

Transmission Issues



Western Electricity
Coordinating Council

Transmission Topics



- **What is transmission?**
- **Network Design**
- **Path Definition & Constraints**
- **AC vs. DC transmission**

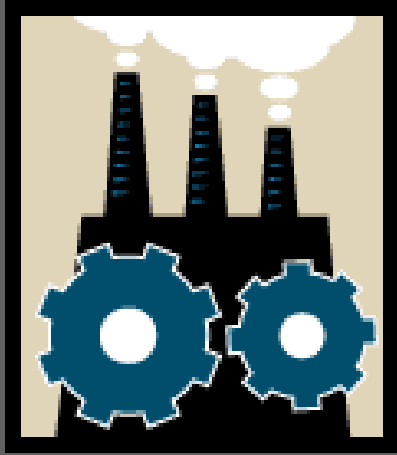
Transmission Topics



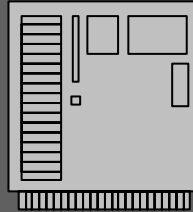
- **System Protection**
- **Remedial Action Schemes**
- **Voltage Control**
- **Unscheduled Flow**

What is transmission?

- **“Highway” for bulk power**
- **High design voltages**
- **High design reliability**



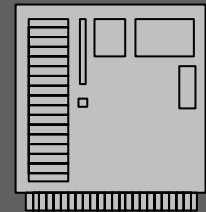
Generator



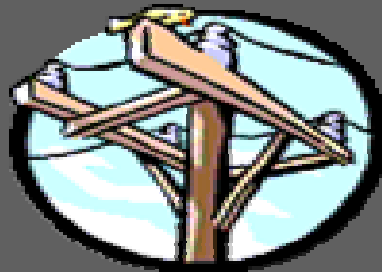
**Step-up
Transformer**



**Transmission
System**



**Distribution
Substation
Transformer**



**Distribution
system**



Customer

Transmission System Components

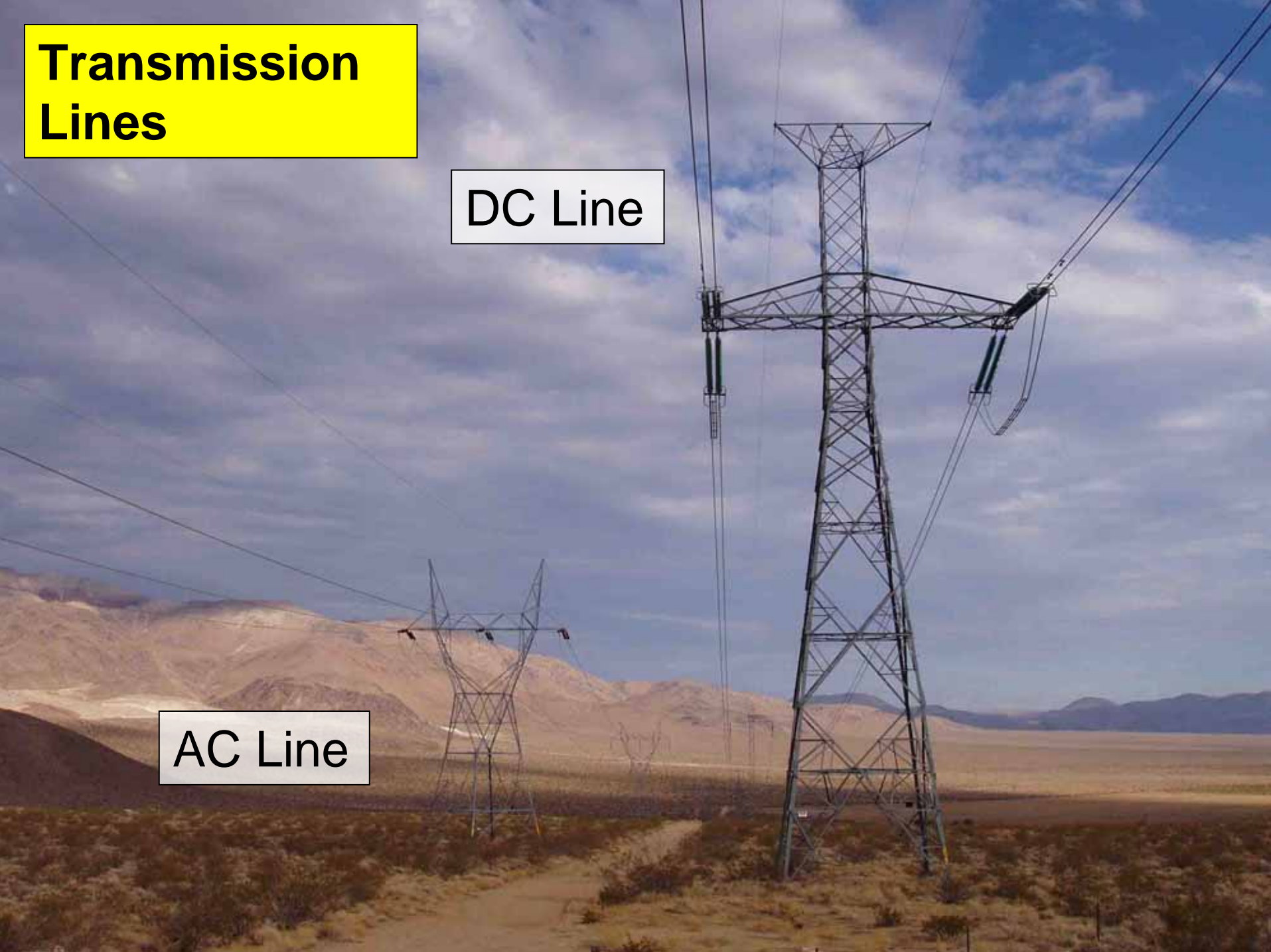


- **Lines and towers**
- **Power Transformers**
- **Circuit breakers, switches, buswork**
- **Capacitors, reactors**
- **Control, metering, and protective equipment**

Transmission Lines

DC Line

AC Line



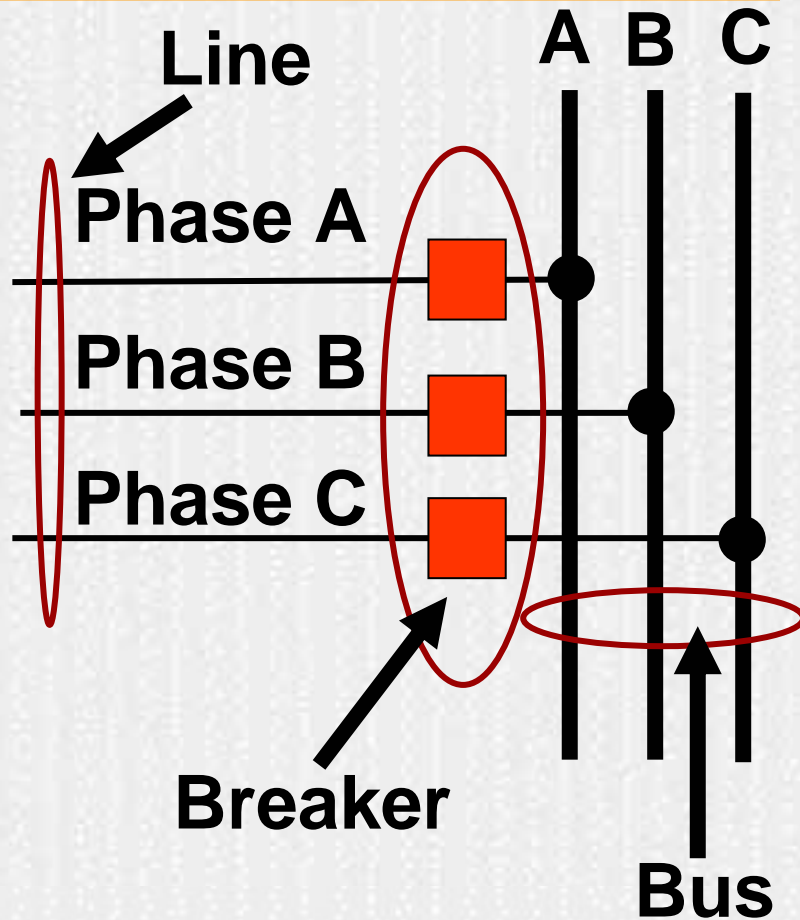
Network Design Effects on Reliability

- **Design influences reliability**
- **Higher reliability designs usually cost more**
- **Reliability considerations:**
 - **Operational reliability**
 - **Ease of repair/restoration**
 - **Ease of maintenance**

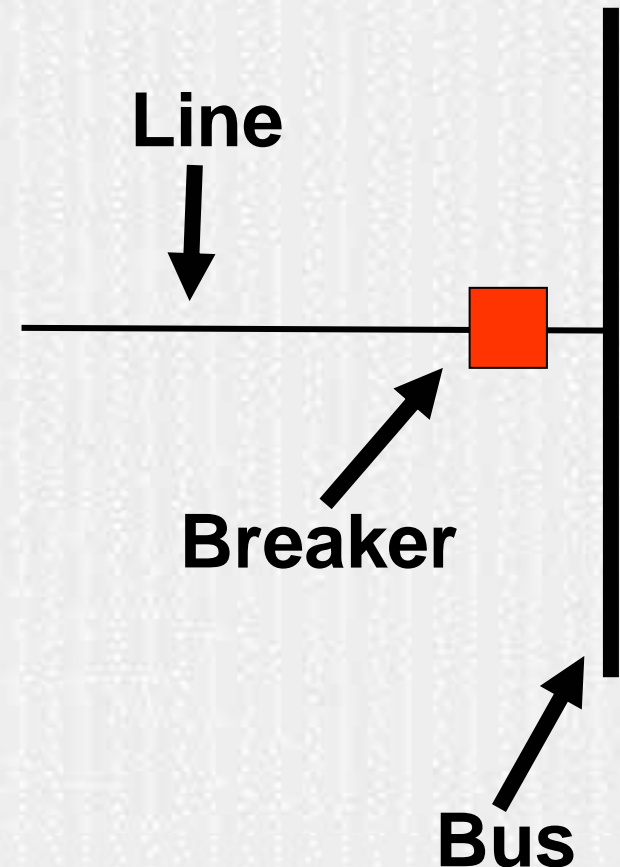
Electrical Diagrams



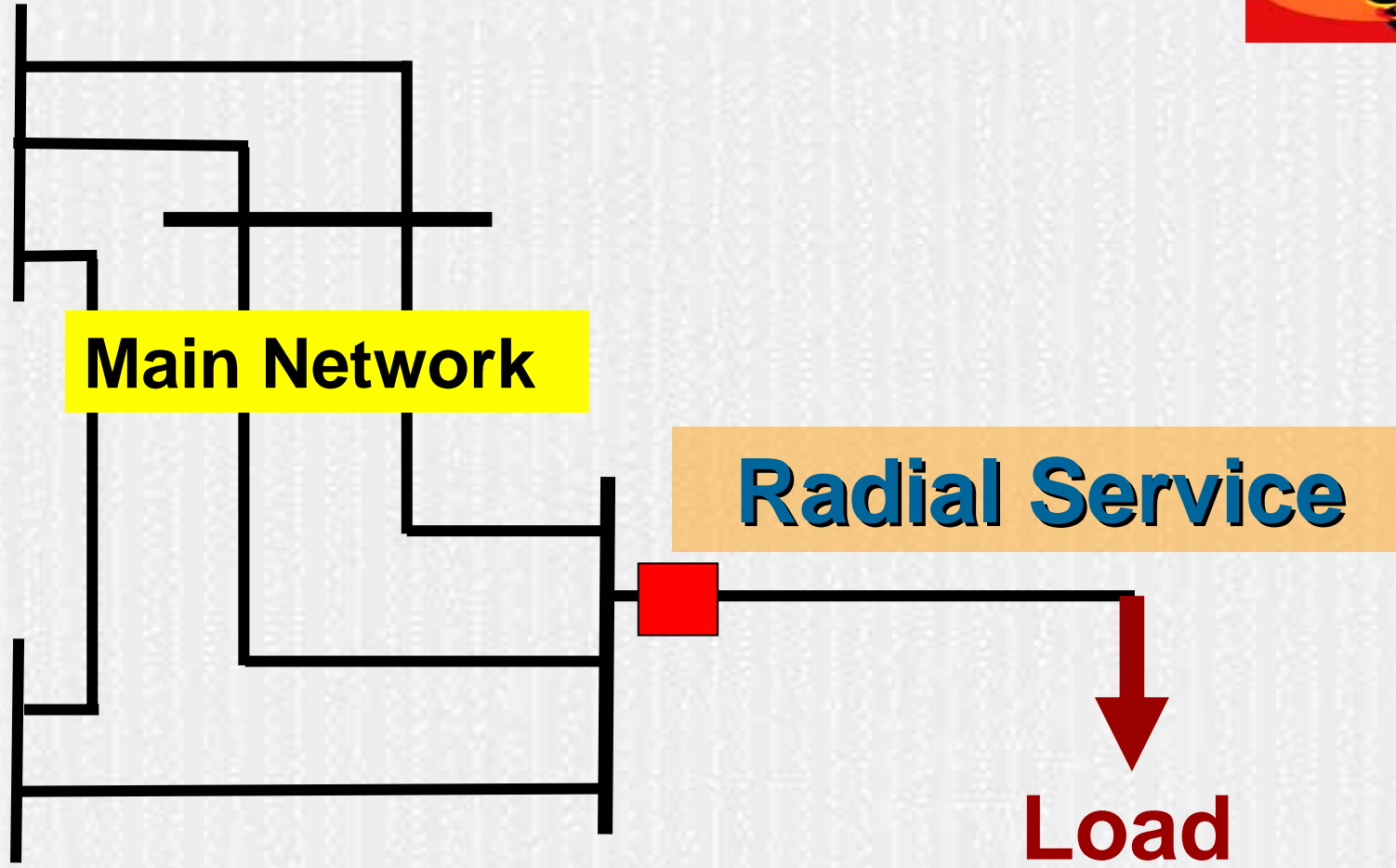
Three phase diagram



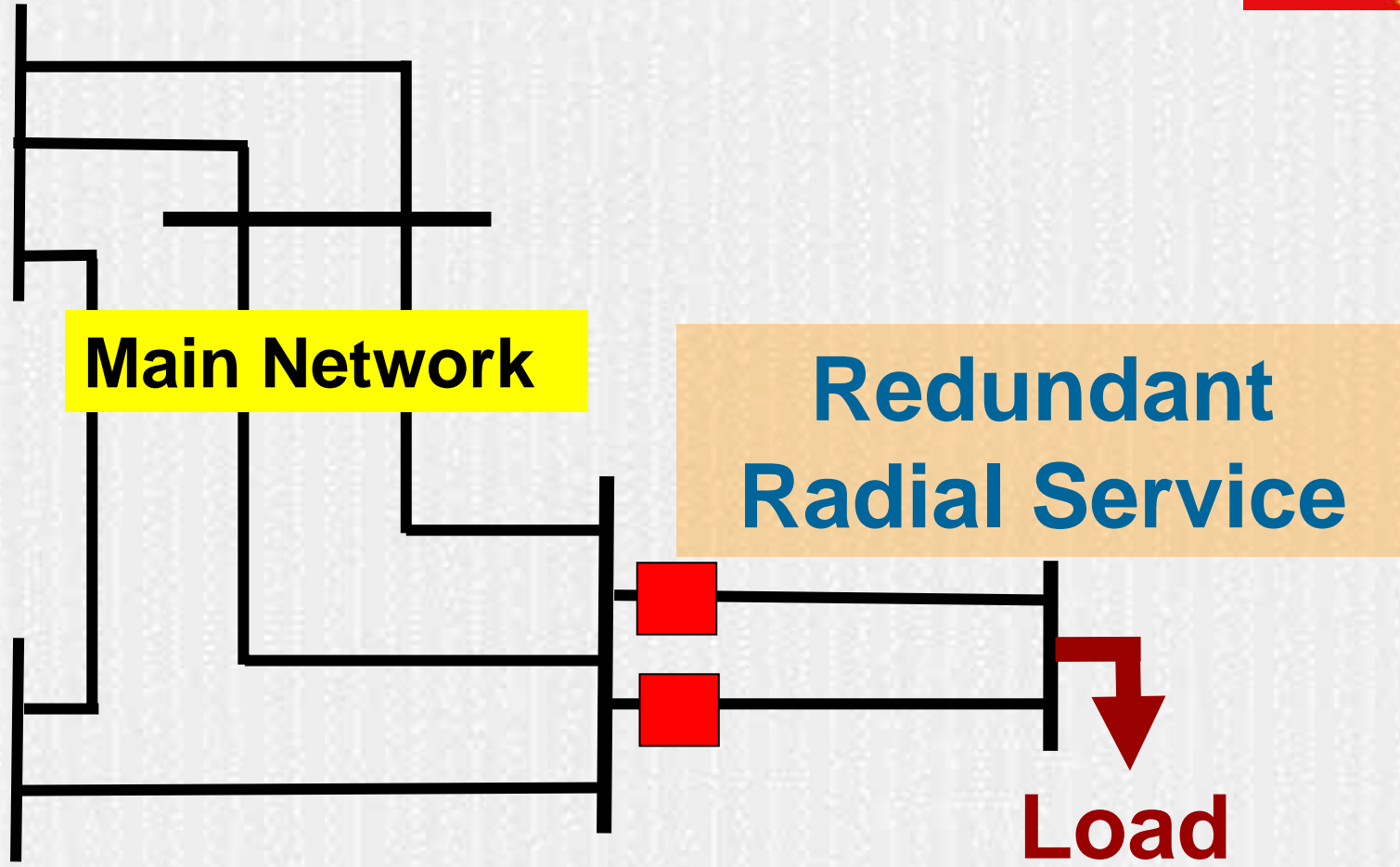
One-line diagram



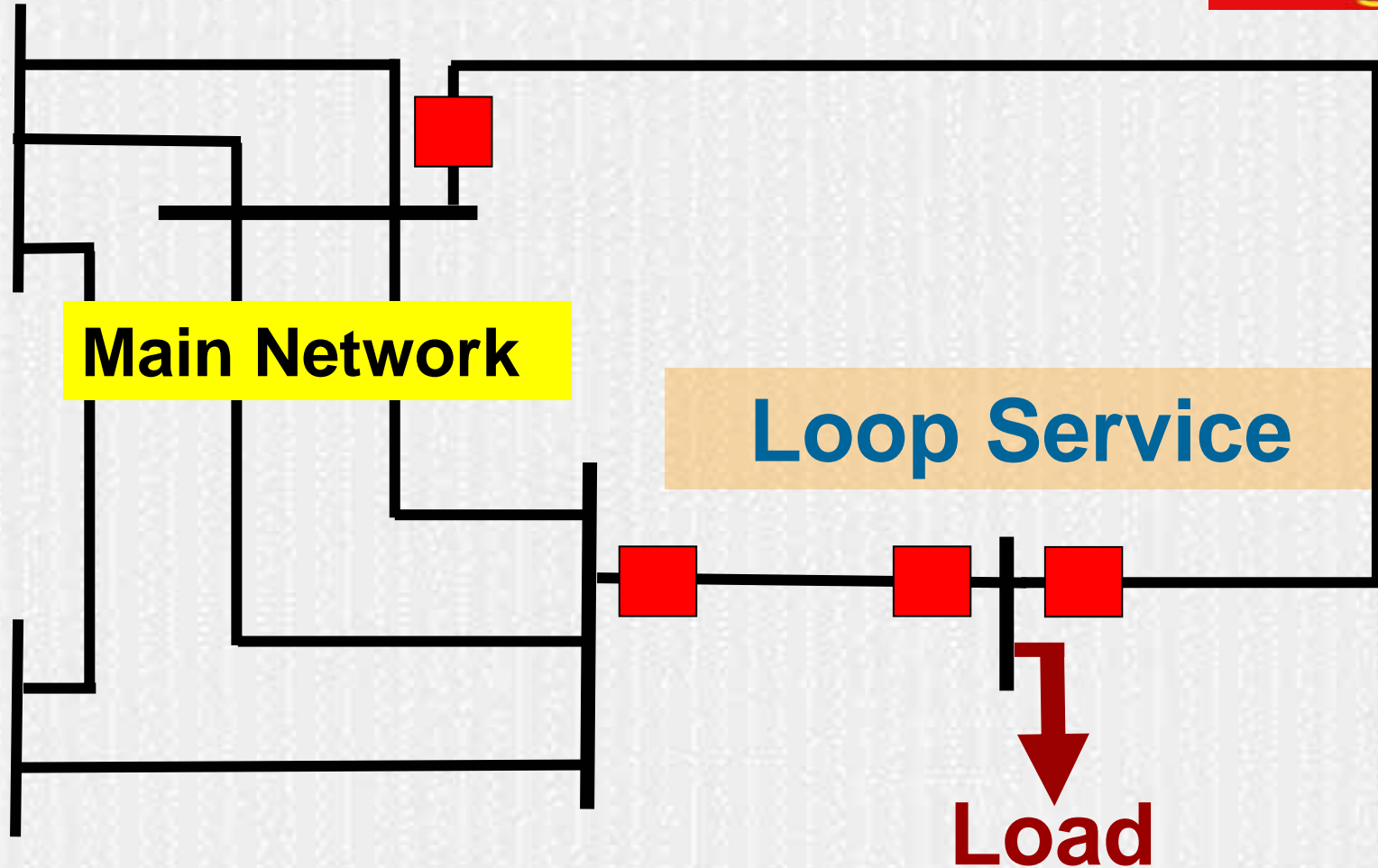
Network Design Effects on Reliability



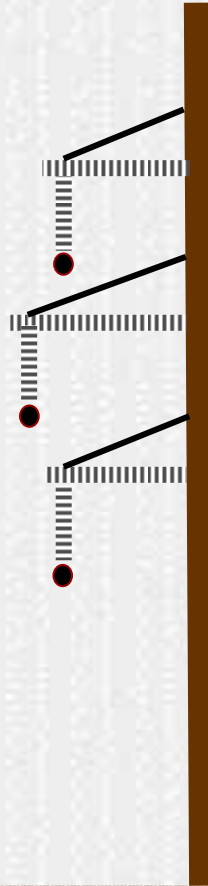
Network Design Effects on Reliability



Network Design Effects on Reliability

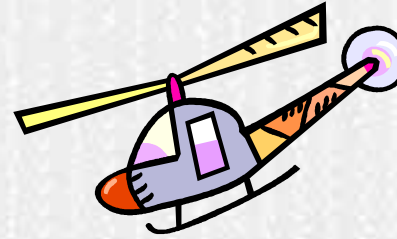
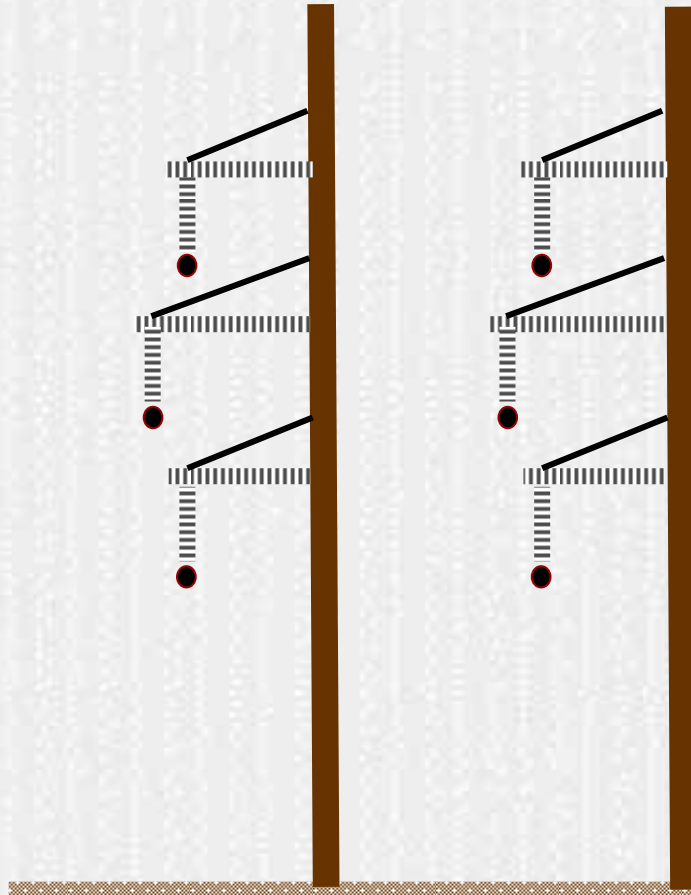


Network Design Effects on Reliability



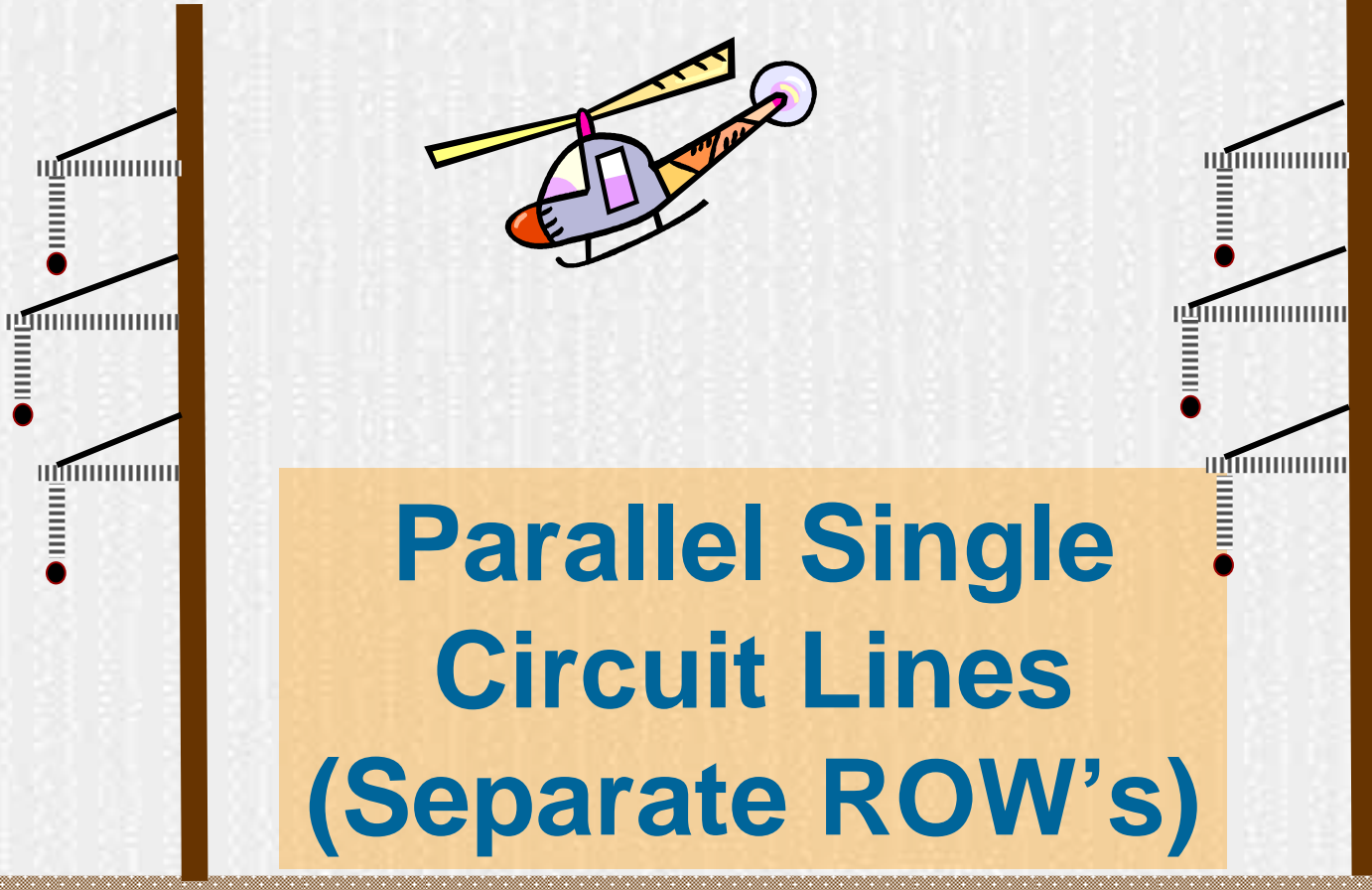
**Single Circuit
Line**

Network Design Effects on Reliability

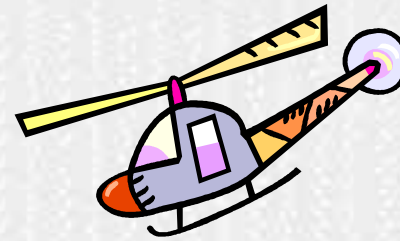
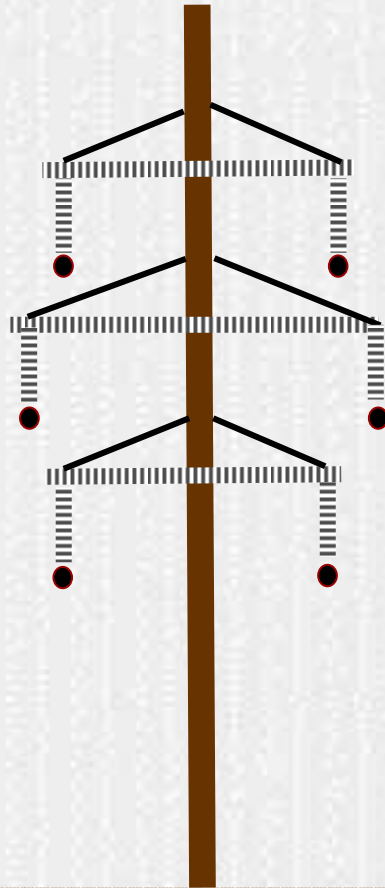


**Parallel Single
Circuit Lines
(Common ROW)**

Network Design Effects on Reliability

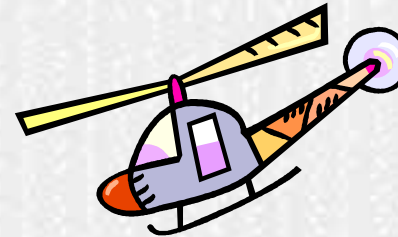
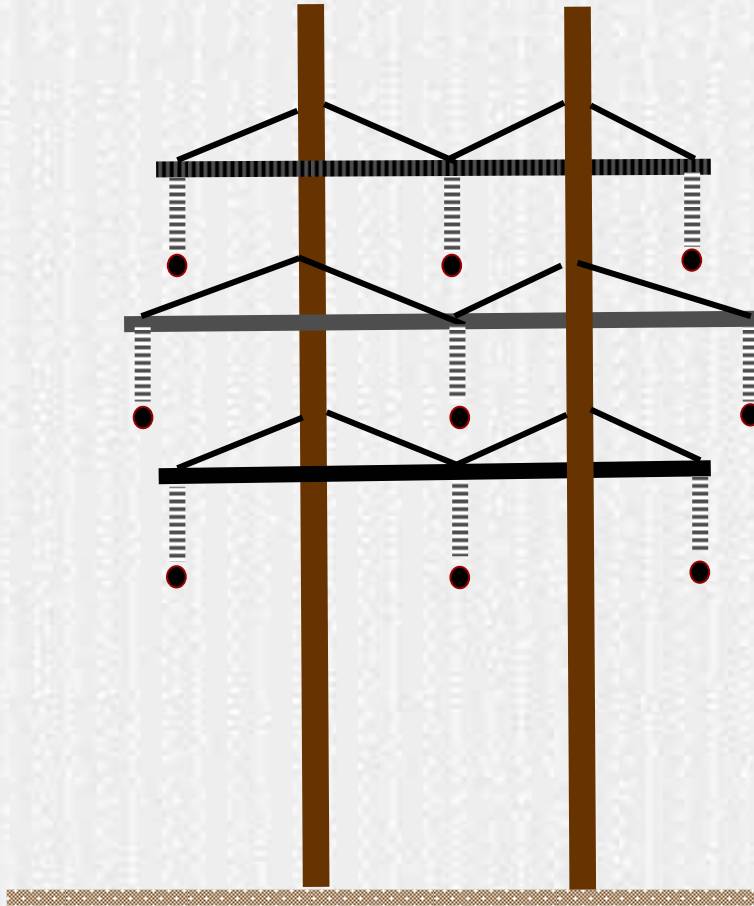


Network Design Effects on Reliability



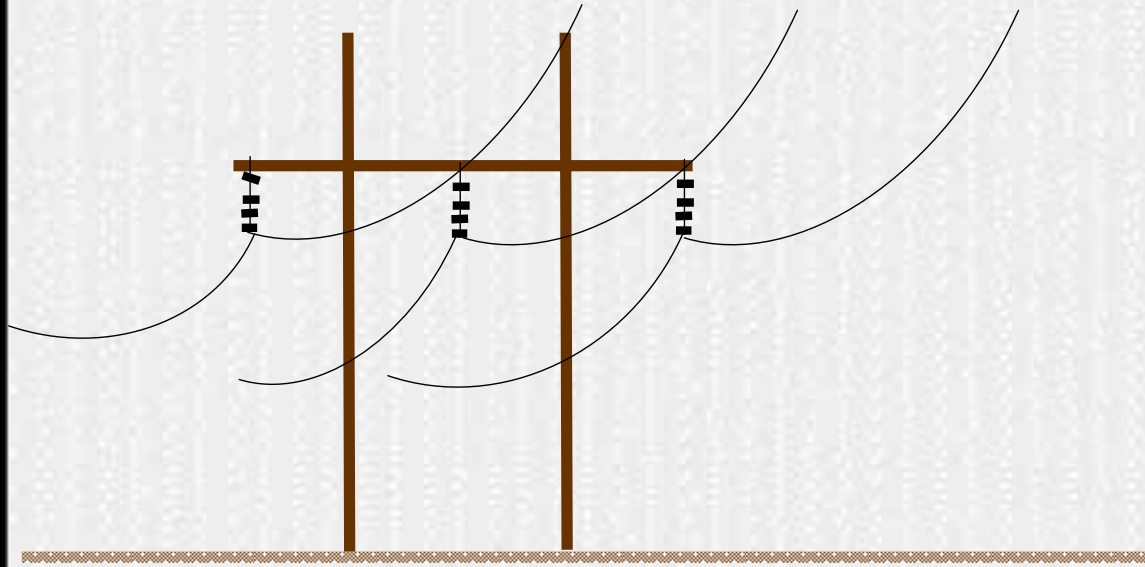
**Double Circuit
Line**

Network Design Effects on Reliability



**Triple Circuit
Line**

Overhead vs. Underground Construction





Overhead Pro's & Con's

- **Least expensive**
- **Easy to locate & repair problems**
- **Vulnerable to weather & hazards**
- **Requires large right-of-way**
- **Difficult to site in congested & pristine areas**
- **Easier to reconfigure & upgrade**

Underground Pro's & Con's



- **Expensive**
- **Protected from most hazards**
- **Difficult to locate & repair problems**
- **Requires minimal right-of-way**
- **Often only option to site in congested & pristine areas**

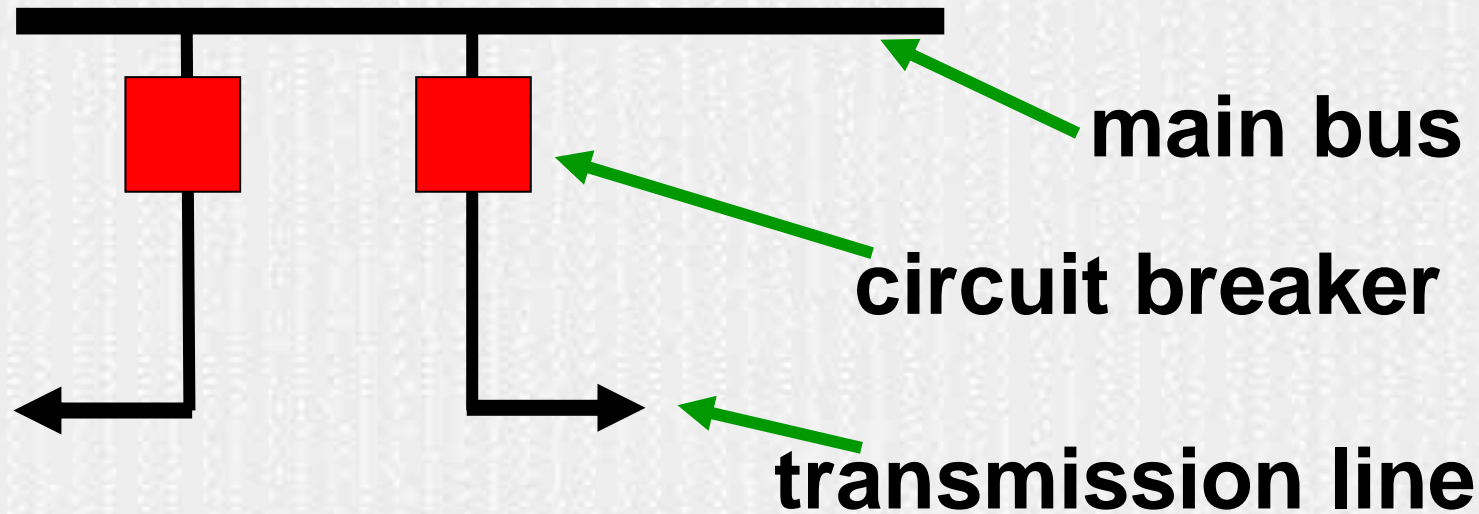
Substation Design



- **Station design can greatly affect reliability**
- **Complex designs allow more configuration options**
 - **Enhanced ability to isolate problems**
 - **Greater continuity of service**
 - **More maintenance options**
- **Flexibility comes at a cost**

Substation Bus Configurations

Single Bus / Single Breaker

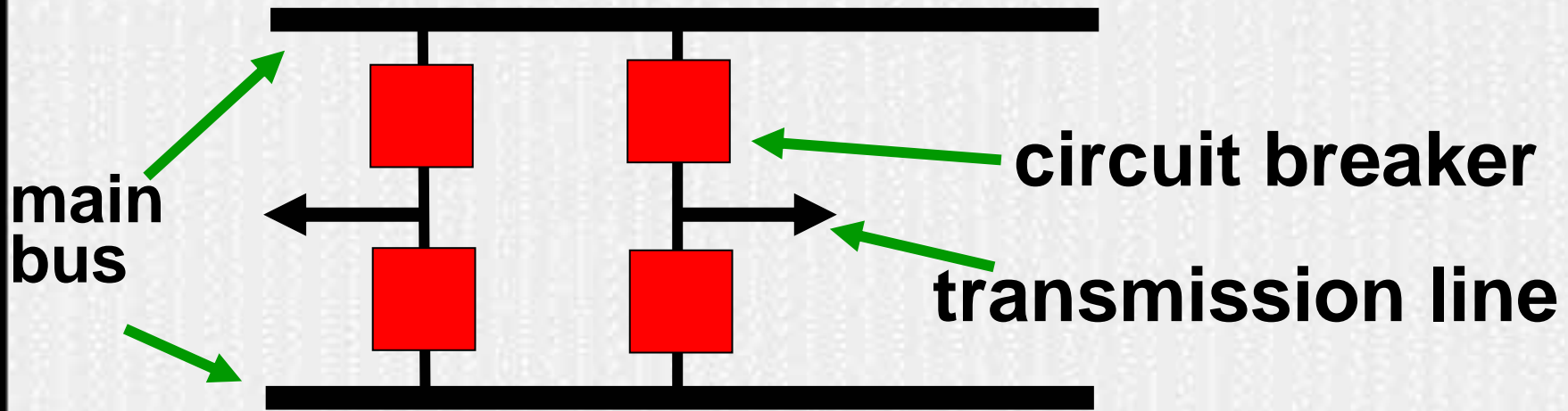


Each line is protected by a single circuit breaker.
Breaker outage opens line

An outage of the bus opens all lines at this station

Substation Bus Configurations

Double Bus / Double Breaker

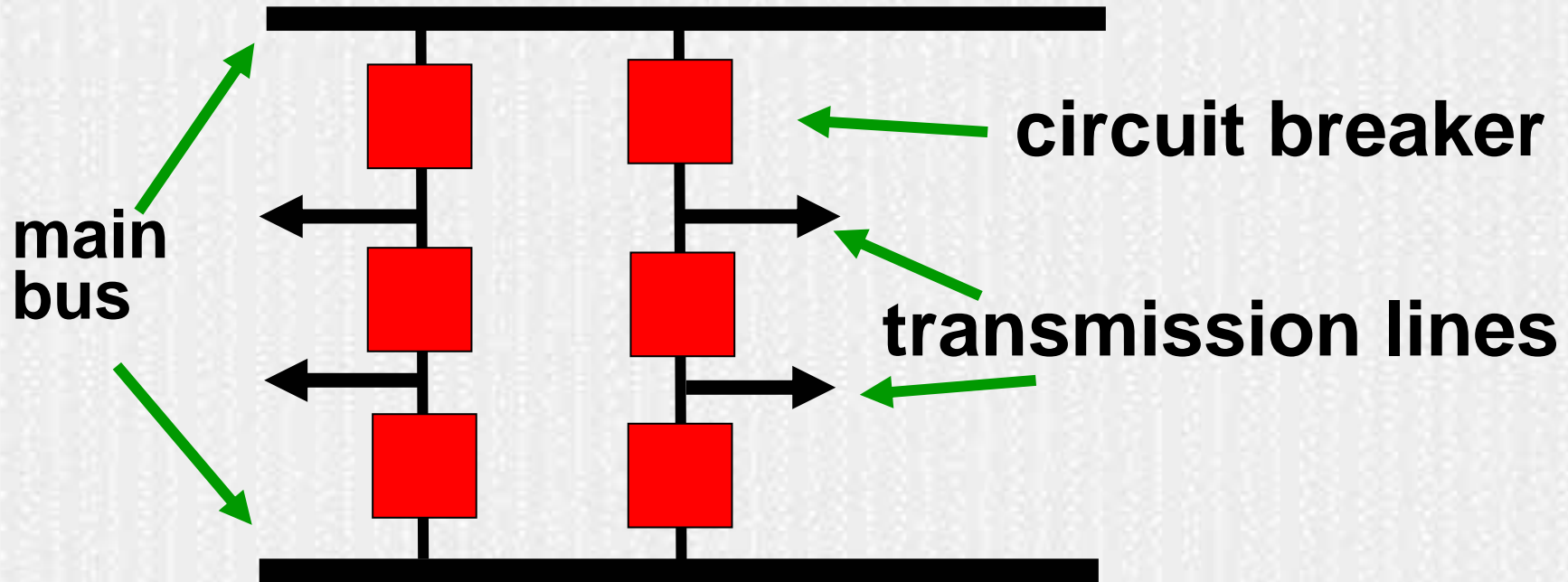


Each line is protected by two circuit breakers.

An outage of either bus or any breaker does not outage any lines.

Substation Bus Configurations

Breaker-and-a-half

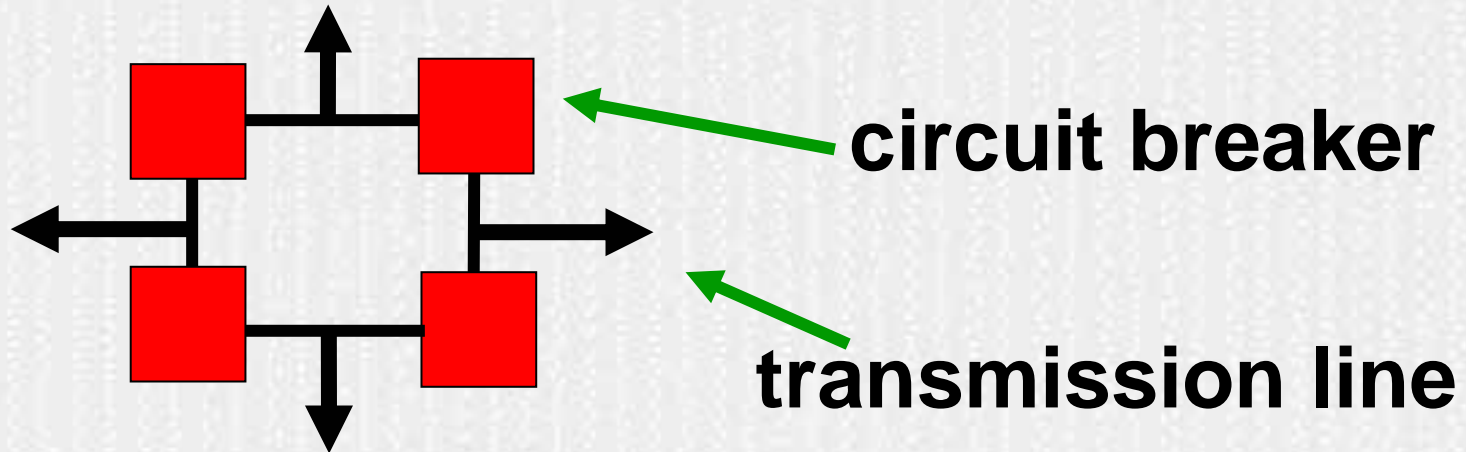


Each line is protected by “1-1/2” circuit breakers.

An outage of any bus or any breaker does not outage any lines.

Substation Bus Configurations

Ring Bus

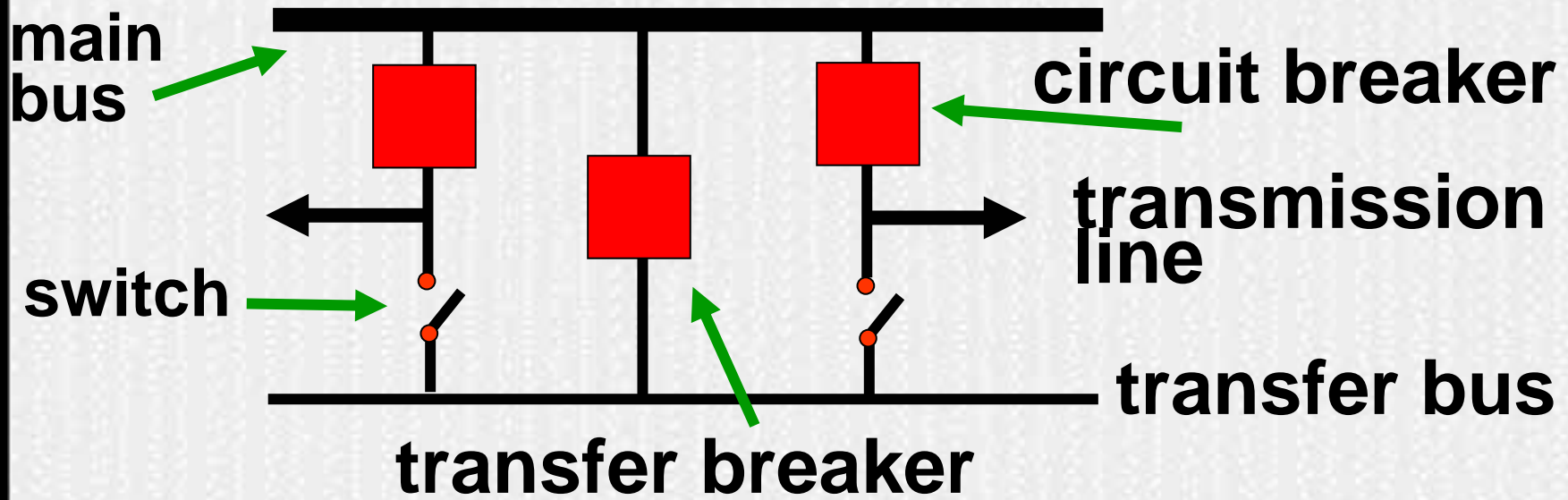


Each line is protected by two circuit breakers.

An outage of any breaker does not outage any lines.

Substation Bus Configurations

Main & transfer bus



Transfer breaker and switch allows either line to remain energized while its normal breaker is out for maintenance

Basics of Transmission Path Limitations

- A number of lines operating in proximity to each other can form a line corridor or path.
- Interactions among the lines can be significant enough to require a path limit or rating.

Basics of Transmission Path Limitations

- Limiting factors can be thermal overload, poor voltage performance, instability.
- The path rating considers the N-1 reliability requirement.

Basics of Transmission Path Limitations

“The bulk power systems will be operated at all times so that general system instability, uncontrolled separation, cascading outages, or voltage collapse will not occur as a result of the most severe single contingency. (N-1)”

-WECC Minimum Operating Reliability Criteria

Example of a Path Limit

Line X - rating 550 Mw Normal Conditions

Actual flow = 350 Mw

Line Y - rating 445 Mw

Actual flow = 250 Mw

Line Z - rating 400 Mw

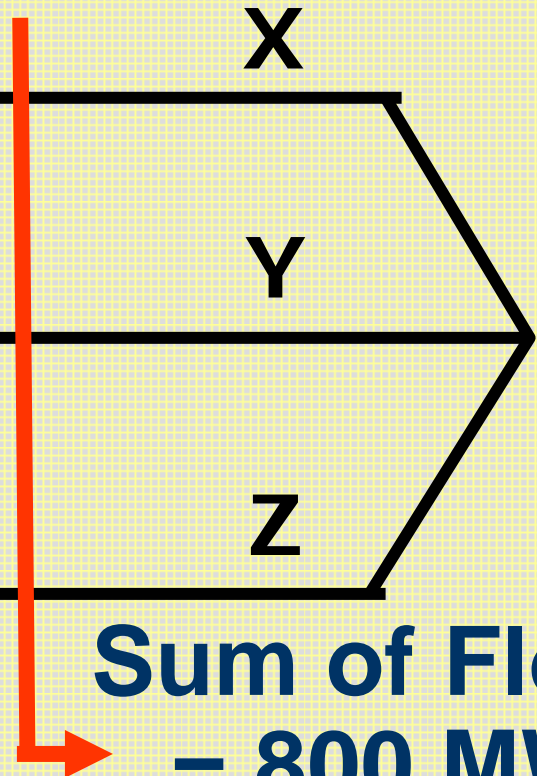
Actual flow = 200 Mw

Sum of ratings = 1395 Mw

**Sum of Flows
= 800 MW**

What is the Path Limit?

- a. 1395 Mw b. 800 Mw c. 845 Mw d. 928 Mw



Transmission Path Rating

- A Transmission Path Rating is based on maximum reliable power transfer capability under all conditions.
- Rating is determined by mutual agreement of regional utility peers and then blessed by WECC.
- Operating conditions may limit the path below its max rating.

Stability Limits versus Thermal Limits

- A Thermally Rated line – a line where the limitation is equipment heating.
- A Stability Rated line – a line where power transfer limits are voltage angle stability limits.
- The Western Interconnection transmission lines tend to be limited more by stability than by thermal ratings.

Transmission Constraints

- **Inadequate design capacity**
- **Scheduled maintenance**
- **Forced outages**
- **Poor voltage conditions**
- **Unscheduled flow**
- **Conservative operation**
 - **Weather**
 - **Potential sabotage**
 - **Uncertain or lost operating data**
 - **Compromised protection**

AC vs. DC Transmission

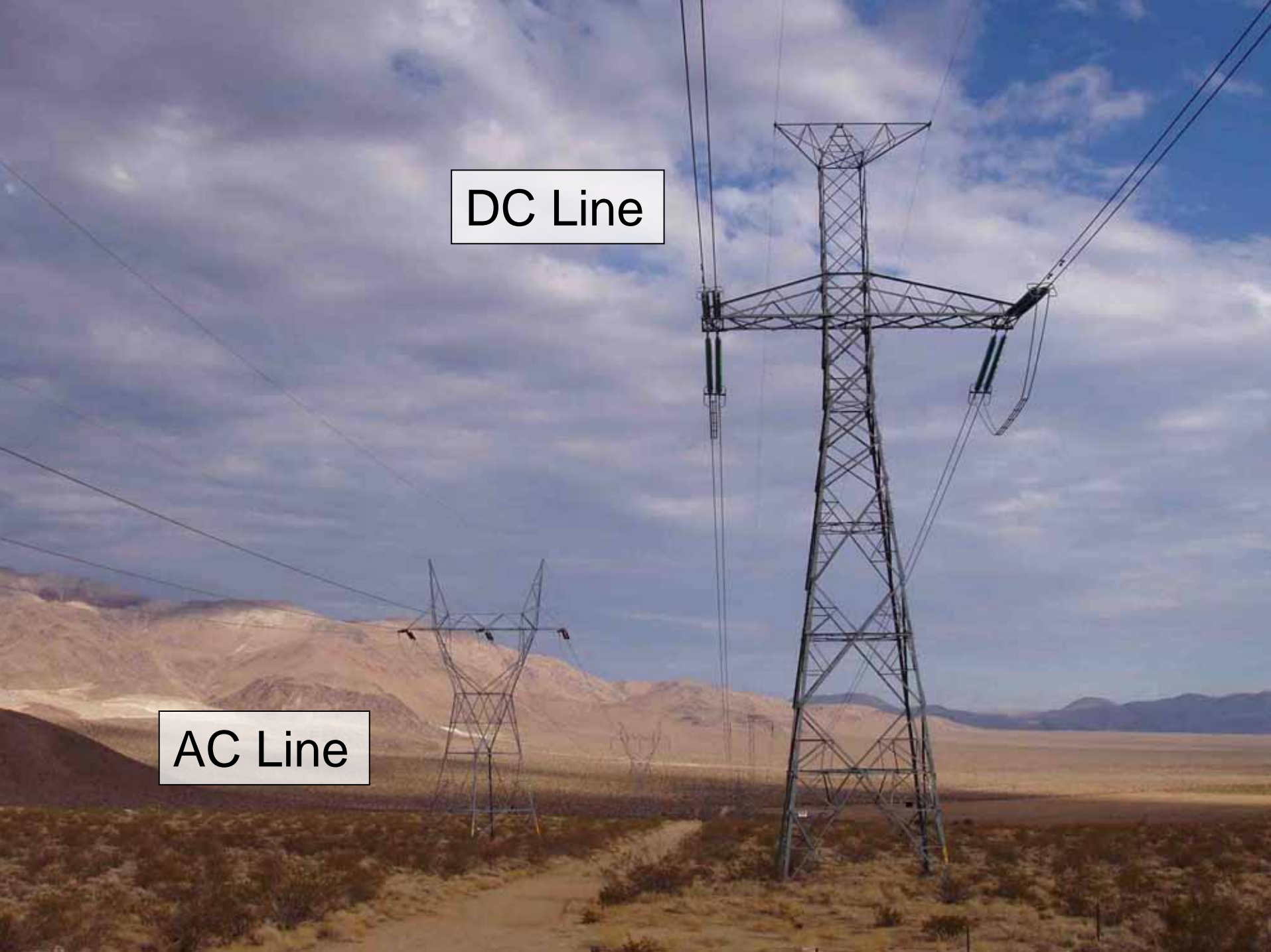
- Most transmission facilities are AC (alternating current), primarily due to its lower construction cost.
- AC allows easy voltage transformation and circuit configuration.
- Transmission losses are much greater on AC lines.

AC vs. DC Transmission

- AC lines are vulnerable to stability and unscheduled flow problems.
- Power flow over DC transmission line can be very well controlled.
- DC transmission requires expensive converter stations, though line construction is cheaper.

DC Line

AC Line



AC vs. DC Transmission

- DC is used when the additional cost can be justified.
 - Very long, high capacity lines
 - Back-to-back ties
- DC provides no dynamic response without special controls.

System Protection

- **Abnormalities, or faults, can occur on the system.**
 - **Short-circuits**
 - **Open circuits**
 - **Overloads**
 - **Other problems**

Typical Causes of Faults

- **Lightning, wind, & ice**
- **Contacts with trees & animals**
- **Broken wires and towers**
- **Failed system equipment**

System Protection

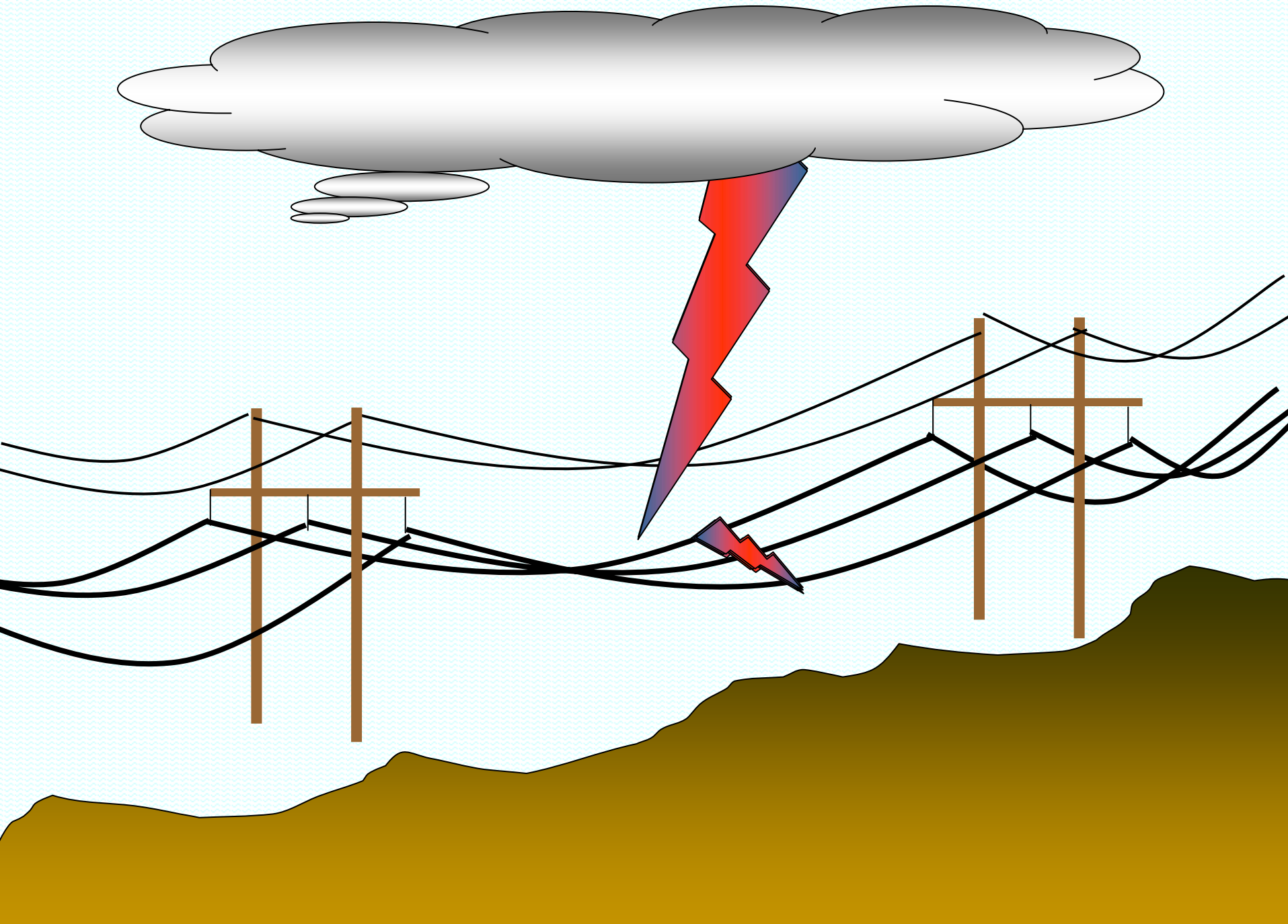
- **Fault conditions can:**
 - **Damage equipment**
 - **Endanger the public**
 - **Compromise system reliability**

System Protection

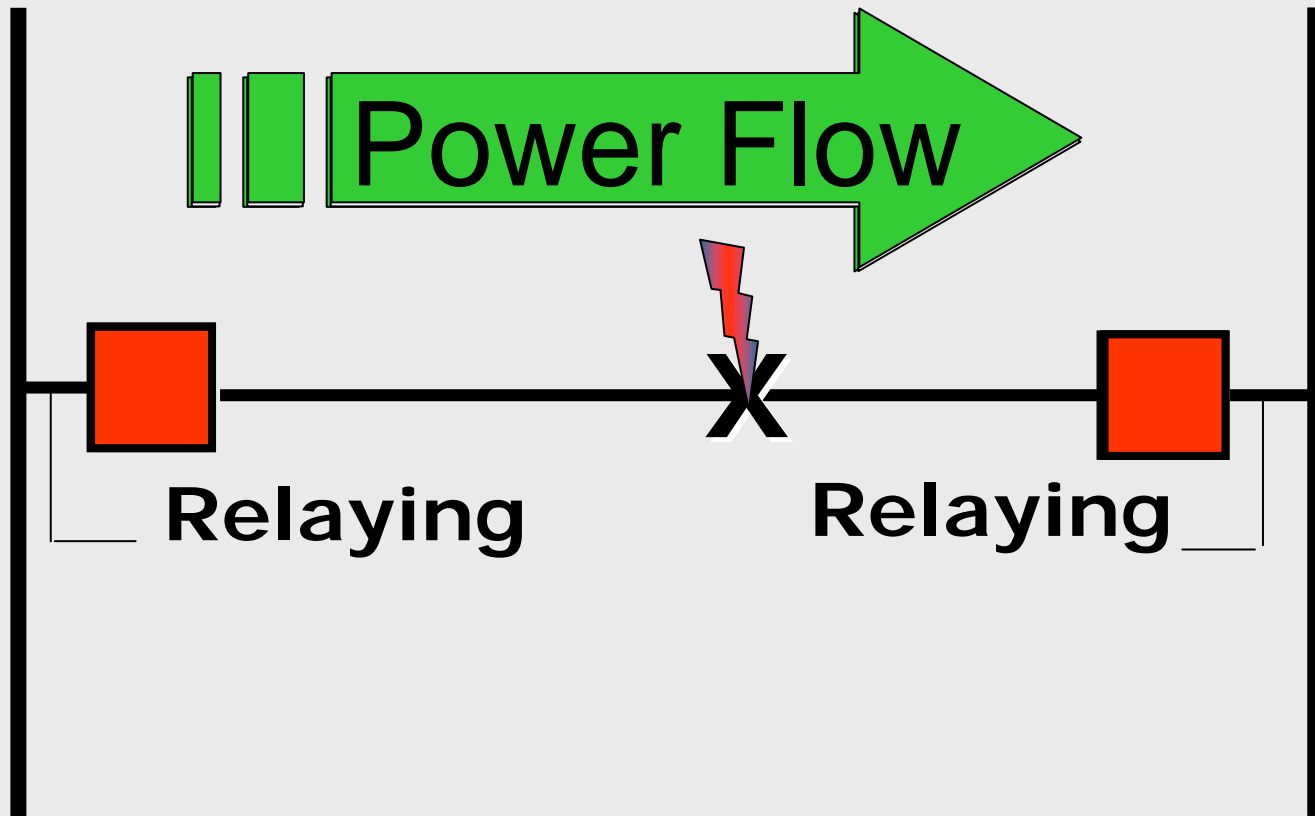
- **Protective equipment detects and clears faults.**
- **Restores reliable function quickly**

Primary System Protection Components

- **Measuring devices**
- **Protective relays**
- **Control equipment**
- **Circuit Breakers**



Example of Fault Clearing



 = Breaker Closed  = Breaker Open

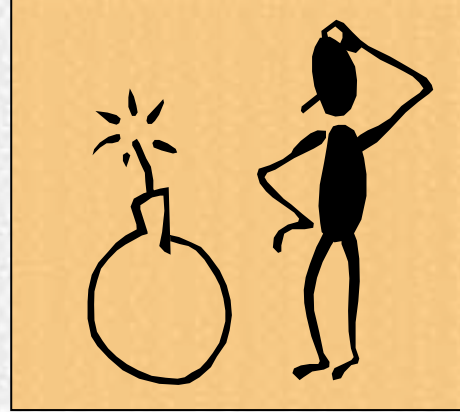
System Protection

- Protection schemes must trip when needed.
- Back-up schemes are common.
- Protection schemes should not trip falsely.

Remedial Action Schemes

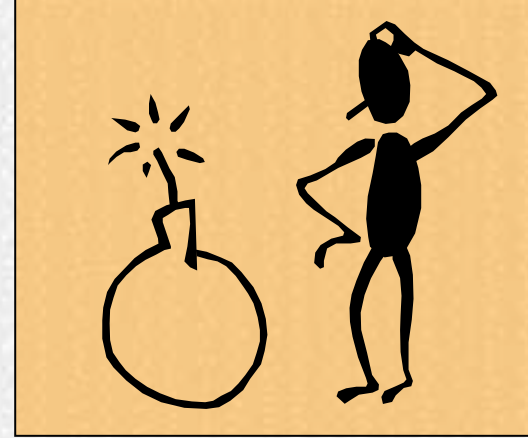


Remedial Action Scheme



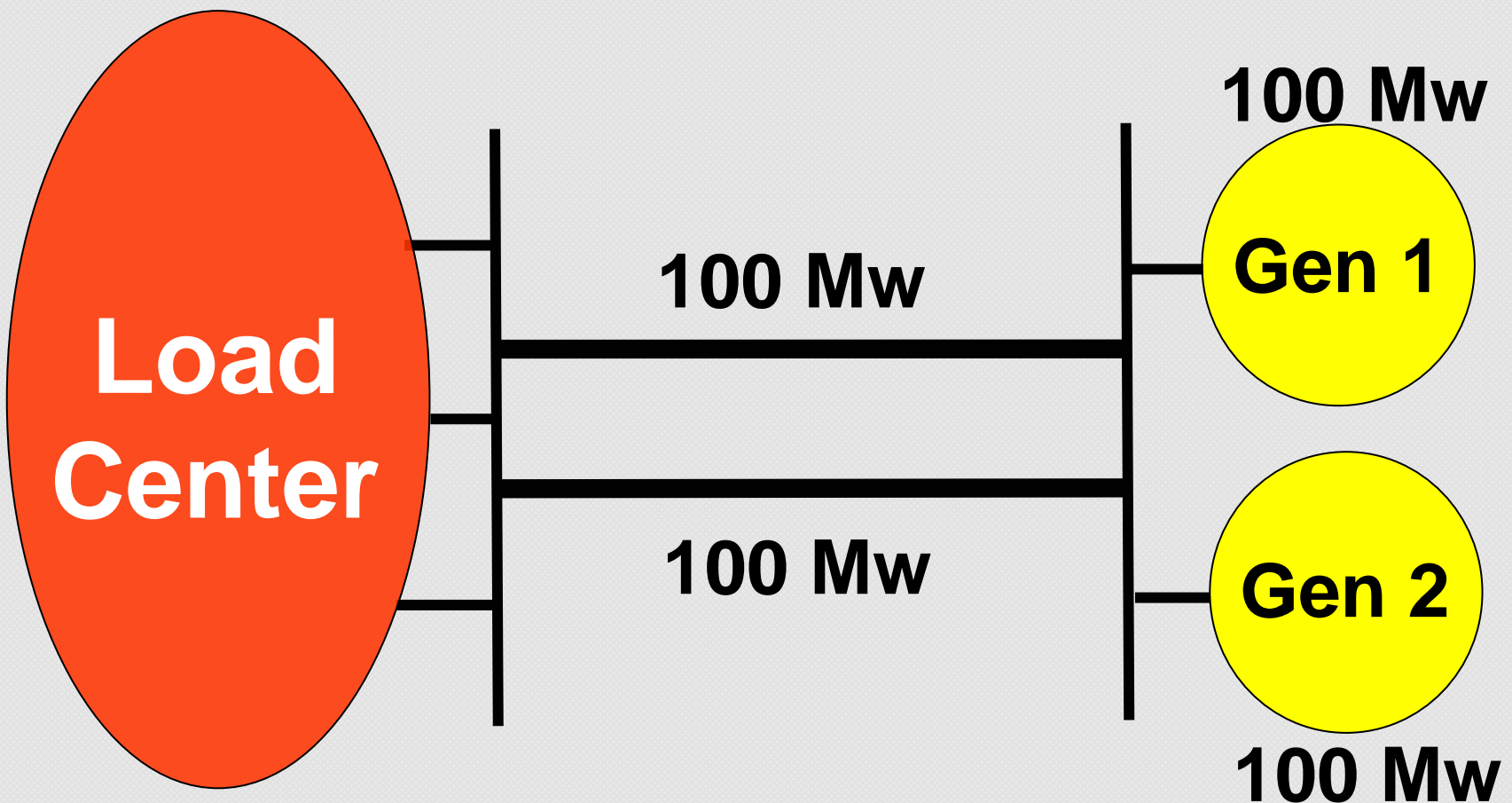
- An automated process of detecting a system problem and automatically executing steps to mitigate the adverse affects

Why Use Remedial Action Schemes?

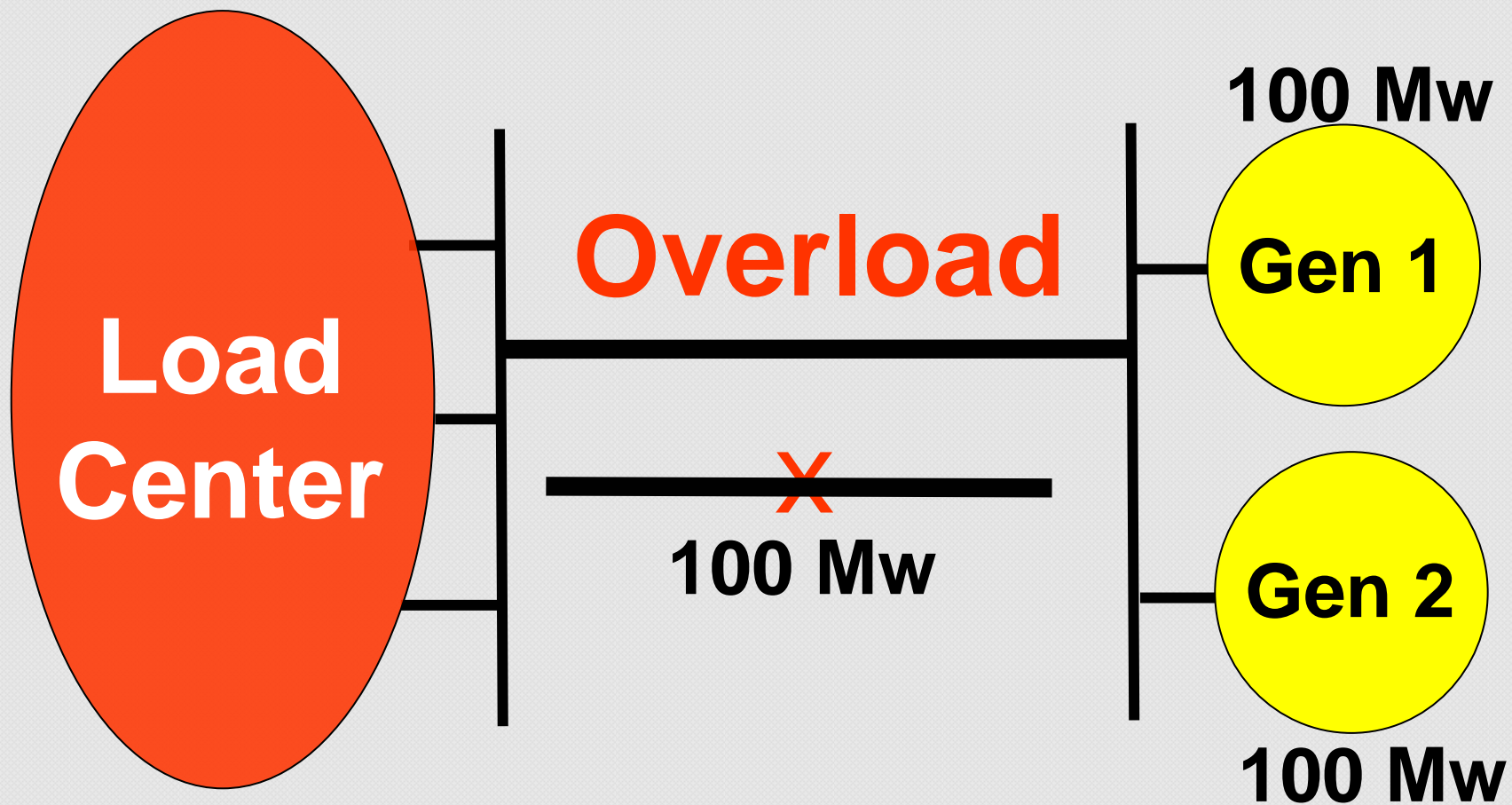


- **Faster detection and execution than a human**
- **Allows operation otherwise not permissible**
- **Avoids or delays spending money on system upgrades**

Remedial Action Example

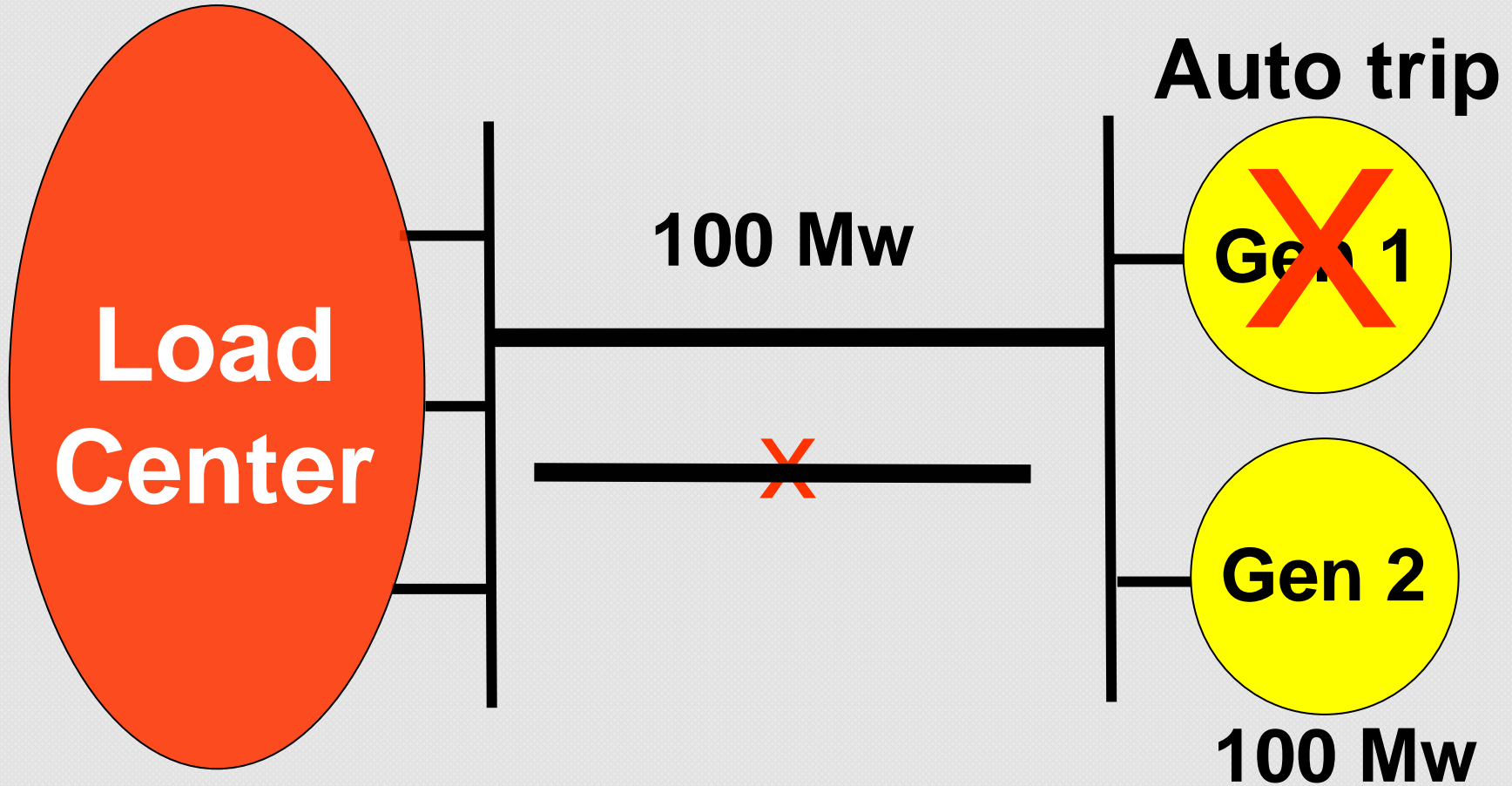


Remedial Action Example



**Transmission system inadequate
for full load operation of both
generators**

Power System Example



Remedial action scheme that trips a unit for loss off a line may be acceptable

Remedial Action Schemes

- **Concerns about false operation**
- **Schemes may be “armed” and “disarmed”**

NW-SE Separation Scheme-normal

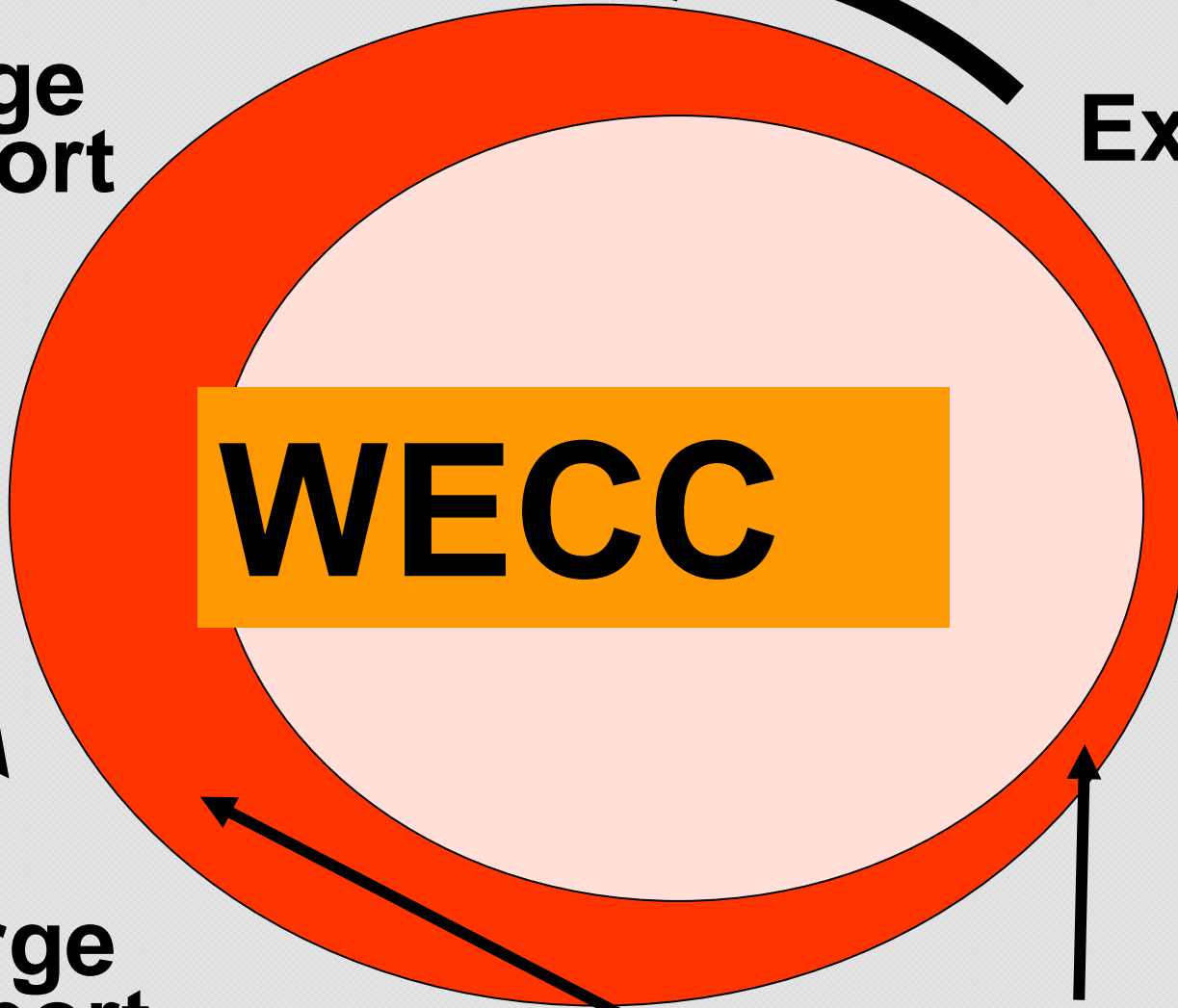
Large
export

Export

WECC

Large
import

Transmission
Capability



NW-SE Separation Scheme-problem

Large export

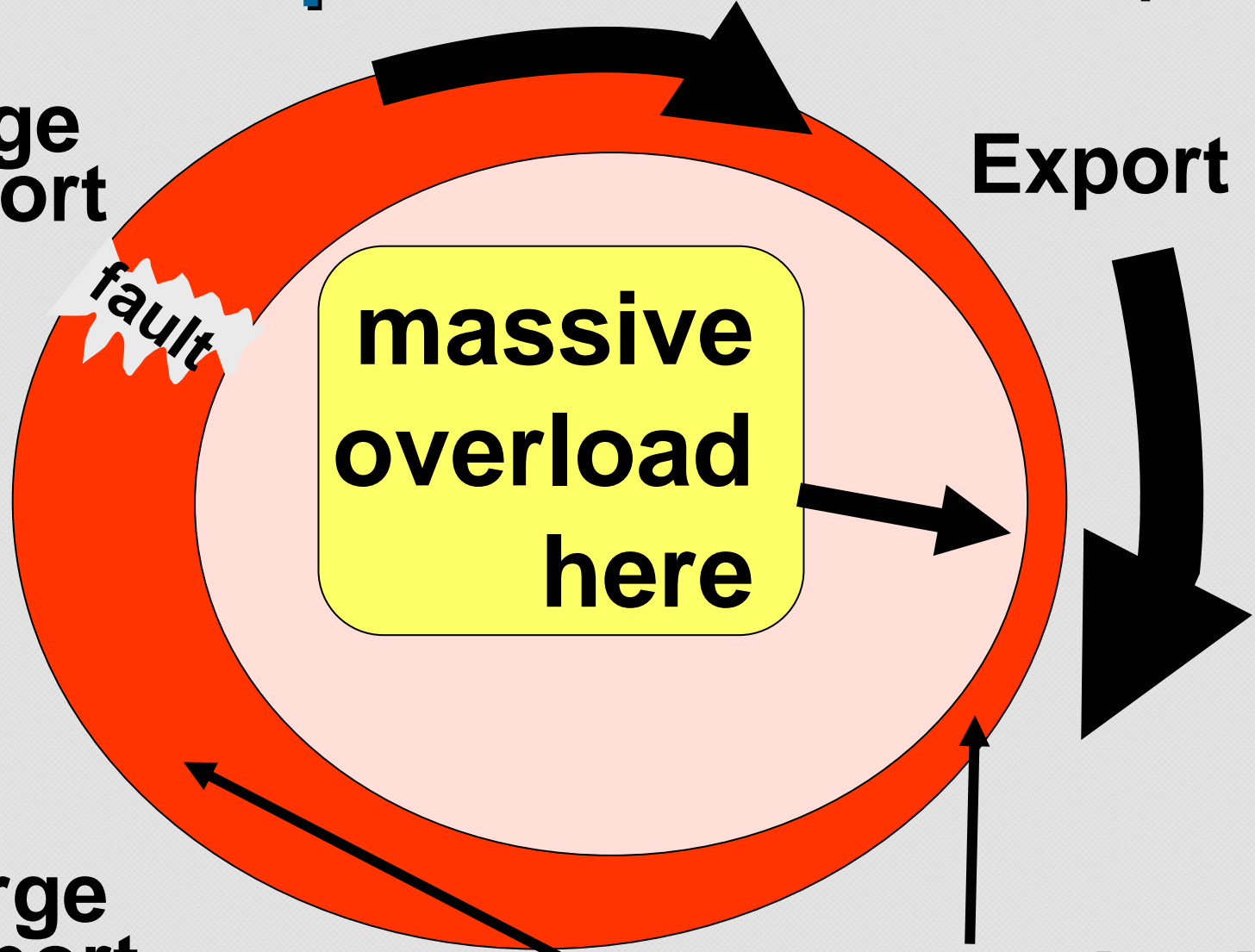
Export

fault

massive
overload
here

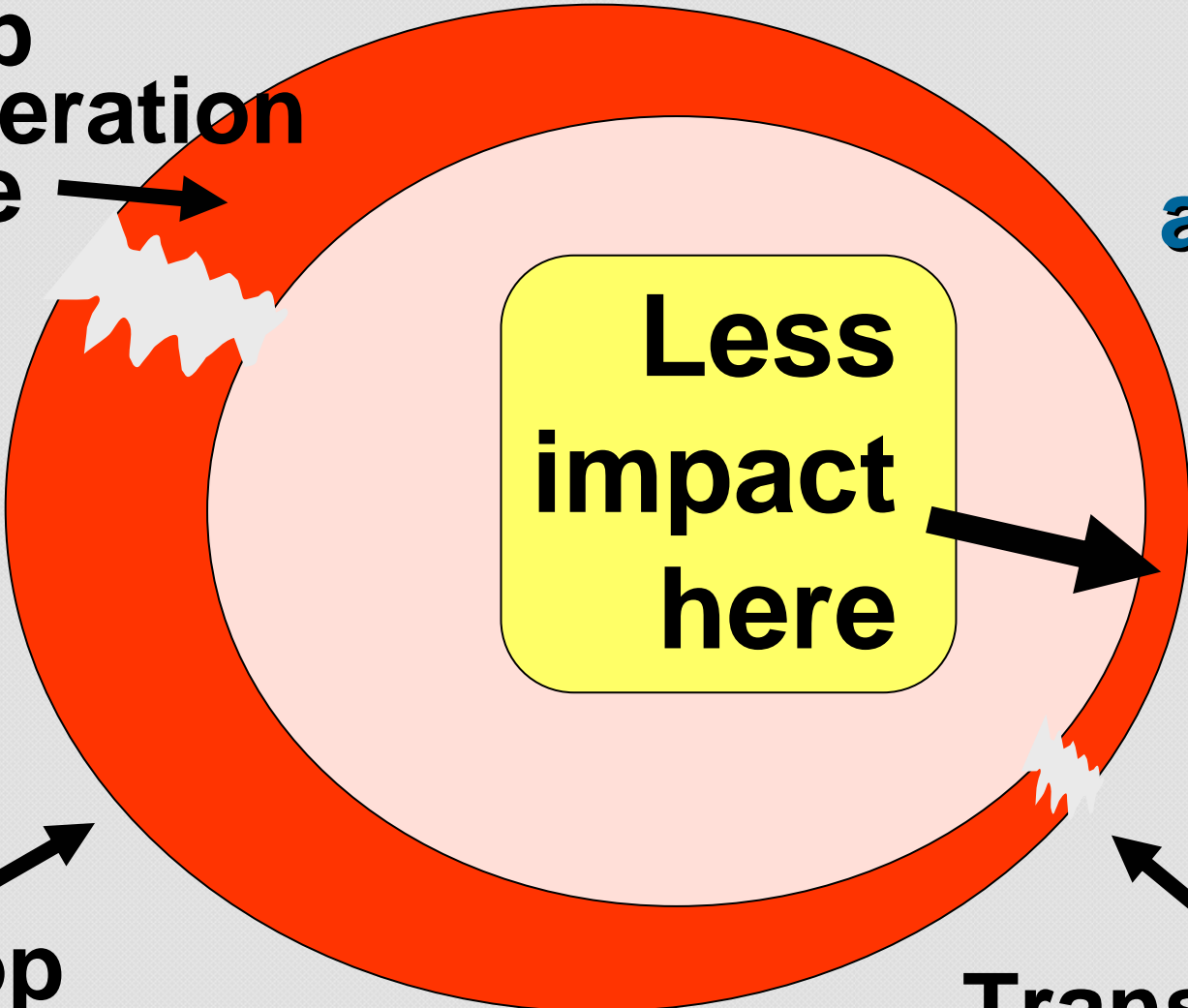
Large import

Transmission
Capability



NW-SE Separation Scheme-solution

**Drop
Generation
Here**



**automatic
actions
shown**

**Drop
Load Here**



**Transfer Trip
Transmission**
(Four Corners area)



Voltage Control

- **Power systems require voltage and good voltage control to function properly.**

Voltage Control

- AC electric power consists of two components:
 - Real power
 - Reactive power

Voltage Control

- **Real power** does the work of heating, lighting, and turning motors.
- It is measured in **Watts**.

Voltage Control

- **Reactive power** supports magnetic and electric fields required for AC systems to function.
- It is measured in **Volt-Amperes-*R*reactive** or **VARs**

Voltage Control

- **Reactive power supply is the most important element in controlling voltage.**

Voltage Control Equipment

- Generators **supply** or **consume** VARs by adjusting field excitation.
- Transformers have taps that can be changed to **raise** and **lower** voltage.

Voltage Control Equipment

- Shunt reactors consume VARs.
- Shunt capacitors produce VARs.
- Static VAR compensators combine these elements to produce a variable source.

Voltage Control Equipment

- Transmission lines, when lightly loaded, produce VARs.
- Transmission lines, when heavily loaded, consume VARs.

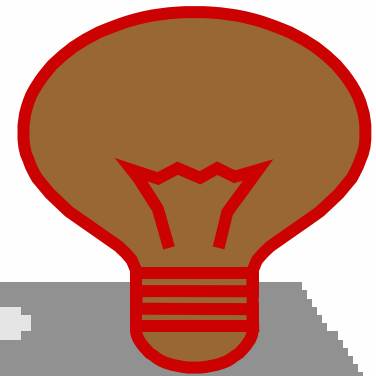
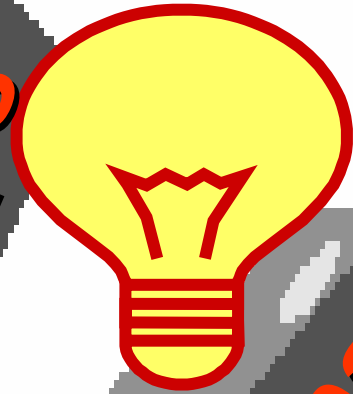
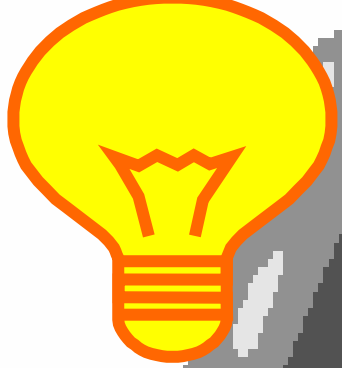
How operators correct for **LOW** voltage

- Insert shunt capacitors
- Remove shunt reactors
- Raise transformer tap positions
- Raise generator voltage
- Energize open transmission lines
- Curtail loads

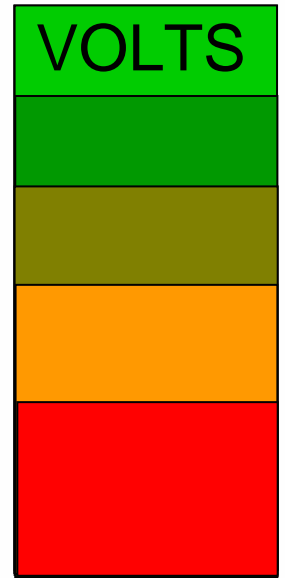
How operators correct for **HIGH** voltage

- Remove shunt capacitors
- Insert shunt reactors
- Lower transformer taps
- Close open-ended transmission lines
- Absorb Vars with generators
- Remove transmission lines from service

Voltage Collapse



VOLTS



Line or generator trips

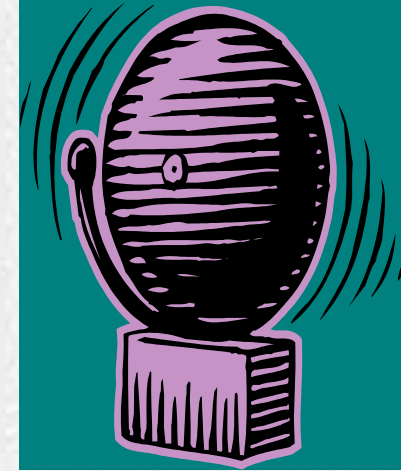
Dynamic sources max out

Tap changers respond

Load current grows

Capacitors lose capability

Preventing Voltage Emergencies



- **Be aware of collapse mechanisms**
- **Maintain VAR reserves**
- **Maximize local VAR support**
- **Boost voltage early on peak days**
- **Curtail imports**
- **Curtail loads if necessary**

Unscheduled Flow (USF)



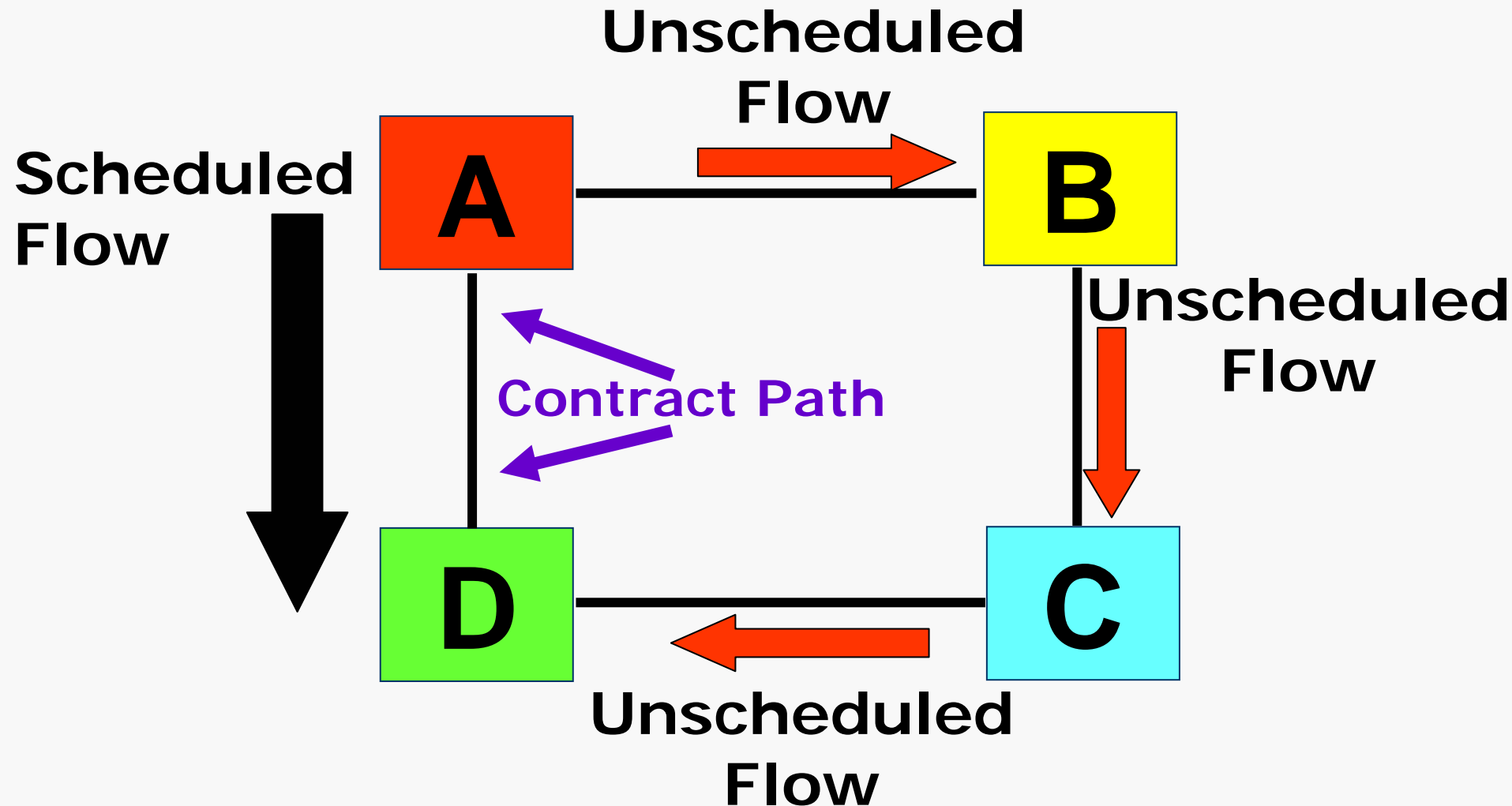
- **What is Unscheduled flow?**
- **Why is it a problem?**
- **Managing USF**
 - **WECC USF Procedures**

Unscheduled Flow (USF)

- **Inherent in interconnected system operation**
- **Power flows in all parallel paths.**
- **Scheduled path will not carry all the power.**
- **USF creates problems for others.**

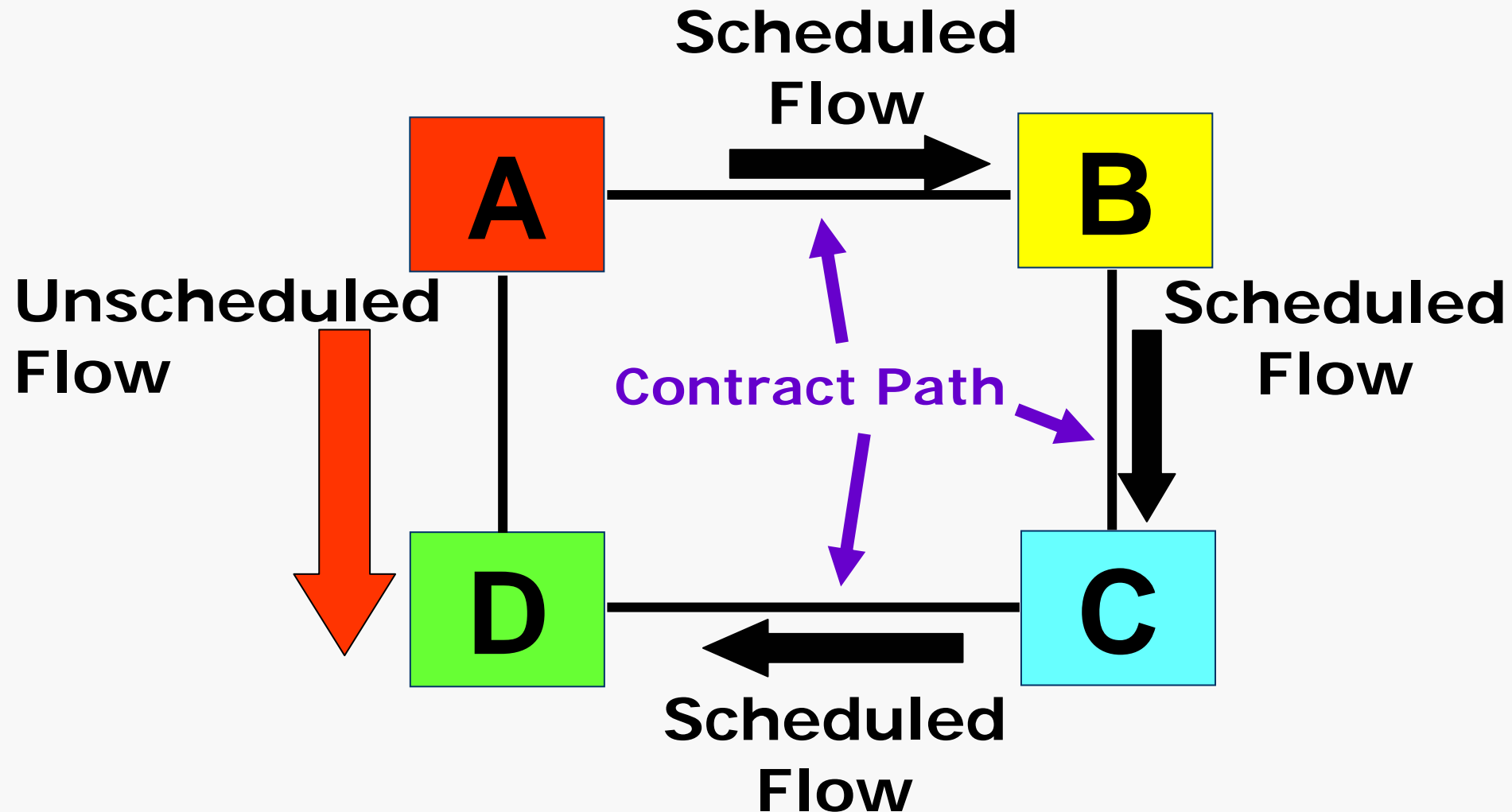
Scheduled & Unscheduled Flow

Schedule from A to D



Scheduled & Unscheduled Flow

Schedule from A to D



Managing USF in WECC

- **Use phase shifters, DC line, capacitors in the path**
(controllable devices)
- **Accommodate some USF**
- **Coordinate phase shifters WECC-wide**
- **Curtail schedules causing USF** (receivers make cuts)

References on USF

- **WECC Unscheduled Flow Procedure and Administrative Practices**
- **WECC Unscheduled Flow Training Document.**
- **Find these and others at:**
www.wecc.biz
 - **Publications & Docs ⇒**
Unscheduled Flow (UFAS)

Example of a Path Limit

Line X - rating 550 Mw

Actual flow = 0 Mw

Line Y - rating 445 Mw

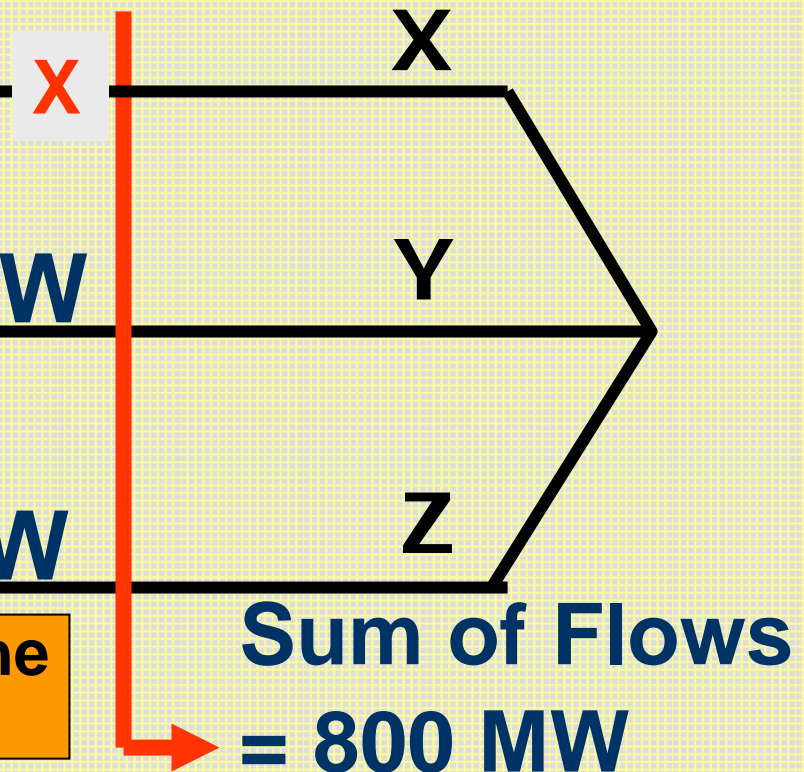
Actual Flow = 445 MW

Line Z - rating 400 Mw

Actual Flow = 355 MW

Line Y will always carry 55.6% of the combined flows of Lines Y and Z.

**Most Severe N-1
(Outage of line X)**



**In this simplified example,
the path is at its limit of 800 Mw**