Arc-Flash Mitigation Technologies

Dennis Balickie

The purpose of the session is to provide an overall understanding of the strategic impact of arc-flash.

Special focus is on the tactical means to minimize operational exposure of the users to the electrical equipment.

Risk Reduction through Design & Technology

ARC-FLASH ENERGY MITIGATION BY FAST ENERGY CAPTURE

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Paper No. PCIC-2009-2

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Abstract – The predominant technologies for reducing arc-flash incident energy today rely on the speed of protective devices, remote operation, encapsulating arc-flash energy in arc-resistant enclosures, which channel energy where it is less dangerous, and on crowbars to divert the arc energy into a bolted fault. Though more thoughtfully applied than they may have been in the past, none of these methods has provided a solution for all situations, particularly in existing installations. This paper will describe a method and include test results of an arc-flash energy sequestration that is able to divert an arcing fault's energy into a specific environment within a half-cycle after initiation of the arc. This is achieved without the need to introduce bolted fault current like a crowbar or for fast current interruption, such as a current-limiting fuse. The system protection provided has the benefits of arc-resistant switchgear without reliance on equipment sheathing and can be added after normal equipment is installed. Further advantages include the protection system and switchgear's ability for reuse after an arcing event, as well as the ability to easily test without the need for cumbersome high-current test equipment.

Index Terms – Arc-flash, Arc-flash Protection, Arcing Fault Diversion, Crow Bar, Arc-Resistant Switchgear, Fast Arc-flash Protection.

I. INTRODUCTION

A. Background

Arc-flash protection has emerged as an important consideration in the design and operation of power distribution systems. The industry has developed several methods and products to address the hazard posed by arc-flash energy in new systems. For reducing the arc-flash hazard in existing systems without complete replacement of equipment, , the available solutions are more limited. All of the existing methods provide solutions that are limited in one extent or another and can incur significant costs in terms of material or operational risk. The most common low-voltage arc-flash incident-energy or hazard reduction methods are listed and compared in Table 1.

B. Current and Time; the Effect upon Arc-Fault Current Interruption

The model developed for IEEE 1584-2002 "Guide for Performing Arc-Flash Hazard Calculations" [1] includes several empirically derived formulas for predicting arcing current and consequently incident arcing energy. Once a system is designed, the fault clearing-time at the expected arcing fault level is usually the only variable for control of the incident energy.

Seminar Handouts

Arc-Flash Mitigation Technologies

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Risk Reduction through Design & Technology

Method	Detection	Mechanism	
Discourage Energized Work-Permitting	None	De-energized equipment with lockout tagout	- Provi haza
Fuses as protective devices	Direct current energy	Relies on current-limiting interruption	- Faste curre - Long usag
Current-limiting circuit breakers	Direct current energy	Relies on current-limiting interruption	- Fast simil curre - Expa ratin value
Circuit breakers with instantaneous trips	Current; may be combined with light detection	Relies on fast fault interruption	- Provi Inter - Poss coor
Bus differential protection	Current differential	Relay based system	- Fast contr - Long usag
Zone selective interlocking	Current with restraint signal	Trip unit or relay based	- Spee ST a prote - Main settir
Remote operation	None	Operator outside arc flash boundary	- No in selec - Some devic exist
Arc-resistant switchgear	None	Enclose switchgear volume	- Prote switc and - Mech solut
Crowbar system	Light detection and current	Fast protection from arc blast and flash	- Prote switc and - May equi
Temporary reduced settings	Current measurement	More sensitive and faster temporarily	- Redu unde
Single processor protection	Current and voltage combined with intelligent algorithms	Multiple inputs to centralized redundant processor	- Equi prote intell - Upgr softv
Fast energy capture	Light detection and current	Fast protection from arc blast and flash	- Provi ener open - Multi main - Redu dam

GE
Electrical Distribution

How to reduce exposure to arc flash hazards

Multiple solutions for new and existing facilities

imagination at work

GE
Electrical Distribution

Out of the box thinking. Inside the box protection.

Arc Vault™ Protection System

The Arc Vault™ protection system from GE is an innovative leap forward in arc flash protection. Compared to existing products and systems, it offers significant benefits: the ability to offer arc flash protection with doors and compartments open, reduced energy of operation, reduced construction costs, and the ability to retrofit existing switchgear.

imagination at work

Worker safety is important - Why?

It is the right thing to do &… realize increased productivity, higher worker morale & improved operational efficiency

Machinery, processes & facilities are designed with worker safety in mind …

However, electrical safety is often an afterthought !

It should not be !

Electrical safety needs to be considered as part of the initially defined mission for the facility's power distribution system & contemplated at "every" decision point in the design, purchasing & installation process.

System reliability and long term productivity is best enhanced while keeping initial & long term costs down.

Electrical safety needs to be part of a multifaceted approach to electrical infrastructure planning

What is electrical worker safety ?

Its more than just an Arc Flash Incident Energy Study

US National Institute for Occupational Safety & Health (NIOSH)

"Electrical current exposes workers to a serious, widespread occupational hazard; practically all members of the workforce are exposed to electrical energy during the performance of their daily duties, and electrocutions occur to workers in various job categories. Many workers are unaware of the potential electrical hazards present in their work environment, which makes them more vulnerable to the danger of electrocution.

Electrical injuries consist of four main types: electrocution (fatal), electric shock, burns, and falls caused as a result of contact with electrical energy."

- Practically all members of the work force . . . Not just electricians
- Many workers unaware . . . Not all exposures are planned
- Electrocution, shock, burns and falls . . . Not JUST arc flash

Some data

US National Institute of Health (NIOSH) Studies for 1980-1995 identified 93,338 fatalities in the American work place.

- Of those ~ 1/15 was caused by electricity
- 389 electrically induced fatalities per year . . . > 1/day

Not all arc flash

Not all factory or process facility floor

Shock and overhead lines are significant contributors

How to address safety needs ?

Multiple Issues

An energized circuit/conductor represents the potential for:

- Electric shock
- Arc-flash
- Arc Blast

Operators and designers of electrical equipment desire to:

- Minimize the need to touch
- Lower energy levels
- Lower interruption time
- Absorb energy
- Barrier the equipment

How to address safety needs ?
Multiple Solutions

The Easiest Solution is

Discourage Energized Work-Permitting

- Provides no arc-flash hazard
- De-energized conductors and cold busses are no electrical threat
- No voltage potential and zero current flow eliminate power contribution

Still need to follow all necessary lock-out/tag-out procedures

This is very difficult in today's 24-7-365 environment

Most historical solutions don't exist

- Off-hour scheduling
- Periodic/Scheduled maintenance shutdowns
- Area/Sector isolation

How to address safety needs ?
Multiple Solutions – In an Energized Environment

Ground Zero is the proper Personnel Protective Equipment (PPE)

Dependent upon knowing the Hazard Risk Category value (HRC)

Multiple Solutions – In an Energized Environment
Design Based Solutions

Primary focus is on new installations

Some can be implemented on existing equipment (retro-fit)

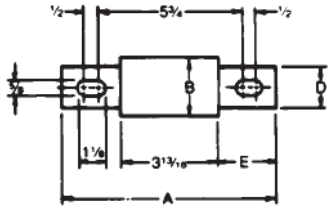
- Detail the Detection Method and the Design Mechanism
- Provide both the Benefits and the Drawbacks

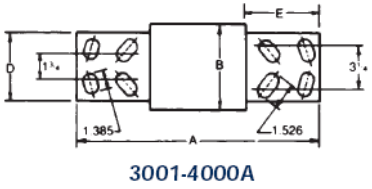
Practical equipment implementation on Switchgear, Switchboards, Unit Substations and Downstream Motor Control Centers

Bottom-Line = Provide Design Options

The choice is up to you

Multiple Solutions – In an Energized Environment
Method – Fuses as a Protective Device





Detection = Direct current energy

Mechanism = Relies on current-limiting interruption

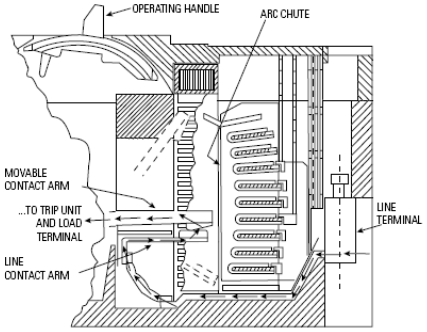
Benefit

- Fastest interruption if Ia > current-limiting energy threshold
- Long history of industry usage

Drawback

- Large fuses have CL thresholds > arcing current and hence may be slow to react
- Concern over fuse replacement and lack of other capabilities offered by circuit breakers

Multiple Solutions – In an Energized Environment
Method – Current-Limiting Circuit Breakers



Detection = Direct current energy

Mechanism = Relies on current-limiting interruption

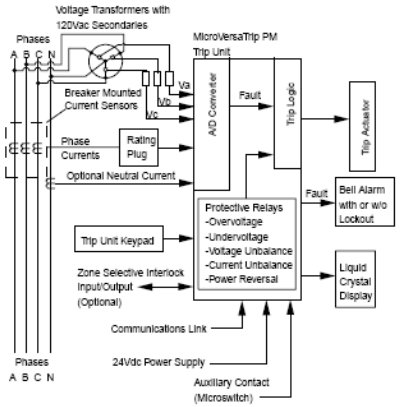
Benefit

- Fast current interruption similar to fuses if Ia > current-limiting threshold
- Expands standard AIC ratings of breakers to values as high as 200KAIC

Drawback

- Limited in availability relative to fuses and subject to similar limitations
- May require replacement after limited number of operations
- Not easily available in a broad range of sizes

Multiple Solutions – In an Energized Environment
Method – Circuit Breakers with Instantaneous Trips



Detection = Current; may be combined with light detection

Mechanism = Relies on fast fault interruption

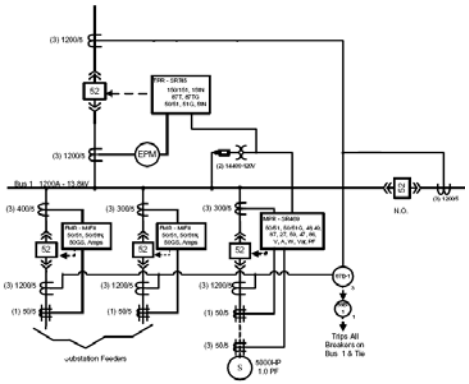
Benefit

- Provides fast current interruption
- Possibly expands coordination capabilities

Drawback

- Not as fast as current-limiting fuses or circuit breakers
- Use of the instantaneous at arcing current levels may negatively affect selectivity
- Requires adjustable-trip circuit breakers

Multiple Solutions – In an Energized Environment
Method – Bus Differential Protection



Detection = Current differential

Mechanism = Relay based system

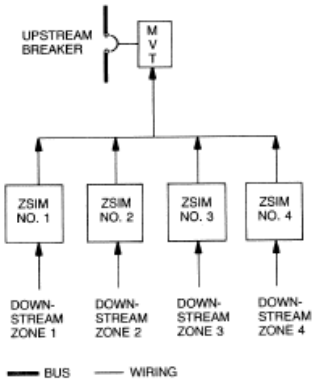
Benefit

- Fast elimination of all contributing fault sources
- Long history of industry usage

Drawback

- Breaker operation speed
- Usually requires dedicated set of CT's for every breaker

Multiple Solutions – In an Energized Environment
Method – Zone Selective Interlocking



Detection = Current with restraint signal

Mechanism = Trip unit or relay based

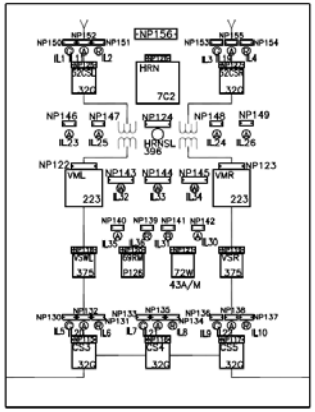
Benefit

- Speeds up interruption of ST and/or GF and/or Inst protective functions
- Maintains coordination settings in normal mode

Drawback

- Breaker operation speed
- Requires specific capable trip/relay system and wiring

Multiple Solutions – In an Energized Environment
Method – Remote Operation



Detection = None

Mechanism = Operator outside arc flash boundary

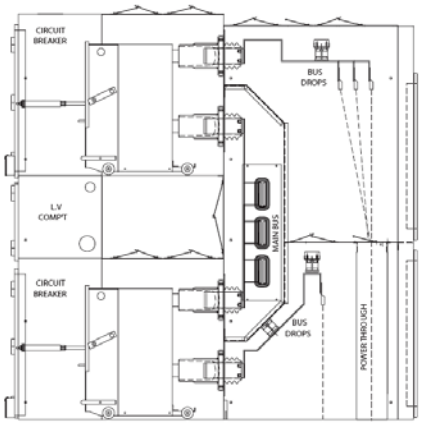
Benefit

- No impact on system selectivity
- Some remote racking devices can be used on existing equipment

Drawback

- Does not improve downstream or equipment protection
- May be costly and difficult to retrofit into existing installations

Multiple Solutions – In an Energized Environment
Method – Arc-resistant Switchgear



Detection = None

Mechanism = Enclose switchgear volume

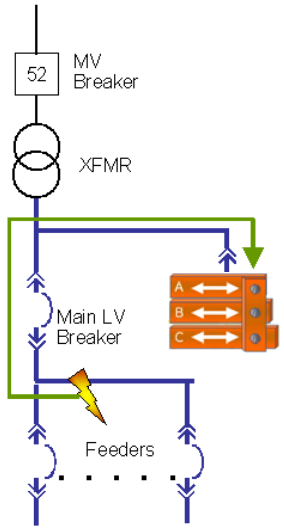
Benefit

- Protects in proximity of the switchgear from arc flash and blast energy
- Mechanical/Structural solution

Drawback

- Enclosure integrity must be maintained (doors closed)
- Blast energy must be exhausted
- Complex installation
- Does not improve equipment protection nor can it be added to existing equipment

Multiple Solutions – In an Energized Environment
Method – Crowbar System



Detection = Light detection and current

Mechanism = Fast protection from arc blast and flash

Benefit

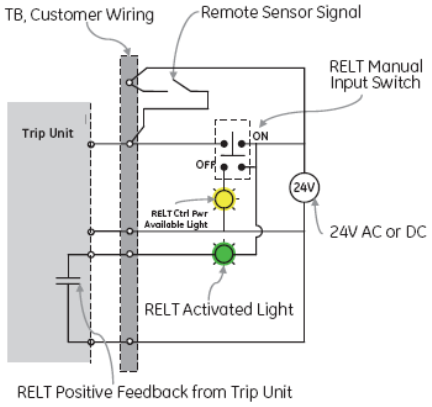
- Protects in proximity to switchgear from arc flash and blast energy
- May reduce immediate equipment damage

Drawback

- One-time use, may damage distribution equipment and other equipment connected in the system
- Localized protection only
- Increased stresses on transformers

Multiple Solutions – In an Energized Environment
Method – Temporary Reduced Settings

Detection = Current measurement



Mechanism = More sensitive and faster temporarily

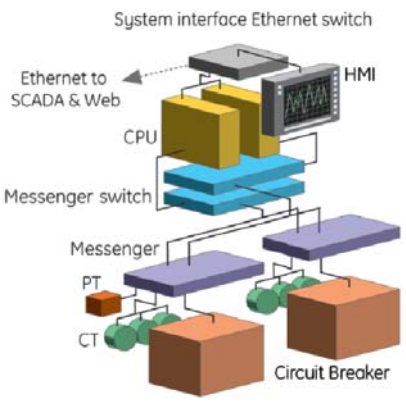
Benefit

- Reduces incident energy under specific conditions

Drawback

- Requires specific capable trip systems and does not provide protection if the event does not occur during planned activity

Multiple Solutions – In an Energized Environment
Method – Single Processor Protection



Detection = Current and voltage combined with intelligent algorithms

Mechanism = Multiple inputs to centralized redundant processor

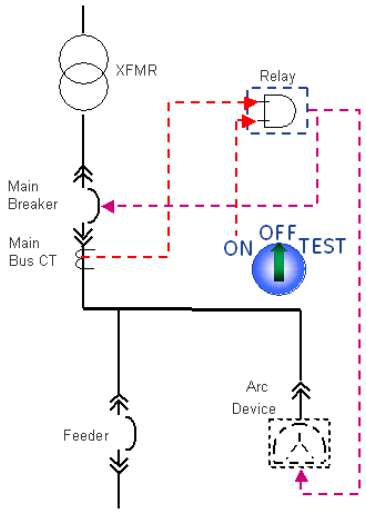
Benefit

- Equipment system protection not islands of intelligence
- Upgrades and options are software based

Drawback

- Requires specific capable trip systems
- Difficult to retrofit into existing installations

Multiple Solutions – In an Energized Environment
Method – Fast Energy Capture



Detection = Current only
(Activation Switch)

Mechanism = Fast protection from arc blast and flash

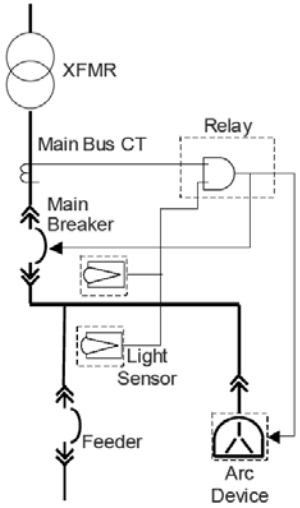
Benefit

- Provides lowest incident energy even with doors open
- Multiple use with minor maintenance
- Reduces equipment damage
- Immediate retrofit application

Drawback

- Current only based activation
- Maintenance Activation

Multiple Solutions – In an Energized Environment
Method – Fast Energy Capture



Detection = Light detection and current
(Always On)

Mechanism = Fast protection from arc blast and flash

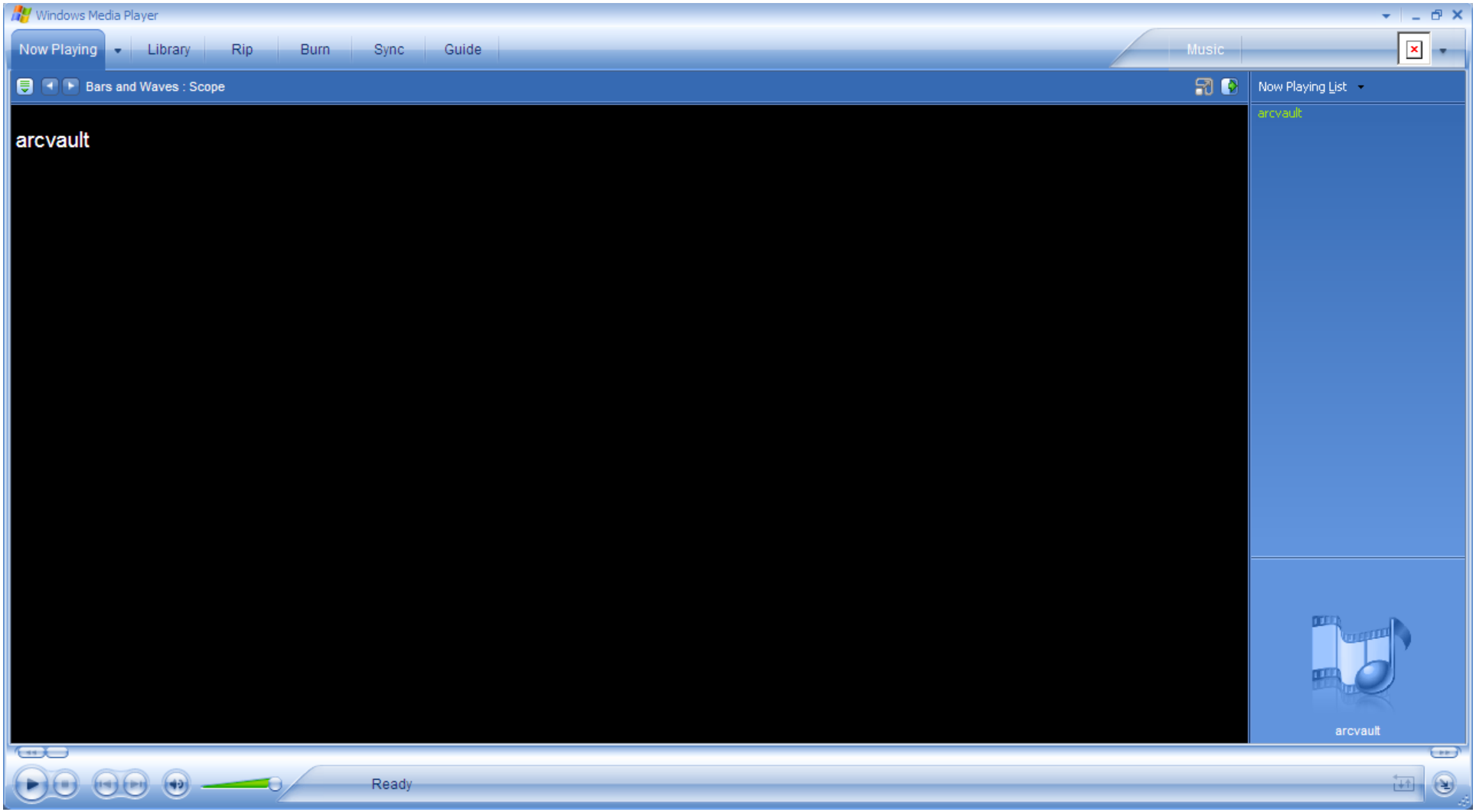
Benefit

- Provides lowest incident energy even with doors open
- Multiple use with minor maintenance
- Reduces equipment damage
- Continuous monitoring

Drawback

- Placement of light sensors in existing gear
- New equipment lineups only

Play Video

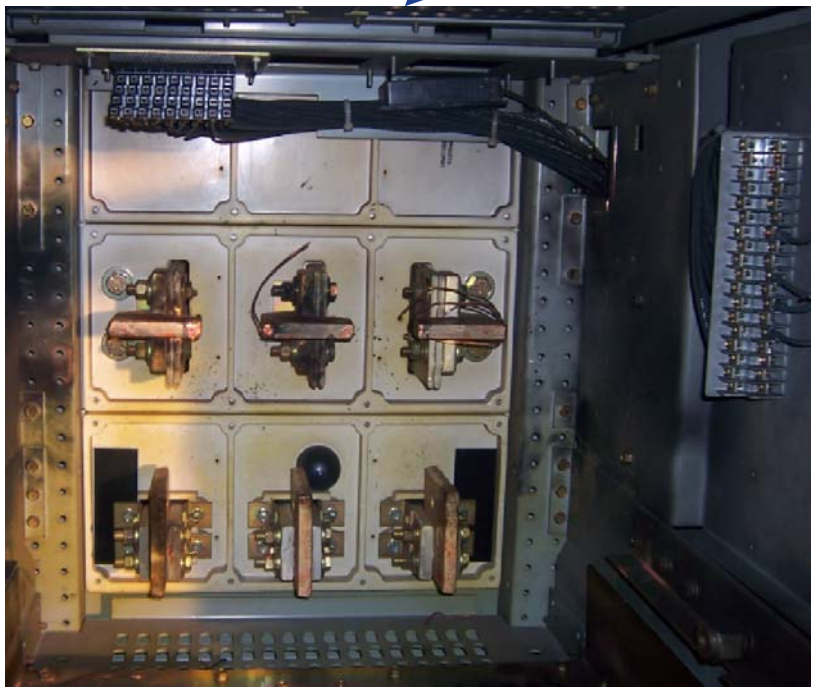

Windows Media Player
Now Playing
Library
Rip
Burn
Sync
Guide
Music
Bars and Waves : Scope
arcvault
Now Playing List
arcvault
arcvault
Ready

12 Cycle / 3 Cycle / 1.5 Cycle / 0.5 Cycle

200 msec / 50 msec / 25 msec / 8 msec

Video Left / Picture Left / Video Right / Picture Right

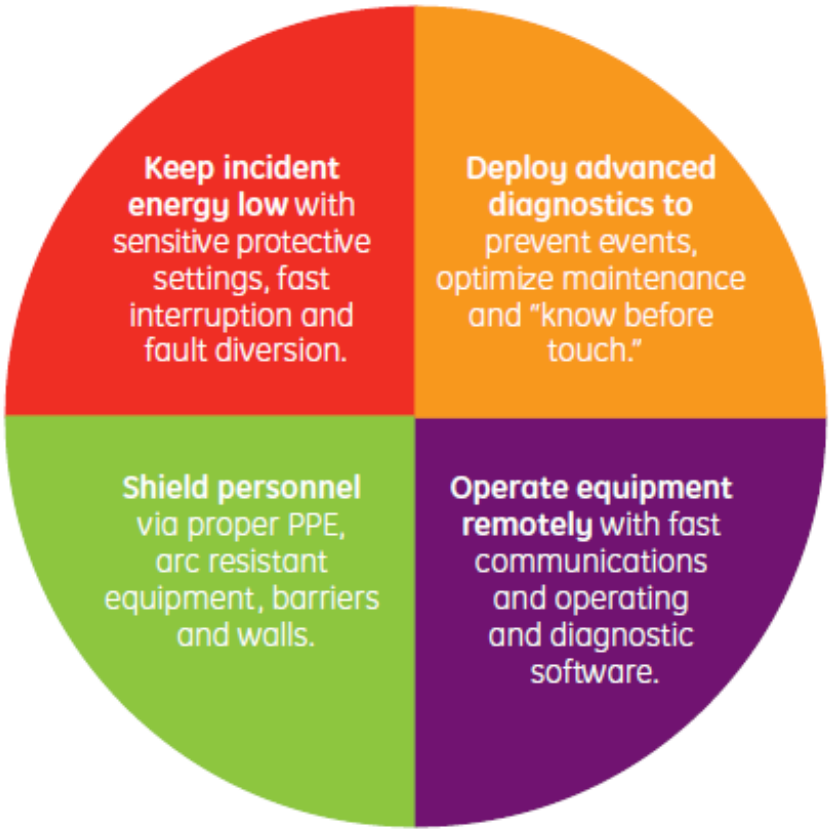
3 cycle CB interruption



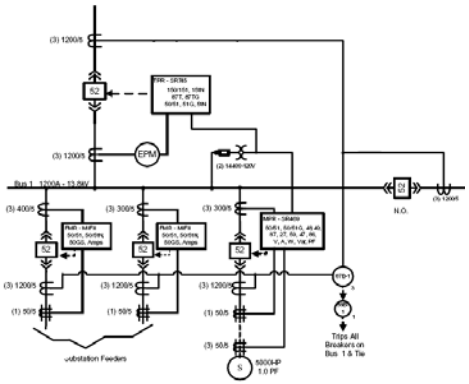
0.5 cycle Arc-Vault protection

Multiple Solutions – In an Energized Environment

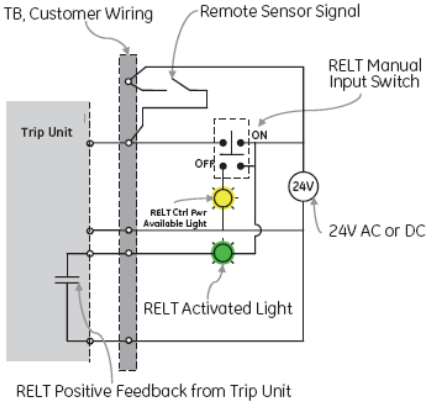
Arc flash hazard exposure is a function of fault clearing time at an arcing current and a worker's distance from the event. Multiple techniques can be employed to limit exposure.



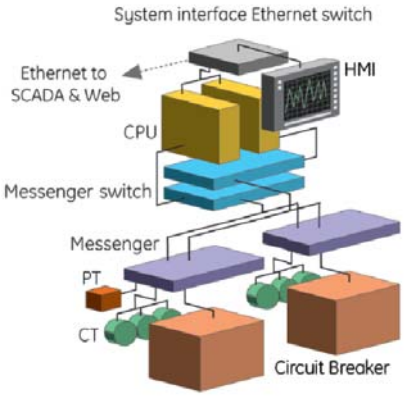
Bus Differential Protection



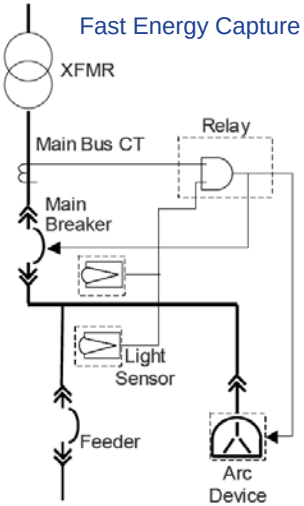
Temporary Reduced Settings



Single Processor Protection



Fast Energy Capture



Bottom-Line = Provide Design Options

The choice is up to you

Some of the methods can be combined

Some can be applied to different pieces of equipment

Any Questions?

Thank-you for your time

Other References

http://standards.ieee.org
www.nfpa.org
www.nfpacatalog.org
www.plantengineering.com/webcast