GARD

Unparalleled Protection

Mitigating Arc Flash by Following CSA Z462

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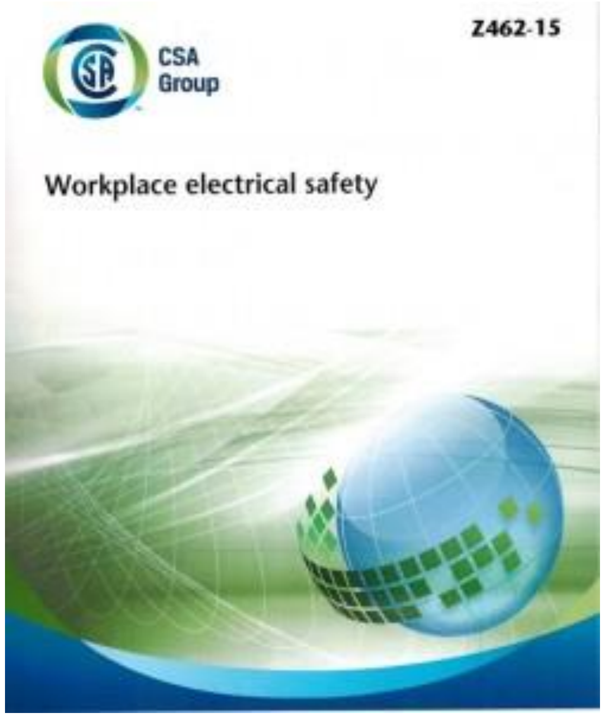
What is an Arc Flash?



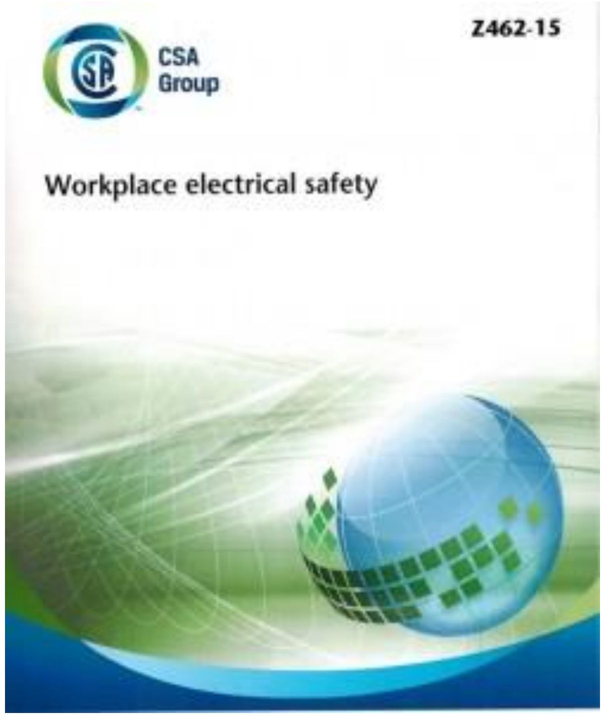
According to CSA Z462:

A dangerous condition associated with the release of energy caused by an electric arc.

A hazard beyond shock and electrocution.

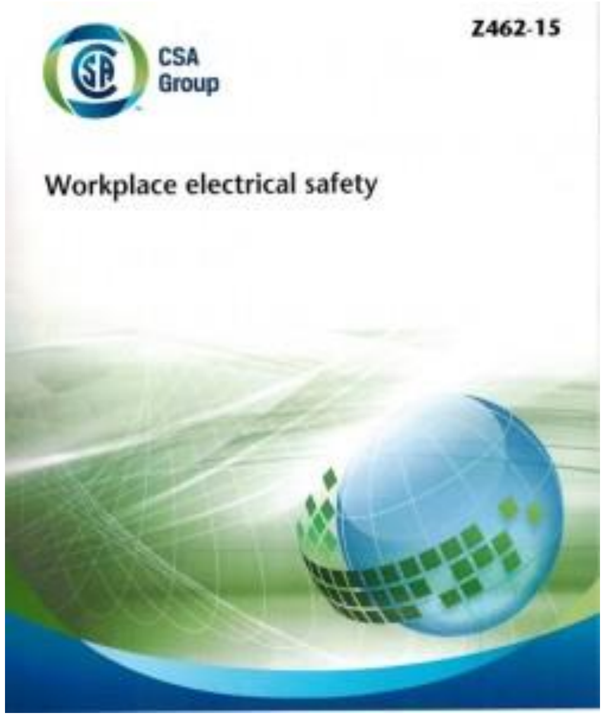
What does an Arc Flash Do?

- Injures people
- Destroys equipment
- Penalties from OSHA
- Causes outages
- Affects morale



CSA Z462 has been updated to a Risk based standard versus the previous hazard based standard.

What does this really mean?



- ✓ **Hazard Based Standard.**
- ✓ **Identify and Quantify the Hazard.**
- ✓ **Indicate / Communicate the Presence of the Hazard.**
- ✓ **Protect Against the Hazard.**

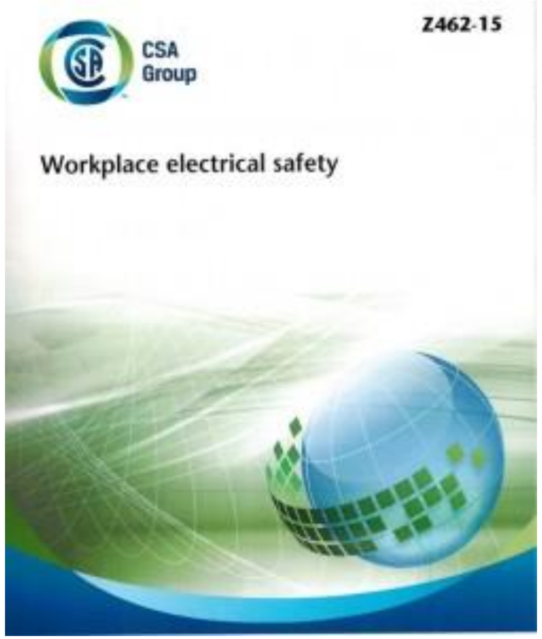
Conventional Approach

Hierarchy of Hazard Control Measures from ANSI Z10

Control effectiveness →

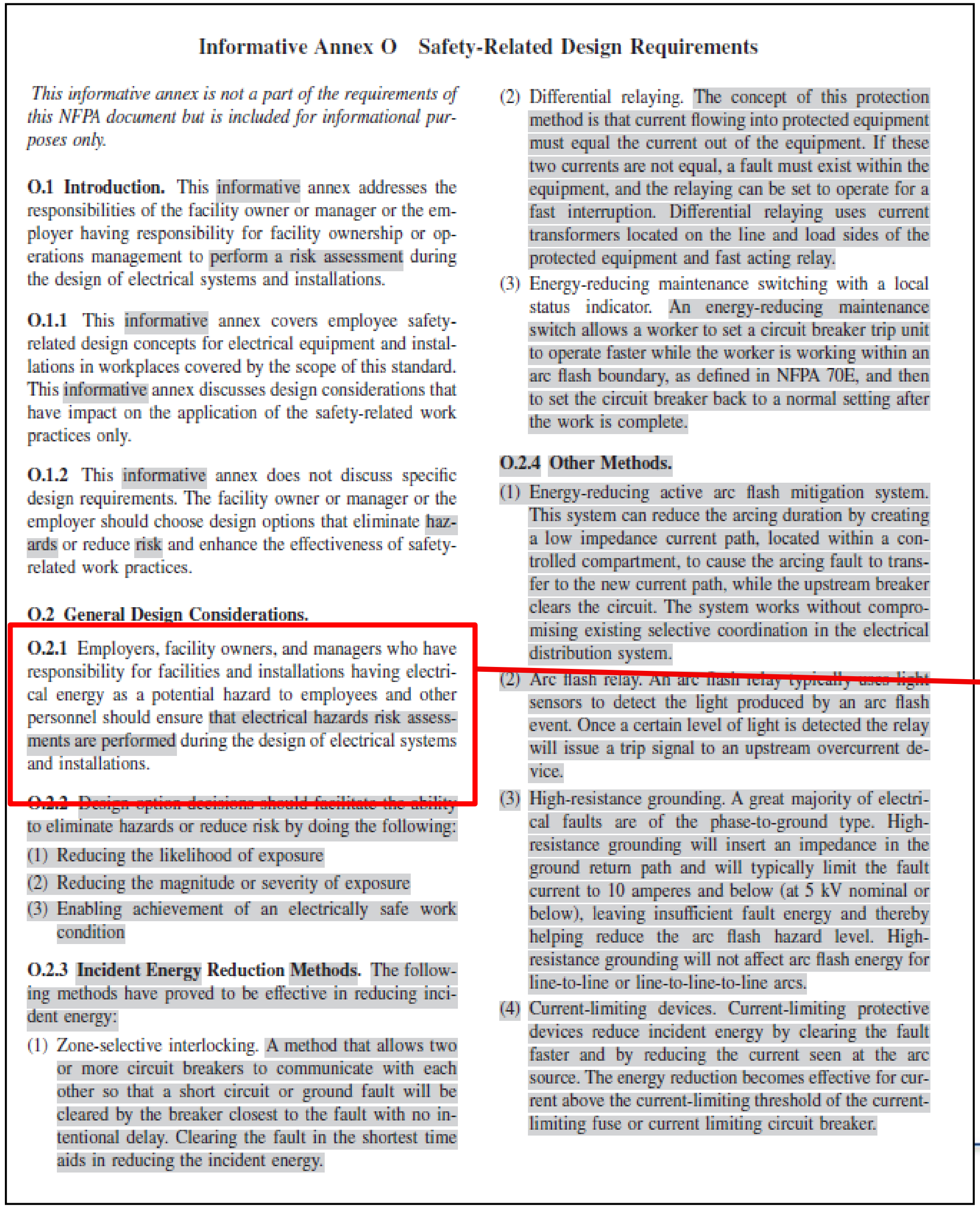
ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ADMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
Eliminate the hazard during the design phase	Substitute for a lower energy level. Reduce the magnitude of the hazard.	Design options that automatically reduce risk. Increase distance away from hazard.	Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels.	Planning processes, training permits, safe work practices, maintenance systems, communications and work management	Available, effective, easy to use.

Life Cycle Value →



- ✓ **Hazard Based Standard.**
- ✓ **Identify and Quantify the Hazard.**
  Complete Arc Flash Study.
- ✓ **Indicate / Communicate the Presence of the Hazard.**
  Post Warning Labels and Signage.
- ✓ **Protect Against the Hazard.**
  Provide necessary PPE.

Job Done !



Informative Annex O Safety-Related Design Requirements

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1 Introduction. This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

O.1.1 This informative annex covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this standard. This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2 This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1 Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazards risk assessments are performed during the design of electrical systems and installations.

O.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure
(2) Reducing the magnitude or severity of exposure
(3) Enabling achievement of an electrically safe work condition

O.2.3 Incident Energy Reduction Methods. The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. A method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.
(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.
(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

O.2.4 Other Methods.

(1) Energy-reducing active arc flash mitigation system. This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit. The system works without compromising existing selective coordination in the electrical distribution system.
(2) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected the relay will issue a trip signal to an upstream overcurrent device.
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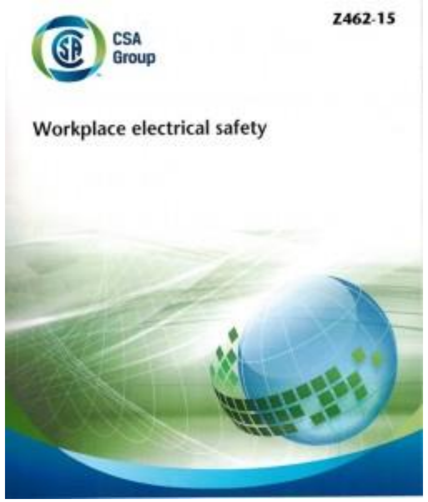

0.2.1 General Design Requirements.

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(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.

(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

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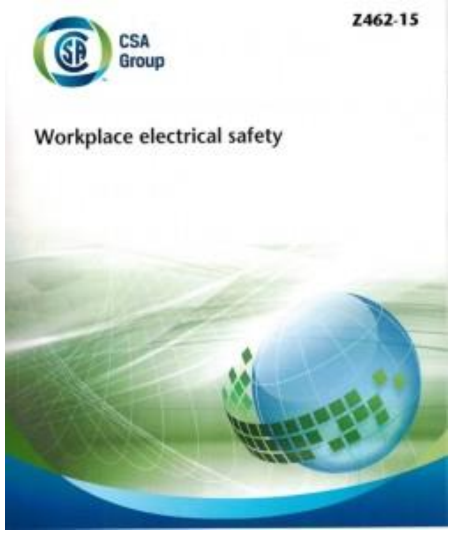

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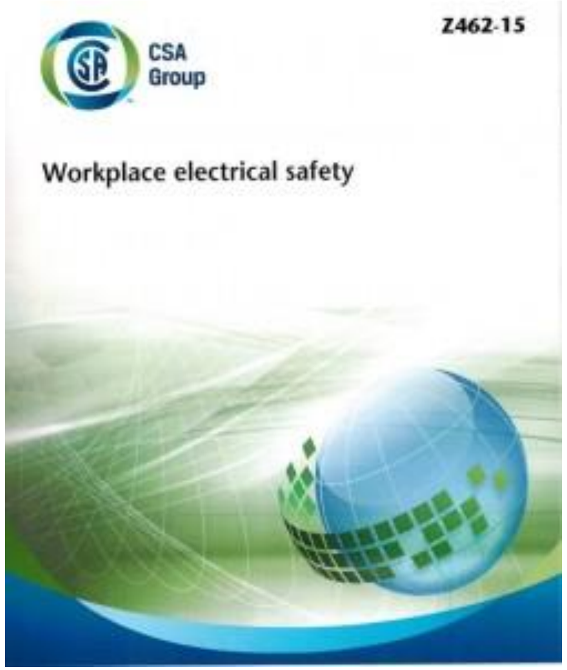

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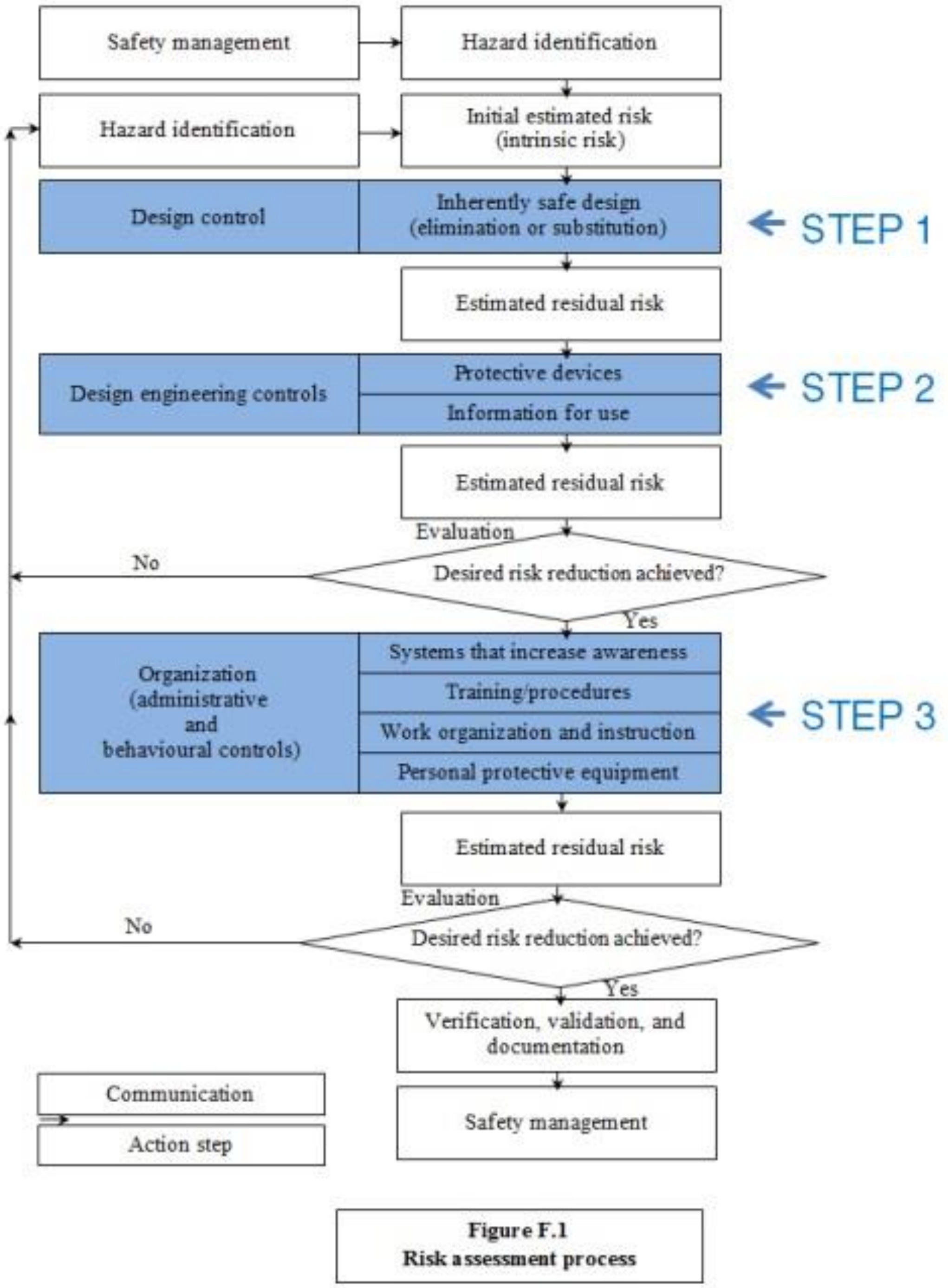
  Post Warning Labels and Signage.
- ✓ **Protect Against the Hazard.**
  Provide necessary PPE.

None of the above steps reduces the likelihood of exposure nor the magnitude of exposure and are therefore no longer sufficient.

A different approach is required.



CSA Z462 Figure F.1
Risk Assessment Process

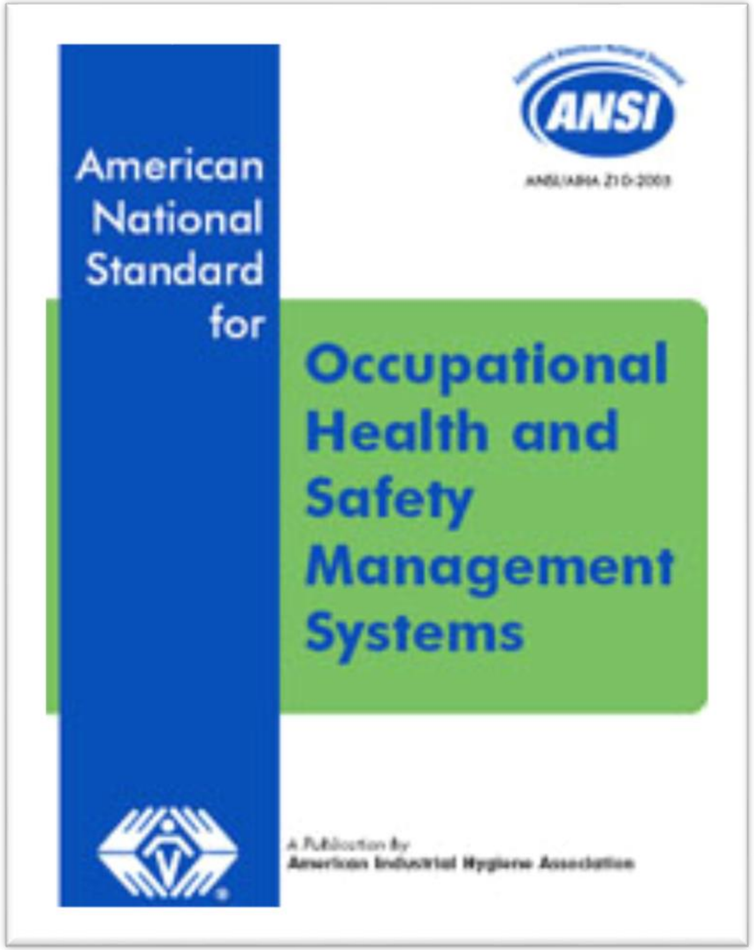
Design Control :

Elimination or
Substitution of Risk.

Figure F.1 follows on ANSI Z10.

Recommendation is to execute Step 1, 2, 3 but the conventional approach is to only do Step 3.
--This doesn't reduce risk!

ANSI Z10

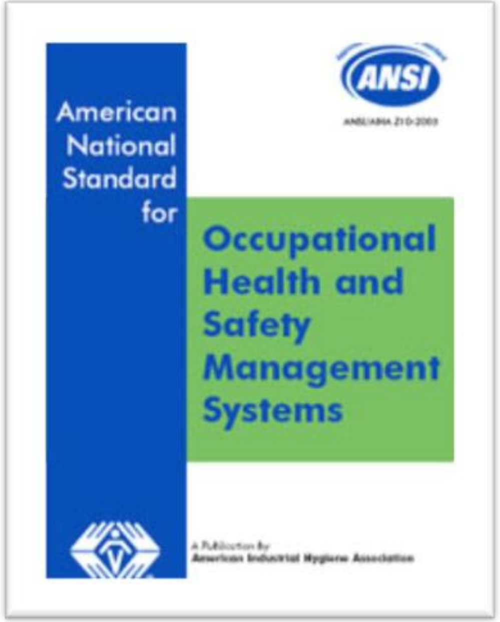


1.1 Scope. This standard defines minimum requirements for occupational health and safety management systems (OHSMS).

1.2 Purpose. The primary purpose of this standard is to provide a management tool to reduce the risk of occupational injuries, illnesses, and fatalities.

1.3 Application. This standard is applicable to organizations of all sizes and types.

ANSI Z10: Hazard Analysis & Risk Assessment Guide



1) Select a manageable task, system or process to be analyzed.

2) Identify the hazards.

3) Define possible failure modes that result in exposure to hazards and the realization of the potential harm.

4) Estimate the frequency and duration of exposure to the hazard.

5) Assess the severity of injury/illness.

6) Determine the likelihood of the occurrence of a hazardous event.

7) Define the level of risk using a risk assessment matrix, The level of risk is determined by plotting the likelihood of an occurrence or exposure and the potential severity of the injury or illness. The organization must then determine if the level of risk is acceptable or unacceptable.

8) Hazard risks can then be listed and ranked.

9) The organization selects prioritized OHSMS issues and develops documented objectives and implementation plans.

ANSI Z10 Hierarchy

Hierarchy of Hazard Control Measures
From ANSI Z10

Control Effectiveness ↑ | Life Cycle Value ↑

Elimination
Eliminate the hazard during design

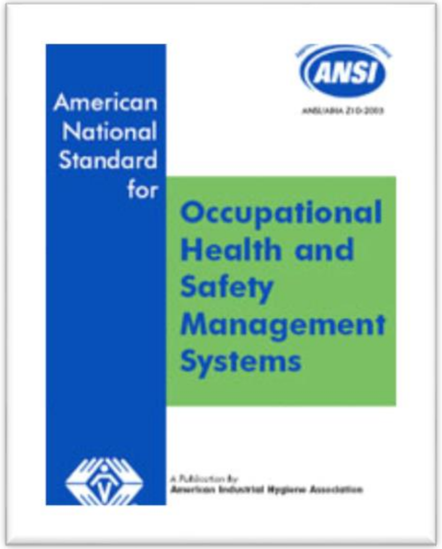
Substitution
Substitution of less hazardous equipment, system or energy

Engineering Controls
Design options that automatically reduces risk

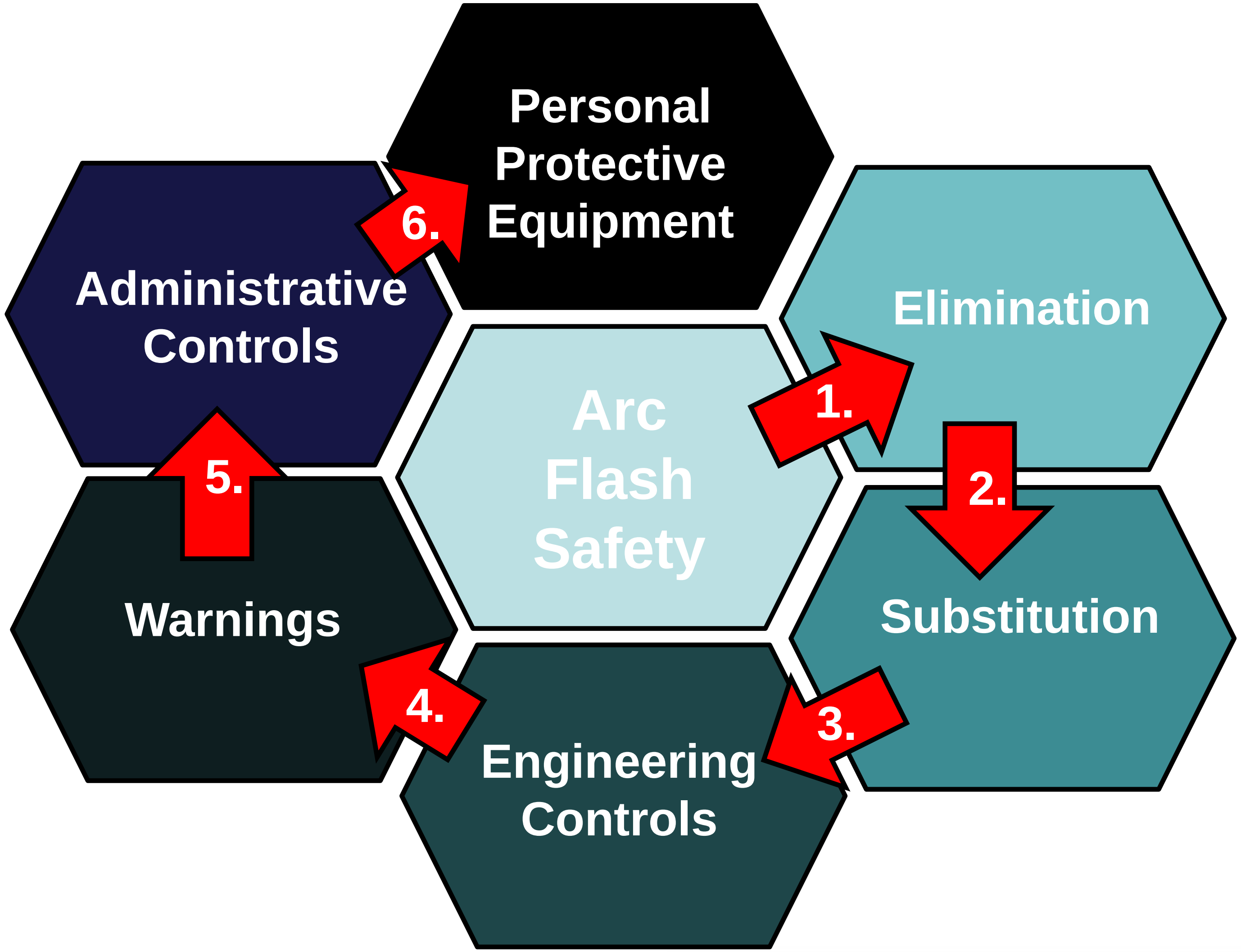
Warnings
Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels

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

Personal Protective Equipment
Available, effective, easy to use



ANSI Z10 Hierarchy Reformatted



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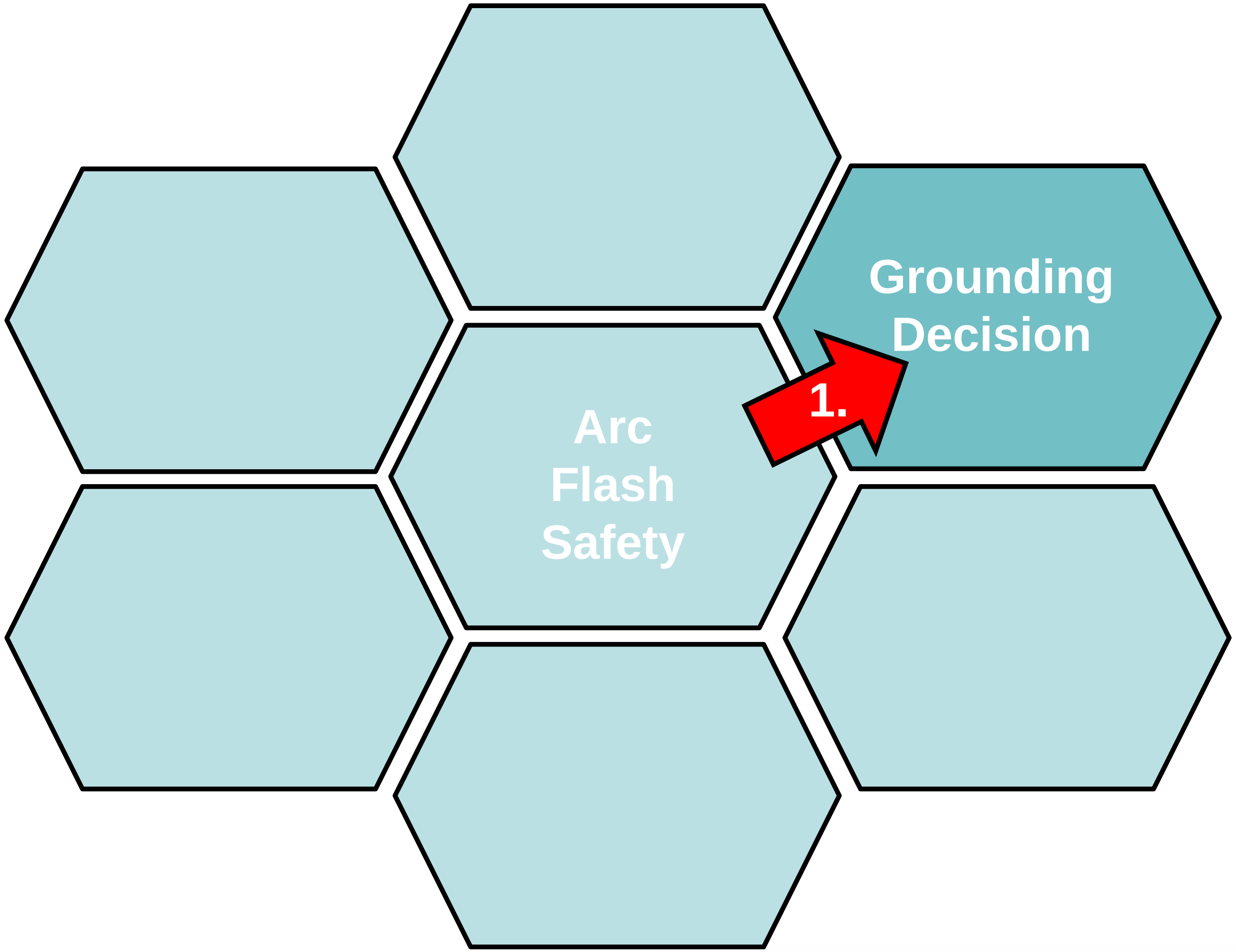
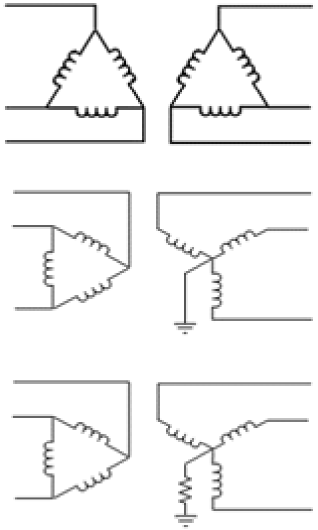
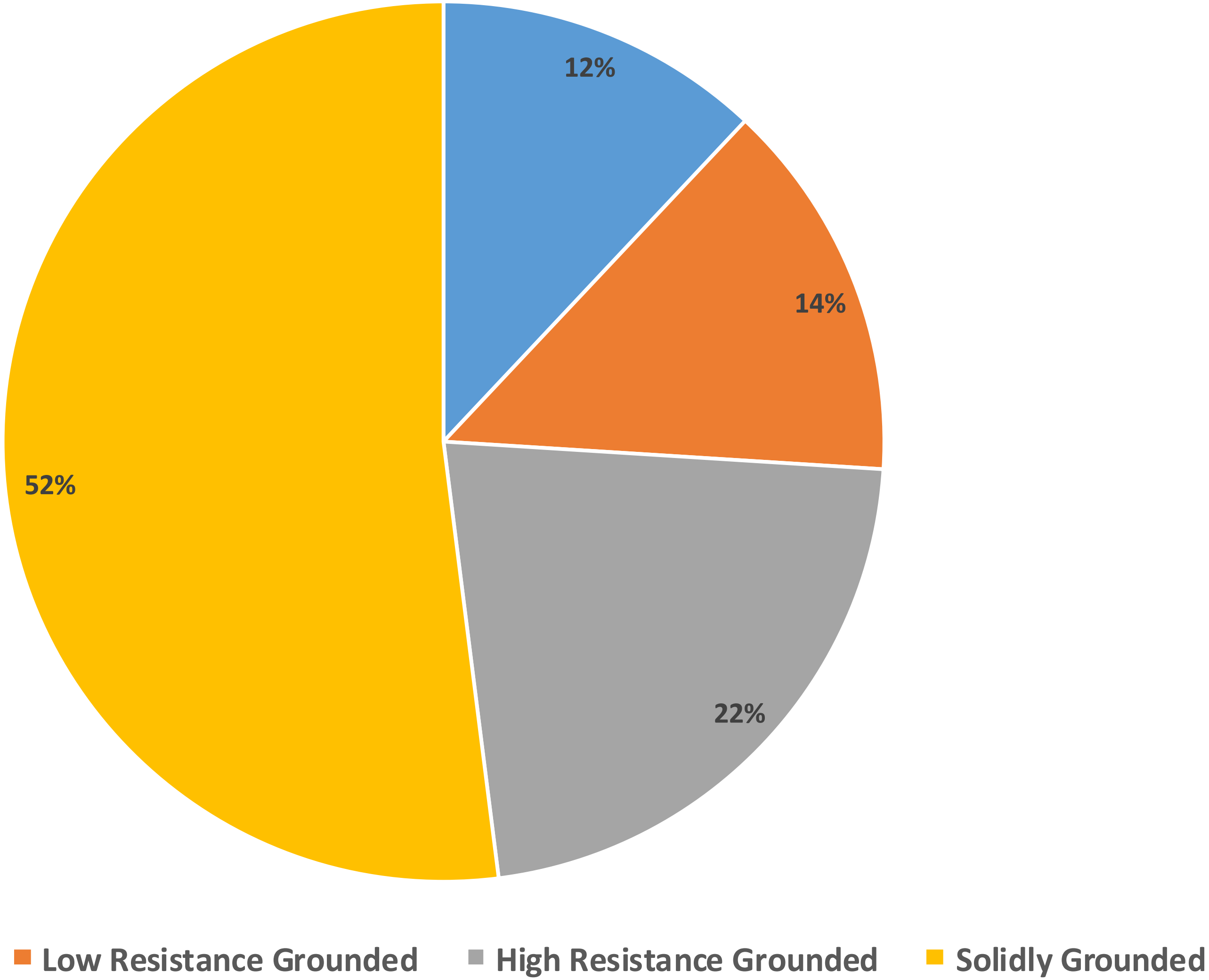
ANSI Z10 Hierarchy Reformatted



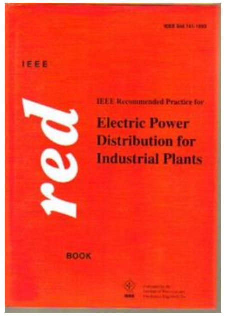
Type of Grounding System





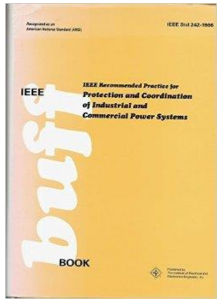
Elimination of Hazard

Ground Faults on Ungrounded Systems



IEEE Std 141-1993 (Red Book)

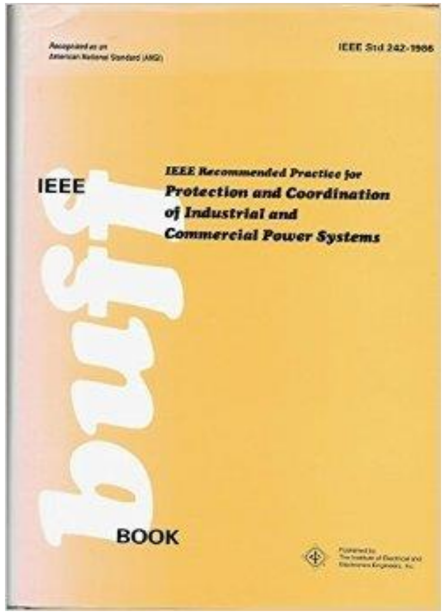
7.2.2. High-resistance grounding provides the same advantages as ungrounded systems yet limits the steady state and severe transient over-voltages associated with ungrounded systems.



IEEE Std 242-1986 Recommended Practice for the Protection and Coordination of Industrial and Commercial Power Systems

7.2.5. Ungrounded systems offer no advantage over high-resistance grounded systems in terms of continuity of service and have the disadvantages of transient over-voltages, locating the first fault and burn-downs from a second ground fault. For these reasons, they are being used less frequently today than high-resistance grounded systems"

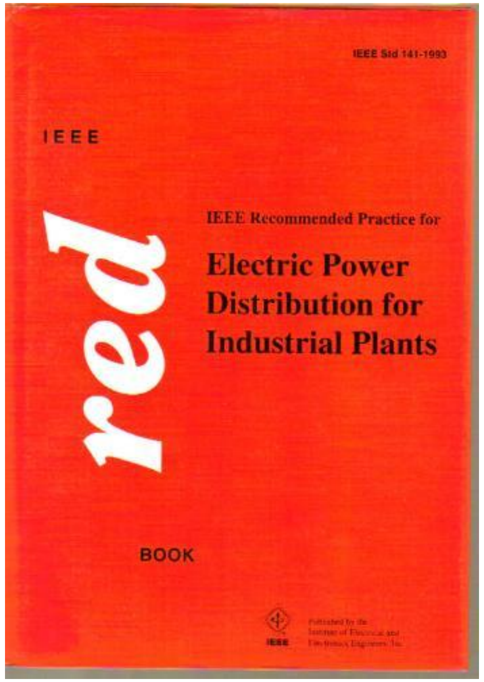
Ungrounded System



IEEE Standard 242-2001 (Buff Book)
Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

8.2.5 If this ground fault is intermittent or allowed to continue, the system could be subjected to possible severe over-voltages to ground, which can be as high as six to eight times phase voltage. Such over-voltages can puncture insulation and result in additional ground faults. These over- voltages are caused by repetitive charging of the system capacitance or by resonance between the system capacitance and the inductance of equipment in the system.

Ungrounded Systems



IEEE Std 141-1993 (Red Book)
Recommended Practice for Electric Power Distribution for Industrial Plants

7.2.1 Accumulated operating experience indicates that, in general purpose industrial power distribution systems, the over-voltage incidents associated with ungrounded operation reduce the useful life of insulation so that electric current and machine failures occur more frequently than they do on grounded power systems.

Ungrounded Systems

FM Global 5-18 Protection of Electrical Equipment Single Phase and Other Related Faults

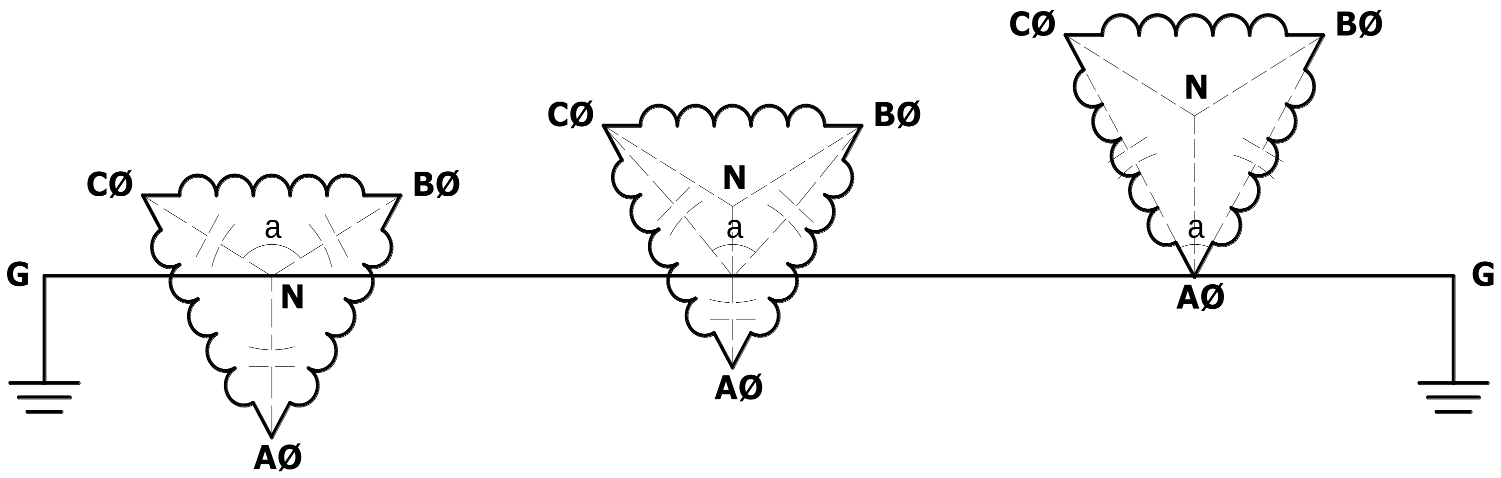
- In ungrounded systems a phase to ground fault often produces dangerous overvoltage…
- Sustained arcing faults in low voltage apparatus are often initiated by a single-phase fault to ground which results in extensive damage to switchgear and motor control centers.

FM Global 5-10 Protective Grounding for Electric Power Systems and Equipment

- 2.3.3.1 Unlike the ungrounded system the high resistance grounded system prevents transient overvoltage which can cause potential failure of insulation.
- 2.3.4.1 Convert ungrounded systems to high resistance grounded systems.

Ground Faults on Ungrounded System

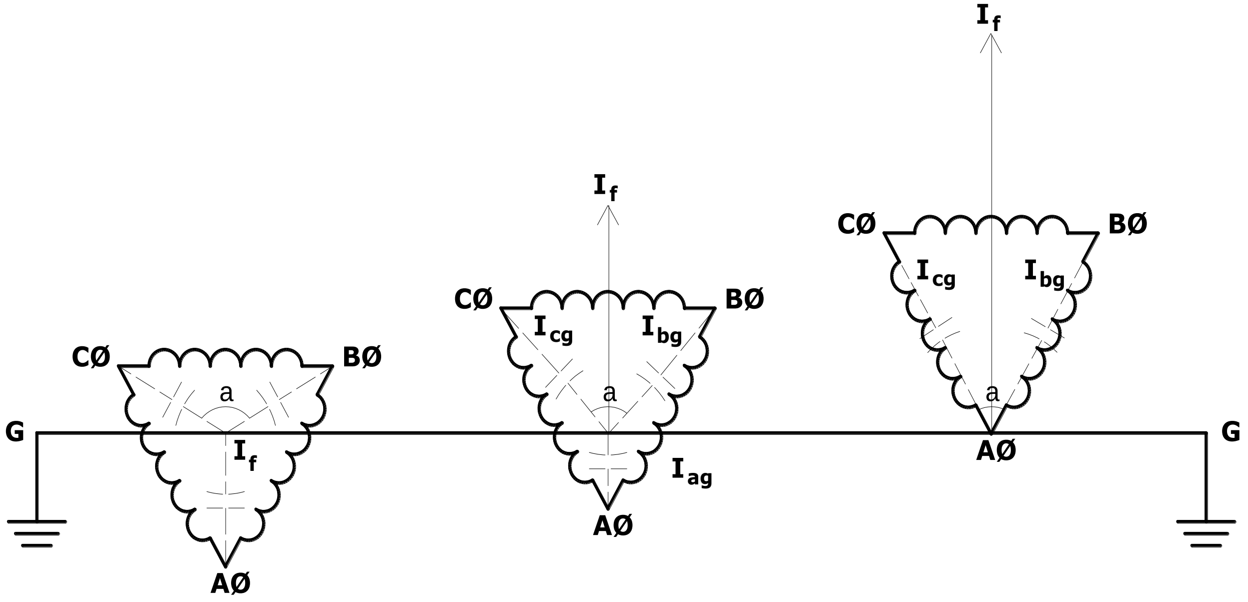
Ground Fault voltage distribution (voltage rise)



V_{ag} = 277V	V_{ag} = 138V	V_{ag} = 0V
V_{bg} = 277V	V_{bg} = 367V	V_{bg} = 480V
V_{cg} = 277V	V_{cg} = 367V	V_{cg} = 480V
V_{ng} = 0V	V_{ng} = 138V	V_{ng} = 277V
a = 120°	a = 82°	a = 60°
(0% Fault)	(50% Fault)	(100% Fault)

Ground Faults on Ungrounded System

Ground Fault current distribution (current rise)



I_{ag} = 1.00A<0°
I_{bg} = 1.00A<120°
I_{cg} = 1.00A<240°
I_f = 0A
a = 120°
(0% Fault)

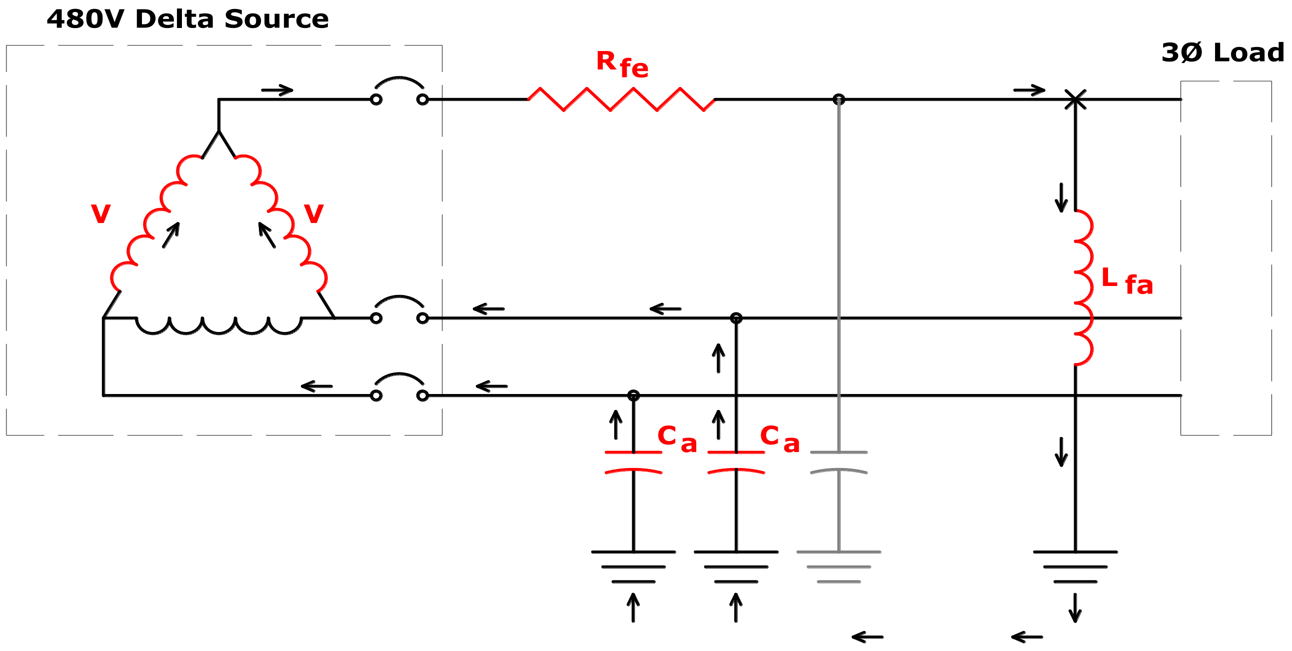
I_{ag} = 0.50A<0°
I_{bg} = 1.32A<139°
I_{cg} = 1.32A<221°
I_f = 1.50A<180°
a = 82°
(50% Fault)

I_{ag} = 0.00A
I_{bg} = 1.73A<60°
I_{cg} = 1.73A<120°
I_f = 3.00A<90°
a = 60°
(100% Fault)

Bolted Ground Faults
High Inductive Reactance Ground Fault

<u>Bolted ground fault:</u> A highly inductive reactance ground fault in series with system capacitance can create a resonant circuit causing high transient over-voltages.

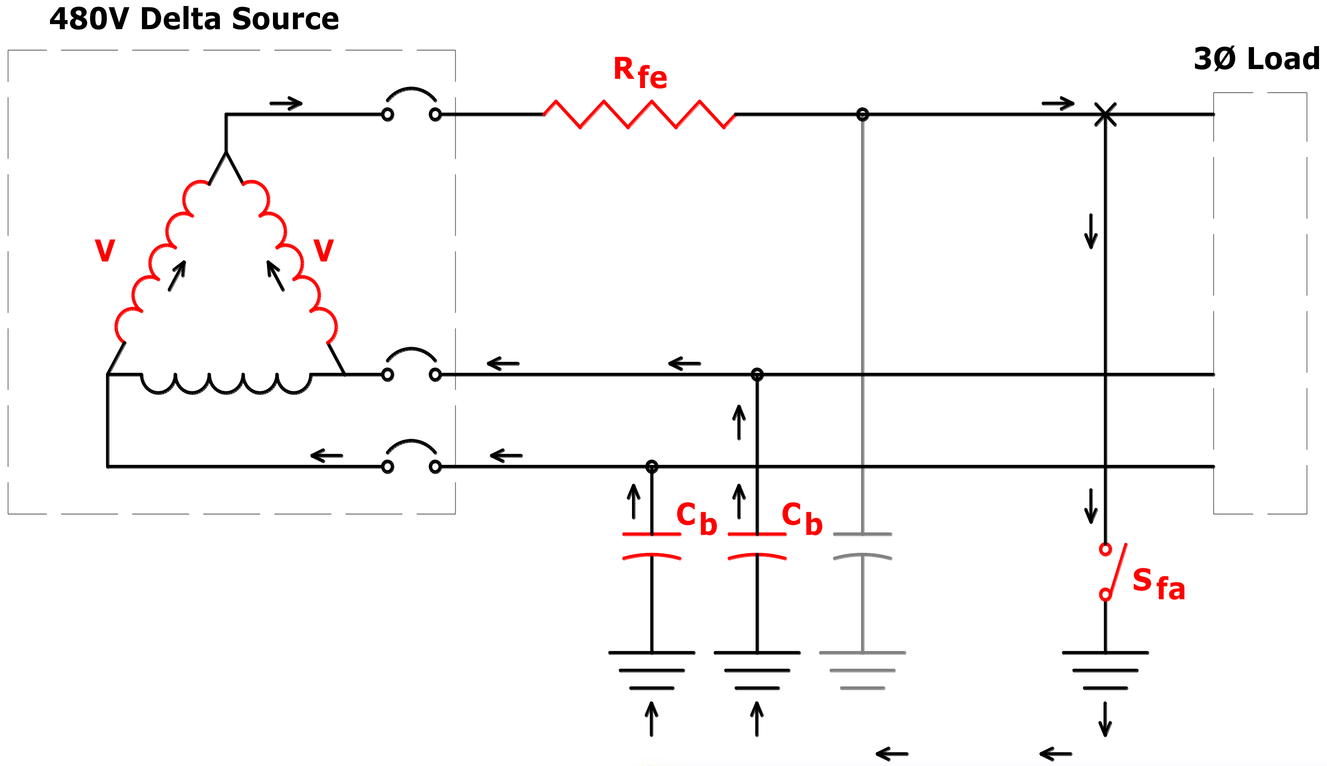
– i.e. grounding of one side of the operating coil of a motor starter, grounding of one control wire to a push button station, or grounding of one side of a transformer winding



Arcing Ground Faults Intermittent or Re-strike

<u>Intermittent ground fault:</u> A re-striking ground fault can create a high frequency oscillator (RLC circuit), independent of L and C values, causing high transient over-voltages.

- i.e. re-striking due to ac voltage waveform or loose wire caused by vibration

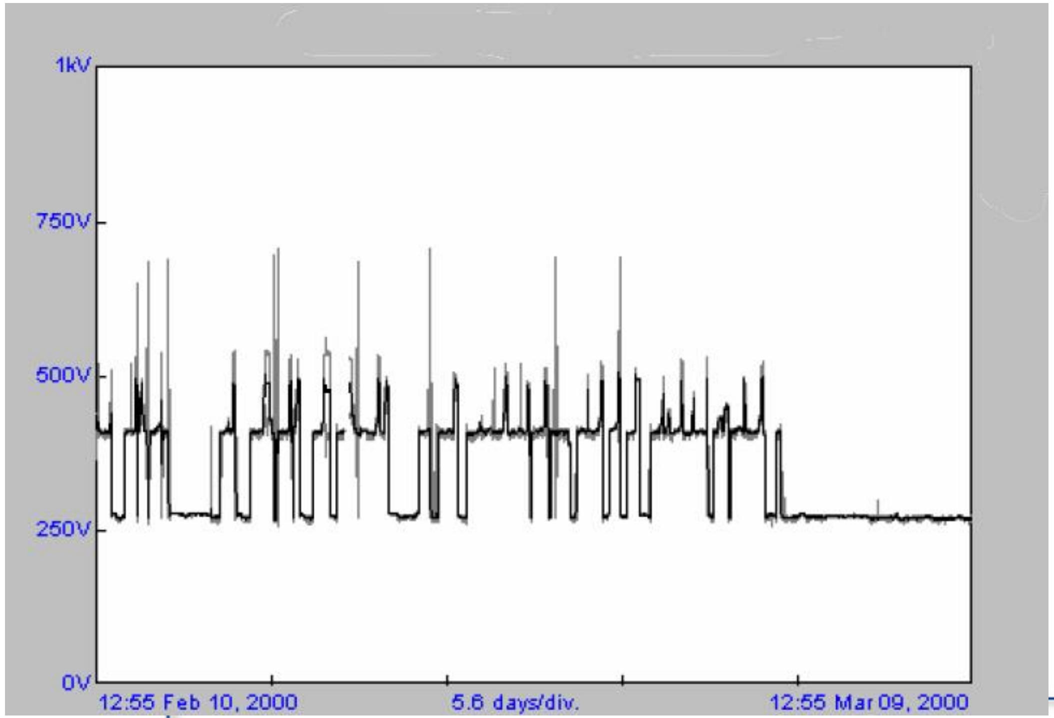


Case Study

Automotive Facility **Troy Michigan**

- Phase to Ground voltage monitored for 4 weeks ungrounded and 4 weeks high resistance grounded.

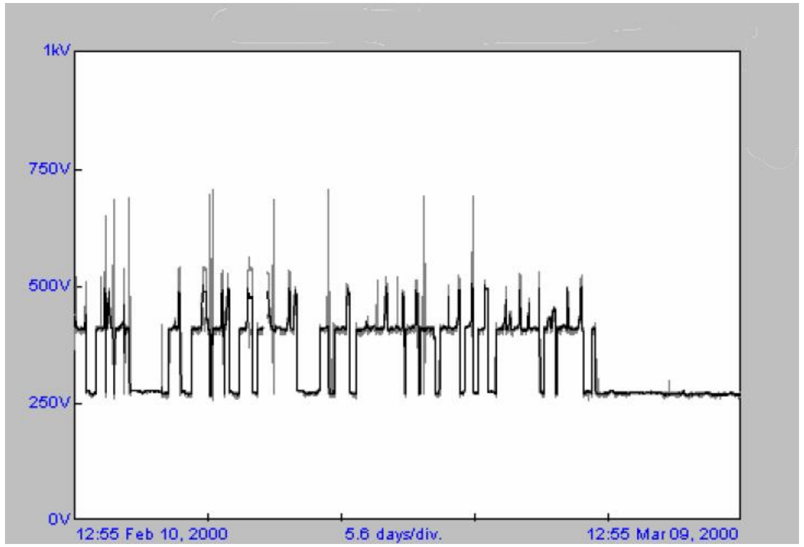
- 485 events with peak voltage above 700 volts due to intermittent ground faults.
- Peak voltage 1050 volts
- Transients lead to insulation degradation.



Case Study

Automotive Facility

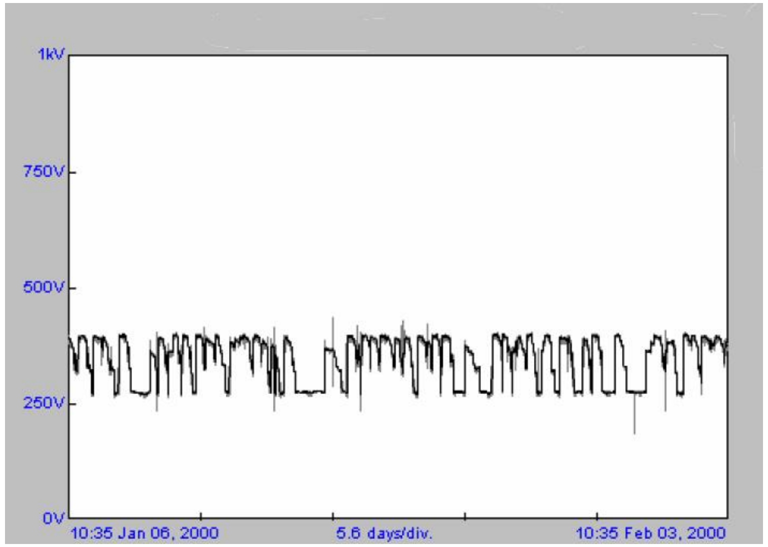
Phase voltage ungrounded



High level of transients
485 peak events over 700 volts
Peak voltage 1050 volts

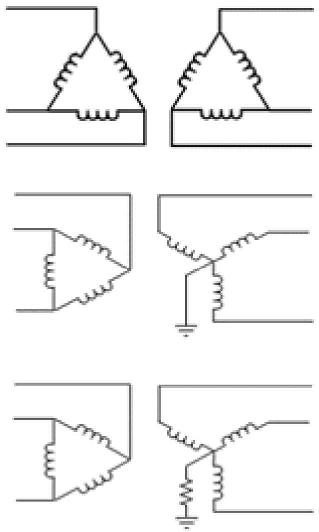
Troy Michigan

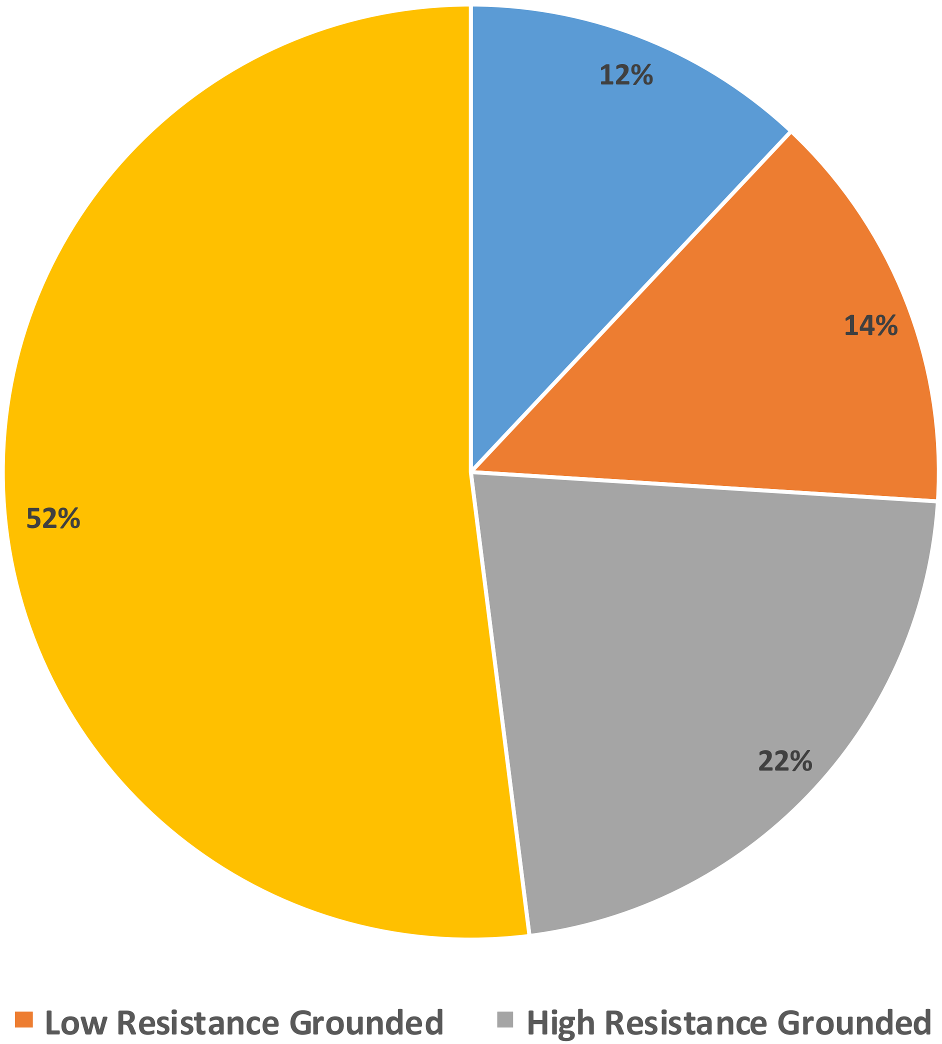
Phase voltage HRG



Transients controlled
0 peak events over 700 volts
Peak voltage 660 volts

Type of Grounding System



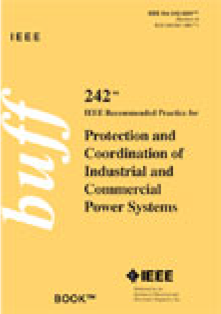


Solidly Grounding System

- ✓ Eliminates transient overvoltage problem
- ✓ Permits line-to-neutral loads (lighting, heating cables)
- ✓ Ground faults easy to locate, but cause unscheduled service interruption
- ✓ Danger from low-level arcing ground faults
- ✓ Since 1970s, ground fault protection mandatory for solidly grounded 600V services rated 1000A and higher by the CEC and the NEC

Solidly Grounded Systems

IEEE Std 242-2001 (Buff Book)

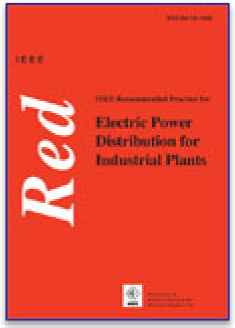


8.2.2. One disadvantage of the solidly grounded system involves the high magnitude of destructive, arcing ground-fault currents that can occur.

IEEE Std 141-1993 (Red Book)

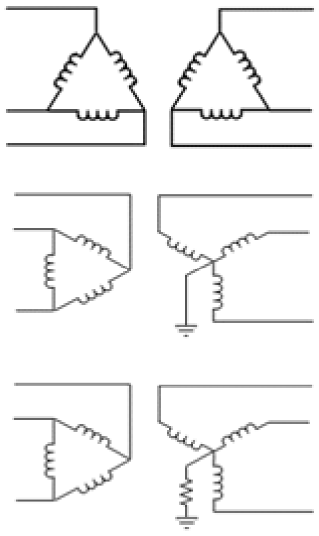
7.2.2 There is no arc flash hazard, as there is with solidly grounded systems, since the fault current is limited to approximately 5A.

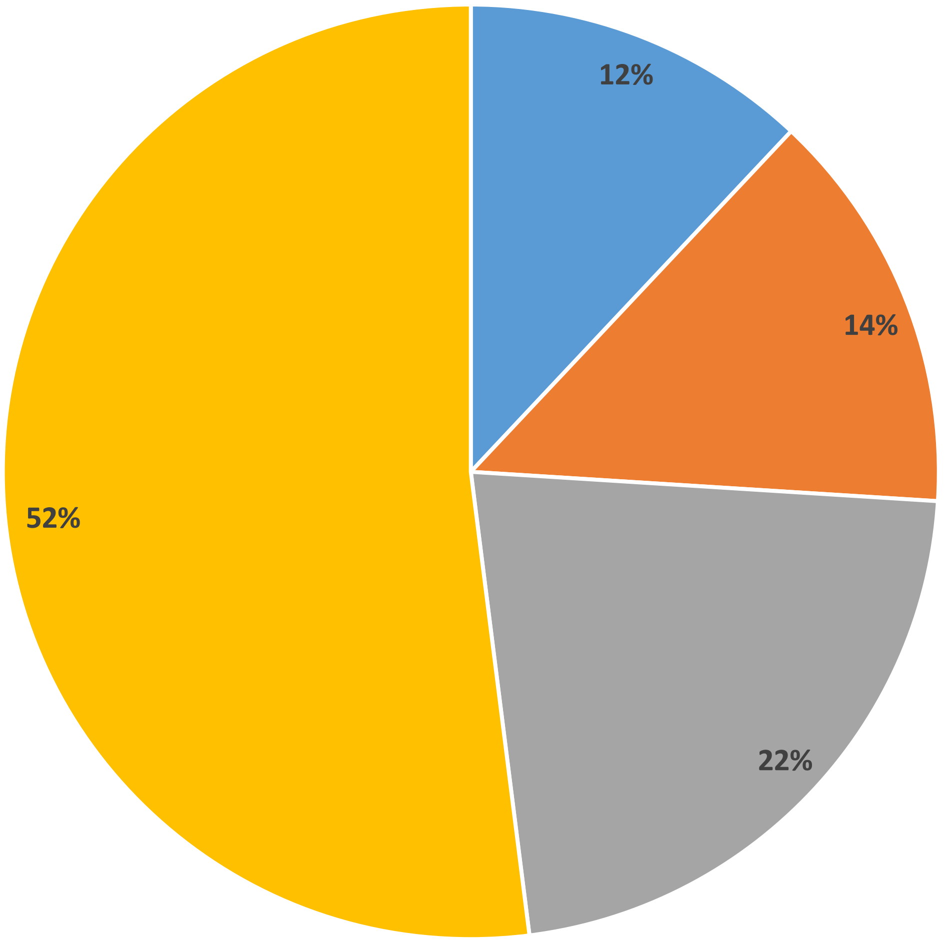
Another benefit of high-resistance grounded systems is the limitation of ground fault current to prevent damage to equipment



7.2.4. The solidly grounded system has the high probability of escalating into a phase-to-phase or three-phase arcing fault, particularly for the 480V and 600V systems. The danger of sustained arcing for phase-to-ground fault…is also high for the 480V and 600V systems, and low or near zero for the 208V system

Type of Grounding System



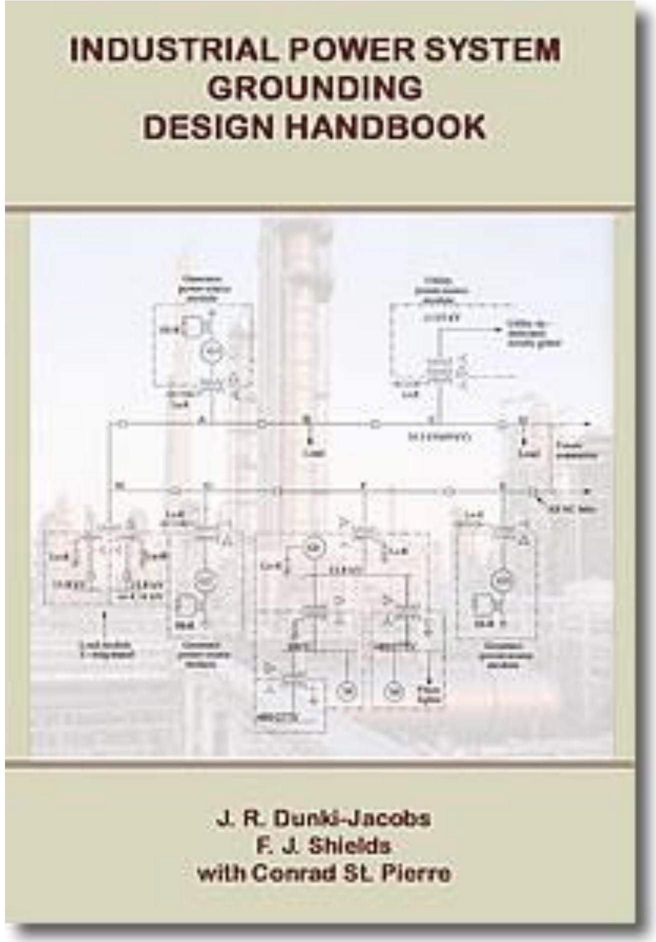


Elimination of Hazard
High Resistance Grounding

How Does HRG reduce Arc Flash?

95% of all electrical faults are phase to ground faults.

By limiting the fault current to a low level, 10 amps or less, there is insufficient current for the arc to re-strike and it self-extinguishes.

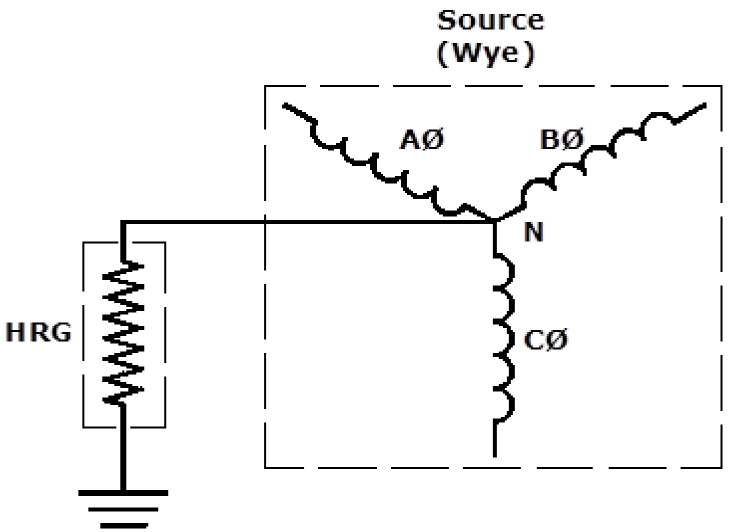


Elimination of Hazard

High Resistance Grounding

High resistance grounding of the neutral limits the ground fault current to a very low level (typically from 1 to10 amps) and this is achieved by connecting a current limiting resistor between the neutral of the transformer secondary and the earth ground and is used on low voltage systems of 5000 volts or less, under 3000 amp.

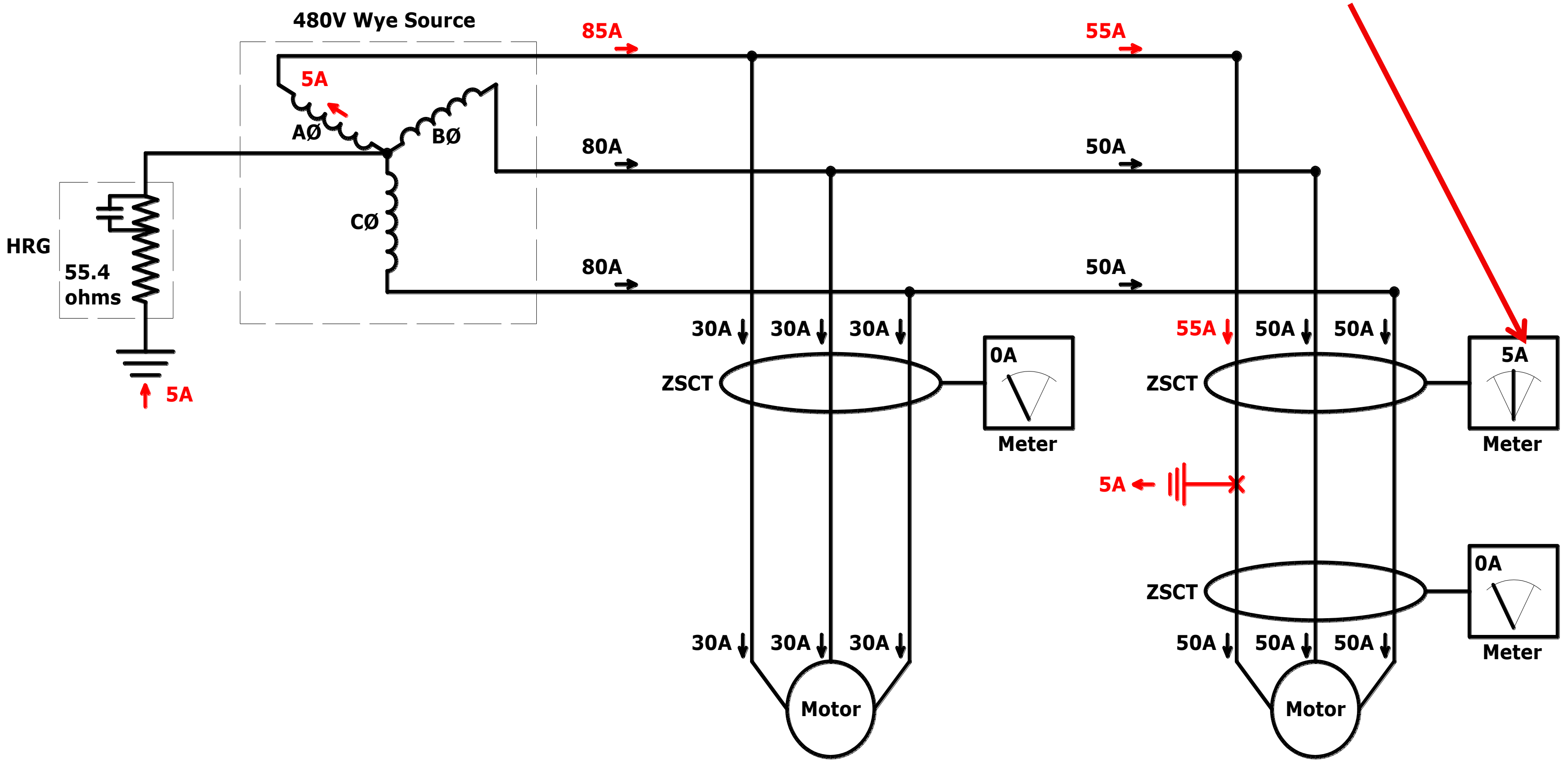
By limiting the ground fault current, the fault can be tolerated on the system until it can be located, and then isolated or removed at a convenient time.



High Resistance Grounding

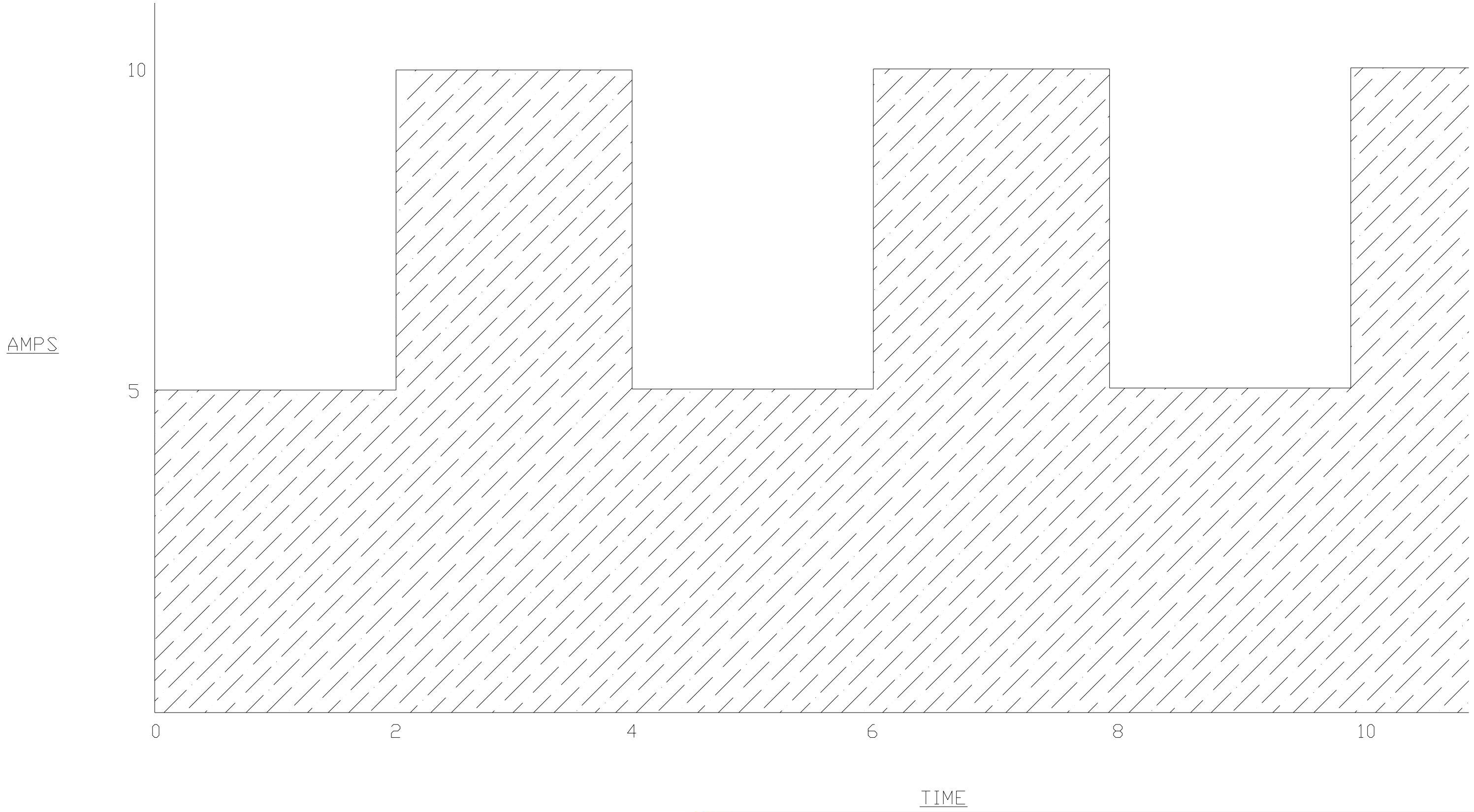
Method to quickly locate ground faults

Meter reading will alternate showing high low pattern every 2 seconds.

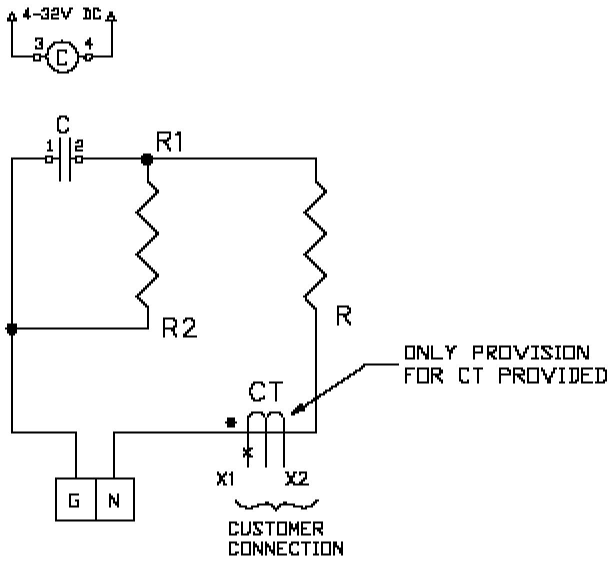


High Resistance Grounding

Contactor shorts out ½ resistance, thus, doubling current to 10A at ~30 pulses / minute.



Portable Current Sensor for Fault Tracing

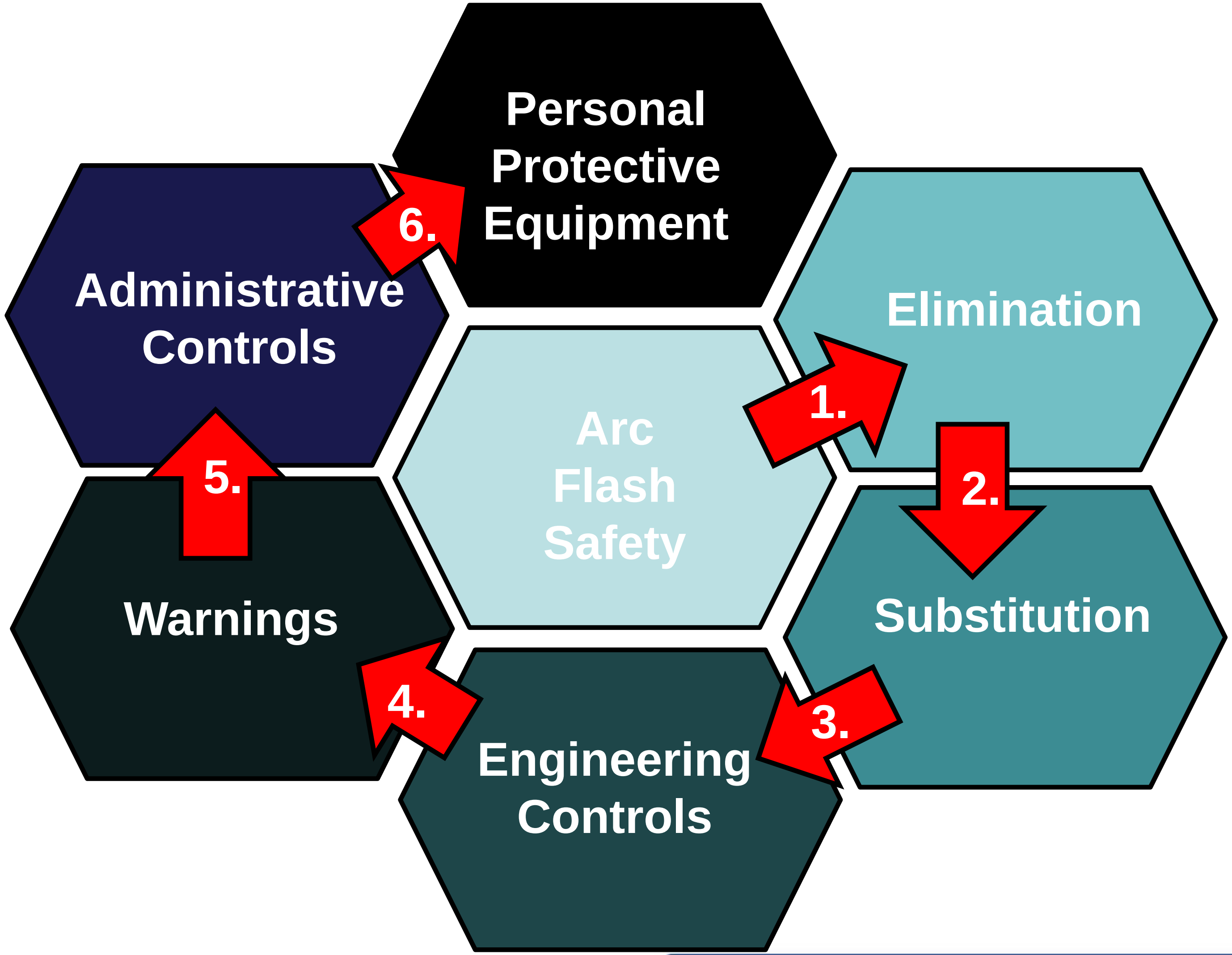


Pulsing NGR

Ground Fault Pulse Locating

Technology	Reduces the Likelihood of Exposure	Reduces the Severity of the Arc Flash Hazard	Protects Personnel in the event of an Arc Flash	Remarks
Zone Selective				
Differential Relay				
Maintenance Switch				
Active Arc Mitigation				
Arc Flash Relay				
High Resistance Grounding	✓			**Risk reduction by design, eliminate up to 95% of occurrences**
Current Limiting Fuse				
Remote Switching				
Remote Racking				
Arc Resistant Switchgear				.

ANSI Z10 Hierarchy Reformatted



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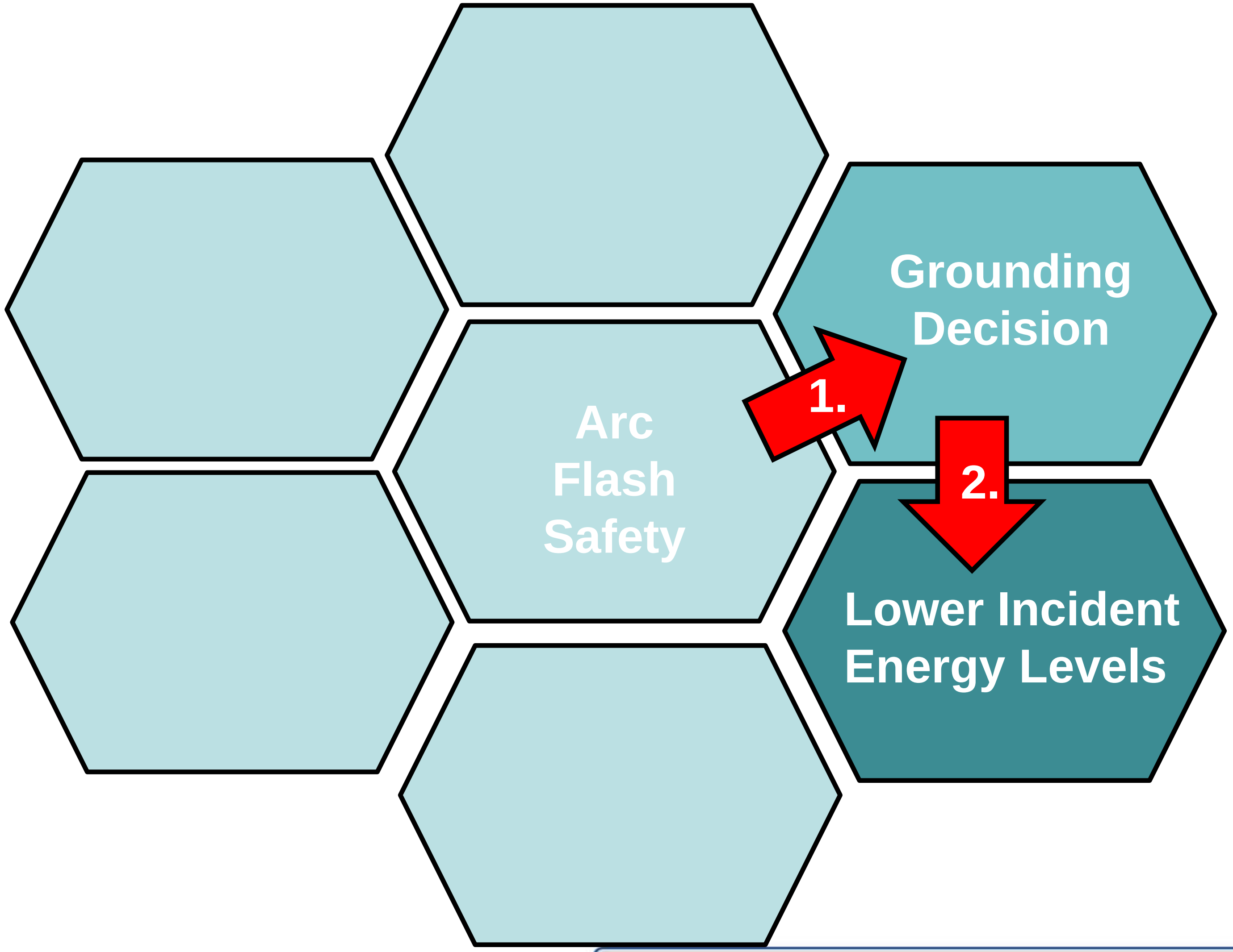
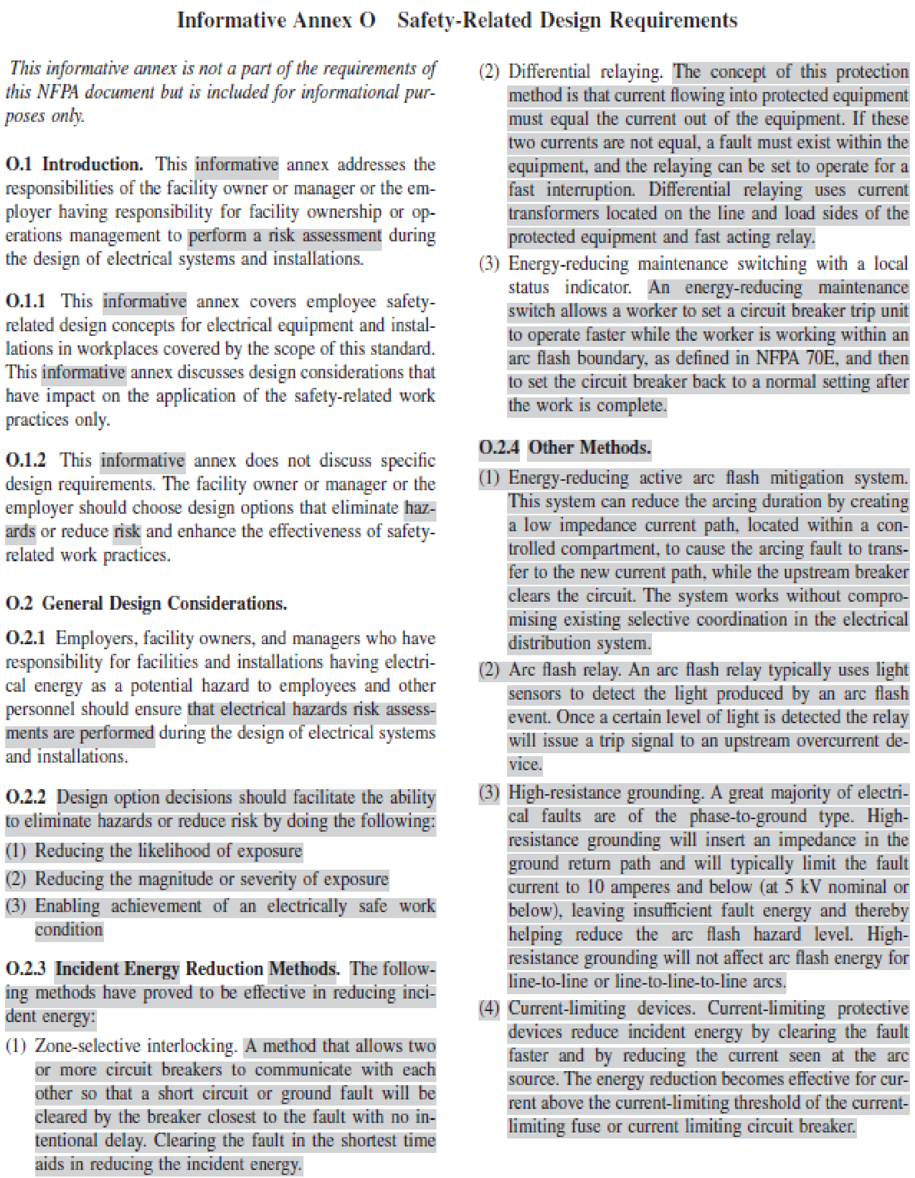




Informative Annex O Safety-Related Design Requirements

This informative annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

O.1 Introduction. This informative annex addresses the responsibilities of the facility owner or manager or the employer having responsibility for facility ownership or operations management to perform a risk assessment during the design of electrical systems and installations.

O.1.1 This informative annex covers employee safety-related design concepts for electrical equipment and installations in workplaces covered by the scope of this standard. This informative annex discusses design considerations that have impact on the application of the safety-related work practices only.

O.1.2 This informative annex does not discuss specific design requirements. The facility owner or manager or the employer should choose design options that eliminate hazards or reduce risk and enhance the effectiveness of safety-related work practices.

O.2 General Design Considerations.

O.2.1 Employers, facility owners, and managers who have responsibility for facilities and installations having electrical energy as a potential hazard to employees and other personnel should ensure that electrical hazards risk assessments are performed during the design of electrical systems and installations.

O.2.2 Design option decisions should facilitate the ability to eliminate hazards or reduce risk by doing the following:

(1) Reducing the likelihood of exposure

(2) Reducing the magnitude or severity of exposure

(3) Enabling achievement of an electrically safe work condition

O.2.3 Incident Energy Reduction Methods. The following methods have proved to be effective in reducing incident energy:

(1) Zone-selective interlocking. A method that allows two or more circuit breakers to communicate with each other so that a short circuit or ground fault will be cleared by the breaker closest to the fault with no intentional delay. Clearing the fault in the shortest time aids in reducing the incident energy.

(2) Differential relaying. The concept of this protection method is that current flowing into protected equipment must equal the current out of the equipment. If these two currents are not equal, a fault must exist within the equipment, and the relaying can be set to operate for a fast interruption. Differential relaying uses current transformers located on the line and load sides of the protected equipment and fast acting relay.

(3) Energy-reducing maintenance switching with a local status indicator. An energy-reducing maintenance switch allows a worker to set a circuit breaker trip unit to operate faster while the worker is working within an arc flash boundary, as defined in NFPA 70E, and then to set the circuit breaker back to a normal setting after the work is complete.

O.2.4 Other Methods.

(1) Energy-reducing active arc flash mitigation system. This system can reduce the arcing duration by creating a low impedance current path, located within a controlled compartment, to cause the arcing fault to transfer to the new current path, while the upstream breaker clears the circuit. The system works without compromising existing selective coordination in the electrical distribution system.

(2) Arc flash relay. An arc flash relay typically uses light sensors to detect the light produced by an arc flash event. Once a certain level of light is detected the relay will issue a trip signal to an upstream overcurrent device.

(3) High-resistance grounding. A great majority of electrical faults are of the phase-to-ground type. High-resistance grounding will insert an impedance in the ground return path and will typically limit the fault current to 10 amperes and below (at 5 kV nominal or below), leaving insufficient fault energy and thereby helping reduce the arc flash hazard level. High-resistance grounding will not affect arc flash energy for line-to-line or line-to-line-to-line arcs.

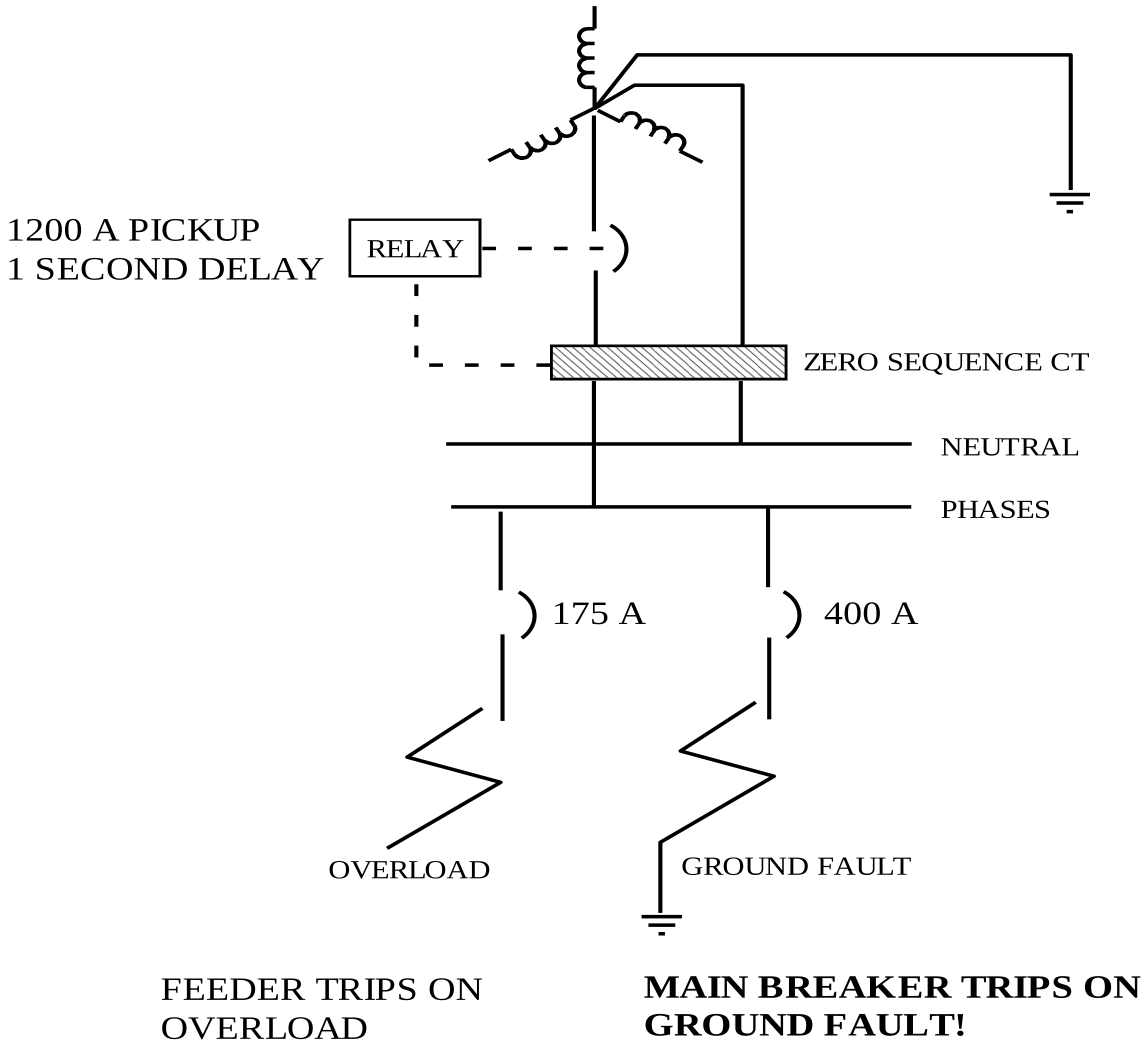
(4) Current-limiting devices. Current-limiting protective devices reduce incident energy by clearing the fault faster and by reducing the current seen at the arc source. The energy reduction becomes effective for current above the current-limiting threshold of the current-limiting fuse or current limiting circuit breaker.

Incident Energy Reduction Methods:

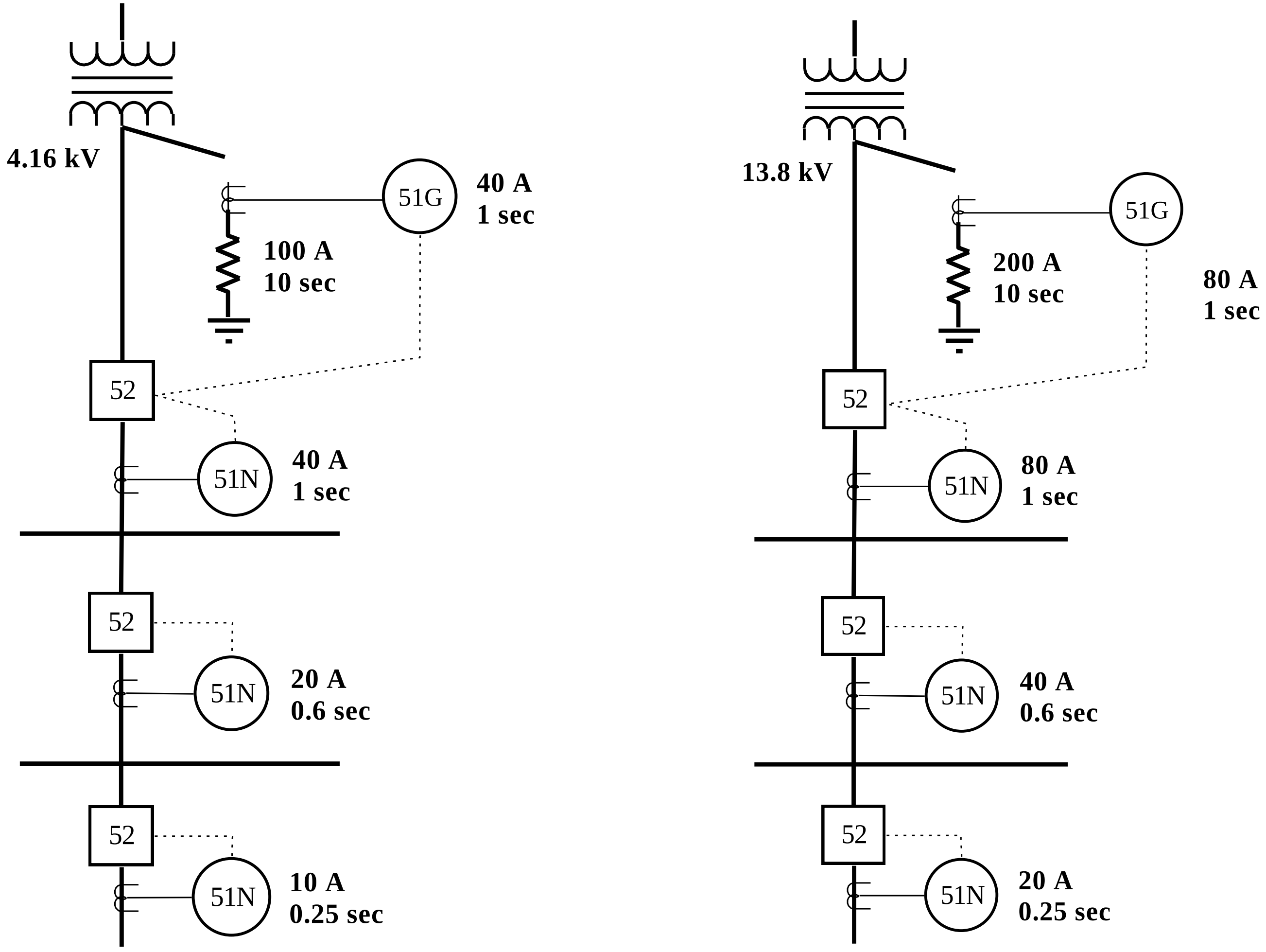
- ✓ Zone-selective interlocking
- ✓ Differential relaying
- ✓ Energy reducing maintenance switch
- ✓ Energy reducing active arc mitigation
- ✓ Arc flash relay
- ✓ Current limiting devices

Zone Selective Instantaneous

- Coordination for ground faults difficult unless branch breakers have ground fault relays



Zone Selective Instantaneous

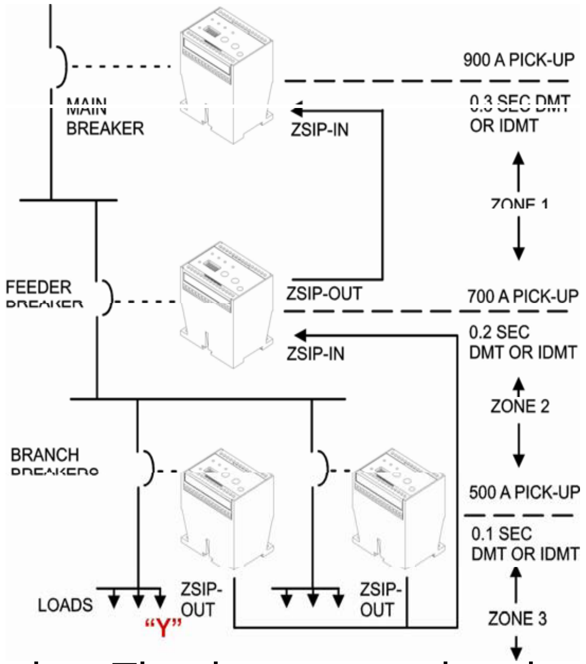


System Charging Current 5 A

System Charging Current 10 A

Zone Selective Instantaneous

Zone Selective Interlocking (ZSI), offers an excellent solution to this problem. It improves arc flash safety upstream in the plant distribution system without affecting service continuity. ZSI is applied both to phase overcurrent devices (on the short-time protection function), and to ground fault protective devices. It is available on electronic trip units and relays of circuit breakers.



With ZSI, a breaker that senses a fault will trip with no intentional time delay unless it receives a restraint signal from the breaker immediately downstream.

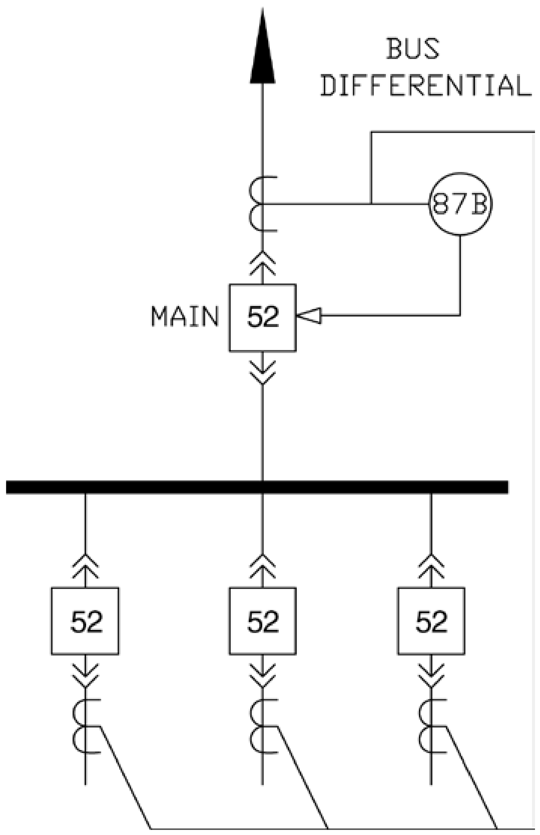
If so restrained, the breaker will wait to time out before tripping. The downstream breaker only sends a restraint signal upstream if it also senses the fault, i.e. only for faults located downstream of both breakers.

For the fault at point Y, the Sub-Feeder breaker will restrain the Feeder breaker; and the Feeder breaker will restrain the Main breaker.

Hence the Main and Feeder will wait to time out. In the meantime, the Sub-Feeder breaker will clear the fault.

Bus Differential Relay

BUS DIFFERENTIAL PROTECTION SCHEMES



Relay class current transformers (CTs) are connected to each external connection to the bus, upstream at the main breaker and downstream of the feeder breakers. The CTs are connected such that if all the currents entering the bus equal all the currents leaving the bus, there is no net current flow into the relay. A bus fault will cause an unbalance of the incoming and outgoing currents and cause the relay to operate. This mechanism is very sensitive to bus faults but immune to load inrushes or pass-through faults. The relay set-point can be less than the rating of the bus.

Differential relaying protection is applied at medium voltage but is less common at low voltage.

Since arc-flash incident energy varies linearly with clearing time, a faster clearing time can be advantageous. The differential protection will protect the bus and the source breakers can still selectively coordinate with the feeders. The advantages of differential relaying protection are faster clearing times and improved selectivity.

Energy Reducing Maintenance Switch

An energy-reducing maintenance switch is a device that has been designed specifically to be used by personnel only while they are required to perform work on energized electrical equipment. This device is not intended to be continuously active.

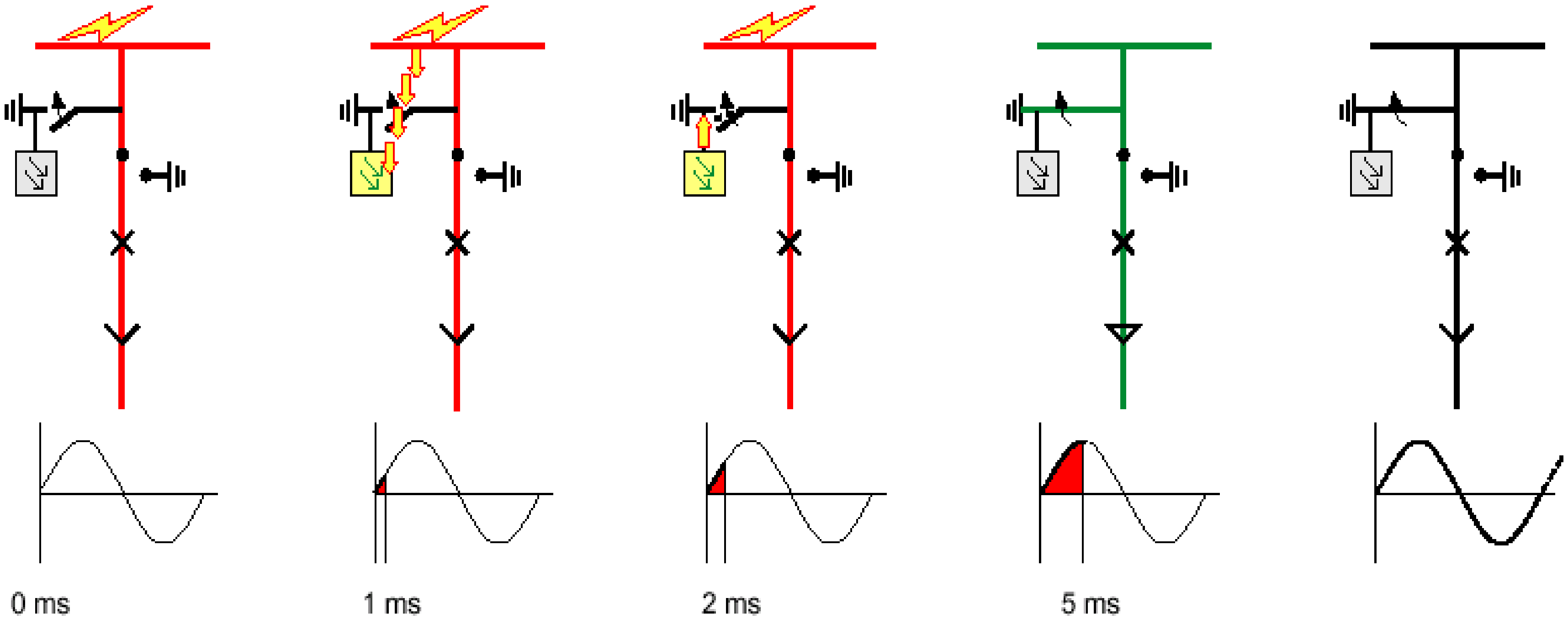
Once activated, the energy-reducing maintenance switch option provides a lockable switch feature that should be included in lock-out/tag-out safety procedures.

Once the work has been completed, the energy-reducing maintenance switch is deactivated and the system returned to its optimal protection state.

The basic energy-reducing maintenance switching design is one that incorporates an additional electronic control circuit that may be separate from the normal instantaneous or short time protection circuits in the trip unit. The purpose of the separate control circuit is to allow the electrical worker, on demand, to “switch-in” a system that will trip the overcurrent protective device in a time that will provide the minimum possible arcing time should an arc flash incident occur while energized work is being performed on that device.

Once the energy-reducing maintenance switching scheme is turned to an active state, a local indicator is turned on and the local protection settings are overridden by the energy-reducing maintenance switching settings.

Active Arc Mitigation



Arcing starts.

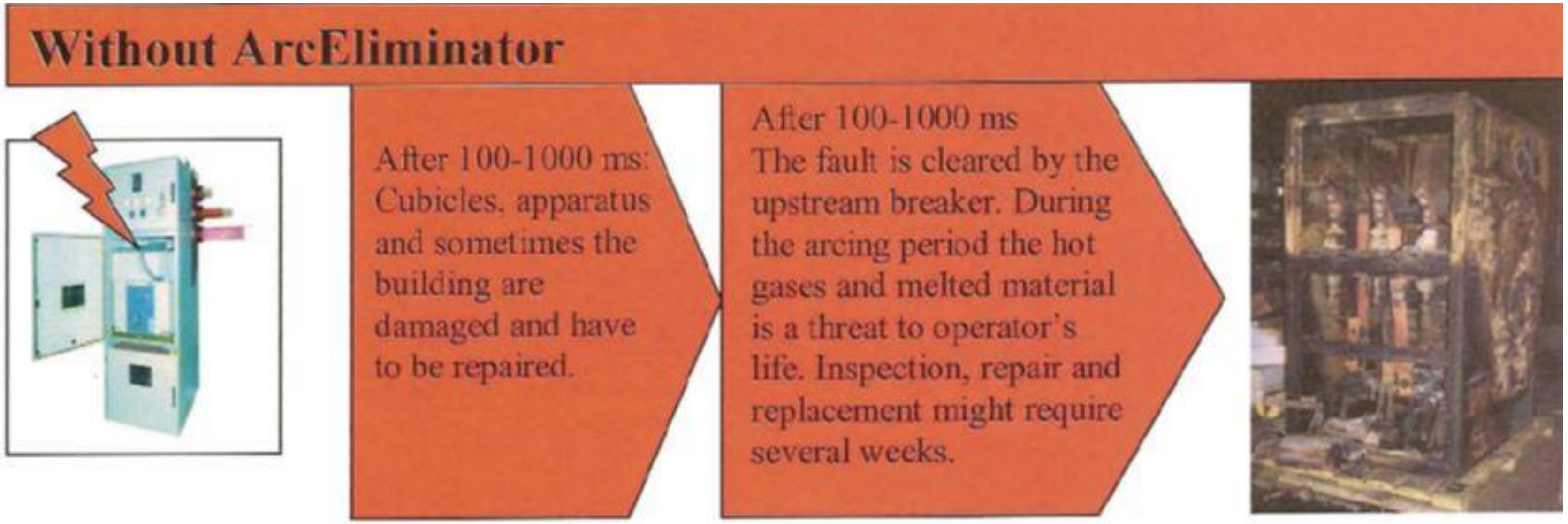
The sensors detect the arc.

The tripsignal is sent.

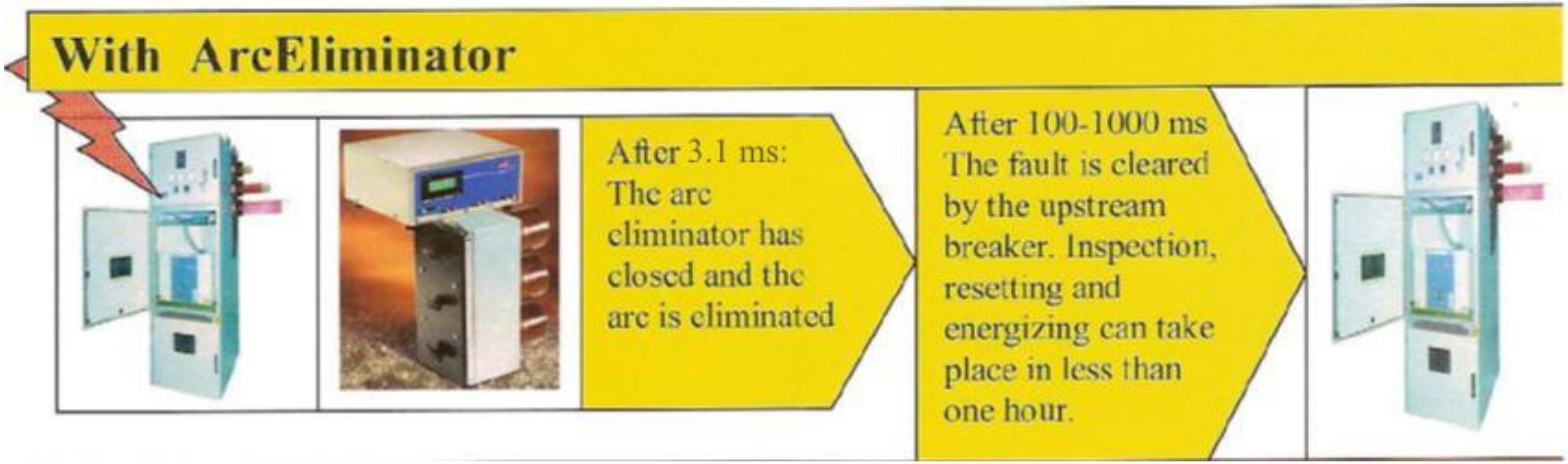
All the phases connected to ground.
The arc is extinguished.

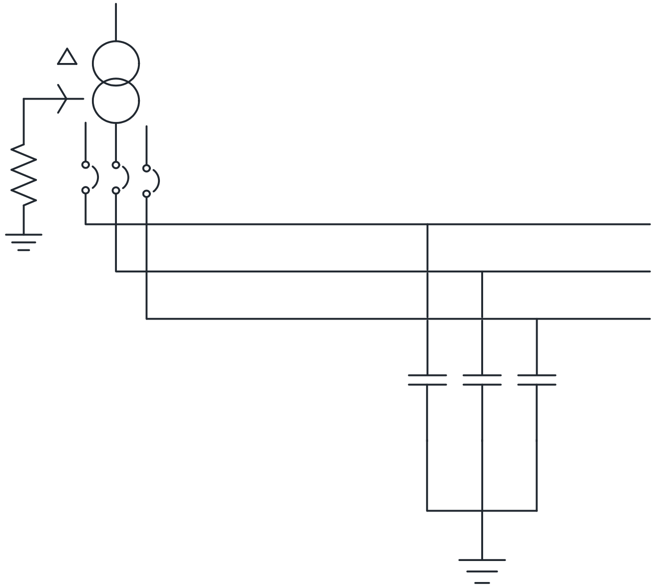
The shortcircuit current is disconnected within less than 3-5 cycles.

Incident Energy without Arc Mitigation



Incident Energy with Arc Eliminator

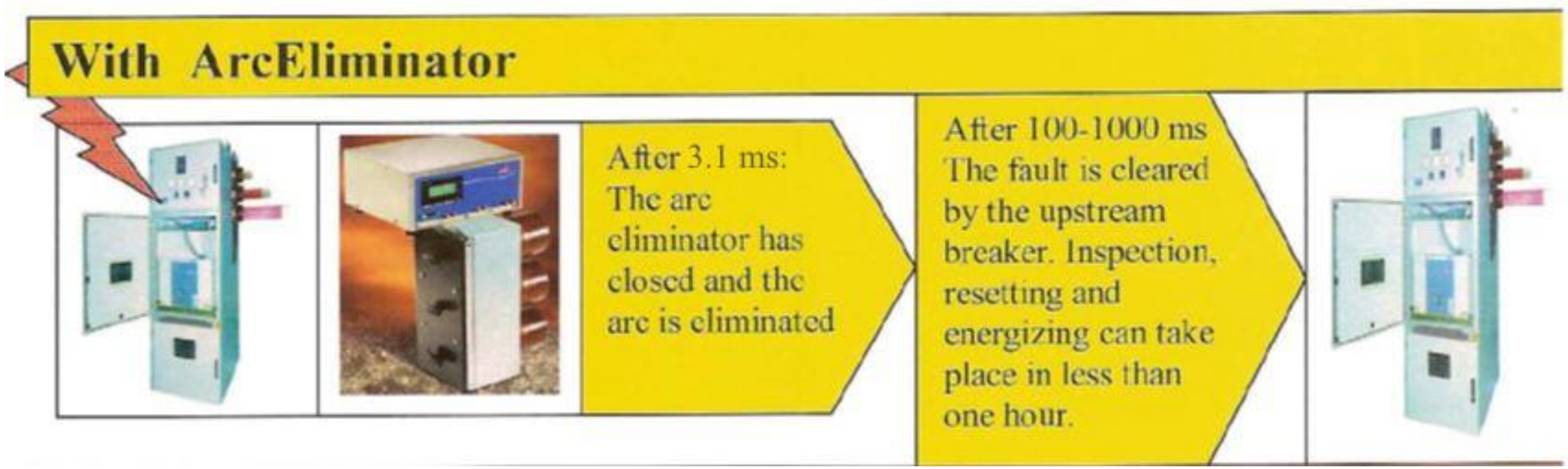


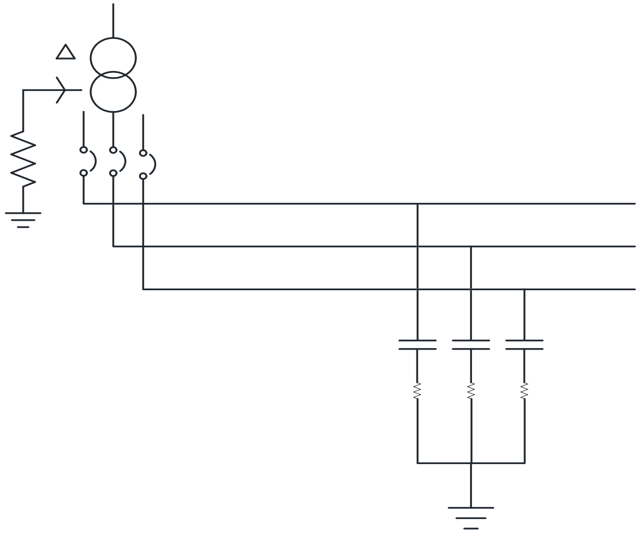


Fault clearing time: 3.1 ms ~ 0.257 cal/cm^2

Possible concern over mechanical stresses due to creating 3 phase bolted fault.

Incident Energy with Alternative Arc Eliminator

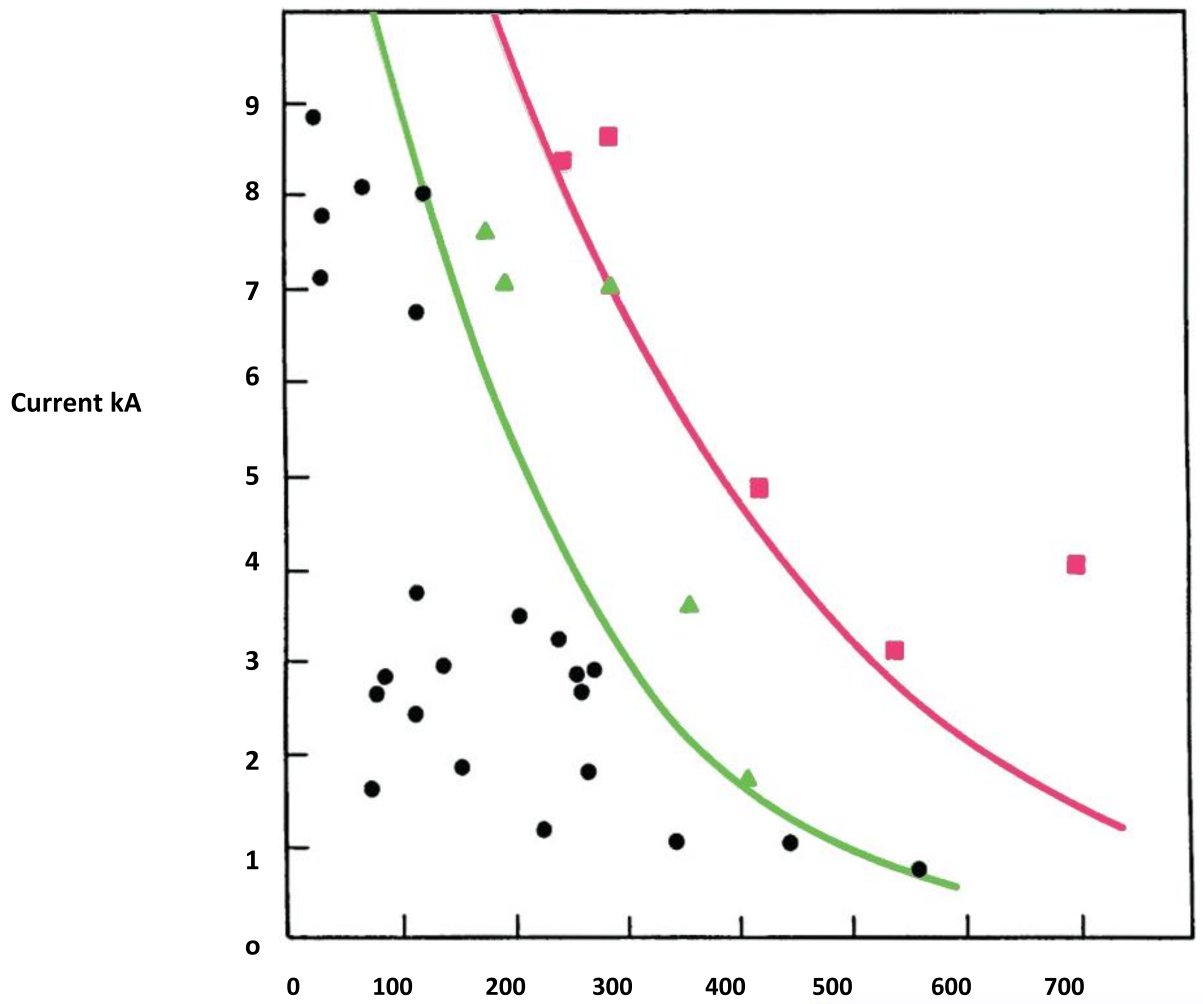




Fault clearing time: 3.1 ms ~ 1.17 cal/cm^2

Introduction of an impedance controls the fault energy eliminating concern over mechanical stresses

Arc Damage versus Arc Duration



An arc is developed within milli-seconds and leads to the discharge of enormous amounts of destructive energy. The energy in the arc is directly proportional to the square of the short-circuit current and the time the arc takes to develop.

- ✓ Reduce the Time,
- ✓ Reduce the Damage,
- ✓ Reduce the Incident Energy.

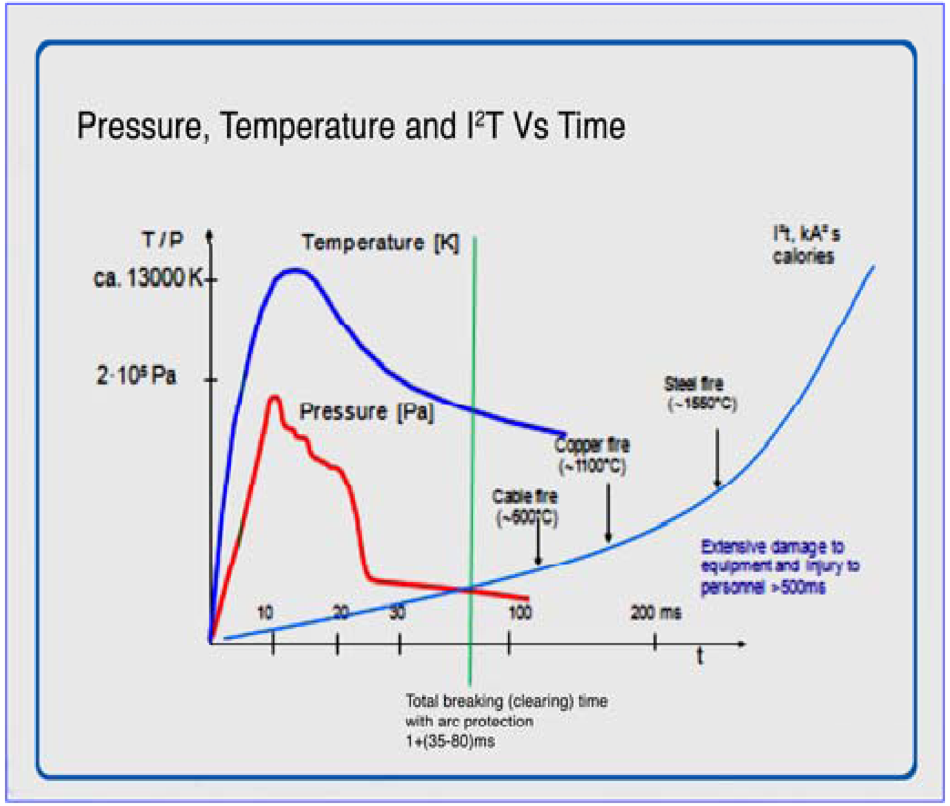
Total Clearing Time is Critical

Reduce the Time	Reduce the Damage	Reduce the Incident Energy
-35ms:	no significant damage to persons or Switchgear, which can often be returned to use after checking the insulation resistances	2.9 Cal /cm2
- 100ms:	small damage, requires cleaning and possibly some minor repair likely	8.31 Cal/cm2
- 500ms:	large damage both for persons and the switchgear, which must be partly replaced.	41.58 Cal/cm2

The arc burning time is the sum of the time to detect the arc and the time to open the correct breaker.

*Based on 50kA maximum bolted fault current on a 480 volt solidly grounded system @ 18 " Working distance.

Optical Detectors



An arc is accompanied by radiation in the form of light, sound, and heat.

Therefore, the presence of an arc can be detected by analyzing visible light, sound waves, and
temperature change.

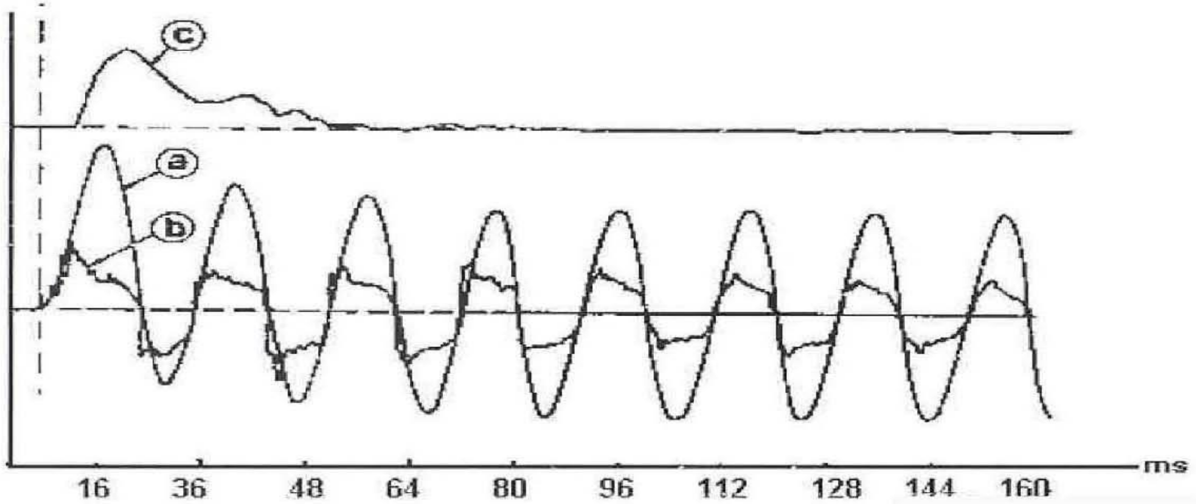
To avoid erroneous trips, it is normal to use a short-circuit current detector along with one of the aforementioned arc indicators.

The most common pairing in
North America is current and light and in Europe it is common to employ light and pressure.

Optical or Pressure Sensors

Arcing is accompanied by radiation in the form of light, sound, heat and electromagnetic waves as well as an associated pressure wave.

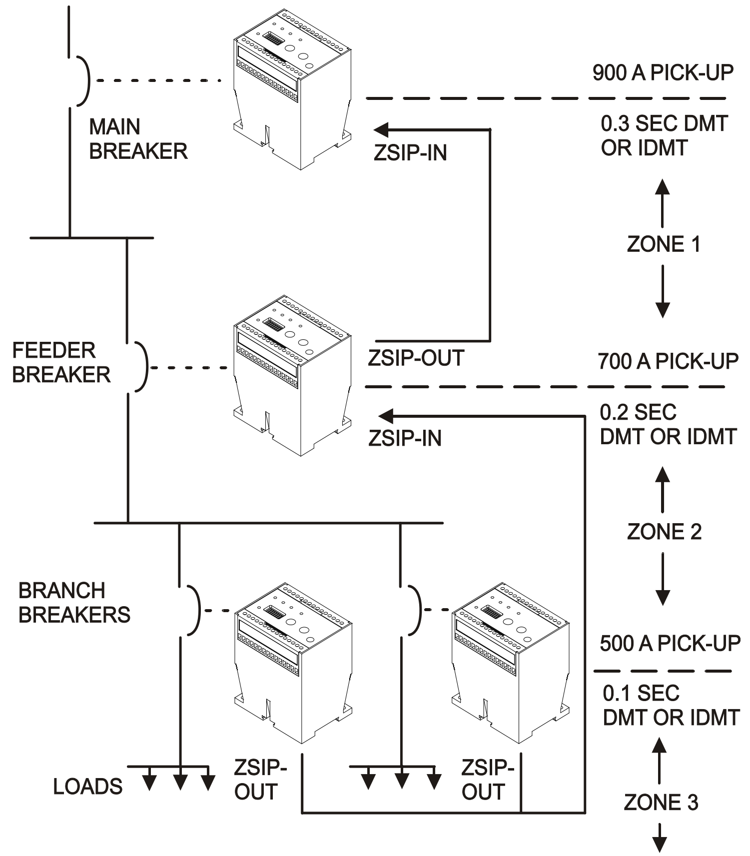
- **The energy developed by the internal arc generates heat and pressure; ex:**

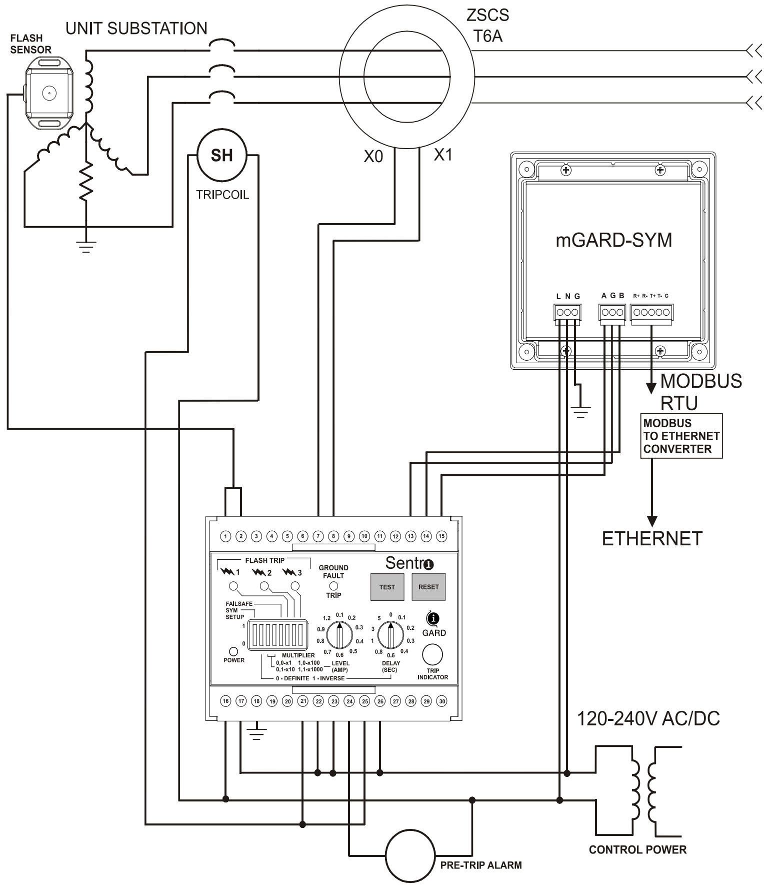


- **a: short circuit current (phase with max asymmetry)**
- **b: arc voltage**
- **c: internal pressure**

Arc Flash Relay

Ground Fault Protection, Zone Interlocking Protection (ZSIP) Remote Monitoring and Arc Flash Mitigation all in one relay





Optical or Pressure Sensors

Protection Type	Clearance Time	Incident Energy
MCGG Over-Current	2.0 seconds	211 Cal / cm^2
MCGG Instantaneous	0.45 seconds	47 Cal / cm^2
Pressure sensor	0.058 seconds	6.1 Cal / cm^2
Optical Arc Detection	0.051 seconds	5.3 Cal / cm^2

Assumes circuit breaker interrupting time of 3 cycles

Reduction in Incident Energy with Active Arc Control

Protection Type	Clearance Time	Incident Energy
Pressure sensor	0.058 seconds	6.1 Cal / cm^2
Optical Arc Detection	0.051 seconds	5.3 Cal / cm^2
Arc Quenching	0.0031 seconds	0.257 Cal / cm^2
Alternative Arc Control	0.0031 seconds	1.17 Cal / cm^2

Assumes circuit breaker interrupting time of 3 cycles

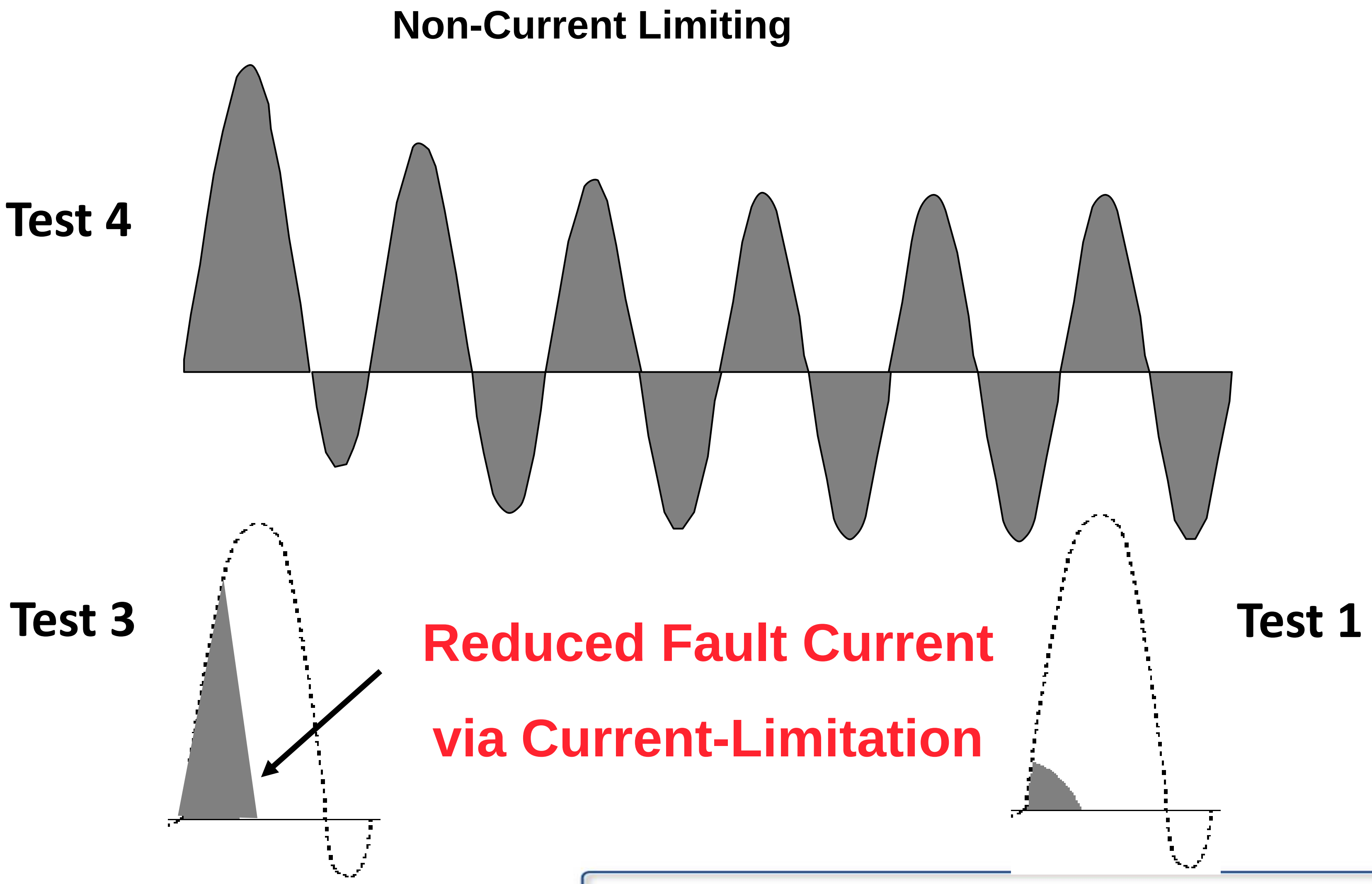
Substitution: Current Limiting Fuses

Current-limiting fuses and circuit breakers are often used in the design of electrical distribution systems to protect electrical equipment under high available short-circuit conditions (NEC® 240.2).

They are able to protect the equipment from the significant thermal damage and magnetic forces associated with high short-circuit currents by actually reducing the current that flows and the time that it flows. Within their current limiting range, they keep the current from reaching its peak during the first ½ cycle. And because they can react so quickly, the current is driven to zero in as little as ¼ cycle, or even less.

This great reduction in damaging current and time not only protects equipment from significant short-circuit currents, but naturally also helps protect workers that might be exposed to horrendous arc-flash energies.

Substitution: Current Limiting Fuses



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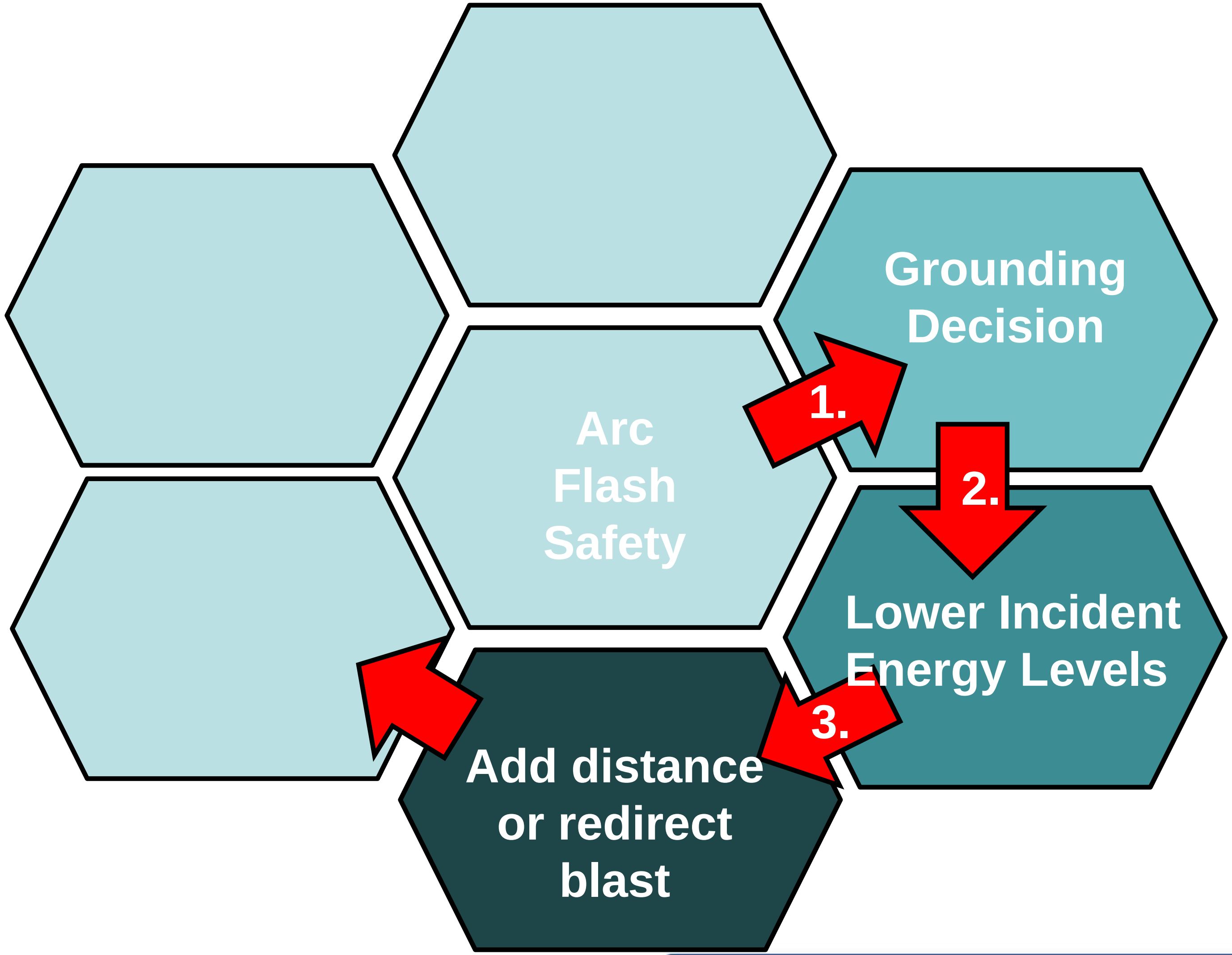
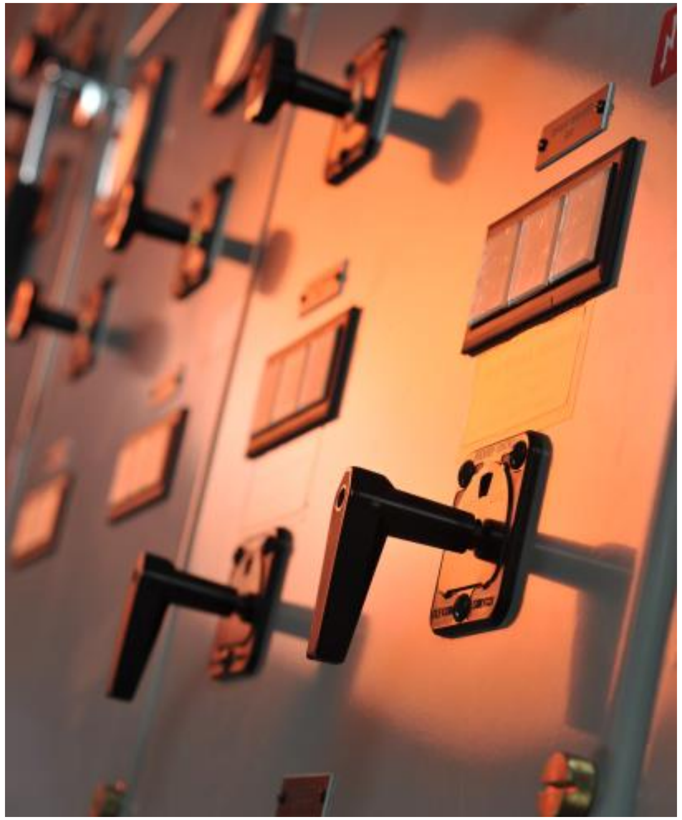


Engineering Controls: Remote Switching

<u>Permanently installed</u> – remote mounted switches, mimic panels, SCADA systems



<u>Advantages:</u>

- Permanently mounted
- May already exist through SCADA systems

<u>Disadvantages:</u>

- Expensive to install
- Increased chance of operating the wrong breaker
- Requires cabinet or wall space located outside of the arc-flash hazard boundary of every breaker

Engineering Controls: Remote Switching

Portable – "Chicken Switch®" motor operated actuator with remote hand-held controller.

Advantages:

- No modification to switchgear – held in place with magnets
- One "Chicken Switch®" can be used on many breakers
- No additional space required in substation
- Most cost effective solution in most all cases
- Reduced chance of operating the wrong breaker
- Models are available for pistol-grip control switches, pushbuttons, and low voltage power circuit breakers

Disadvantages:

- Not permanently installed

Engineering Controls: Remote Switching

Why open enclosures and expose yourself to arc flash hazards when you don't have to?

IR Windows provide increased:

- ✓ Safety – Perform IR scans without opening enclosures – virtually eliminating arc flash risk.
- ✓ Speed – Scan a panel in 5 minutes, not 30 minutes. No panel cover removal/replacement.
- ✓ Frequency of inspection – Inspect more often, on your schedule - with instant access.

Engineering Controls: Arc Resistant Switchgear

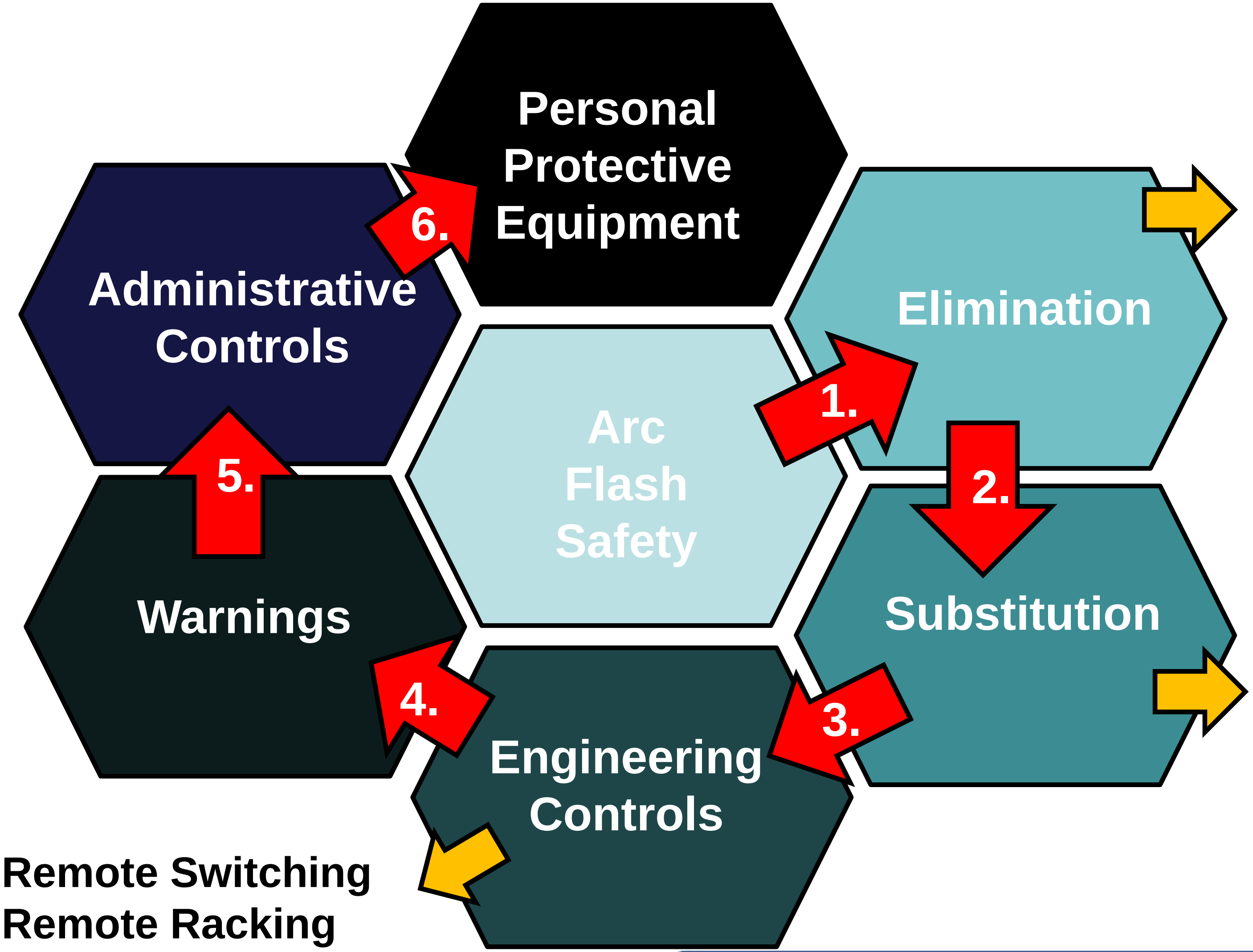
Arc resistant switchgear can assist with the first step effort by providing enhanced safety conditions when the operator task involves energized equipment and possible exposure to an arcing fault .

The purpose of arc resistant switchgear certified to ANSI C37.20.7 is to eliminate the risk from the arc blast and the by-products (heat, pressure, shrapnel, and molten copper) during normal tasks performed on the equipment.

While the focus of NFPA70E is the heat from the arc in medium voltage switchgear, it is the pressure wave associated with the arc fault that dictates the design of the switchgear.

Technology	Reduces the Likelihood of Exposure	Reduces the Severity of the Arc Flash Hazard	Protects Personnel in the event of an Arc Flash	Remarks
Zone Selective		✓		
Differential Relay		✓		
Maintenance Switch		✓		Manual operation required
Active Arc Mitigation		✓		concern over mechanical stresses from bolted fault
Arc Flash Relay		✓		Fast automatic operation
High Resistance Grounding	✓			Risk reduction by design, eliminate up to 95% of occurrences
Current Limiting Fuse		✓		Under specific operating conditions
Remote Switching			✓	Removes personnel from danger zone
Remote Racking			✓	Removes personnel from danger zone
Arc Resistant Switchgear			✓	Redirects blast away from personnel, although equipment is damaged.

ANSI Z10 Hierarchy Reformatted

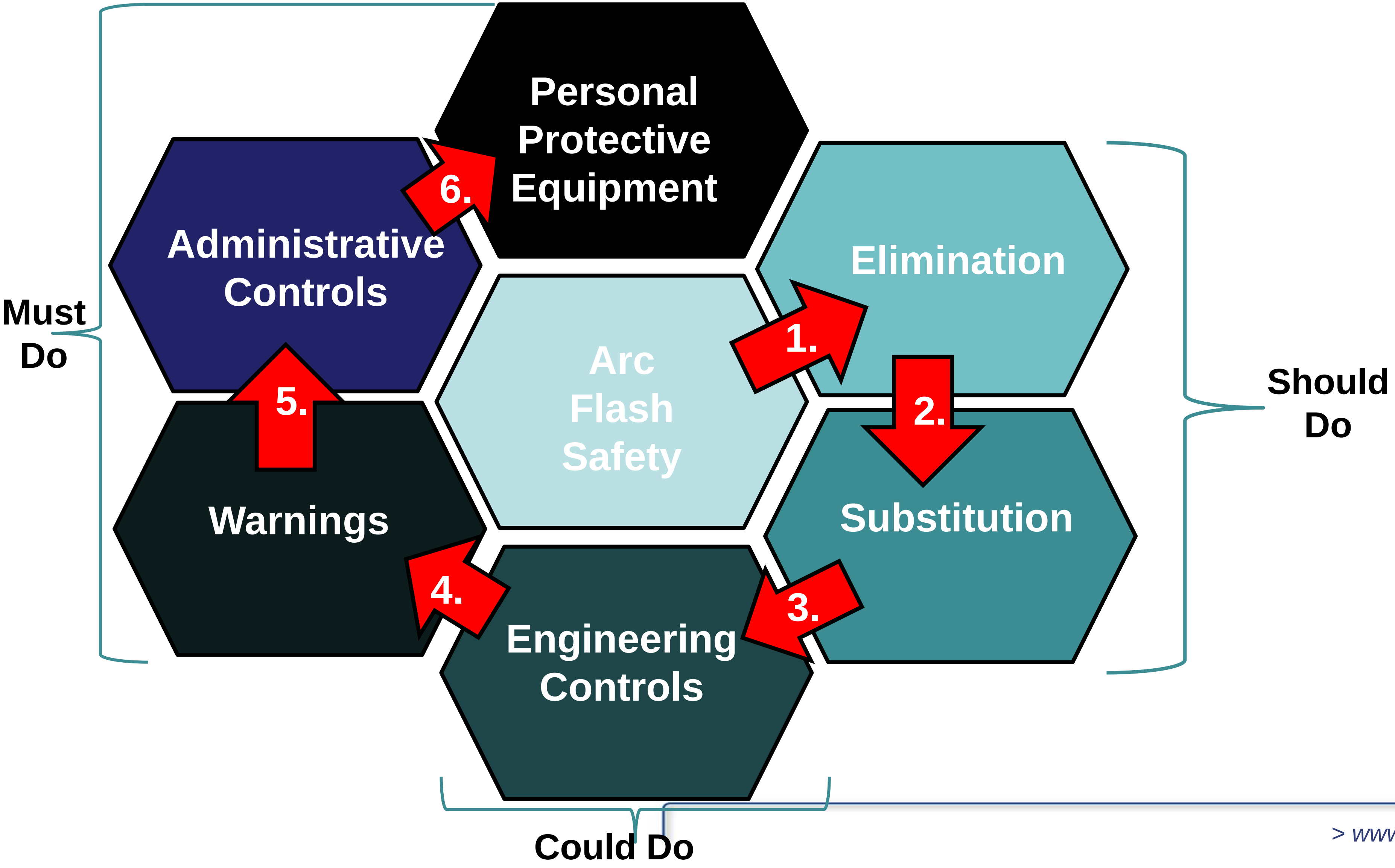


Select High Resistance Grounding

Zone Selective, Maintenance Switch
Active Arc Mitigation
Arc Flash Relay
Current Limiting Fuse

Remote Switching
Remote Racking
Arc Resistant Switchgear

ANSI Z10 Hierarchy Reformatted



Hierarchy of Hazard Control Measures from ANSI Z10

Recommended Approach

Control effectiveness →

ELIMINATION	SUBSTITUTION	ENGINEERING CONTROLS	WARNINGS	ASMINISTRATIVE CONTROLS	PERSONAL PROTECTIVE EQUIPMENT
Eliminate the hazard during the design phase. Design or re-design the system to use High Resistance Grounding.	Substitute for a lower energy level. Reduce the impact of the hazard.	Design options that automatically reduce risk. Increase distance away from the hazard.	Automatic or manual, permanent or temporary, visible or audible warning systems, signs, barriers and labels.	Planning processes, training permits, safe work practices, maintenance systems, communications and work management	Available, effective, easy to use.
Reduces likelihood of arc flash by 95%.	**Lowers the HRC to category 0 or 1 – safer levels.**				

Life Cycle Value →