System Grounding
Impact on reliability and Safety

Presented by:
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Agenda

- System Grounding Considerations for 600 Volts and less system
- Types of System Grounding available
- Pros and Cons of each
- Mitigation strategies
- Selection guideline for mitigation
- Questions

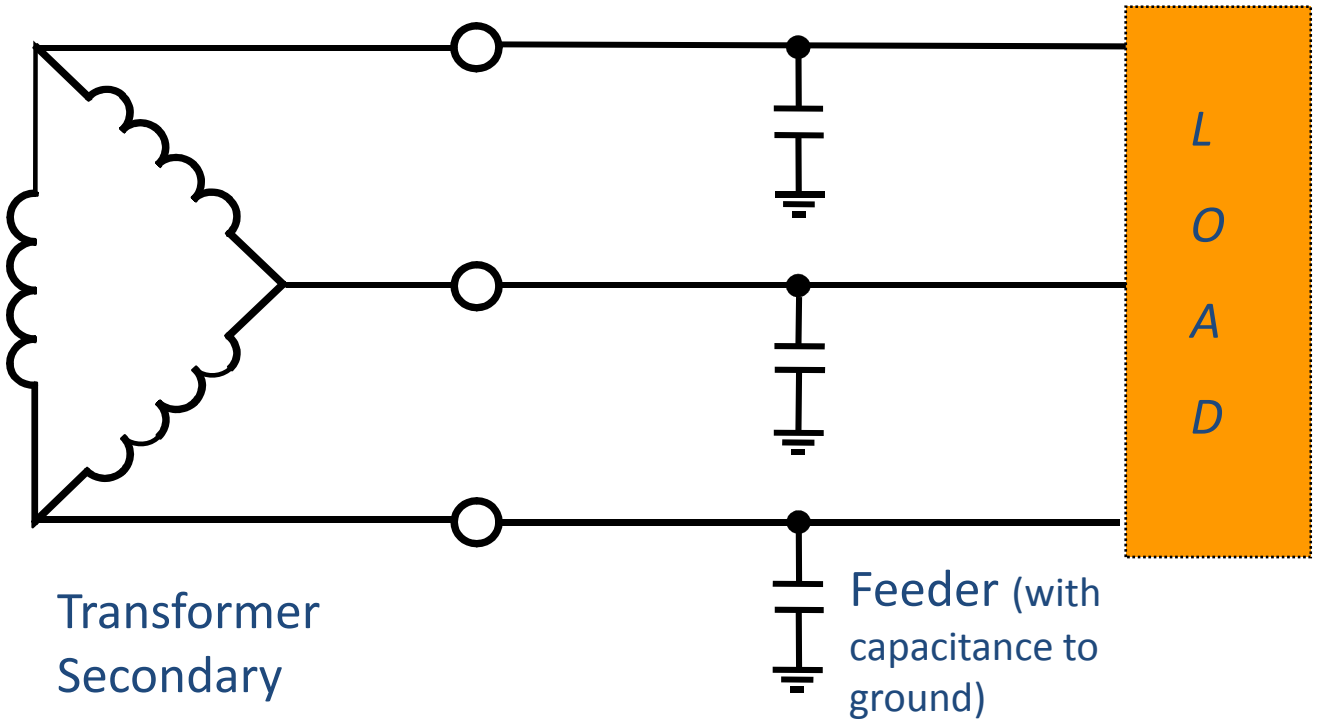
Systems Grounding Considerations

- Cost?
- Safety?
- Reliability ?
- Impact of unintended outages?
  Production loss?
  Environmental?
  Safety?

Types of System Grounding

- Ungrounded
- Solid Grounded
- Impedance Grounded

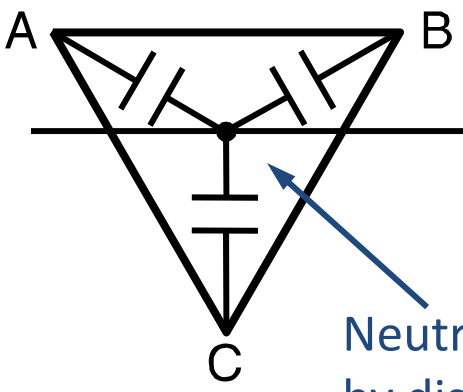
UNGROUNDED (DELTA) SYSTEM



UNGROUNDED SYSTEM:

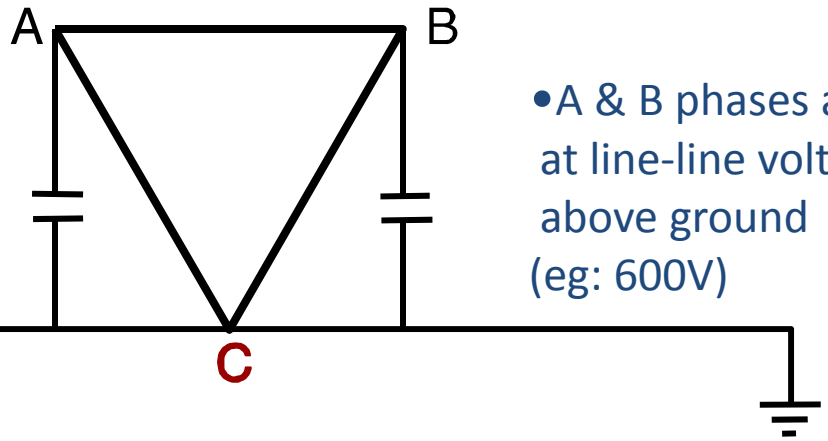
NORMAL OPERATION & FAULTED OPERATION

All phases are at
line-to-neutral voltage
above ground (eg: 347V)



Neutral point established
by distributed capacitance

Normal operation



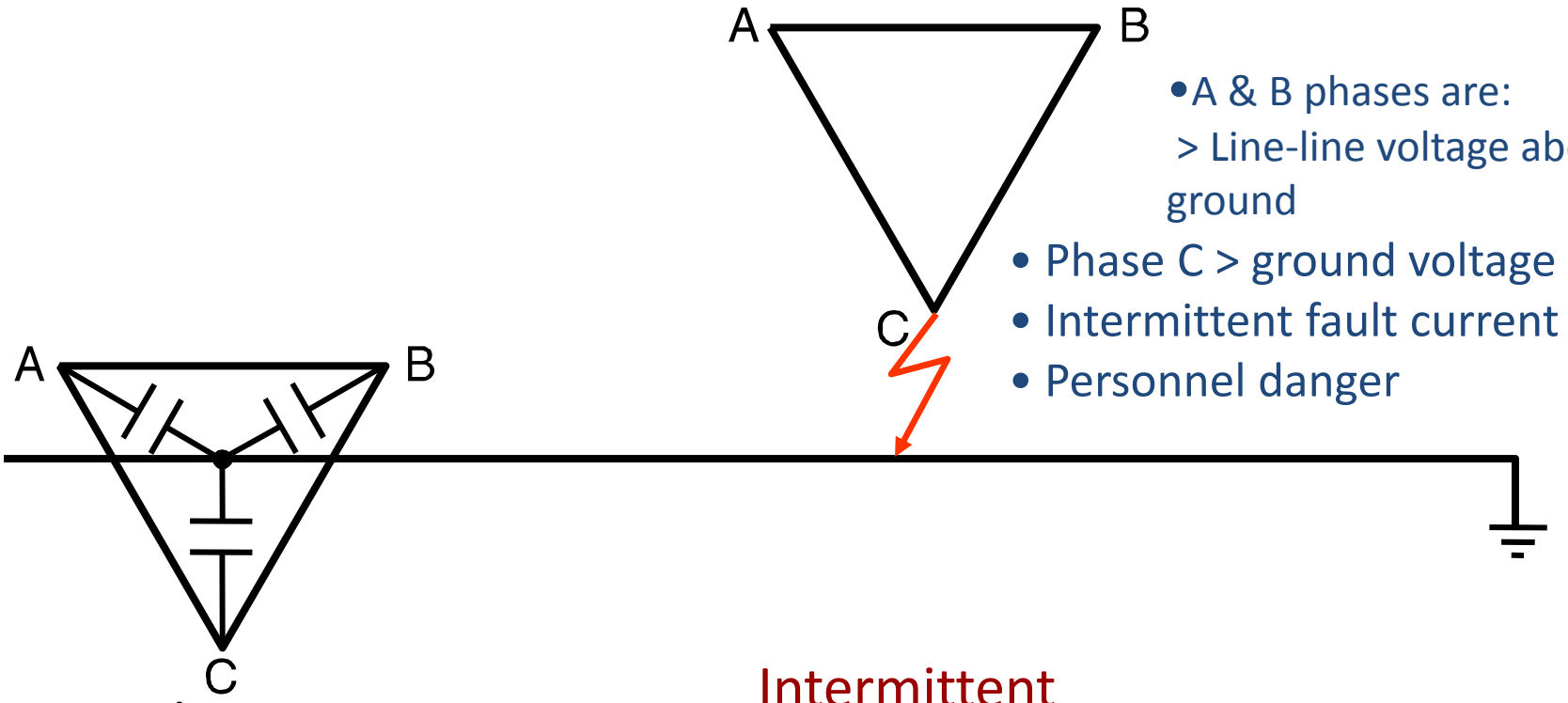
- A & B phases are at line-line voltage above ground (eg: 600V)

- Phase C at ground potential
- No fault current
  (no return path to source)

Ground fault on phase C

UNGROUNDED SYSTEM:

FAULTED OPERATION WITH TRANSIENT OVERVOLTAGE



- A & B phases are:
  > Line-line voltage above ground
- Phase C > ground voltage
- Intermittent fault current
- Personnel danger

Intermittent
ground fault on phase C

UNGROUNDED SYSTEMS:
Pros and Cons

Pros

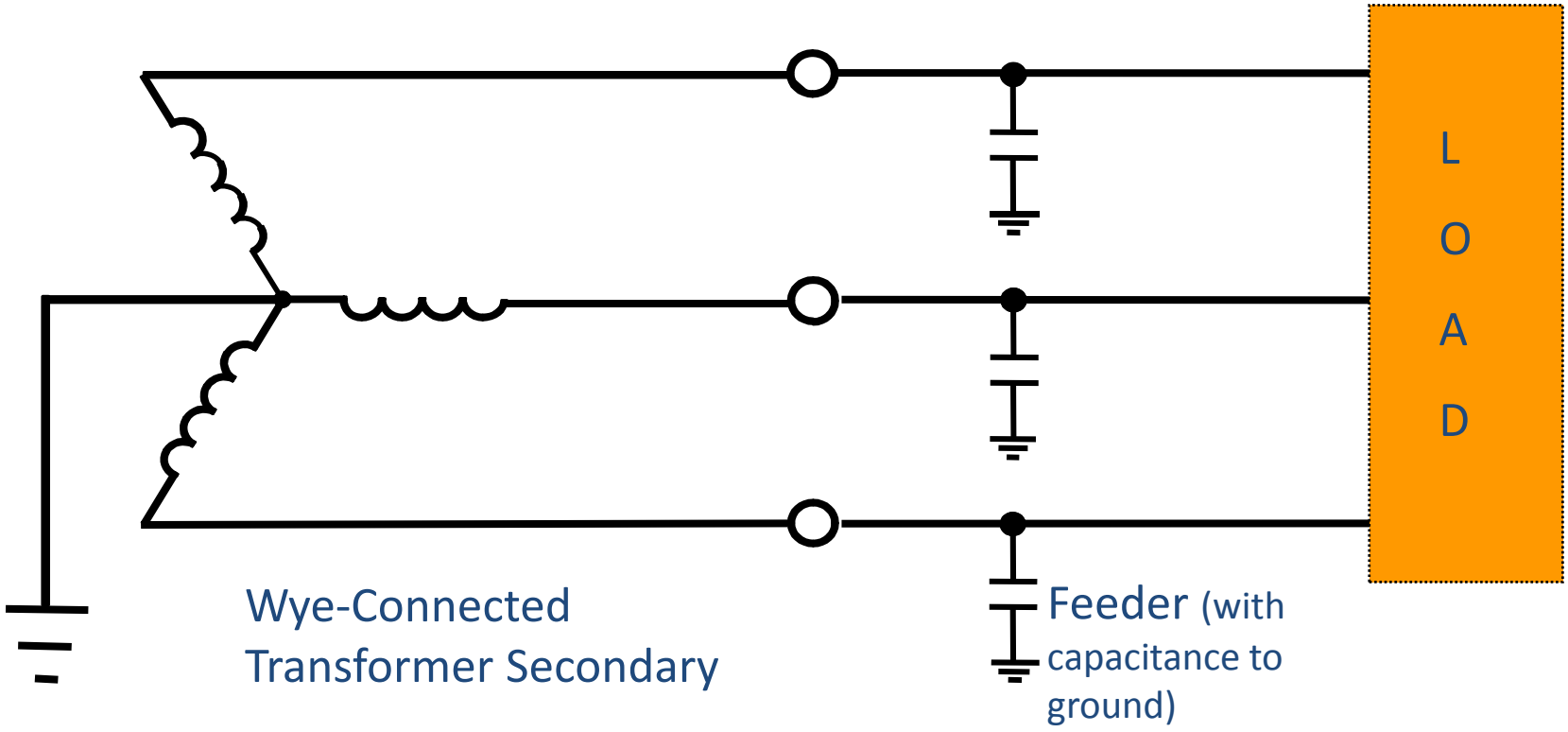
- Minimum Initial cost
- Ability to run with one phase faulted to ground
- Isolation of Primary and Secondary currents (harmonics)

Initially used by the industry to prevent unplanned outages

Ungrounded Systems

- Cons
  - Difficult to detect ground- faults — no fault current
  - Running with a ground-fault increases stress on insulation, leading to phase-to-phase faults
  - Intermittent fault may cause transient overvoltage

SOLIDLY GROUNDED SYSTEM



Solidly Grounding System

Pros

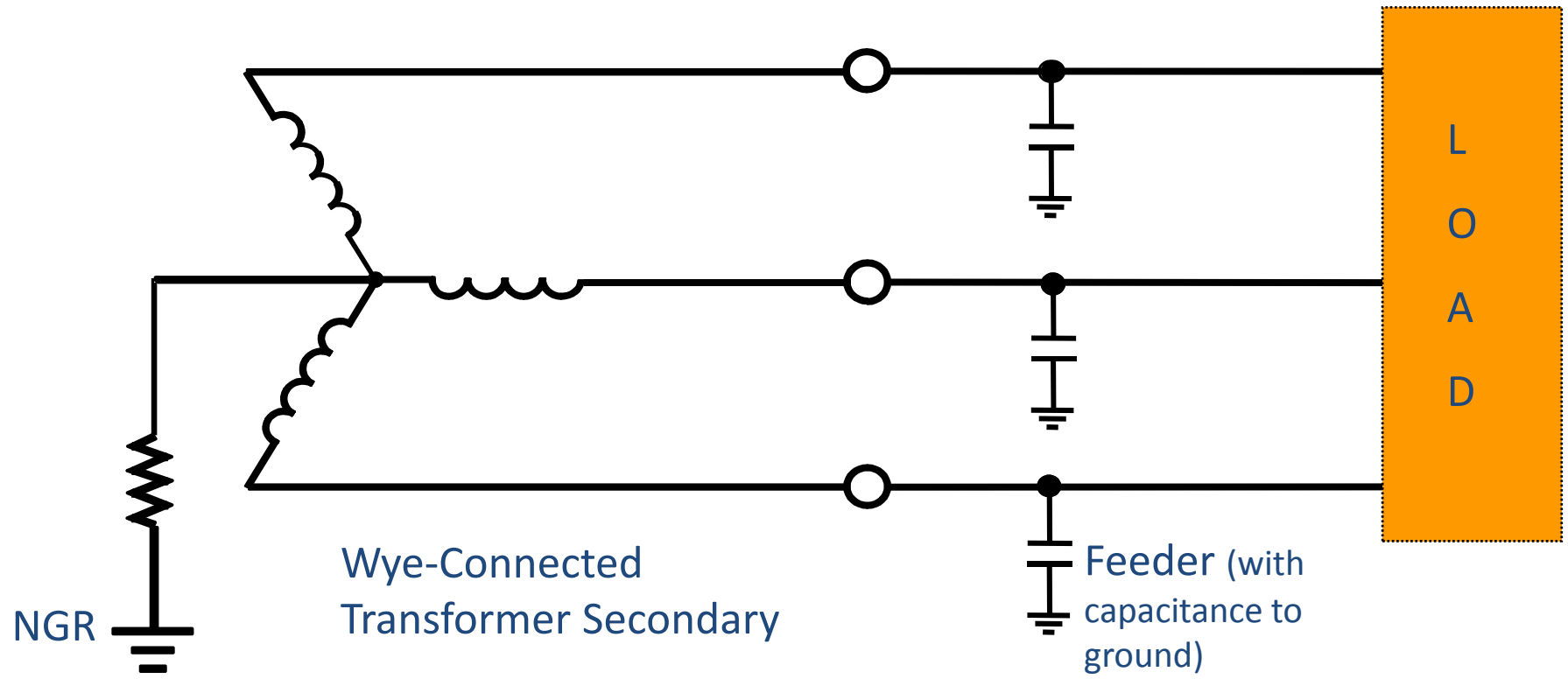
- Minimum first costs
- Immediate isolation of faulted system
- Voltage stabilization
- Allows use of neutral for single phase loads
- *Visible detection of faulted equipment*
- *Equipment insulated rated for phase to ground voltage*

Solidly grounded Systems

CONS

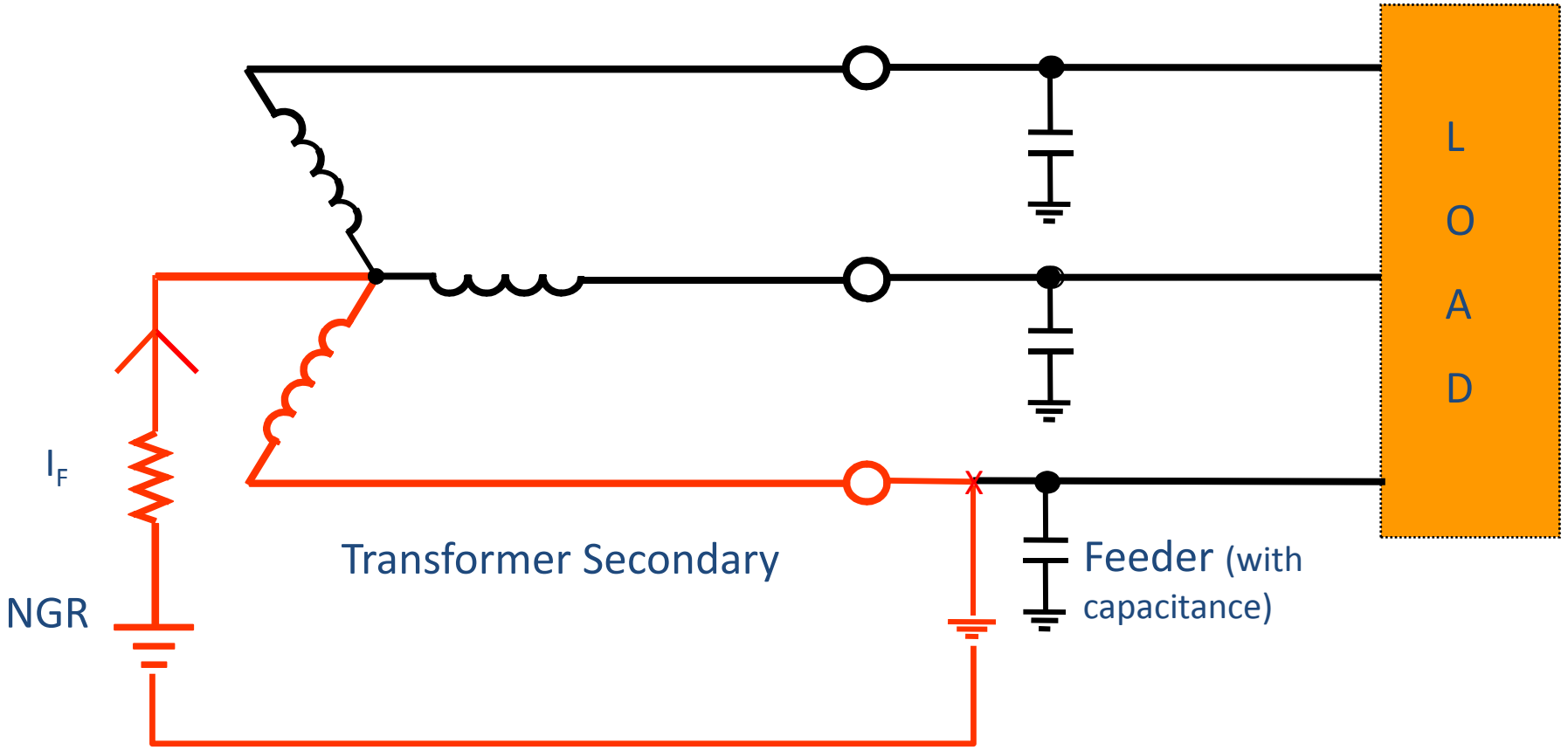
- Unplanned outages
- Voltage dips during fault conditions
- High arcing currents through grounding systems
- Motor terminal box covers have been reported blown away
- Fire Hazard especially in Hazardous (Classified) Areas
- High repair cost and time

RESISTANCE GROUNDED SYSTEM



RESISTANCE-GROUNDED SYSTEM

WITH A GROUND FAULT



Current Limited to NGR Let-Through

Resistance (Impedance) Grounded Systems

Pros

- Reduces unplanned outages
- Transient stability of the system
- Eliminates undesired voltage dips during fault conditions
- Allows fault detection of the faulted equipment
- Minimizes arcing fault current and arc flash hazard

Resistance (Impedance) Grounded Systems

- **CONS**
- Initial investment
- Fault detection and removal required
- System Integrity maintenance required
- Equipment insulation rated for phase to phase voltages

Protection or Prevention: Which is more effective?

- Seat belts, Airbags , *Accident avoidance?
- **alarm and automatic response when close to another car)*
- NFPA 70E/CSA Z 462 primarily address ***protection of personnel*** to minimize personnel injury due to electrical hazards : Shock and Arc Flash by removing power *with some soft suggestion on reduction of hazards*
- Engineering controls minimize the potential of electrical incidents
- Safety By design minimizes injury potential.
- Role of High Resistance Grounding?

Ground Faults

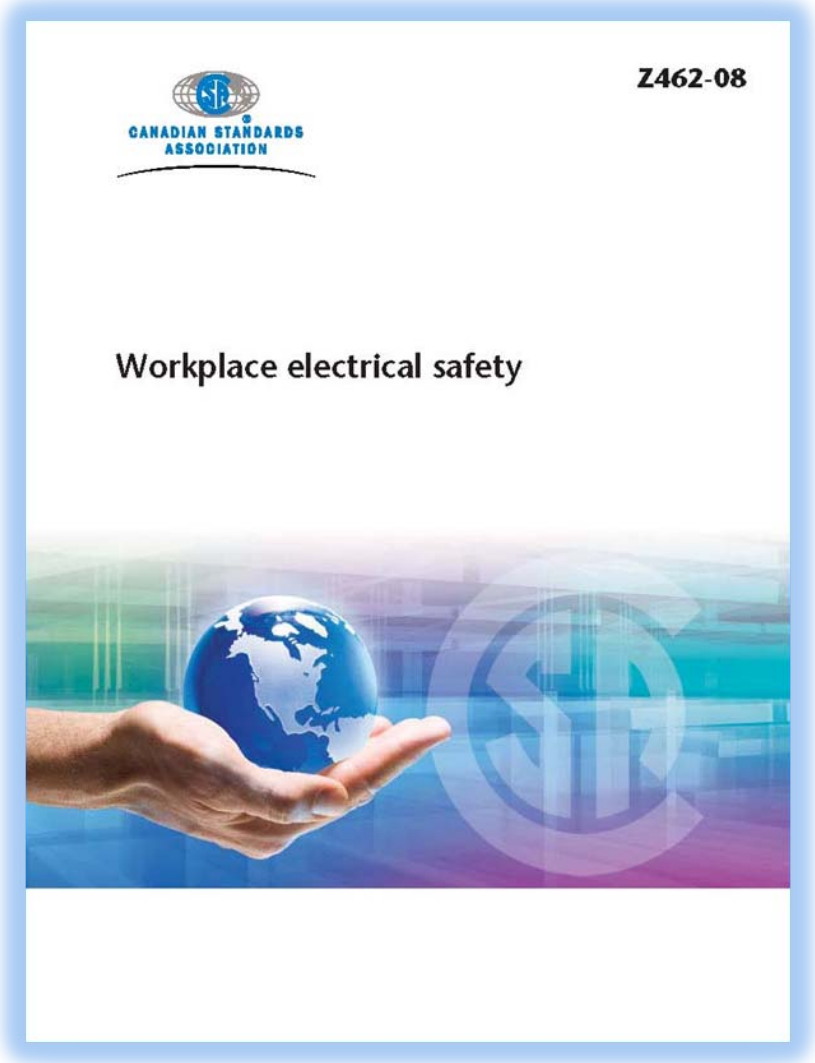
- There has been documentation over the years indicating that between 80% and 95% of all electrical faults initiate as ground faults. By limiting the ground fault current to a small magnitude, a great majority of all phase-to-phase arcing faults can be eliminated.
- Informal numbers are that less than 1% of the faults are initially start as three phase faults (jumpers left installed, snakes etc)

Power System Grounding

- 120.3 FPN No. 3:

  …high-resistance grounding of low-voltage and 5 kV (nominal) systems, … are techniques available to reduce the hazard of the system

Power System Grounding



- 4.3.1.1 Note (3)

  …high-resistance grounding of low-voltage and 5 kV (nominal) systems, … are techniques available to reduce the hazard of the system

70E- 130.5

- Informational Note No. 3: The occurrence of arcing fault
- inside an enclosure produces a variety of physical phenomena For example, the arc energy resulting from an arc developed in the air will cause a sudden pressure increase and localized overheating.
- Equipment and design practices are available to minimize
- the energy levels and the number of at-risk procedures that
- require an employee to be exposed to high level energy
- sources. Proven designs such as arc-resistant switchgear,
- remote racking (insertion or removal), remote opening and
- closing of switching devices, **high-resistance grounding of**
- **low voltage and 5 kV (nominal) systems**, current limitation,
- and specification of covered bus within equipment are techniques available to reduce the hazard of the system

High Resistance Grounding Systems
High-Resistance Grounded

- **There is minimal arc flash hazard, as there is with solidly grounded systems on the first fault, since the fault current is normally limited to a very low value**

High Resistance Grounding

- **Does Resistance Grounding really reduce:**
- **Unplanned System outages?**
- **Potential of arc flash hazard?**

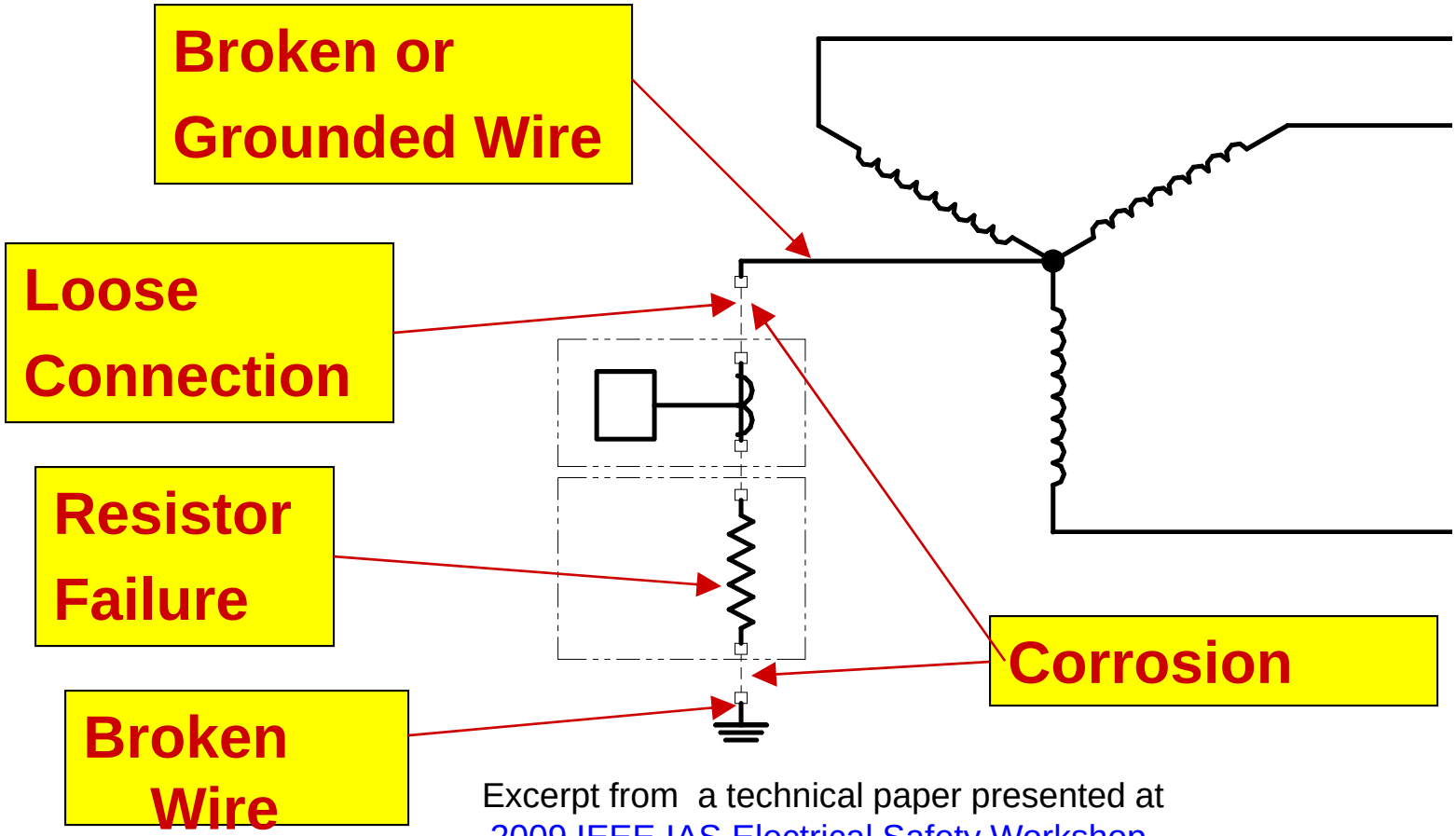
Engineer's answer " It depends"

High Resistance Grounding

- **Yes** ***if and only if***
- ***Neutral grounding system Integrity is maintained .***
  AND
- ***first fault is cleared before inception of second fault.***
  (Second fault on the system will result in a phase to phase fault IF the FIRST FAULT IS NOT CLEARED**)**

Possible Loss of Neutral Path

- Open or Shorted Neutral Path to Ground



Hazard Control Measures

Hierarchy of Hazard Control Measures
from ANSI Z10

Control Effectiveness

Life Cycle Value

Elimination
Eliminate the hazard during design

Substitution
Substitution of less hazardous equipment, system or energy

Engineering Controls
Design options that automatically reduces risk

Warnings
Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels

Administrative Controls
Planning processes, training, permits, safe work practices, maintenance systems, communications, and work management

Personal Protective Equipment
Available, effective, easy to use

Hazard Control Measures

outlined in ANSI Z10

Elimination | **Substitution** | **Engineering Controls** | **Warnings** | **Administrative Controls** | **PPE**

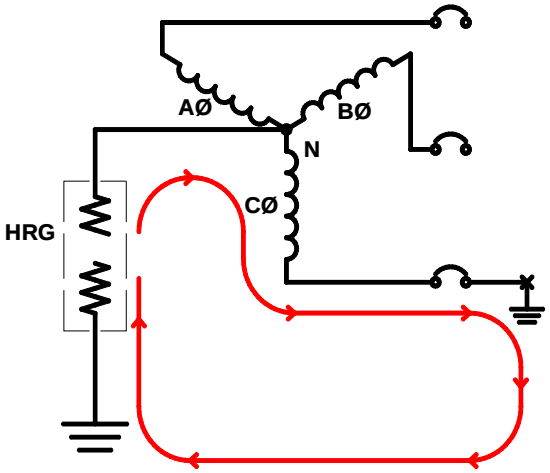
Addressed in 70E Tables

Addressed in NFPA 70E

Prevention ⟷ Protection

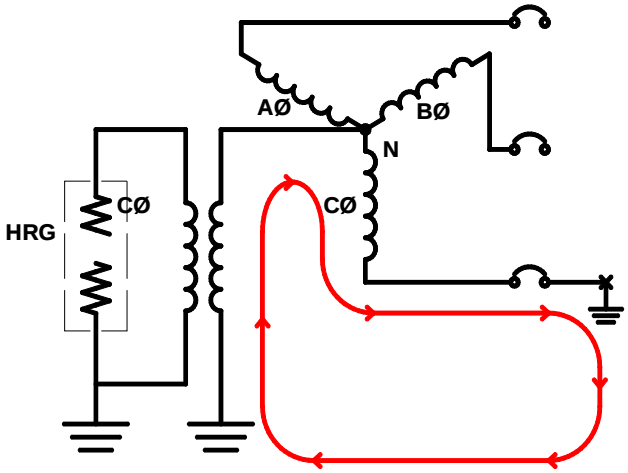
An effective electrical safety program incorporates <u>all</u> control measures

Warning of Risk



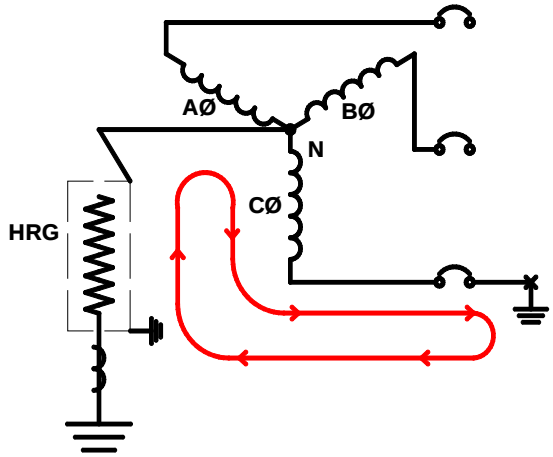
Open Circuit:

- Desired fault current cannot flow.
- Ungrounded System.



Open Circuit:

- Desired fault current cannot flow.
- Grounded thru high inductive transformer.
- Resonance System.

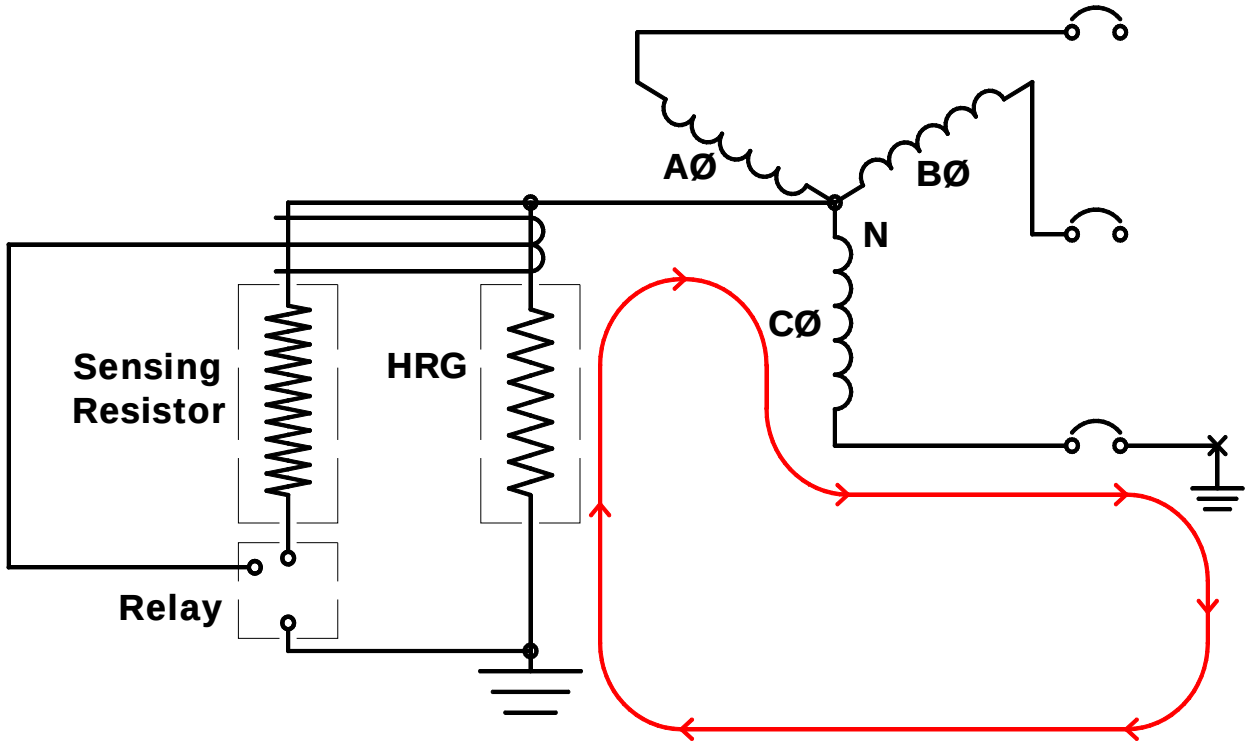


Short Circuit:

- Undesired fault current can flow.
- Place CT close to N, >costs (elevated N).
- Solidly Grounded System.

Automatic Reduction of Risk

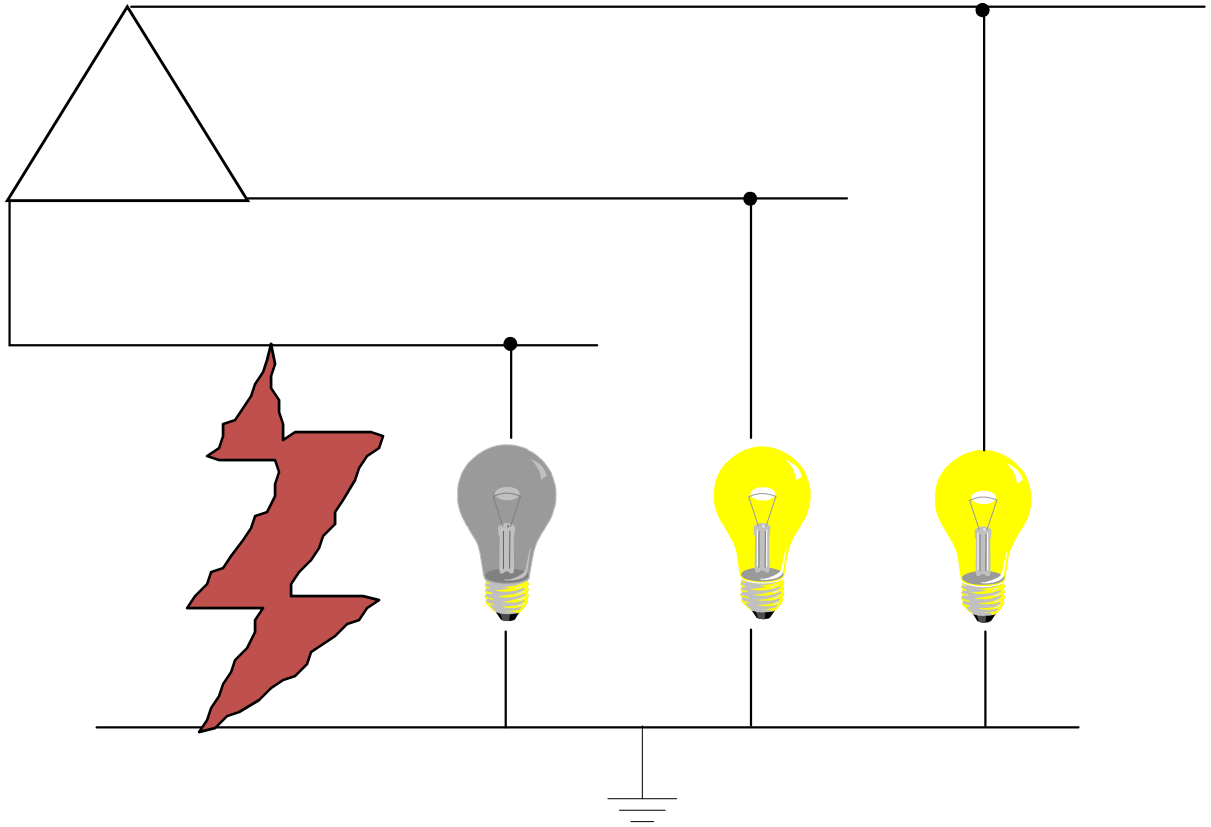
- Ground Fault Relay & Sensing Resistor
  - Detects Open / Short Circuits and maintains Grounding



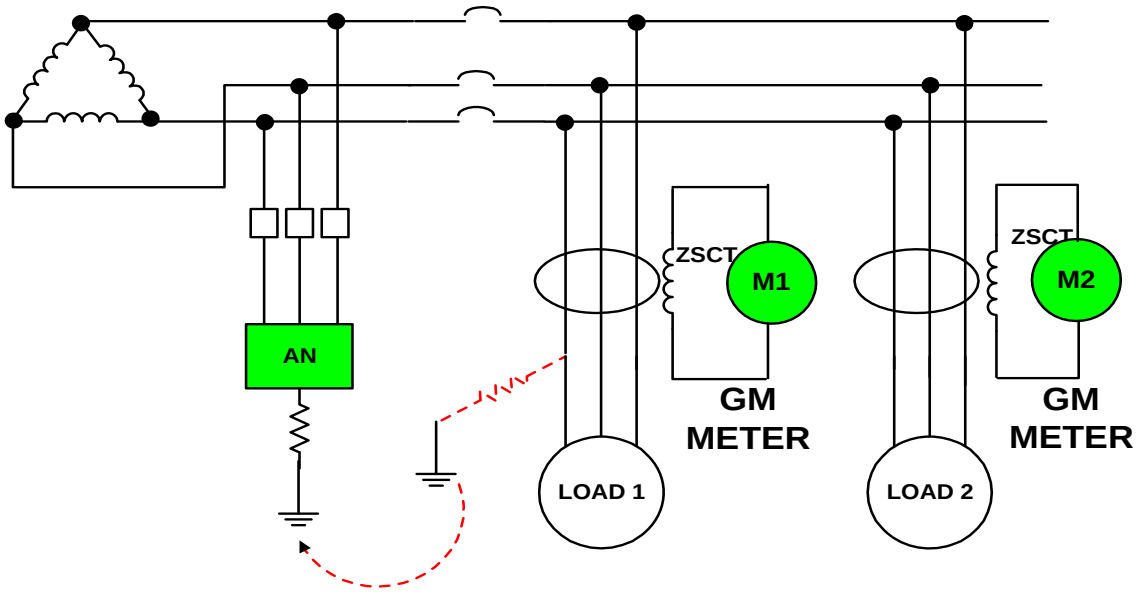
Avoiding Second Ground Fault

- **To reduce arc flash hazard, it is critical to reduce the possibility of two faults at the same time.**
- **How?**
  Warning of risk
- **Either make sure maintenance people remove the ground fault immediately**
- **Automatic reduction of risk**
- **Provide sensing equipment to prioritize feeders to avoid second simultaneous ground fault**

FAULT INDICATION USING 3 LAMPS

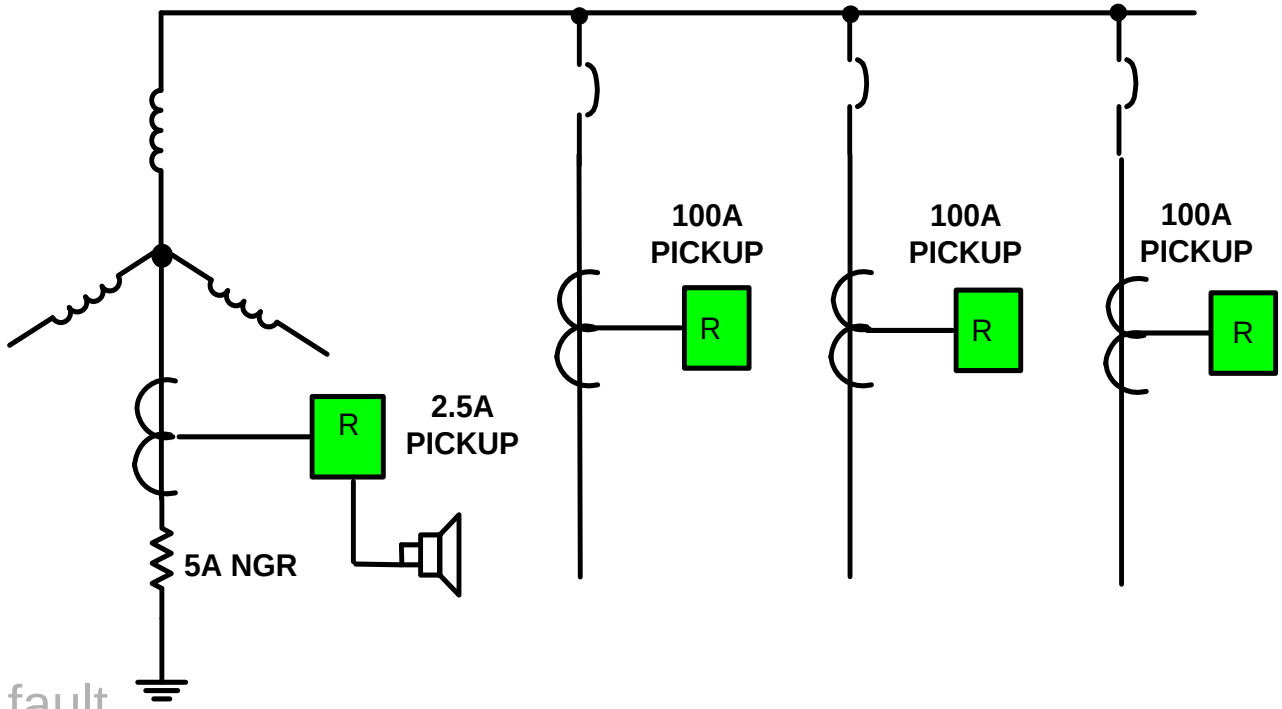


FAULTED FEEDER INDICATION



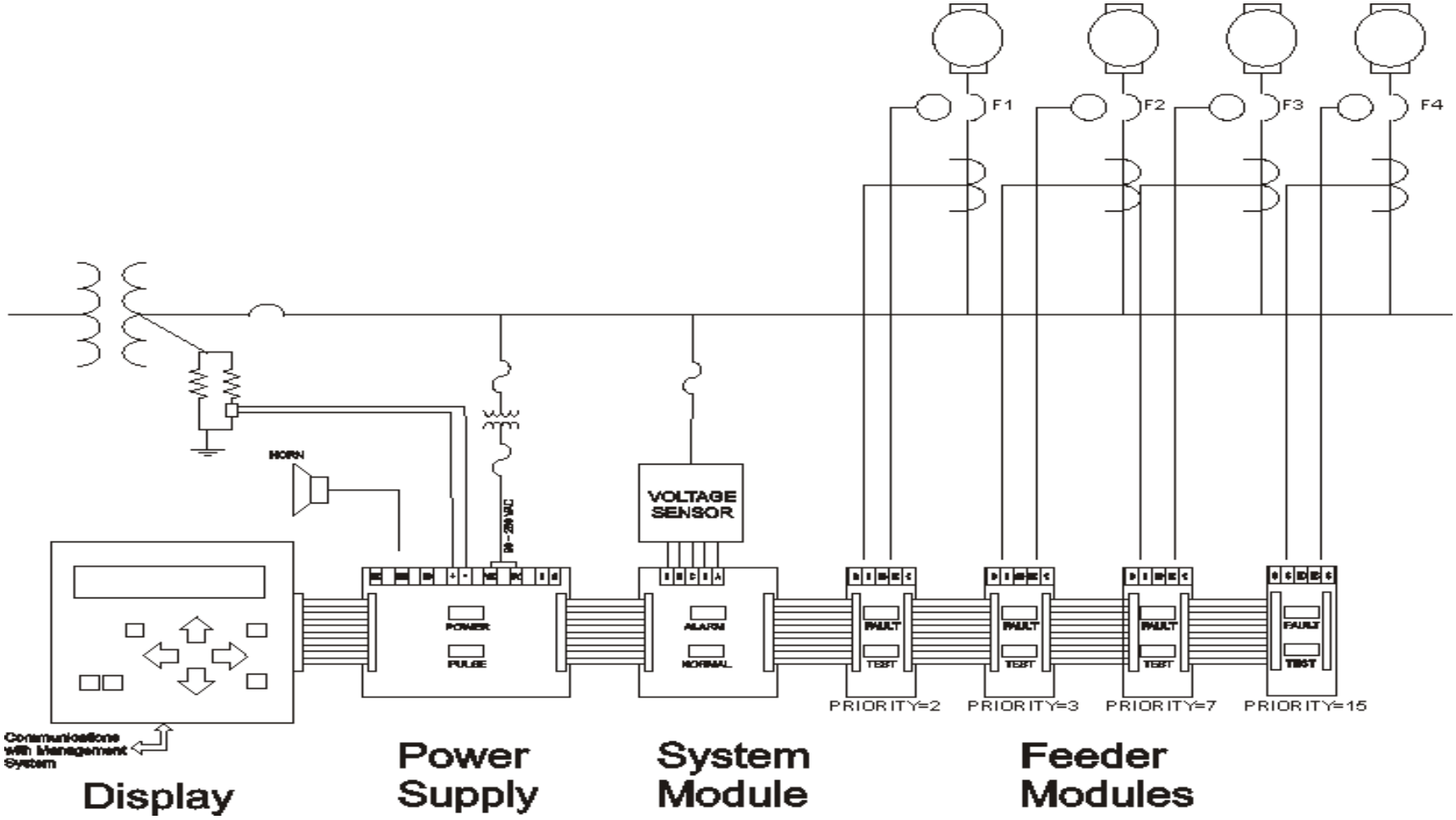
- Indication of first Feeder fault

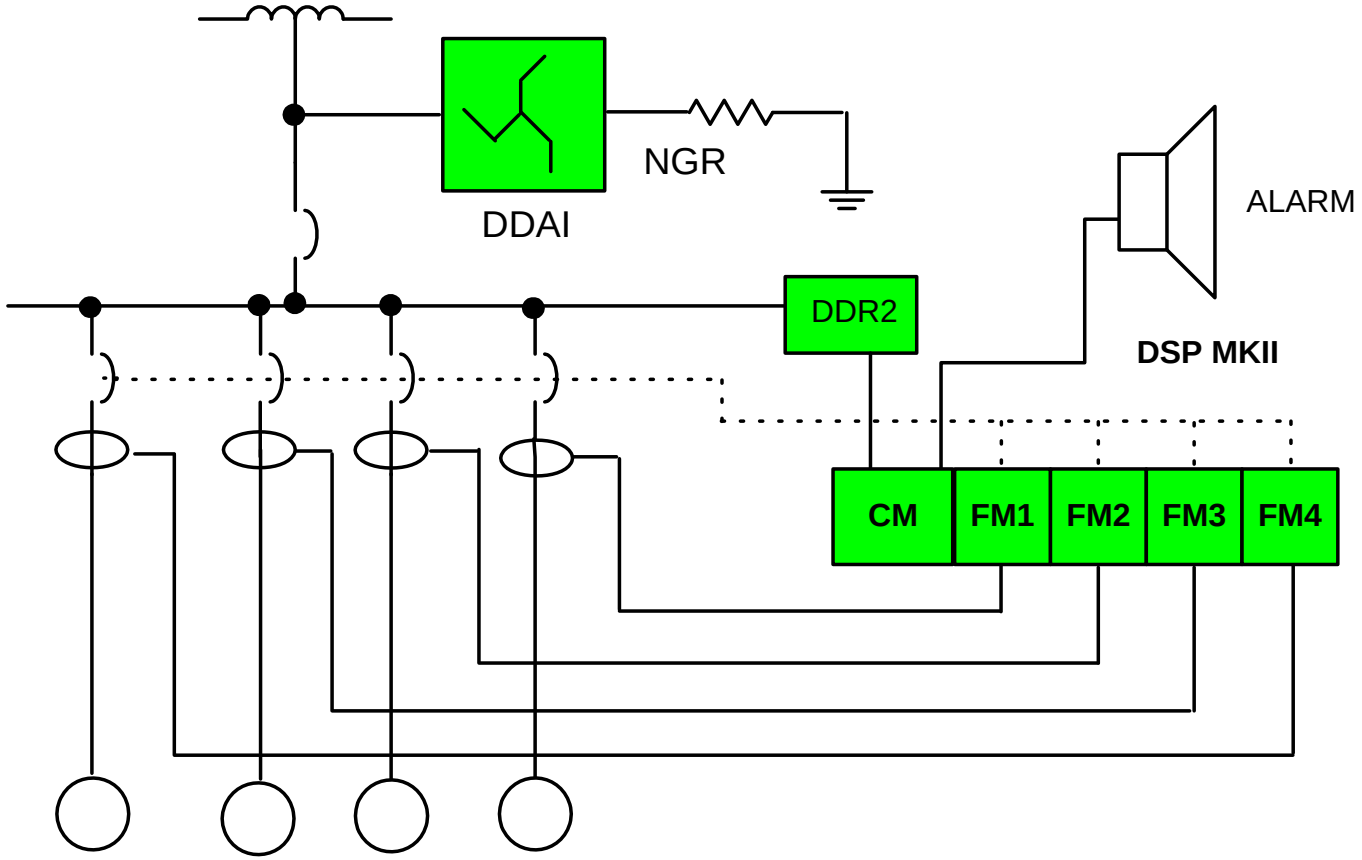
MGFR relays



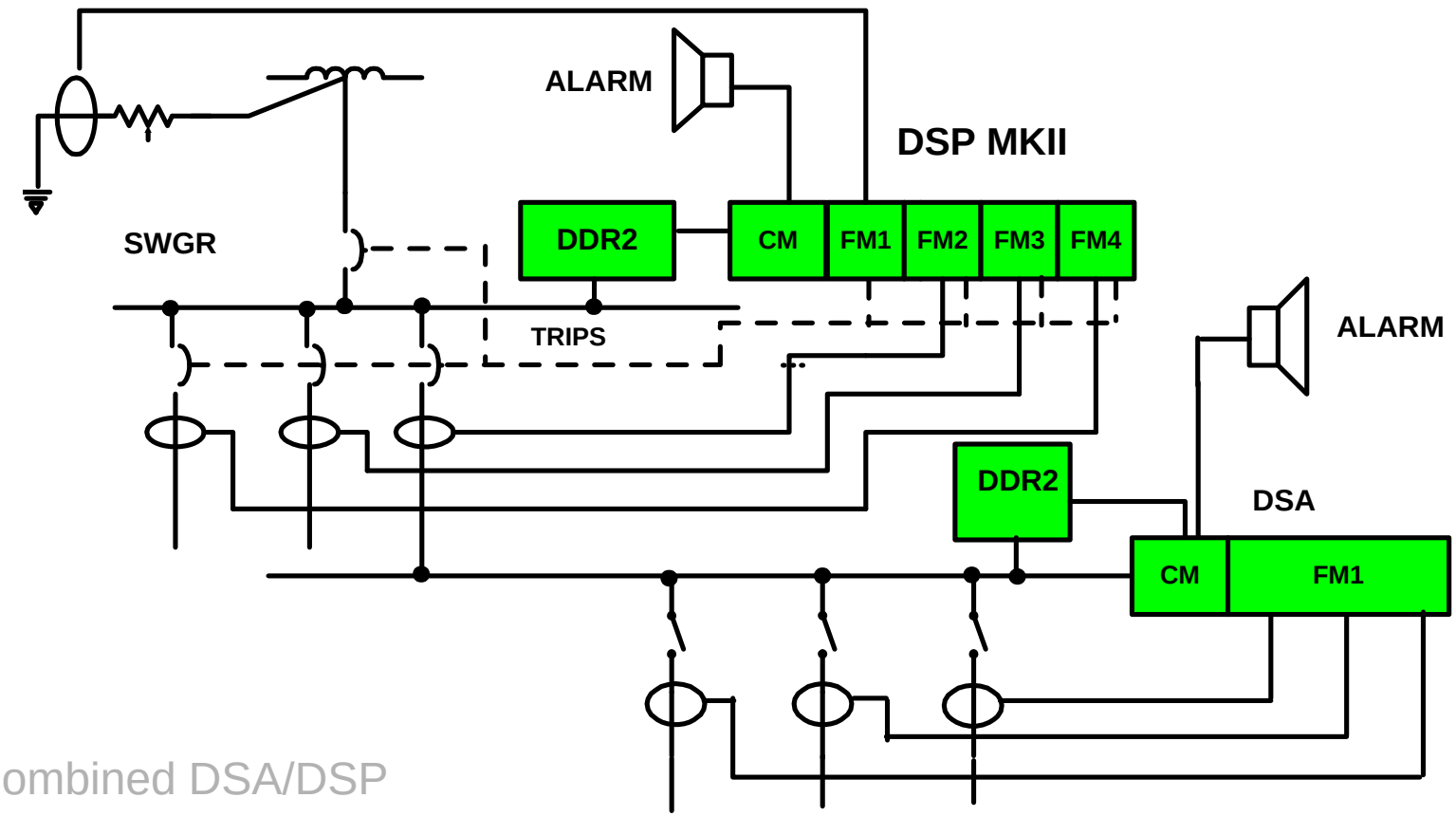
- Alarm on first fault
- Trip on second fault
- Cannot prioritize essential feeders
- Difficult to locate fault(s)

Minimizing Second Simultaneous Ground Fault



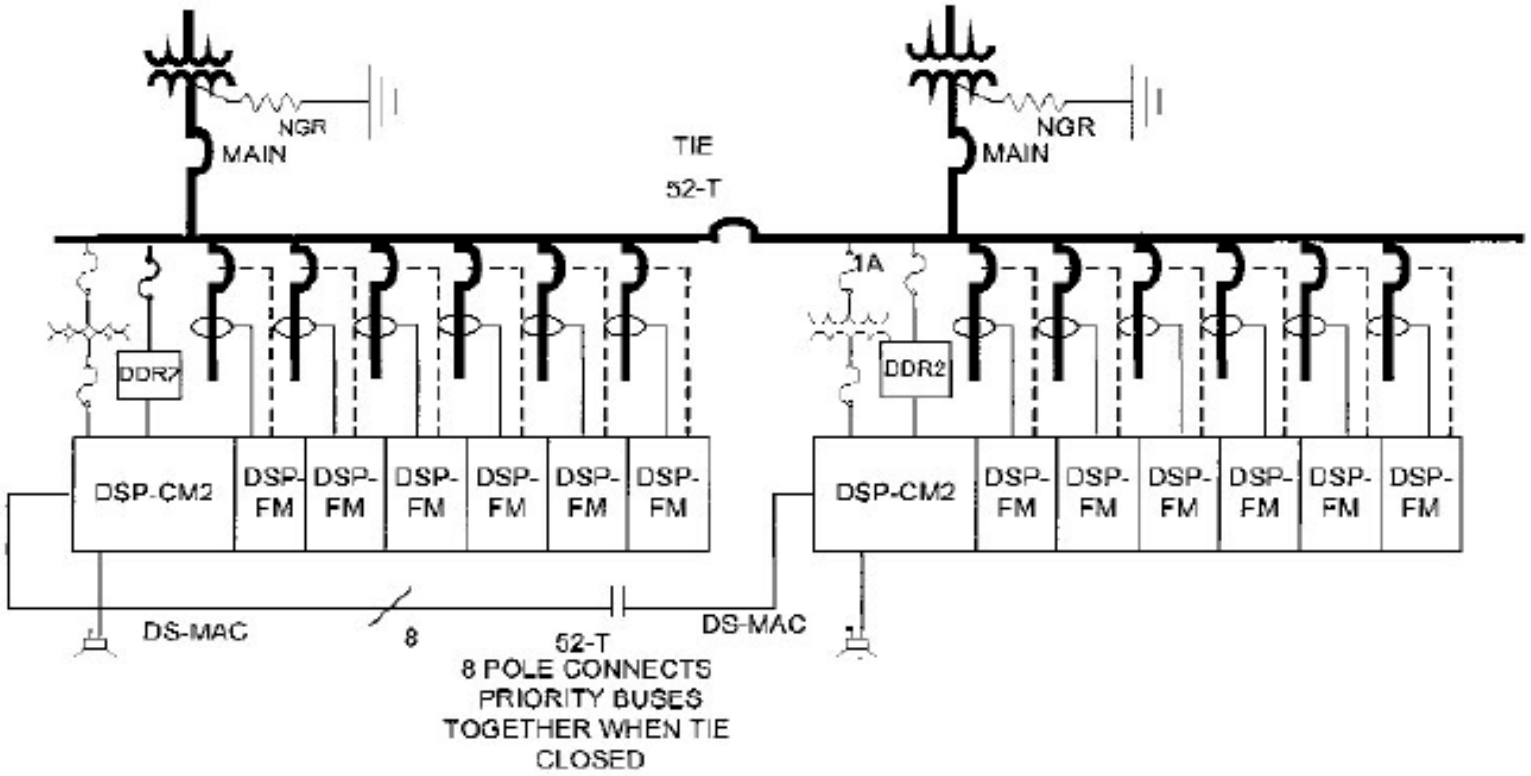


- Faulted Feeder
- First Fault Alarm
- Faulted Phase Indication
- Second Fault Trip
- Selective Inst. Feeder Tripping
- Ground Current as % of Let Through



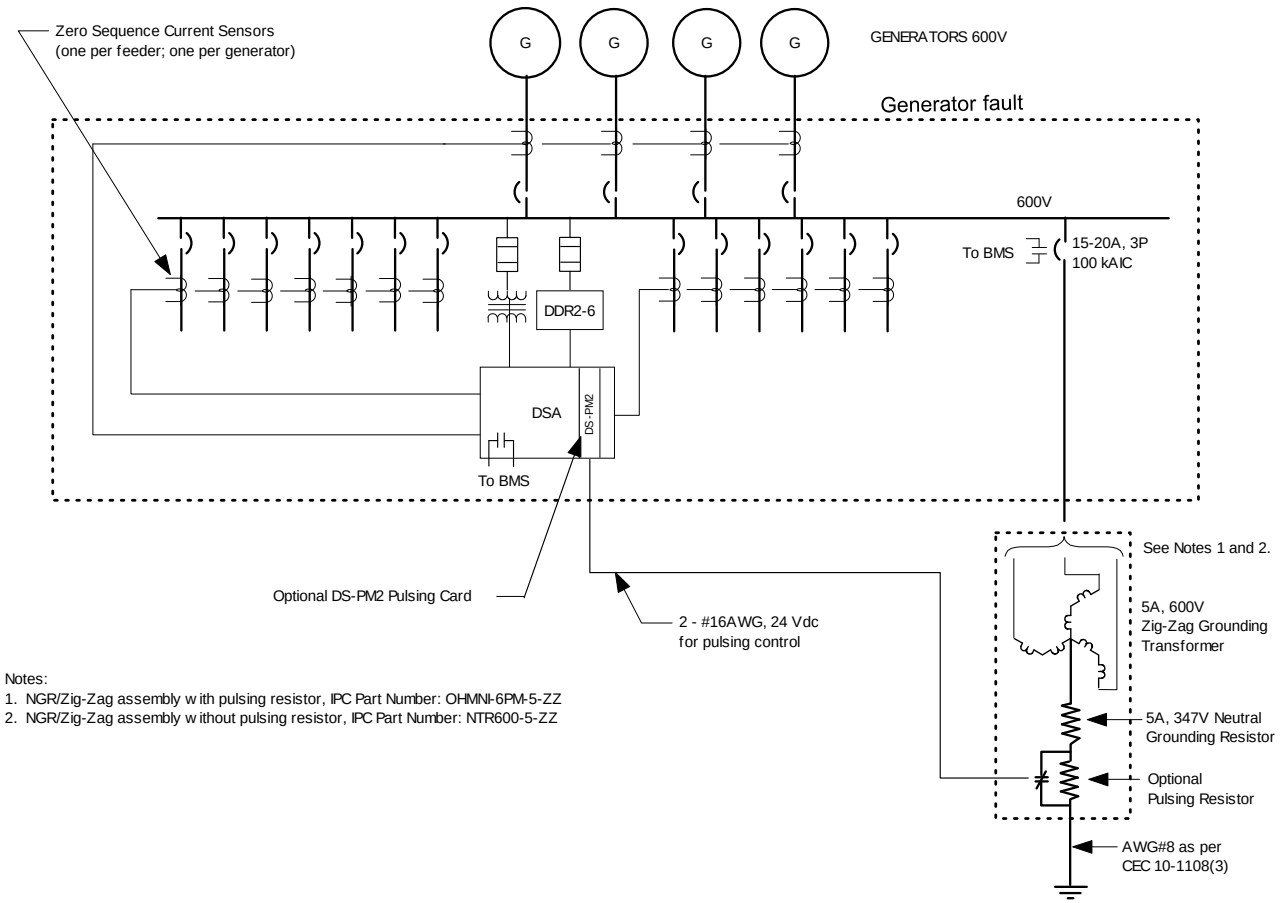
- Combined DSA/DSP
- Identifies individual faulted
- load and Phase
- Second Fault Protection Backup

DSP Relay
Double ended Unit sub Application



Parallel Generators

TYPICAL PARALLEL GENERATOR HIGH RESISTANCE GROUNDING SCHEME



Notes:
1. NGR/Zig-Zag assembly with pulsing resistor, IPC Part Number: OHMNI-6PM-5-ZZ
2. NGR/Zig-Zag assembly without pulsing resistor, IPC Part Number: NTR600-5-ZZ

Mitigation Strategies

- **Good**
  System maintenance practices
- **Better - Warnings**
  Alarms
  Procedures
  PPE
- **Best -Automatic Reduction of Risk**
  Elimination
  Engineering Controls

Mitigation Strategies selection

- **Which one to use?**
- ***" It Depends"***
- *Consider* ***safety/cost/benefit***
- *Impact due to failure in the system*
  Can system be shut down immediately?
  Cost of shutdown?
- *Maintenance practices?*
- *Environmental conditions?*
- *Liability considerations of design?*

Risk reduction

- **Key strategy in 70E/ CSA Z 462 is risk analysis**

- **Risk = Frequency X Consequences**

- **Use of HRG reduces the probability of frequency and thus reduces the risk**

Risk Analysis

- Does HRG reduces the incident energy required to be put on label?

  NO.

  Label is based on 3 phase bolted fault

  BUT

- it does reduce probability of high incident energy (80- 95%) of the time and can be utilized in Risk Analysis.

Questions ?

Thank you for being here !!

- Thanks for providing me with a forum for preaching electrical safety by design

- Daleep Mohla ,IEEE Fellow , P.E
- d.c.mohla@ieee.org

GARD

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Resistance Grounding and Arc Flash Relay Technology Presentation

Please Join us for a System Grounding Seminar
Powerco Canada Inc. is pleased to present an Engineering Seminar on Grounding

Hosted by
I-GARD Corporation

The seminar will include:

- **Understanding Grounding Techniques**
  - **Ungrounded**
  - **Solidly Grounded**
  - **Resistance Grounding (High and Low)**
- **The effects of a ground fault on the three (3) systems**
- **Ground Fault relay systems**
- **Second Fault Protection Schemes**

- **Arc Flash Reduction Through Protective Relays**
  - **New Technologies**
  - **Installation and Design of protection systems**

Key Speaker: Mr. Ajit Bapat (P. Eng., MBA, Life Member of IEEE) is one of the most renowned experts on grounding systems in North America. Don't miss out on this chance to interact with one of the true experts in the field of power system protection.

Dates & Locations:
April 12 – Edmonton – 8AM to Noon *– Mayfield Inn – 16615 – 109 Avenue*
April 13 – Calgary – 8AM to Noon *– Executive Royal Inn – 2828 – 23 Street NE*
April 14 – Burnaby – 8AM to Noon *– Executive Hotel – 4201 Lougheed Highway*

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