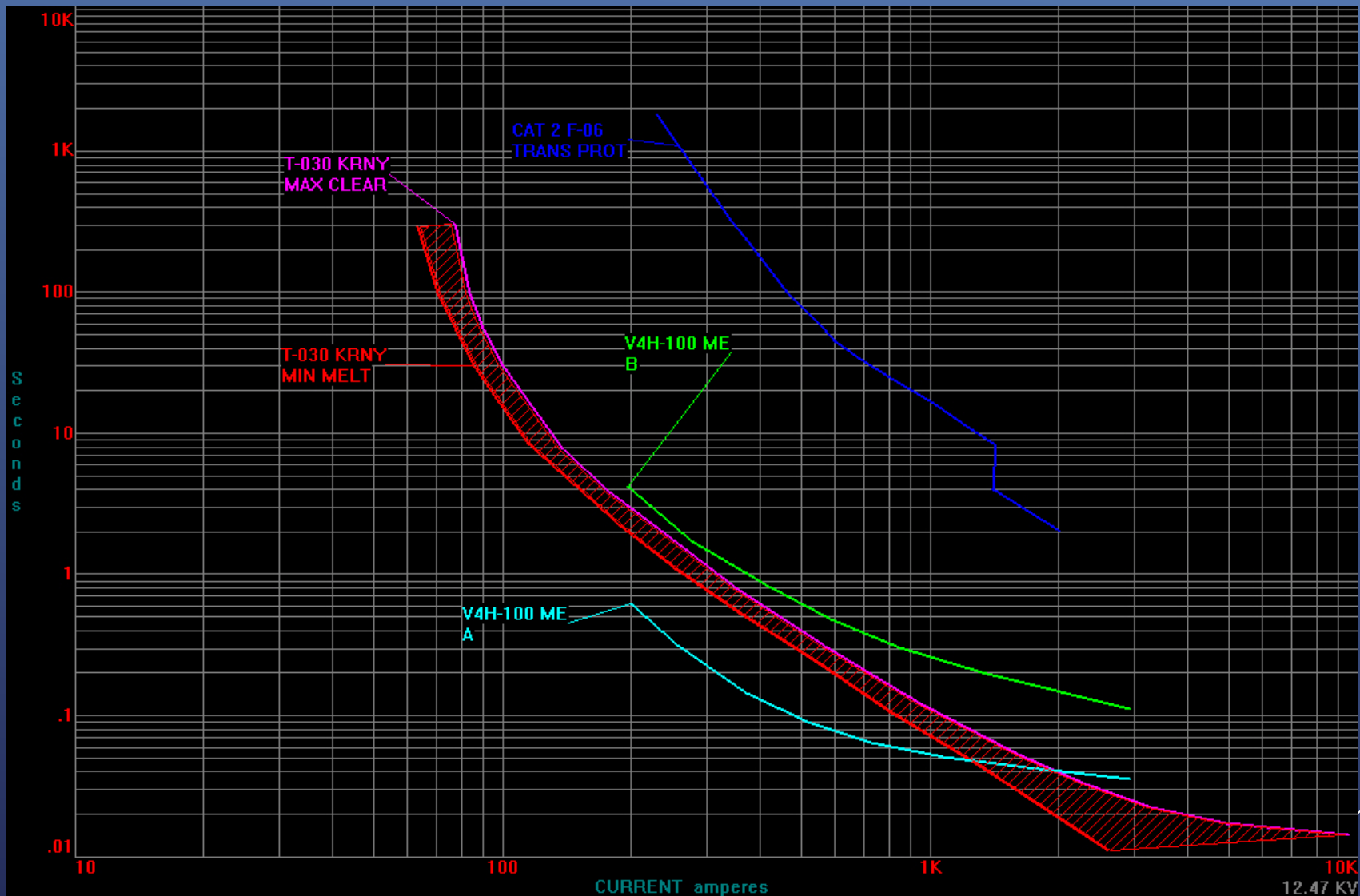
# Fuse – Fuse Correct Coordination



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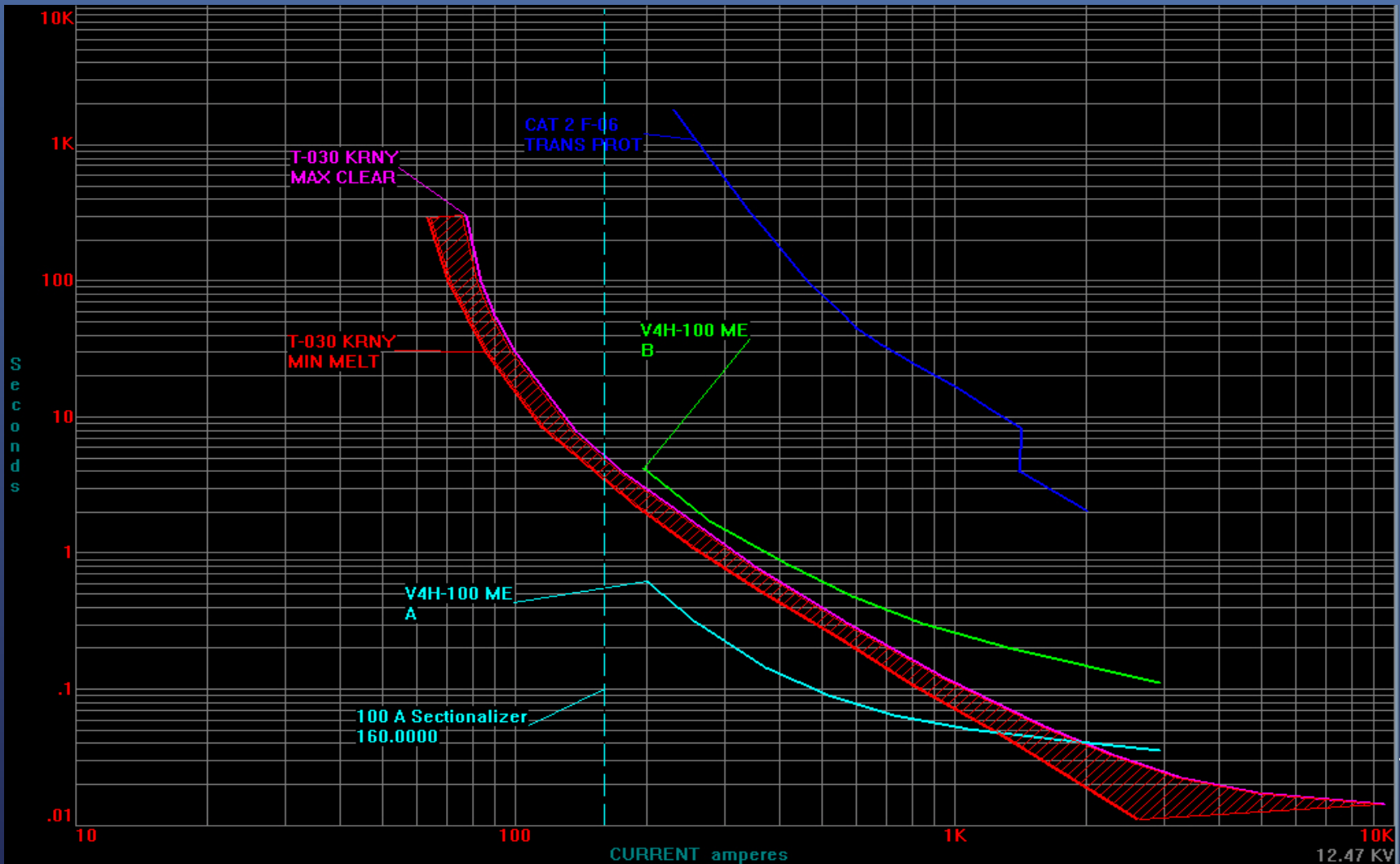
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# Recloser – Fuse Coordination





# Recloser – Fuse - Sectionalizer Coordination



SUBSTATION PROTECTION AND CONTROL

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# TUTORIAL ON ELECTRIC ARC HAZARDS

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# Four Factors Determine Hazard

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- Length of arc
- Distance to arc
- Current in arc
- Duration of arc

# Length of Arc

- Determined by dielectric strength of air (10kV/in)
- Heavily influenced by bus/line spacing
- The longer the arc, the greater the incident energy
- OSHA provides suggested lengths in Table 5 of Appendix E



# Distance to Arc

---

- Distance is single most effective way to reduce arc hazard
- Each doubling of the distance from the arc reduces the hazard to one fourth (inverse square law)
- OSHA provides suggested distances in Table 4 of appendix E

# Current in Arc

---

- The greater the current, the greater the incident energy
- Significantly affected at low voltage by arc impedance
- Very little control over this

# Duration of Arc

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- The sooner that the arc can be extinguished, the lower the incident energy
- High speed tripping can have a dramatic effect on reducing incident energy



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