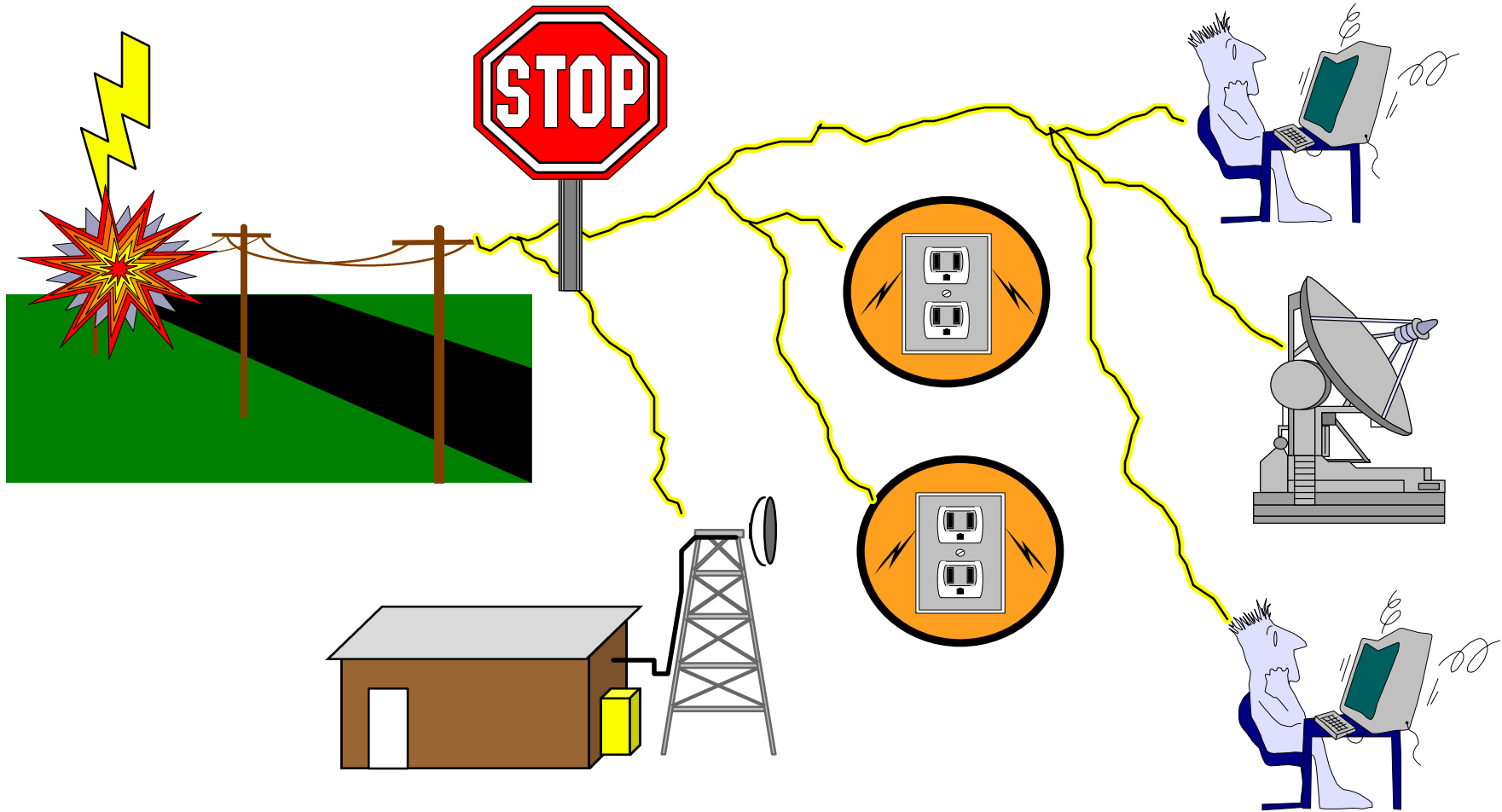
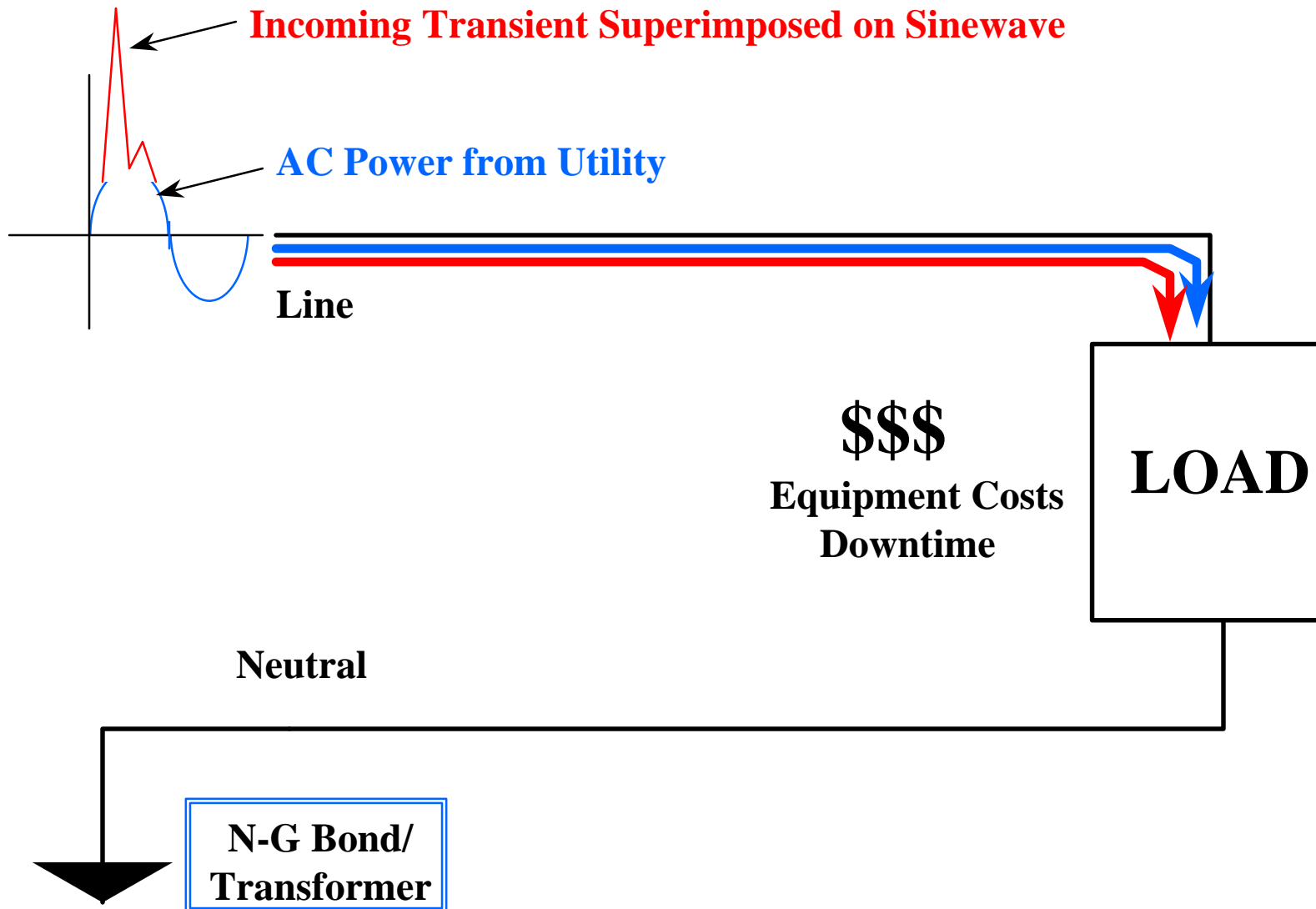


Section 5: TVSS Design & Application



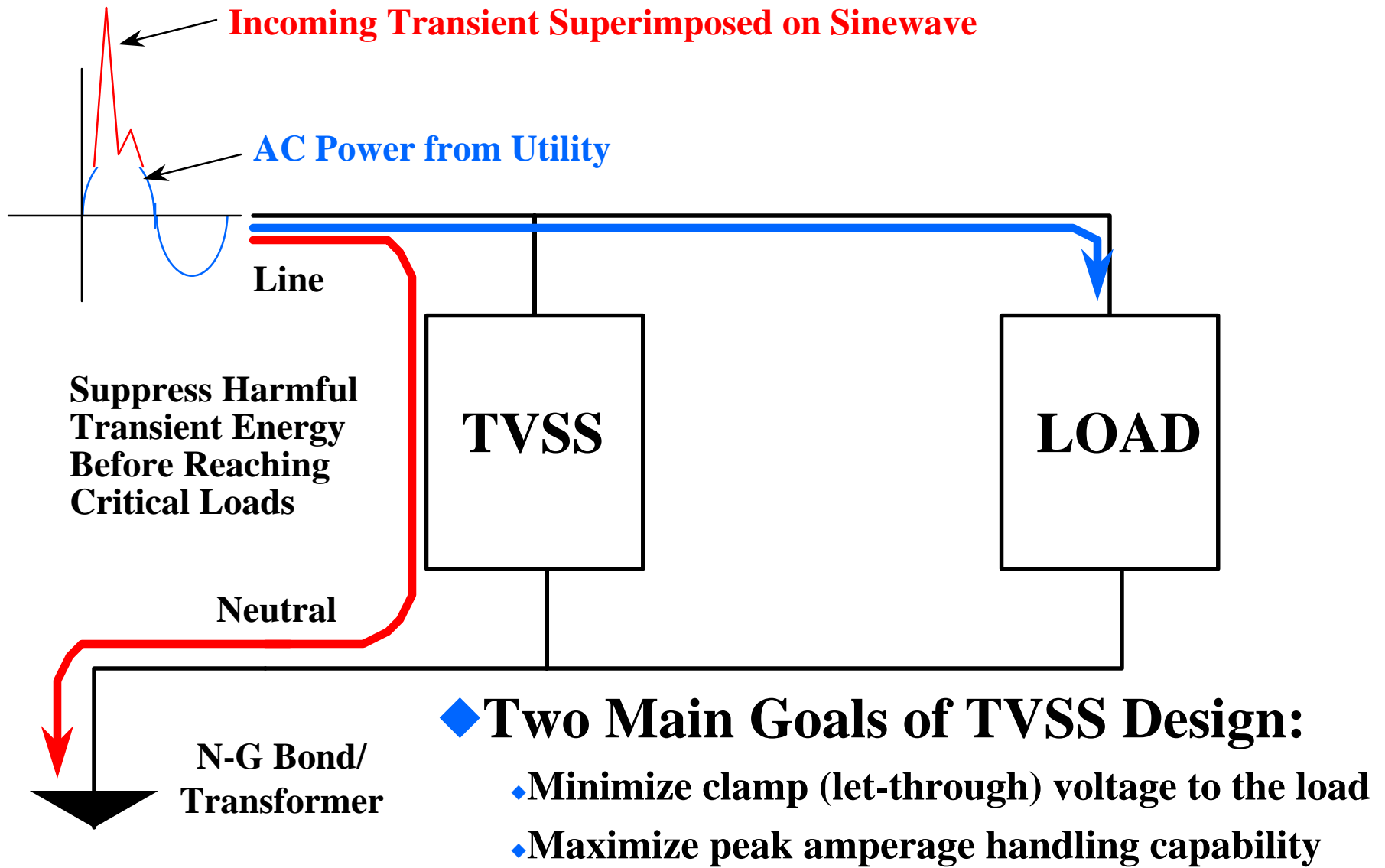


TVSS Design Concept for AC Applications



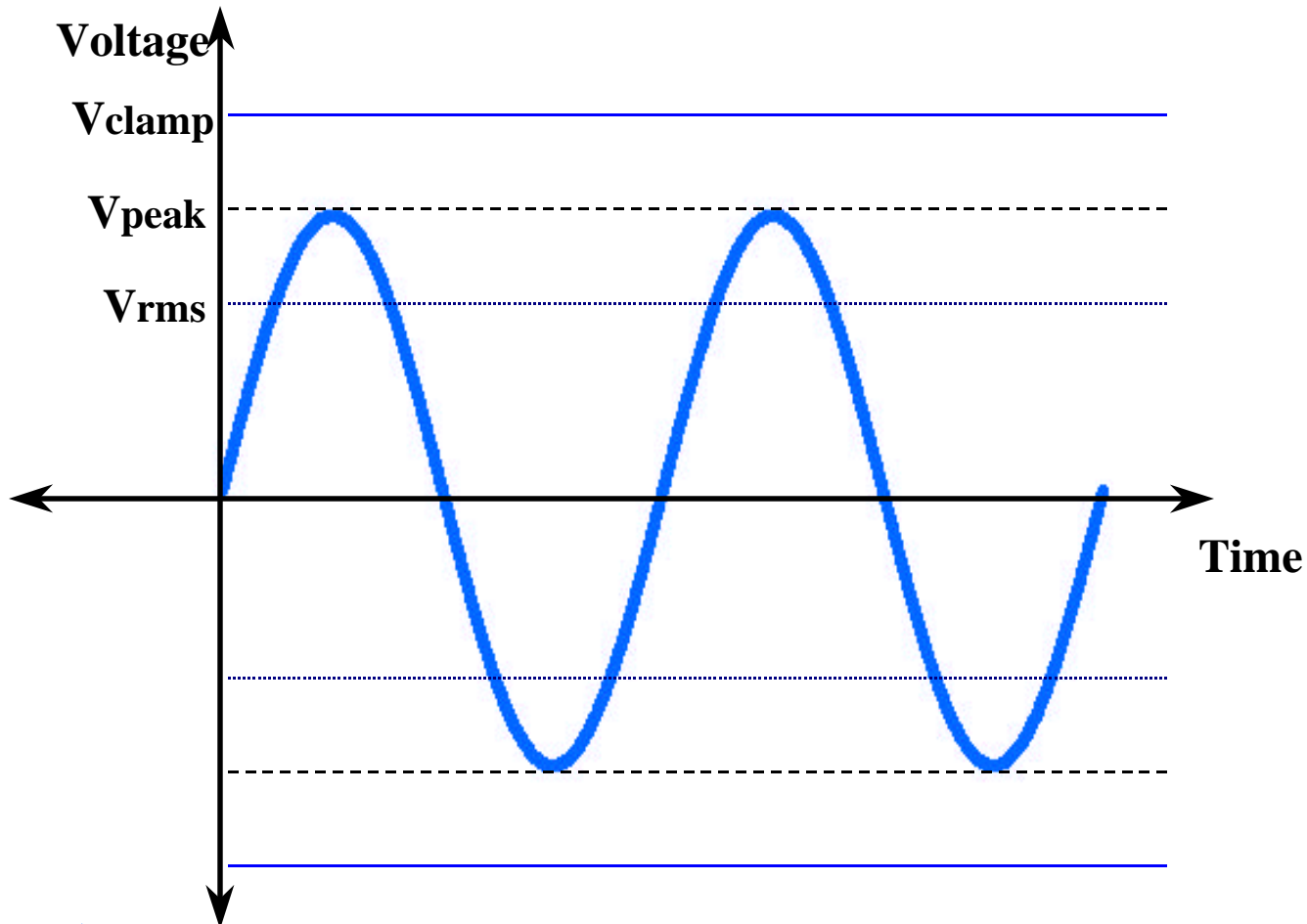


TVSS Design Concept for AC Applications





AC TVSS Design Considerations



- ◆ V_{clamp} must allow for utility voltage variations, but remain low enough to be effective against transients.

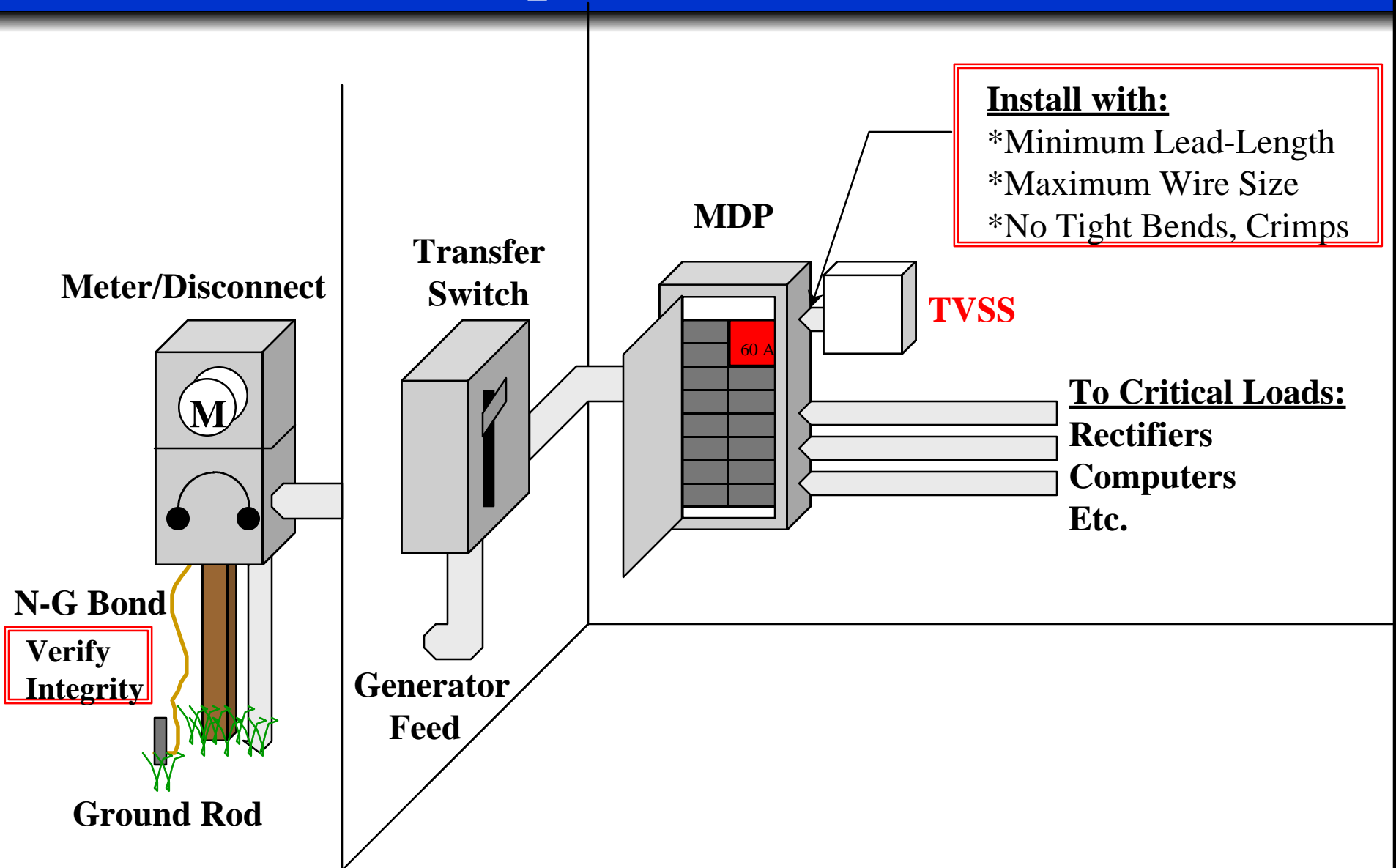


AC TVSS Design Considerations

- ◆ **Factors That Affect TVSS Let-Through Voltage:**
 - ◆ **Type and quality of components**
 - ◆ **Nominal clamp voltage of components**
 - ◆ **TVSS design efficiency**
 - ◆ **System voltage configuration**
 - ◆ **Amount of peak amperage passed through the system**
 - ◆ **Rise time of transient waveform**
 - ◆ **Installation of the TVSS device**

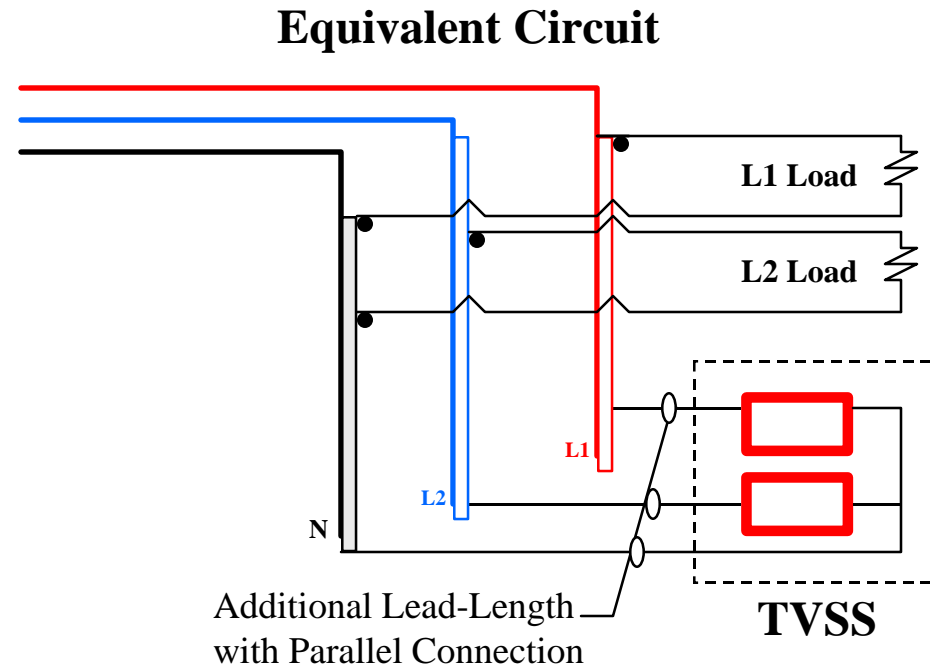
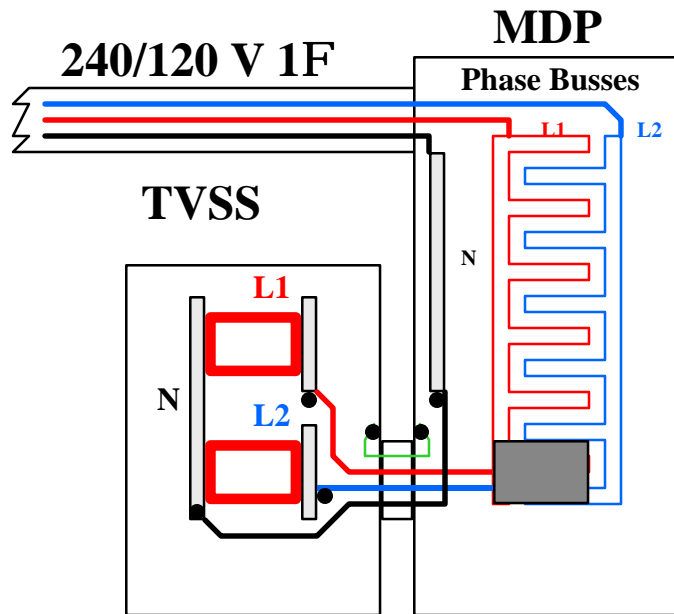


Installation Option: Parallel Connection





Connection Method: Parallel



◆ Features:

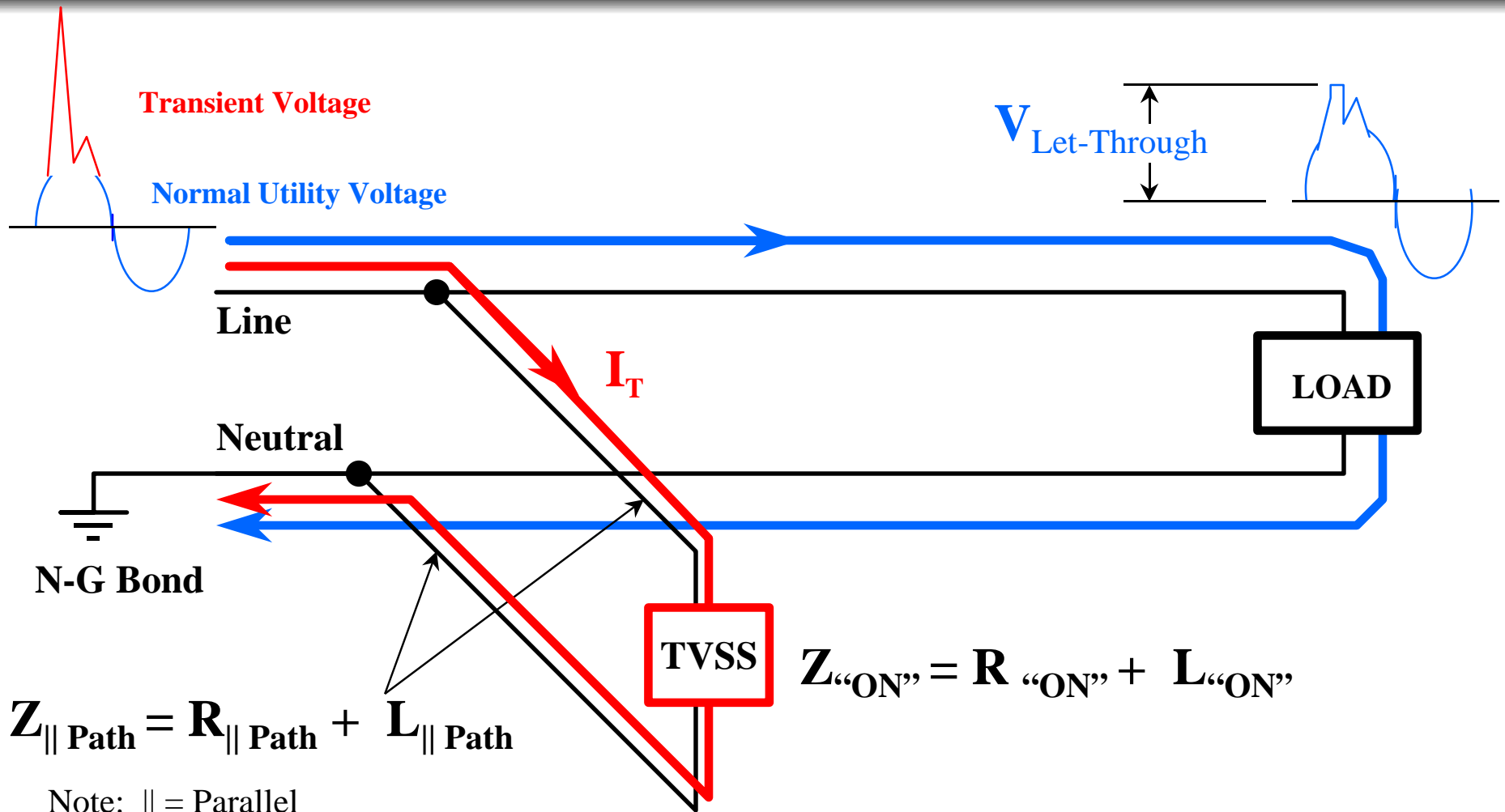
- ◆ Easily installed with existing system
- ◆ To service, may disconnect only power to TVSS
- ◆ If TVSS sacrifices, down line load is still powered

◆ Concerns:

- ◆ Requires some extra lead-length for parallel connection



TVSS Operation: Let-Through Voltage



$$Z_{\parallel \text{ Path}} = R_{\parallel \text{ Path}} + L_{\parallel \text{ Path}}$$

Note: \parallel = Parallel

$$Z_{\text{“ON”}} = R_{\text{“ON”}} + L_{\text{“ON”}}$$

$$V_{\text{Let-Through}} = V_{\text{Clamp}} + I_T (R_{\parallel \text{ Path}} + R_{\text{“ON”}}) + \frac{dI_T}{dt} (L_{\parallel \text{ Path}} + L_{\text{“ON”}})$$



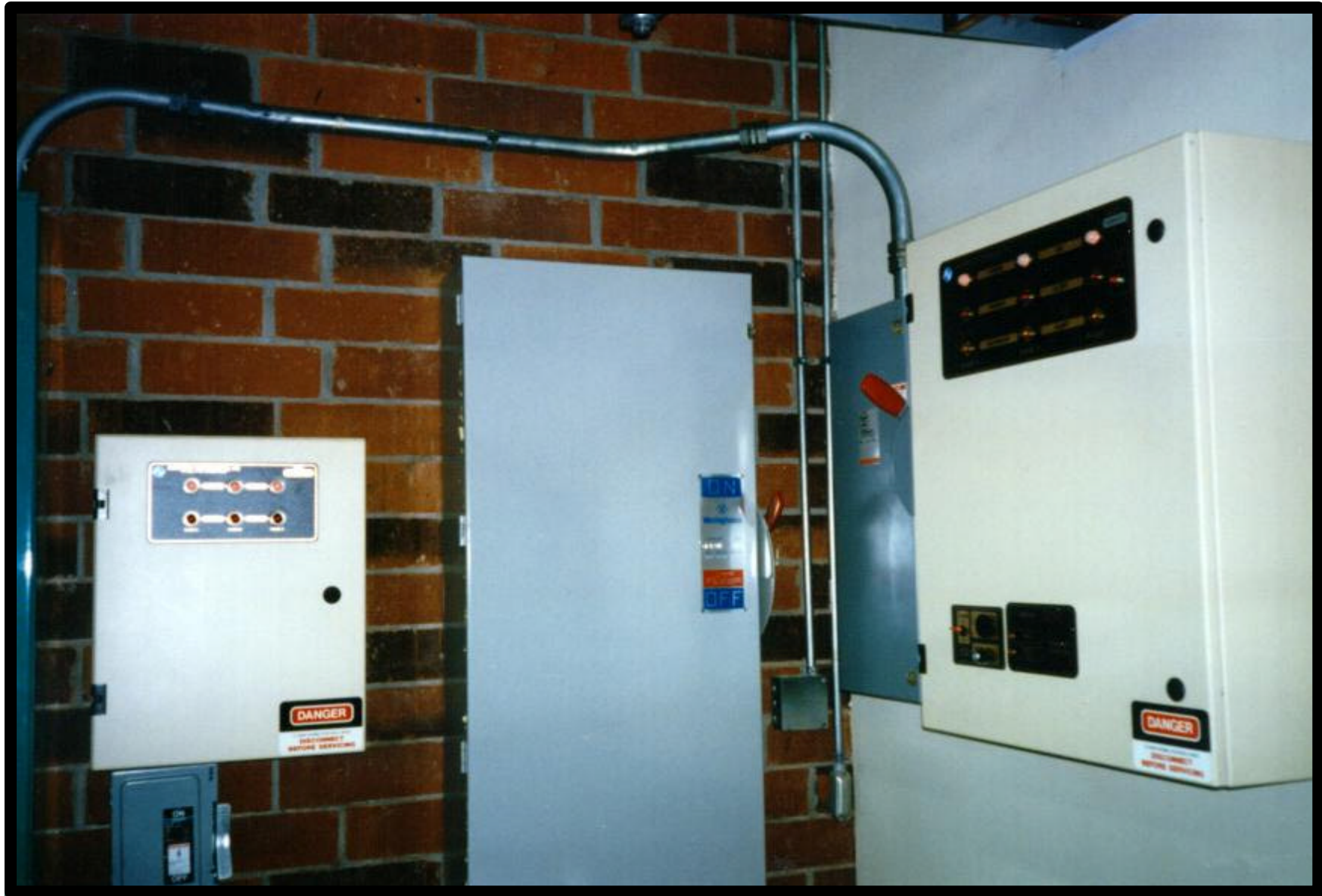
Let-Through Voltage Components

$$V_{\text{Let-Through}} = V_{\text{Clamp}} + I_T (R_{\parallel \text{ Path}} + R_{\text{“ON”}}) + \frac{dI_T}{dt} (L_{\parallel \text{ Path}} + L_{\text{“ON”}})$$

$V_{\text{Let-Through}}$	Peak Voltage Seen by Critical Equipment *Yields UL 1449 Rating
V_{Clamp}	Initial Clamp Voltage of TVSS Device (tested at 1 mA)
I_T	Transient Current Diverted Through Suppressor
$Z_{\parallel \text{ Path}} = R_{\parallel \text{ Path}} + L_{\parallel \text{ Path}}$	Impedance of Wires/Connections To/From Parallel TVSS Device Factors include: Lead-Length, Wire Gauge, Bends in Wire Path....
$Z_{\text{“ON”}} = R_{\text{“ON”}} + L_{\text{“ON”}}$	Finite Resistance of TVSS Technology when Suppressing Current



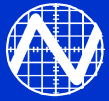
AC TVSS Install Issues



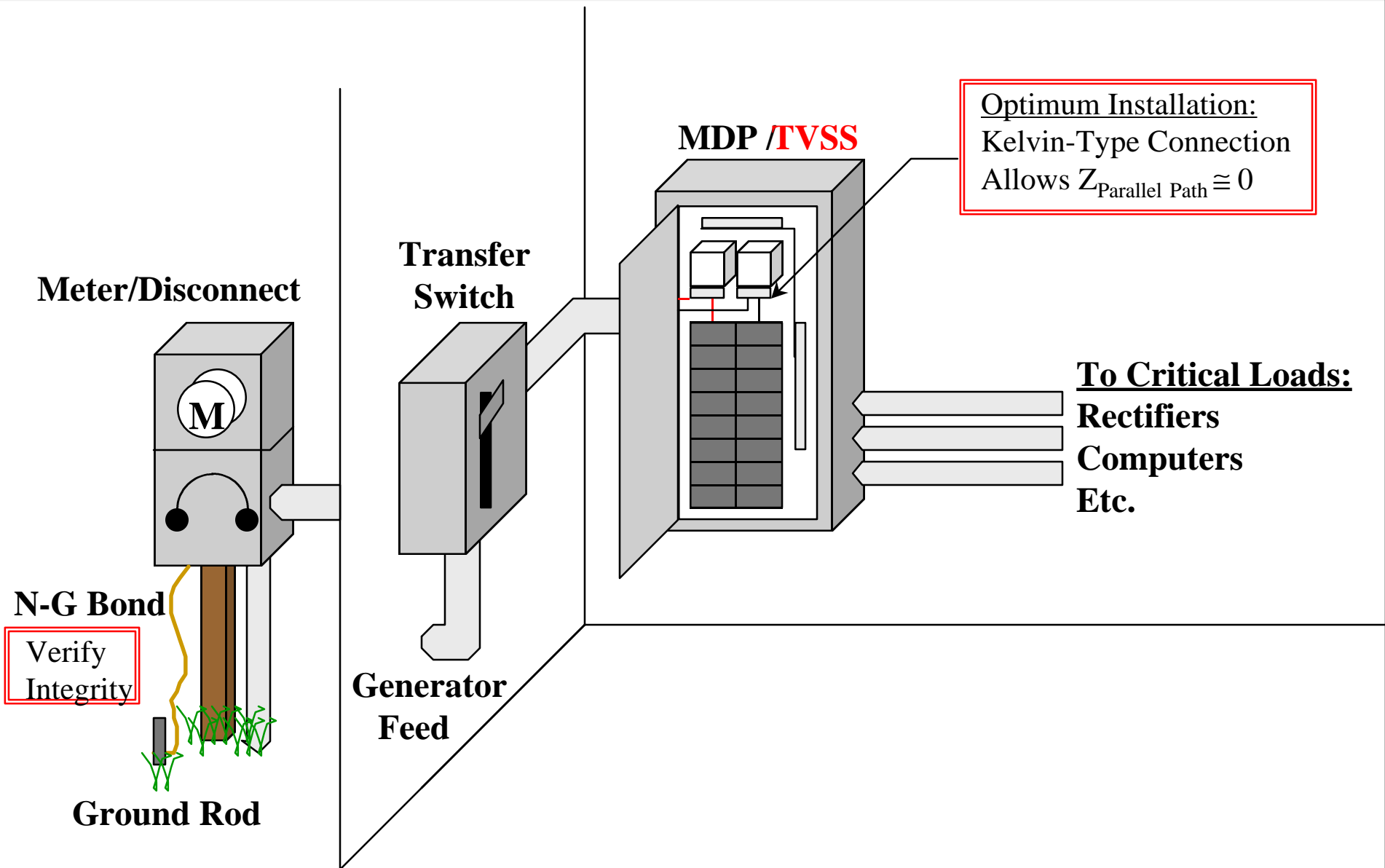


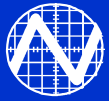
AC TVSS Install Issues



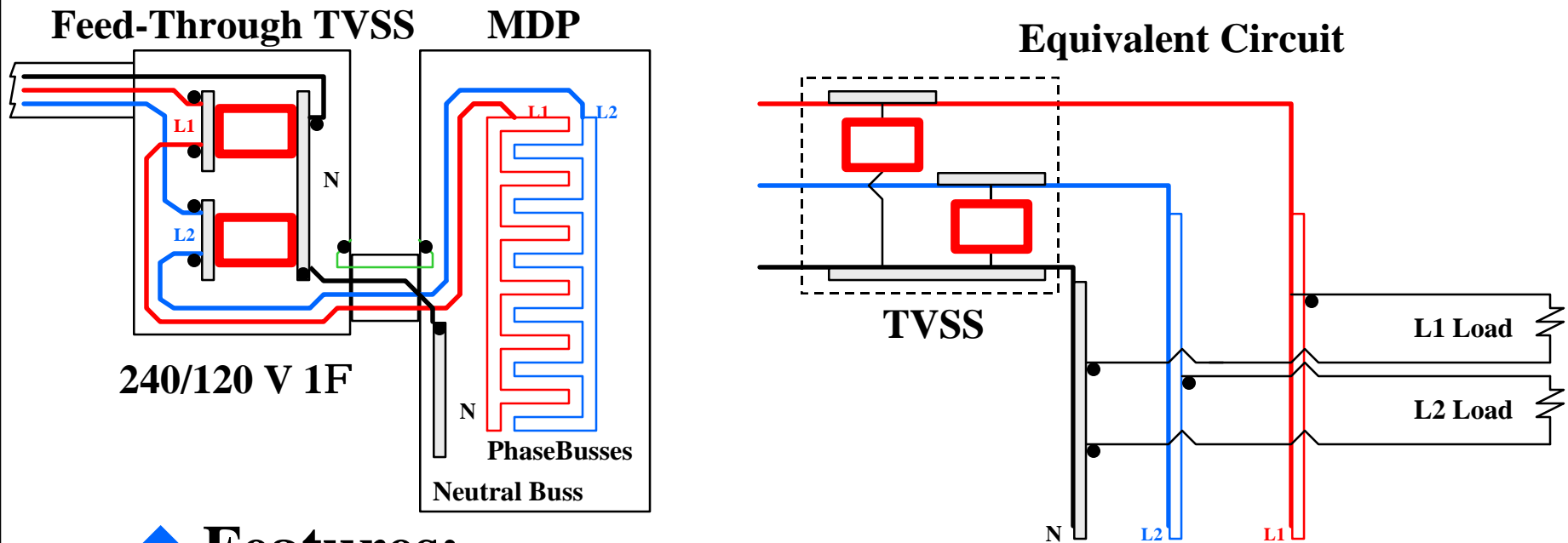


Installation Option: Kelvin Connection





Connection Method: Kelvin

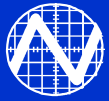


◆ Features:

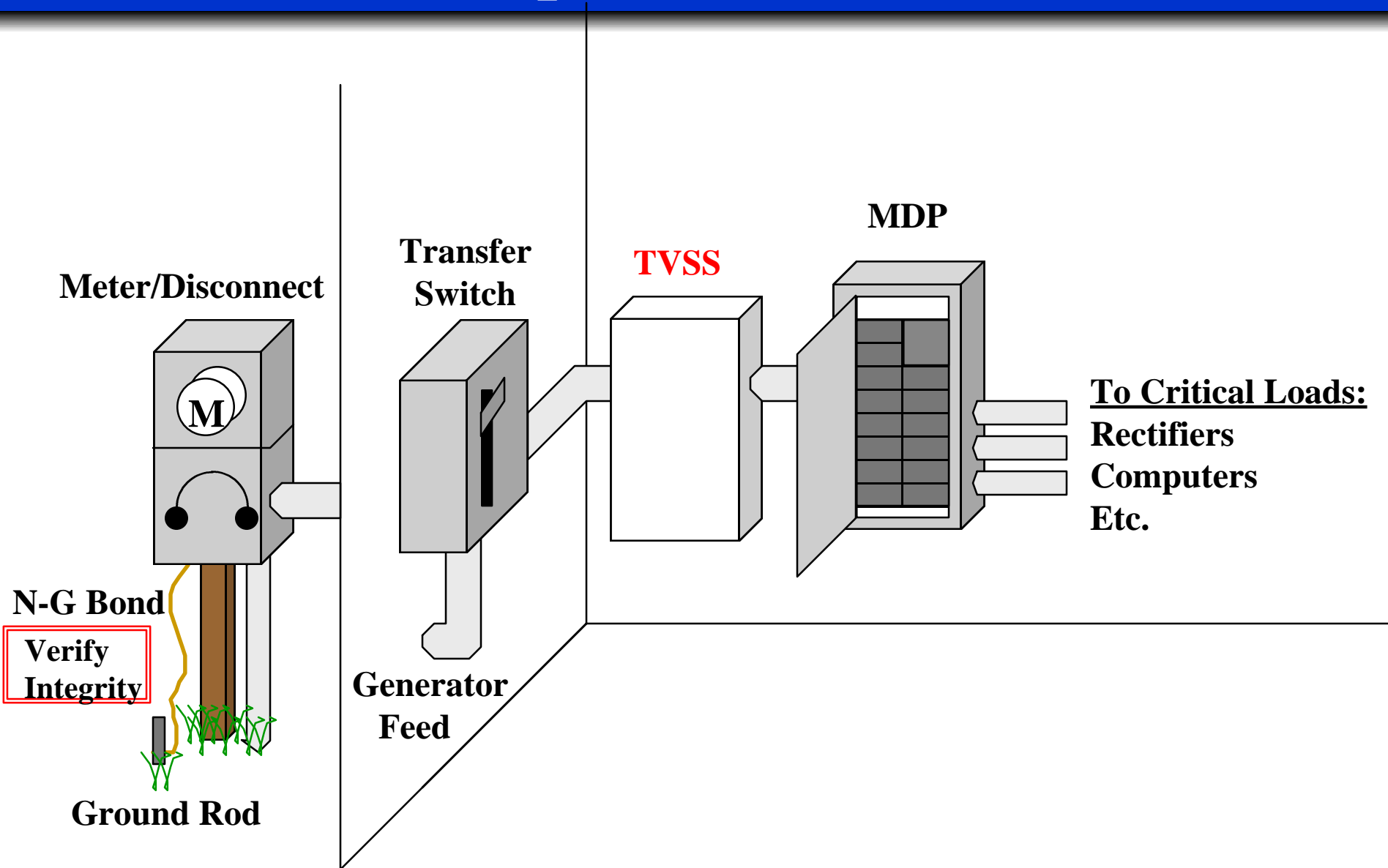
- ◆ Minimum Parallel suppression path only through modules
- ◆ If TVSS sacrifices, down line load is still powered

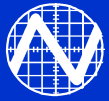
◆ Concerns:

- ◆ May have to reconfigure existing electrical system
- ◆ Input terminals & enclosure must be sized for rated source current (requires larger panels)
- ◆ To service TVSS, may have to de-energize downline MDP and loads

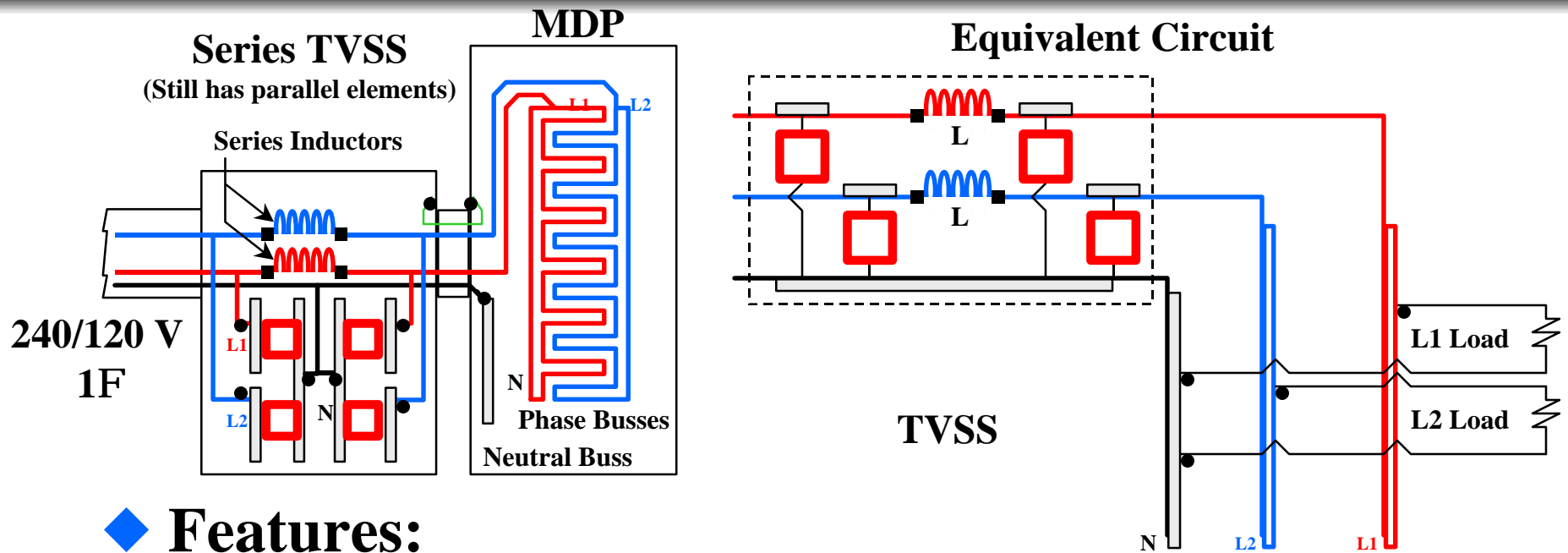


Installation Options: Series Connection





Connection Method: Series



◆ Features:

- ◆ Series Impedance to “Dampen” Incoming Transient
- ◆ Allows more control over parallel path impedance

◆ Concerns:

- ◆ May have to reconfigure existing electrical system
- ◆ TVSS doesn’t suppress load-switching transients (it’s upline)
- ◆ To service TVSS, complete replacement required and downline MDP and loads must be de-energized
- ◆ Larger, heavier panels required for matching rated source current



Summary of Installation Options

Features

Concerns

Parallel:

- Simple Installation
- Servicing requires only disconnecting TVSS
- If TVSS sacrifices, the load is still powered

- Installation sensitive/
conductor length concerns

Kelvin:

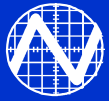
- Minimizes conductor length
- If TVSS sacrifices, the load is still powered

- May have to reconfigure existing electrical system
- Enclosure size increases
- May have to de-energize loads to service unit

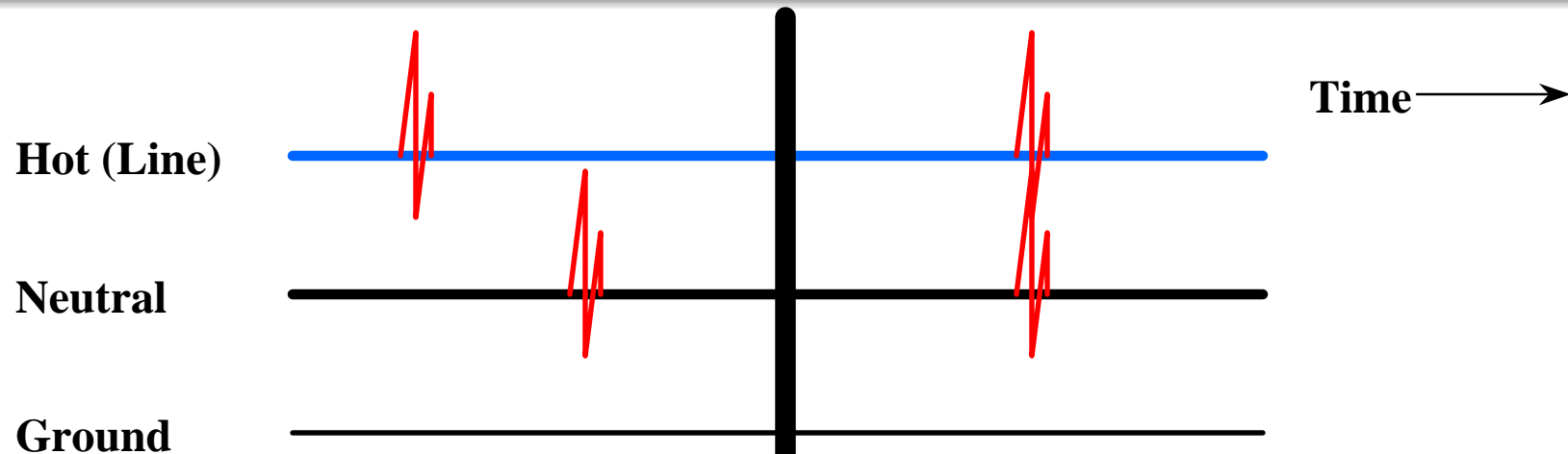
Series:

- Improved transient response
- Minimizes conductor length

- Must reconfigure system
- Enclosure size increases
- May have to de-energize loads to service or replace the complete unit



“Common/Normal” Mode Disturbances



Normal Mode*

Disturbances

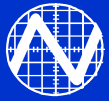
Disturbance occurring between the phase or neutral conductor, but not at the same moment in time.

*Also called Transverse or Differential Mode

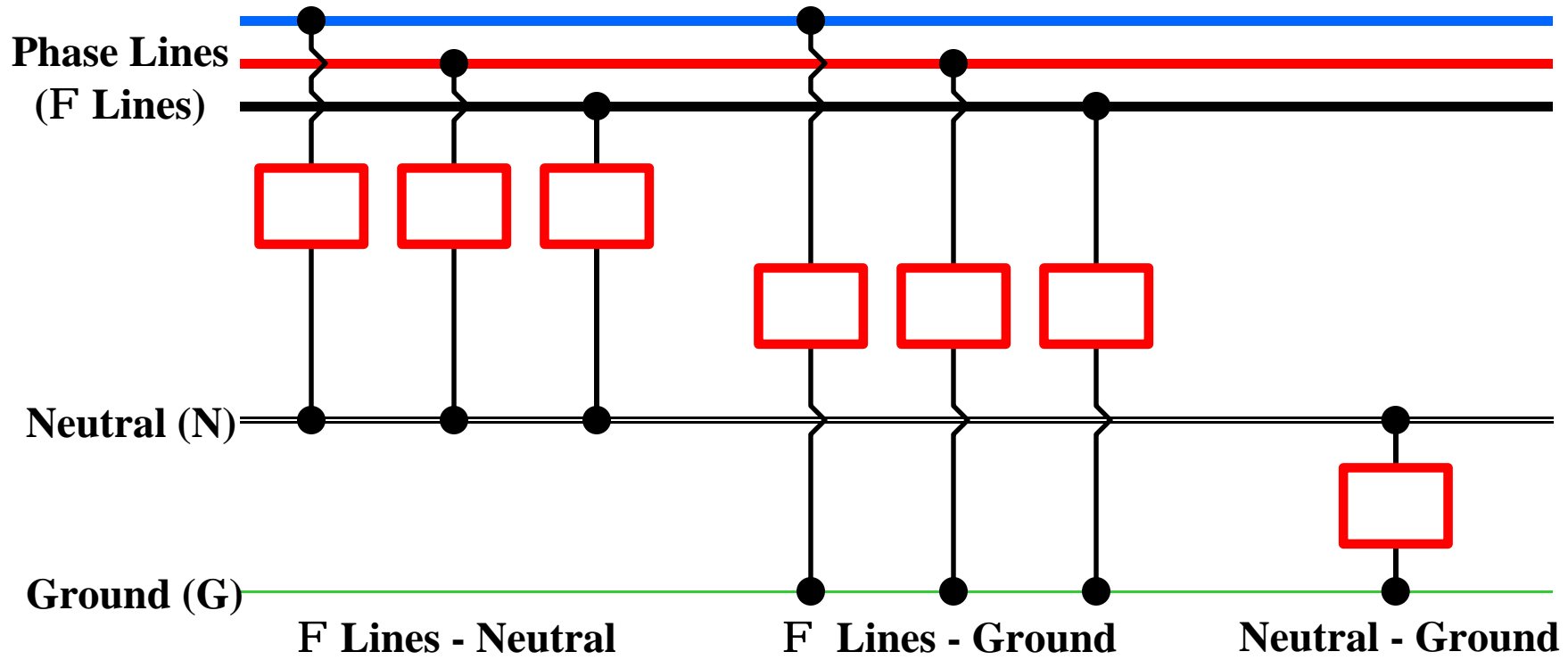
Common Mode

Disturbances

Disturbance occurring on both the phase and neutral conductors simultaneously.



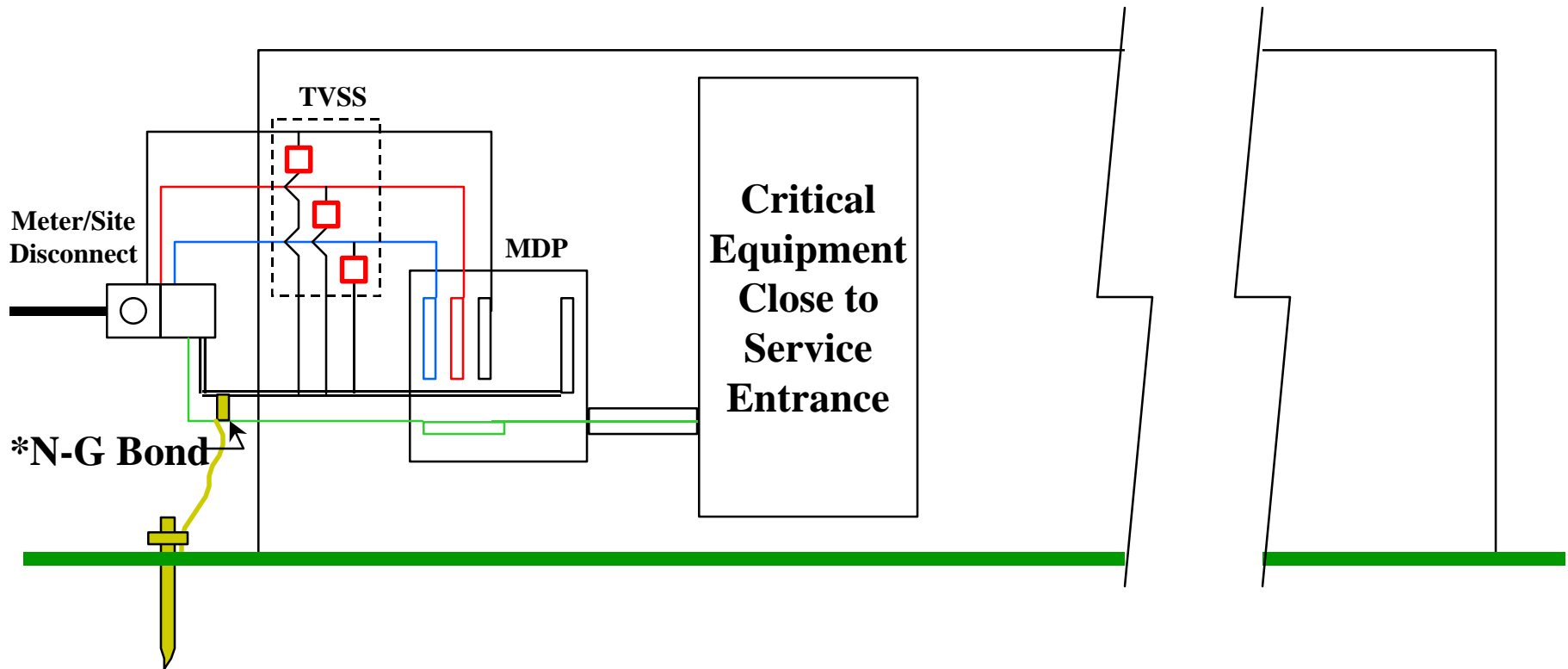
Modes of Protection



- ◆ Line-to-Neutral (L-N) Suppression
- ◆ Line-to-Ground (L-G) Suppression
- ◆ Neutral-to-Ground (N-G) Suppression
- ◆ Line-to-Line (L-L) Suppression [Not Shown]



Service Entrance TVSS (N-G Bond)

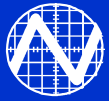


Neutral and Ground are Bonded (Therefore, at the Same Potential)

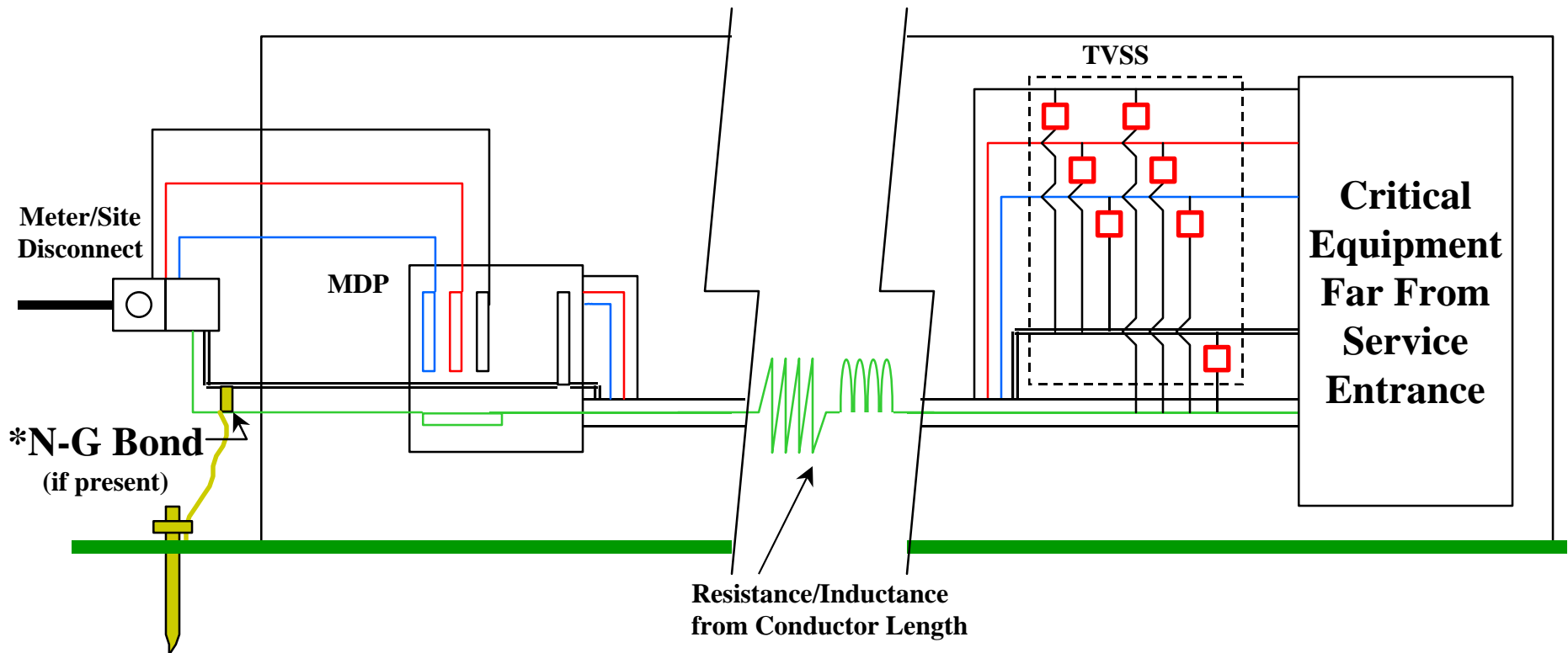
Phase - Neutral TVSS **Required**

Neutral - Ground TVSS **Not Required** (Neutral bonded to Ground)

Phase - Ground TVSS **Redundant** (Neutral bonded to Ground)



Remote Ground TVSS

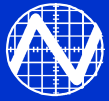


Where there is a Remote Ground or N-G Bond does not exist:

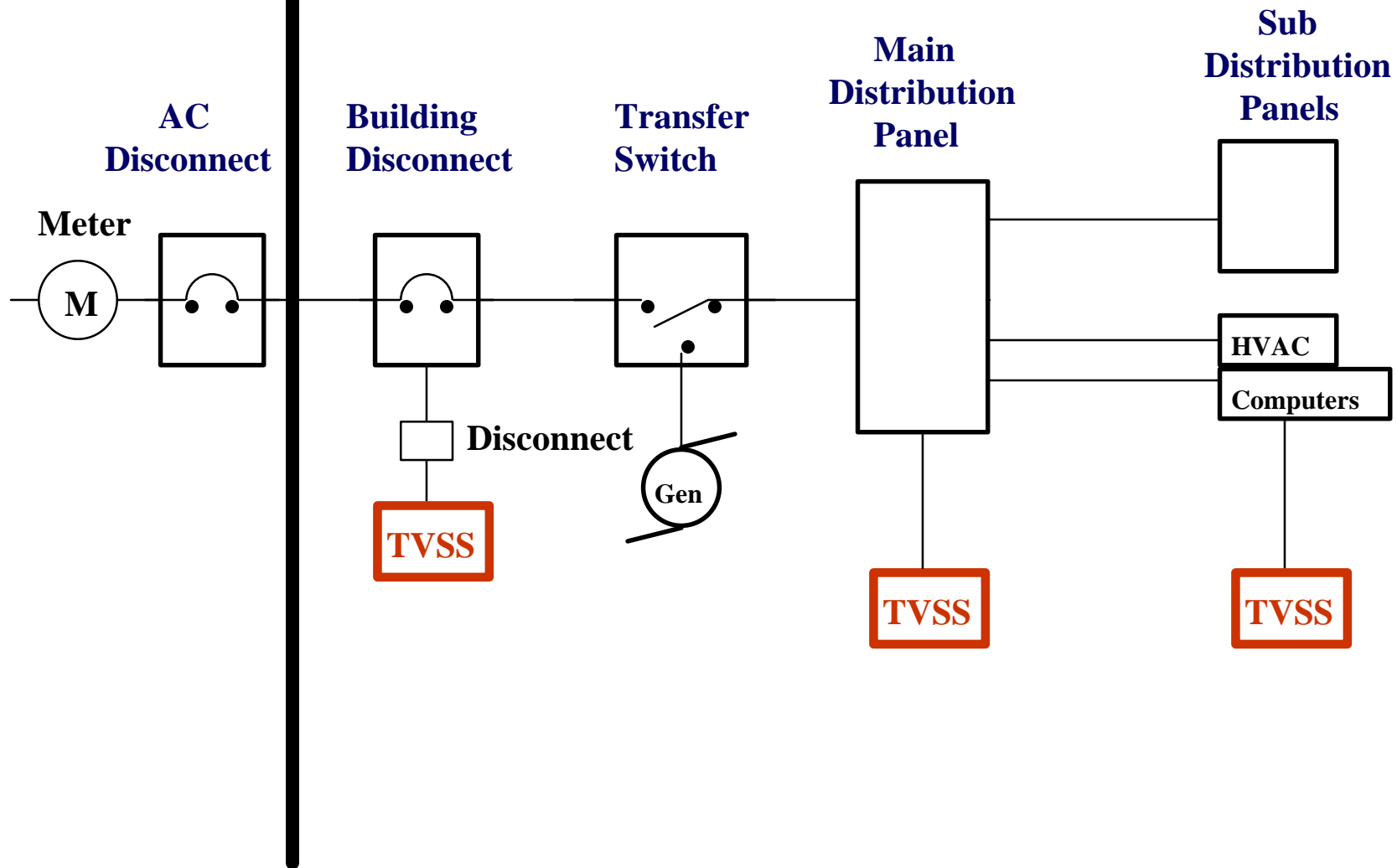
There may be a significant difference in Neutral and Ground Potentials.

Therefore, all modes of suppression may be used (Φ -N, Φ -G, N-G).

* Φ -N along with N-G protection may make Φ -G redundant



AC Electrical Protection





Summary of Protection Modes

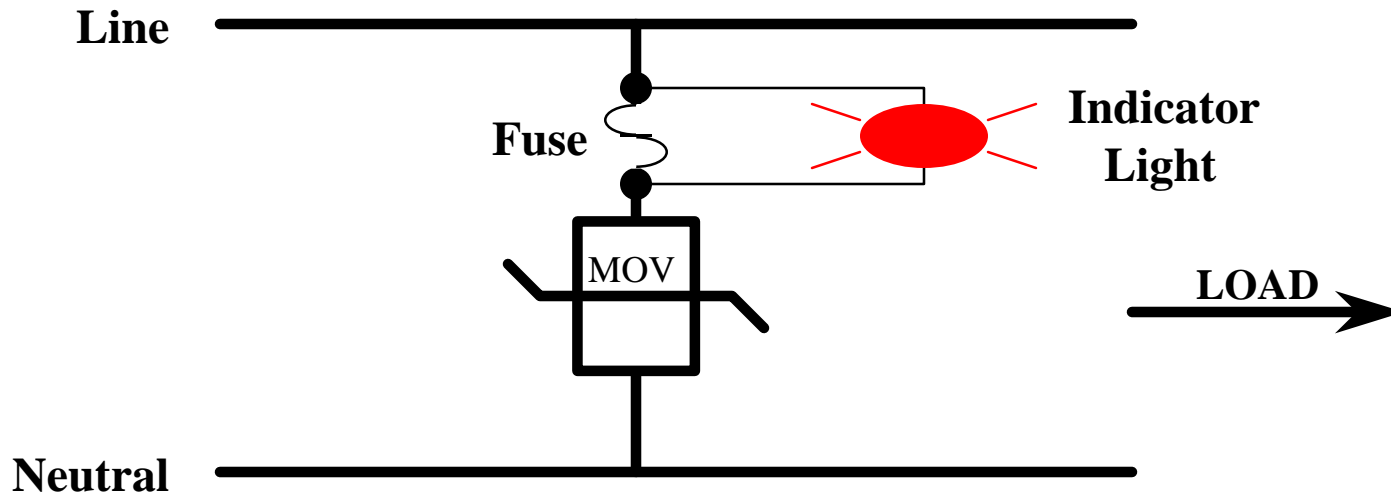
- ◆ **Systems With Neutral (Grounded) Conductor**
 - ◆ **Line to Neutral (L-N) protection is a must!**
 - ◆ N-G may be necessary if far away from a system N-G bond.
 - ◆ L-L will be redundant and often not recommended.
 - ◆ L-G may be necessary if far away from a system N-G bond, but raises safety issues.

- ◆ **Systems Without a Neutral (Grounded) Conductor**
 - ◆ **Line to Line (L-L) protection is a must!**
 - ◆ L-G may be unnecessary and may raise safety issues.

- ◆ **Effectiveness of Protection Modes Depends on the Type, Coordination and Quality of the Components Therein!**



MOV Applications: Simplest Design



◆ Features:

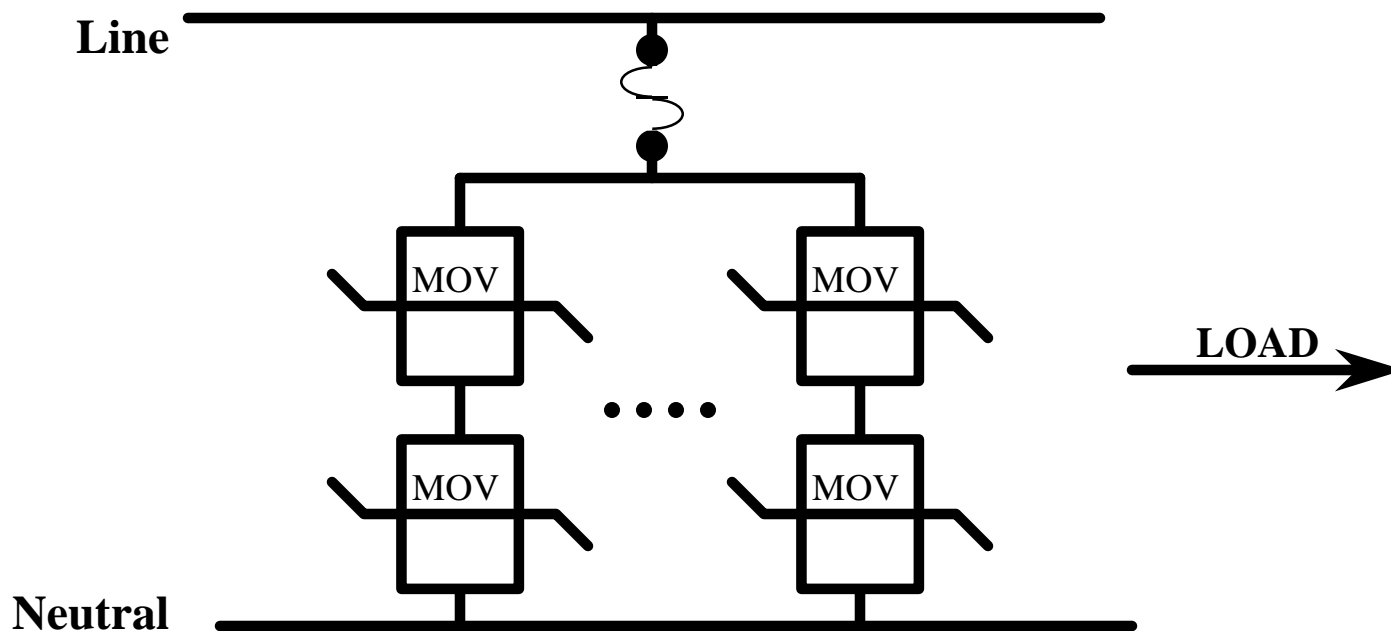
- ◆ Possible High Joule / Peak Amperage Rating
($\text{Joules} = \text{Energy} = \text{Volts} * \text{Amps} * \text{Time}$)

◆ Concerns:

- ◆ MOV Degradation Leads to Device Failure
- ◆ Wide Clamp Voltage Range - Typically 10 - 12%
- ◆ One Current Path - Clamp Voltage Rises as Current Increases

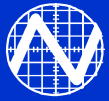


MOV Applications: Matrix Design



◆ MOV Matrix Benefits

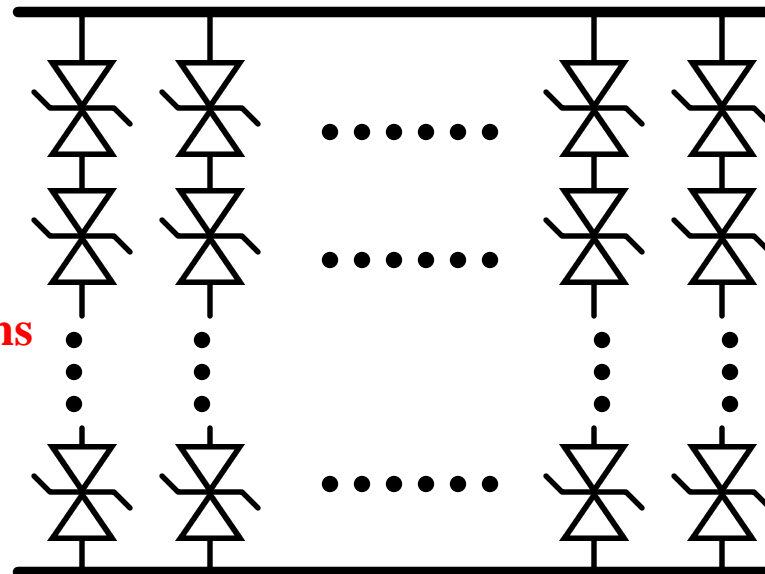
- ◆ Parallel paths increase joule/peak amperage handling
(Joules=Energy=Volts*Amps*Time)
- ◆ Less current per path = less degradation of each MOV
- ◆ Series MOVs allow for precise nominal clamp selection



SAD Applications: Matrix Design

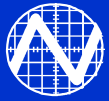
R x C Matrix for TVSS Design

R: # of Rows
C: # of Columns

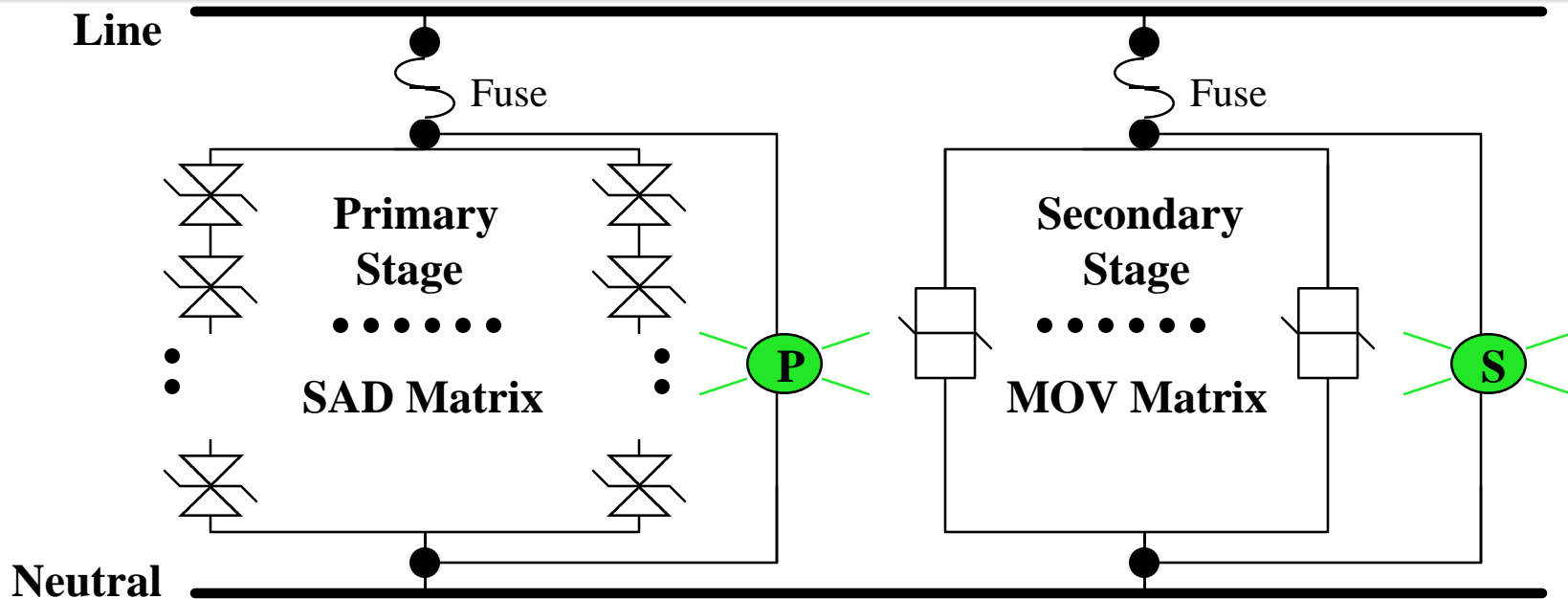


R x (Voltage_{Component})
Yields Initial Voltage
Clamp Level

C x (Current_{Component})
Yields Current Handling



SAD/MOV Applications



◆ Typical Abilities:

- ◆ SAD clamps lower than MOV to take most transients
- ◆ SAD clamping characteristics and response time
- ◆ MOV backup for “insurance” against large events
- ◆ Independent primary and secondary fuses and alarms
- ◆ Remote status and easy field repairability

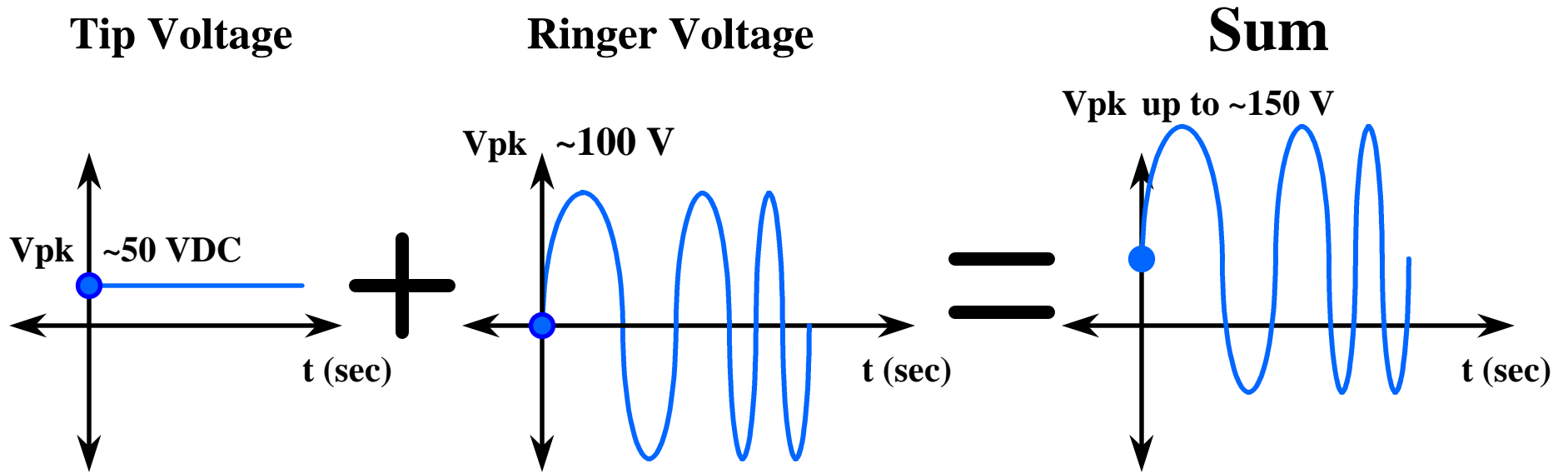


Telco/Data TVSS Design Considerations

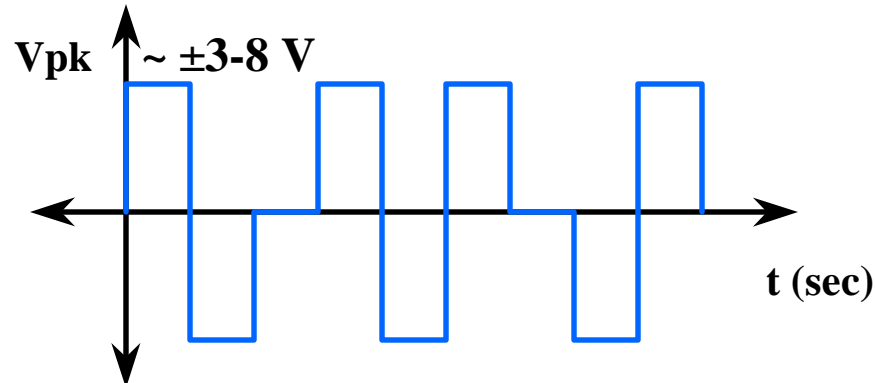
- ◆ **Various signal levels require specific clamp voltages**
 - ◆ Plain Old Telephone Service (POTS) = 120 - 190 V_{peak}
 - ◆ T-1 (data) = 3 - 8 V_{peak}
 - ◆ Twisted pair, coax, PC connections = 5 - 50 V_{peak}
- ◆ **Operating frequency will affect TVSS design used**
 - ◆ Applications range from DC to GHz
- ◆ **Method of interfacing will depend on your equipment**
 - ◆ POTS / T-1 / Data connect via RJ jack, twisted pairs, M66 block...
 - ◆ TV / Cable / Radios utilize coax, twisted pairs, custom cabling...

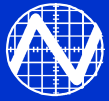


Typical Telco (T1) Signal Types and Levels



Digital-Level Signal (After Smartjack)





T1 TVSS Installation Guidelines

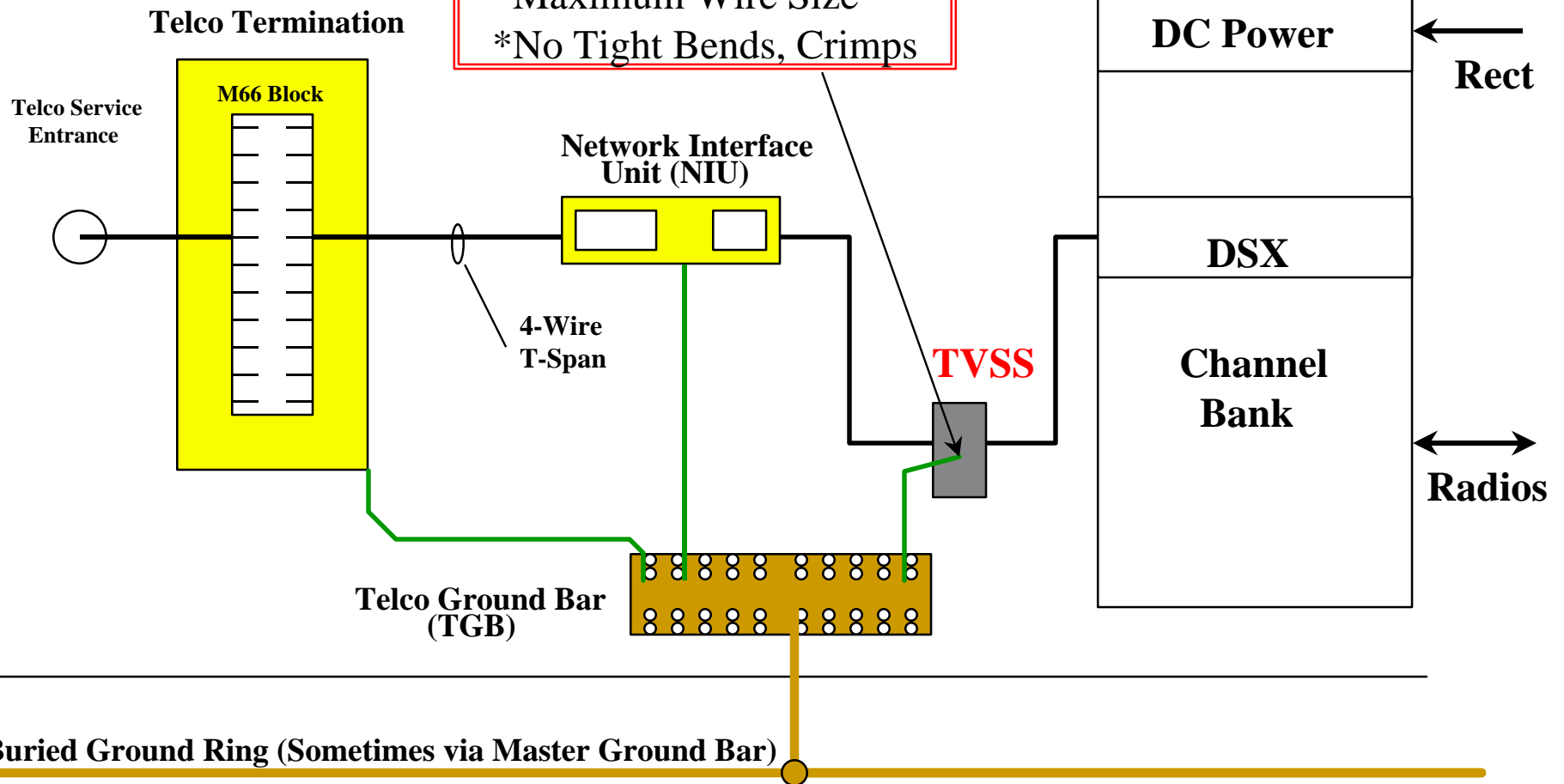
Wireless Communications Facility T-1 Service

TVSS Ground

Install with:

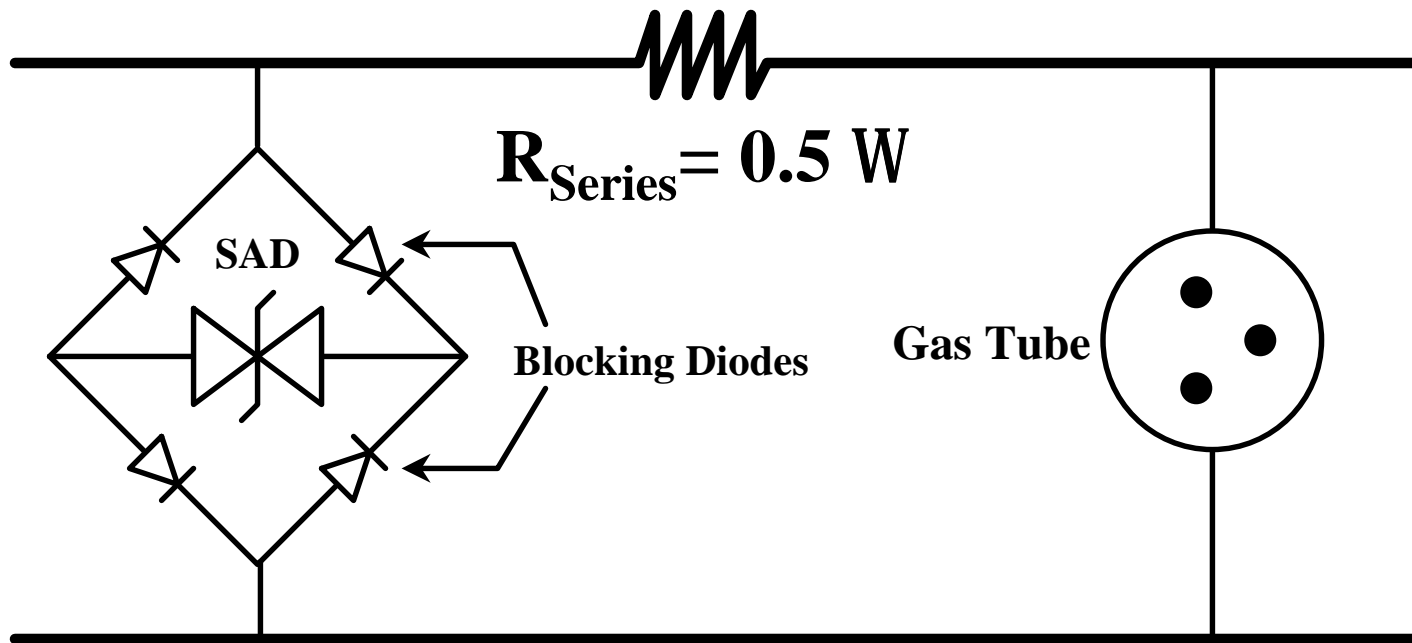
- *Minimum Lead-Length
- *Maximum Wire Size
- *No Tight Bends, Crimps

To Interior Halo and
Master Ground Bar (MGB)





Telco (T1) TVSS Design



Modes of Protection: Tip - Ring
Tip - Ground
Ring - Ground

**Designed Clamp Voltage of SAD
Depends on Peak Signal Level**

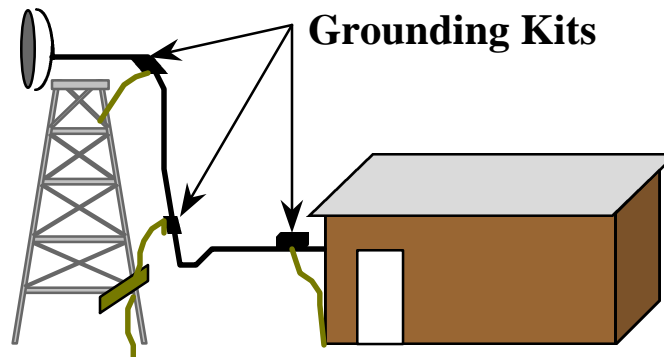


Radio Frequency (RF) TVSS Concepts

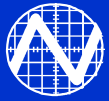
Protect ALL Conduction Paths for Coaxial Cable

◆ Protect Coaxial Cable Sheath

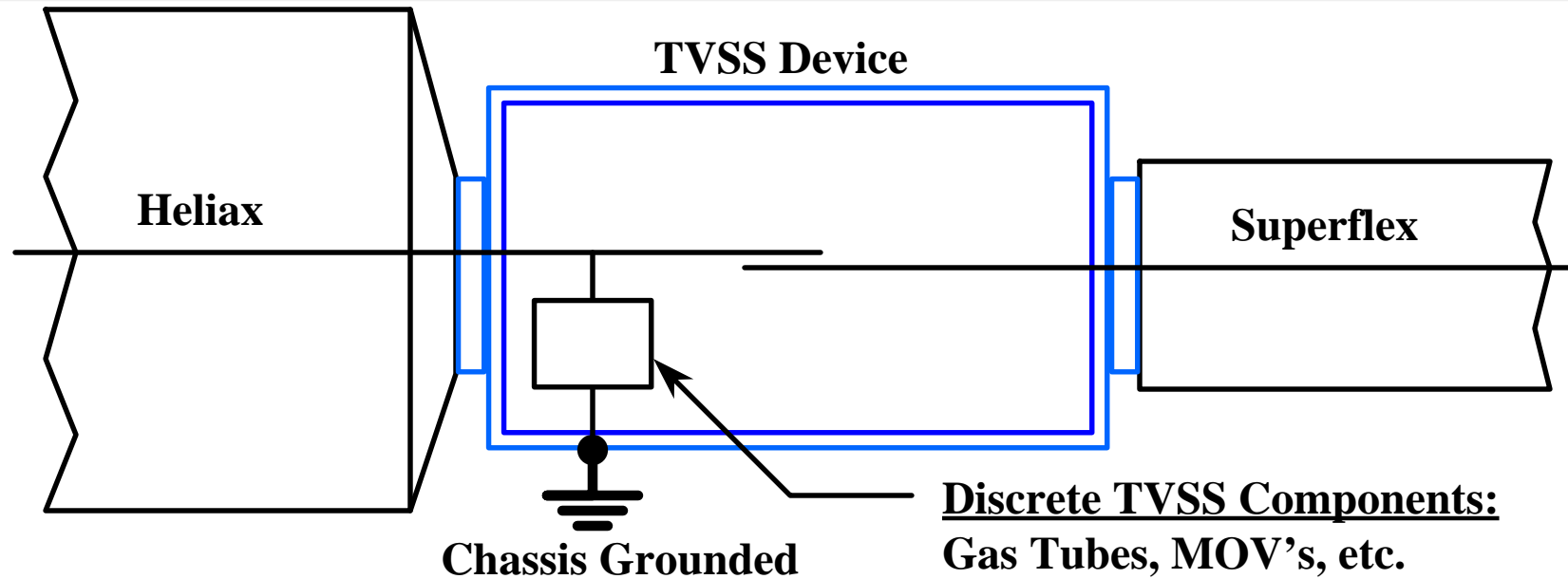
- ◆ Typically done with grounding kits on tower and at RF entrance of building



◆ Protect Center Conductor



RF TVSS Designs: Tuned Isolated Center Conductor

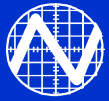


◆ Features

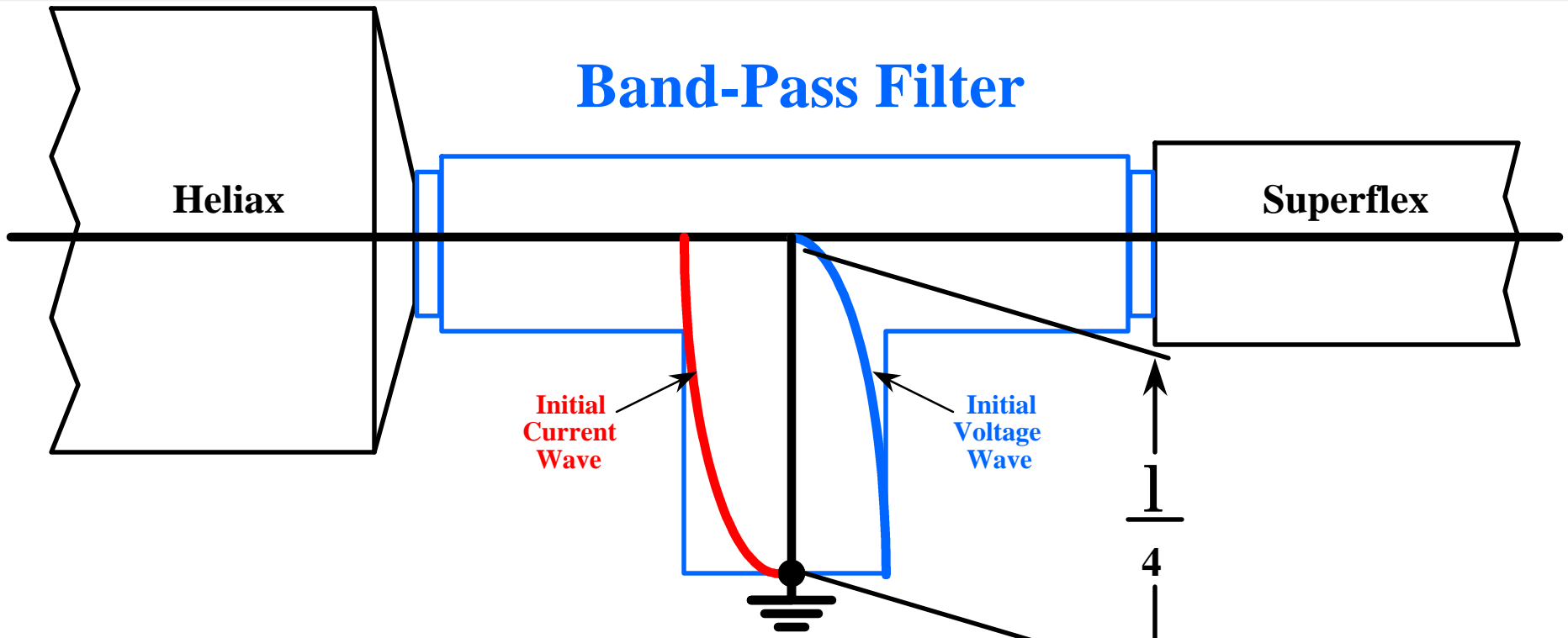
- ◆ Electrical Isolation of Input/Output Center Conductor

◆ Concerns

- ◆ Limited Lifetime of TVSS Components
- ◆ No Indication when TVSS Components Fail
- ◆ Design may be Power Limited (Higher Insertion Losses)
- ◆ Filters Any DC-Injected Transmission



RF TVSS Designs: Quarter Wave Short (QWS)

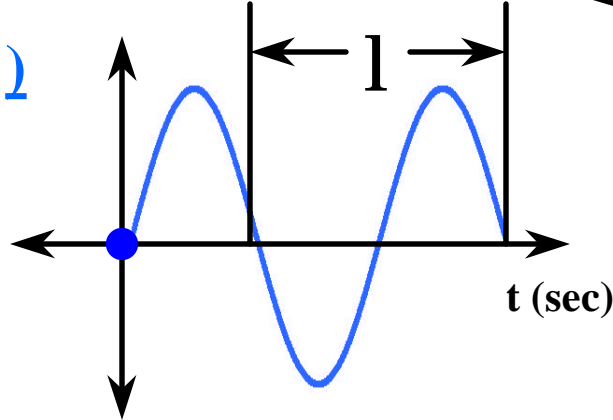


Center Frequency (f)

Cellular: 860 MHz

Paging: 920 MHz

Lightning: 40-100 kHz



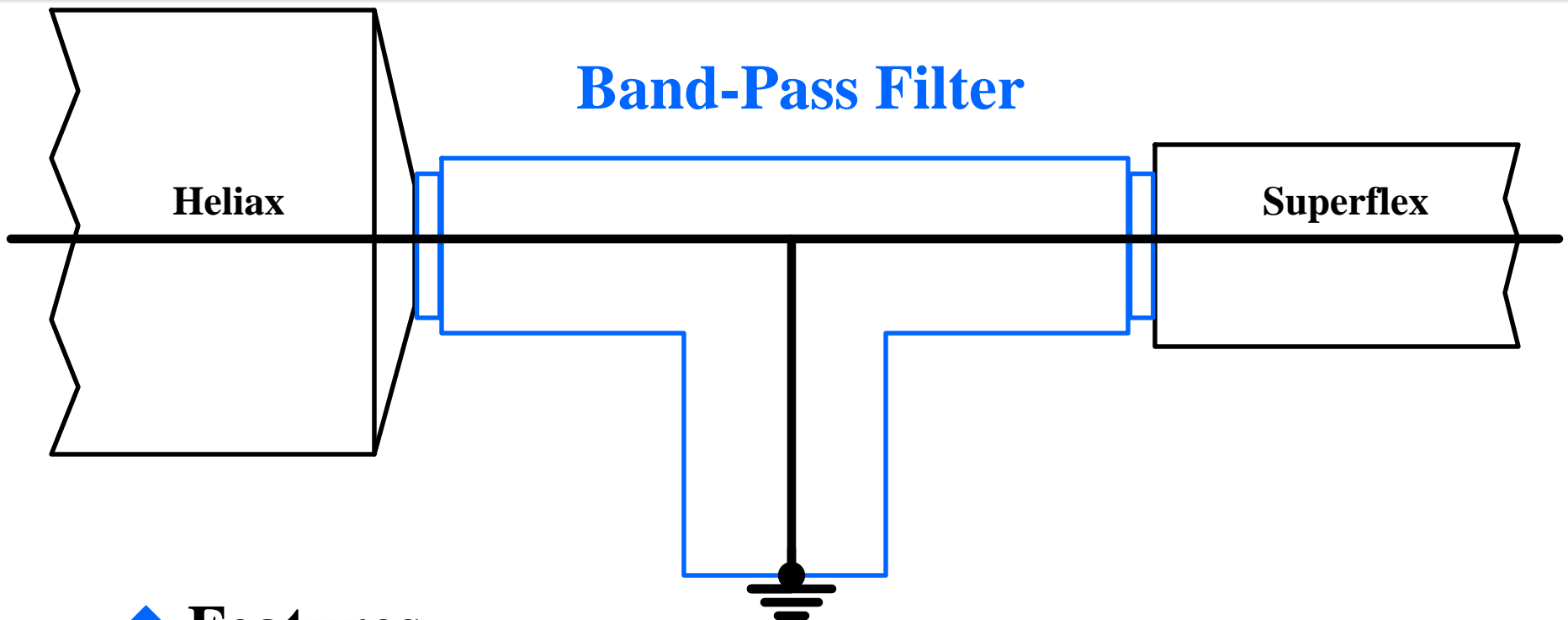
$$l = \frac{c}{f}$$

c = speed of light @ 3.0×10^8 [m/s]

l = wavelength [m]



RF TVSS Designs: Quarter Wave Short (QWS)

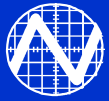


◆ Features

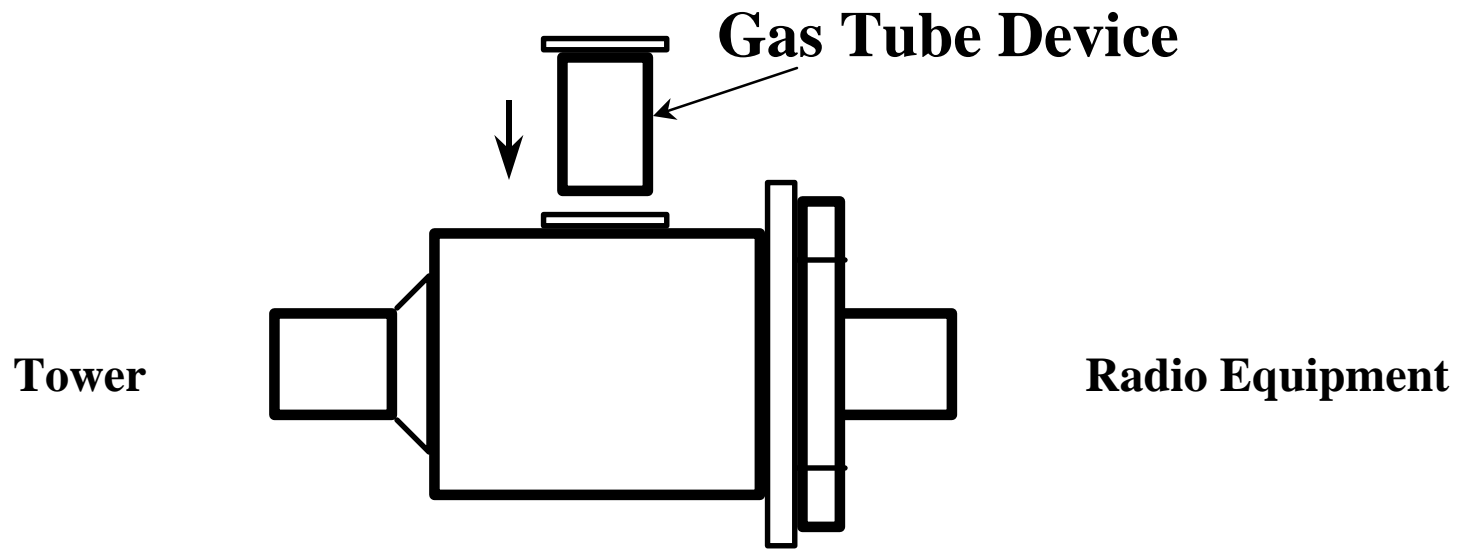
- ◆ Purely Physical Device - No Components to Fail
- ◆ Sandia Tests at 800,000 V: N-Type - 48,000 A; DIN-Type - 93,000 A
- ◆ Not Power Limited - Insertion Losses Extremely Low (≤ 0.05 dB)

◆ Concerns

- ◆ Filters Any DC-Injected Transmission



DC-Injected Center Conductor Protection



◆ Features

- ◆ Passes DC-Injected Transmission to Power External Amplifiers

◆ Concerns

- ◆ Limited Lifetime and Response Time of TVSS Components (Maintenance Required)
- ◆ No Indication when TVSS Components Fail