Electrical System Grounding is Key to Effective Electrical Safety *and Reliability*

Daleep Mohla

I-GARD

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Please Note

The presentation contains certain reference to NFPA and CSA standards. The contents and answers to the questions are the personal technical opinion of the presenter.

These are not to be considered as an official direct or implied interpretation of any NFPA or any other standards.

Why Do We Need to Ground Systems?

250.4 (A) (1) **Electrical System Grounding.** Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

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Systems Required to be Grounded

250.20 (A) **Alternating-Current Systems of Less Than 50 Volts.**

- Alternating-current systems of less than 50 volts shall be grounded under any of the following conditions:
- (1) Where supplied by transformers, if the transformer supply system exceeds 150 volts to ground
- (2) Where supplied by transformers, if the transformer supply system is ungrounded
- (3) Where installed outside as overhead conductors

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Systems Required to be Grounded

250.20 (B) **Alternating-Current Systems of 50 Volts to 1000 Volts.**

- Alternating-current systems of 50 volts to 1000 volts that supply premises wiring and premises wiring systems shall be grounded
- under any of the following conditions:

- (1) Where the system can be grounded so that the maximum voltage to ground on the ungrounded conductors does not exceed 150 volts
- (2) Where the system is 3-phase, 4-wire, wye connected in which the neutral conductor is used as a circuit conductor
- (3) Where the system is 3-phase, 4-wire, delta connected in which the midpoint of one phase winding is used as a circuit conductor

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Electrical System Design Considerations

- **Safety**
  System should be safe for operation
- **Reliability**
  Continuity of power availability be maximized
- **Security of the system**
  Ability to test, maintain system
- **Life Cycle costs**

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Two Common Methods of Grounding

1. **Solid Grounded**
   Direct connection from neutral to earth with no additional impedance
2. **High resistance Grounding**
   Where an intentional impedance is inserted

Ground fault

- Industry data indicates **95- 98%** of electrical faults start as phase to ground fault
  - caused by a single insulation failure
- The ground fault is not cleared instantly will likely to escalate to a phase to phase or 3 phase faults
- High Impedance grounding system minimizes the probability of a phase to phase fault

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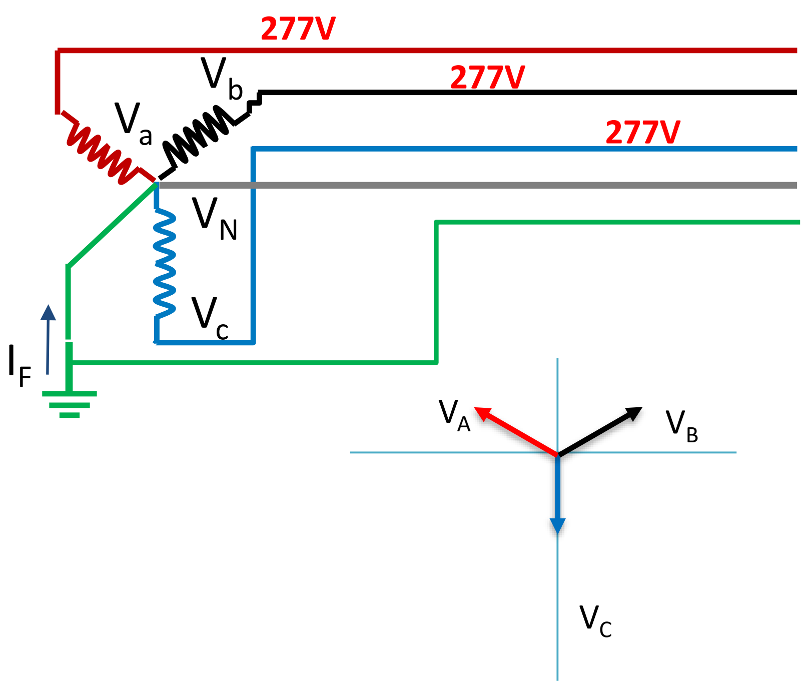
250.36 High-Impedance Grounded Neutral Systems

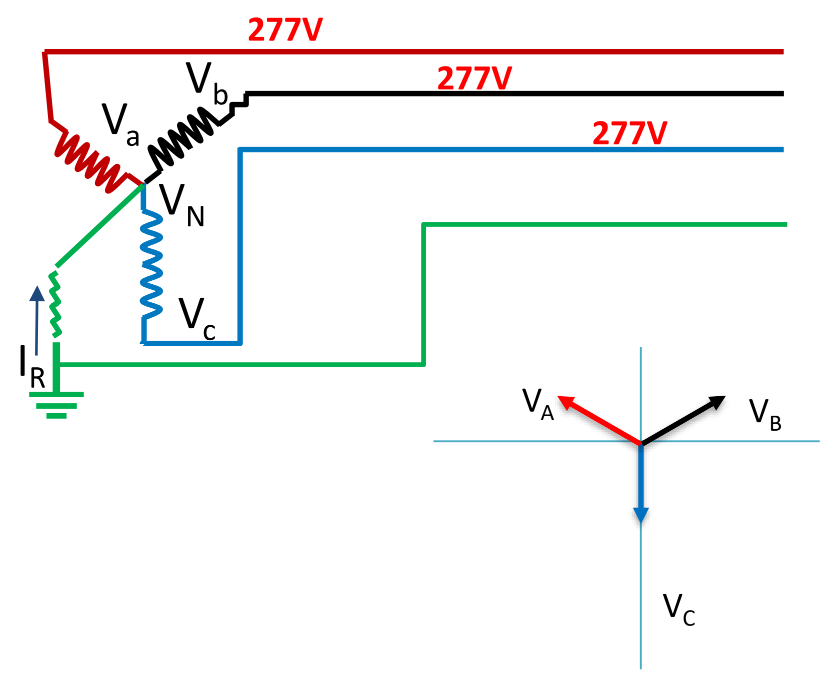
- High impedance grounded neutral systems in which a grounding impedance, usually a resistor, limits the ground-fault current to a low value shall be permitted for 3-phase ac systems of 480 volts to 1000 volts if all the following conditions are met:
- (1) The conditions of maintenance and supervision ensure that only qualified persons service the installation.
- (2) Ground detectors are installed on the system.
- (3) Line-to-neutral loads are not served.

Normal Operation

Solidly Grounded
Normal Operation



High Resistance Grounded
Normal Operation



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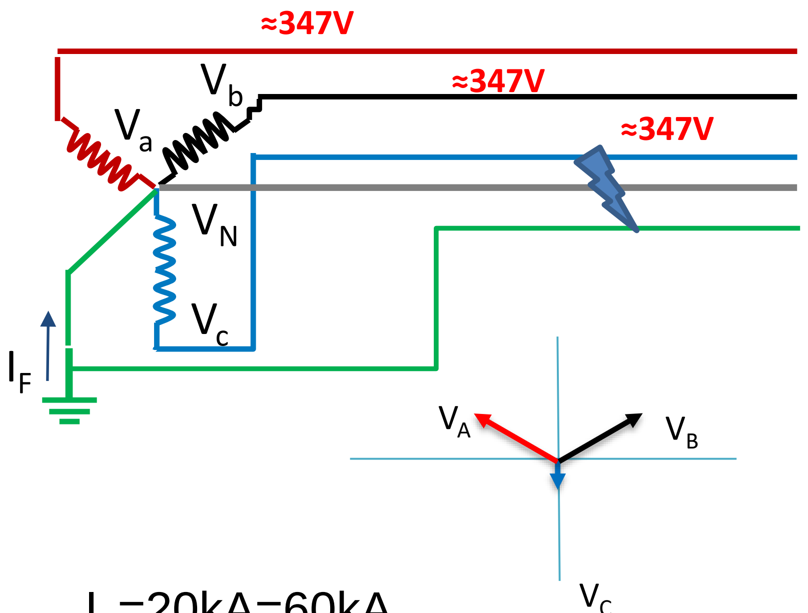
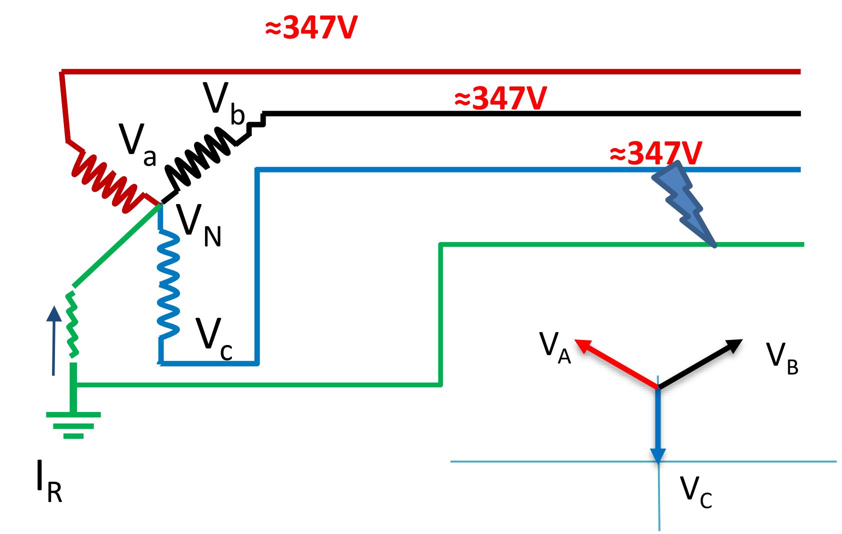
Ground Fault- Reliability

Solidly Grounded
Faulted Operation



I_F=20kA=60kA
Must Trip

High Resistance Grounded
Faulted Operation



I_F=5 A
Can remain Operational

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Why convert from Solidly Grounded to High Resistance Grounding?

- ***Increased*** **Safety**
  Reduced arc flash hazard
- ***Increased*** **Reliability**
  System can safely operate after the first ground fault
- ***Increased*** **Security of the system**
  Integrity and operation *can be tested*
- ***Lower*** **life cycle cost**
  less damage to the equipment due to ground faults
  System and equipment can be repaired at less cost

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NFPA 70E- Annex O
Responsibility for Safety ?

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 hazard risk assessments are performed during the design of electrical systems and installations.*

Safety by Design Requirements for Electrical Systems

NFPA 70E and CSA Z462 Annex 0 General Design Requirements 0.2.2 –

Design option decision 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 and
3. Enabling achievement of an electrically safe work condition.

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Incident Energy Reduction Models

70E O.2.2

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Z462 O.2.2

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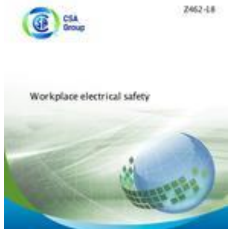

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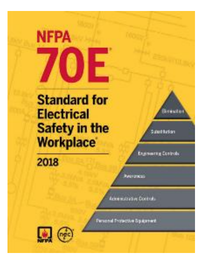
Incident Energy Reduction Models

70E O.2.3

1. Zone-Selective Interlocking
2. Differential relaying
3. Energy-Reducing Maintenance switch
4. Energy-reducing active arc flash mitigation system
5. Arc flash relay
6. High resistance grounding
7. Current limiting devices
8. Shunt trip



Z462 O.2.3

a) Zone-Selective Interlocking
b) Differential relaying
c) Energy-Reducing Maintenance switch
d) Energy-reducing active arc flash mitigation system
e) Arc flash detection relay
f) High resistance grounding
g) Current limiting devices
h) Shunt trip

2 Questions to Answer

1. What is the electrical risk associated with operating a 3 phase 4 wire system and is it any different for a high resistance grounded system?

2. In what way would changing to a HRG system reduce the likelihood of exposure or reduce the magnitude of exposure?

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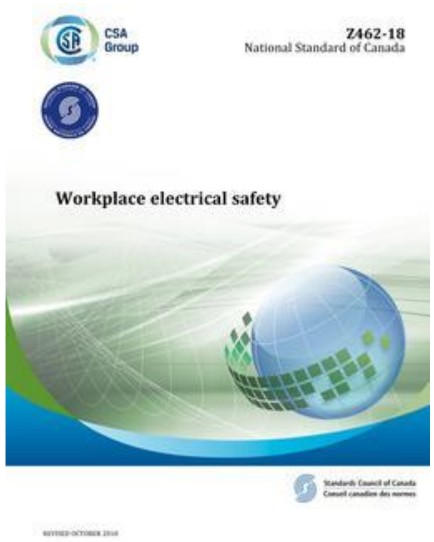
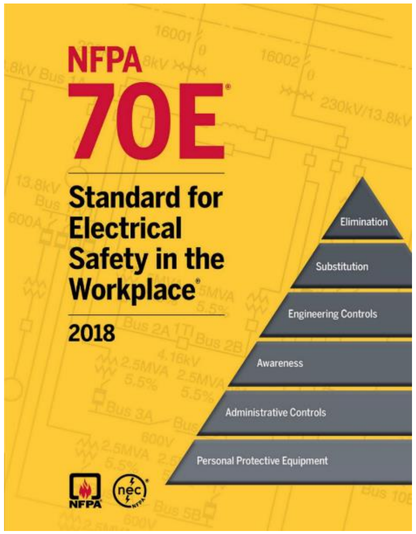
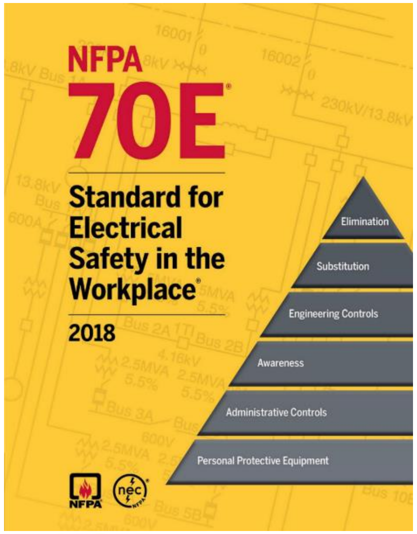
Increased Safety

- HRG is an arc Flash mitigation technique
- Canada and the US state in the HRG is a form of Arc Flash Mitigation.



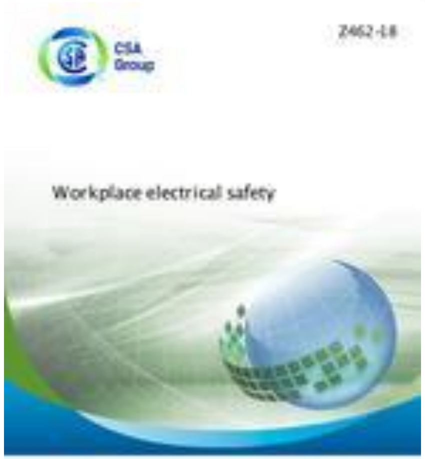


Arc Flash Mitigation



Annex O.2.3

(6) 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.



Annex O.2.3

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Arc Flash Injury Statistics

The table below provides a summary of some arc flash data over a 23 year period (not all arc flash incidents are effectively captured or reported) and validate the occurrence of injuries and unfortunately fatalities associated with arc flash at 480 and 600V.

Voltage	Burns	Smoke inhalation	Shock	Fatalities
Under 400V	19	0	3	0
480V and 600V	283	18	5	33
1kV to 5kV	78	1	0	13
5kV to 15kV	100	3	13	10
Over 15kV	50	16	2	5

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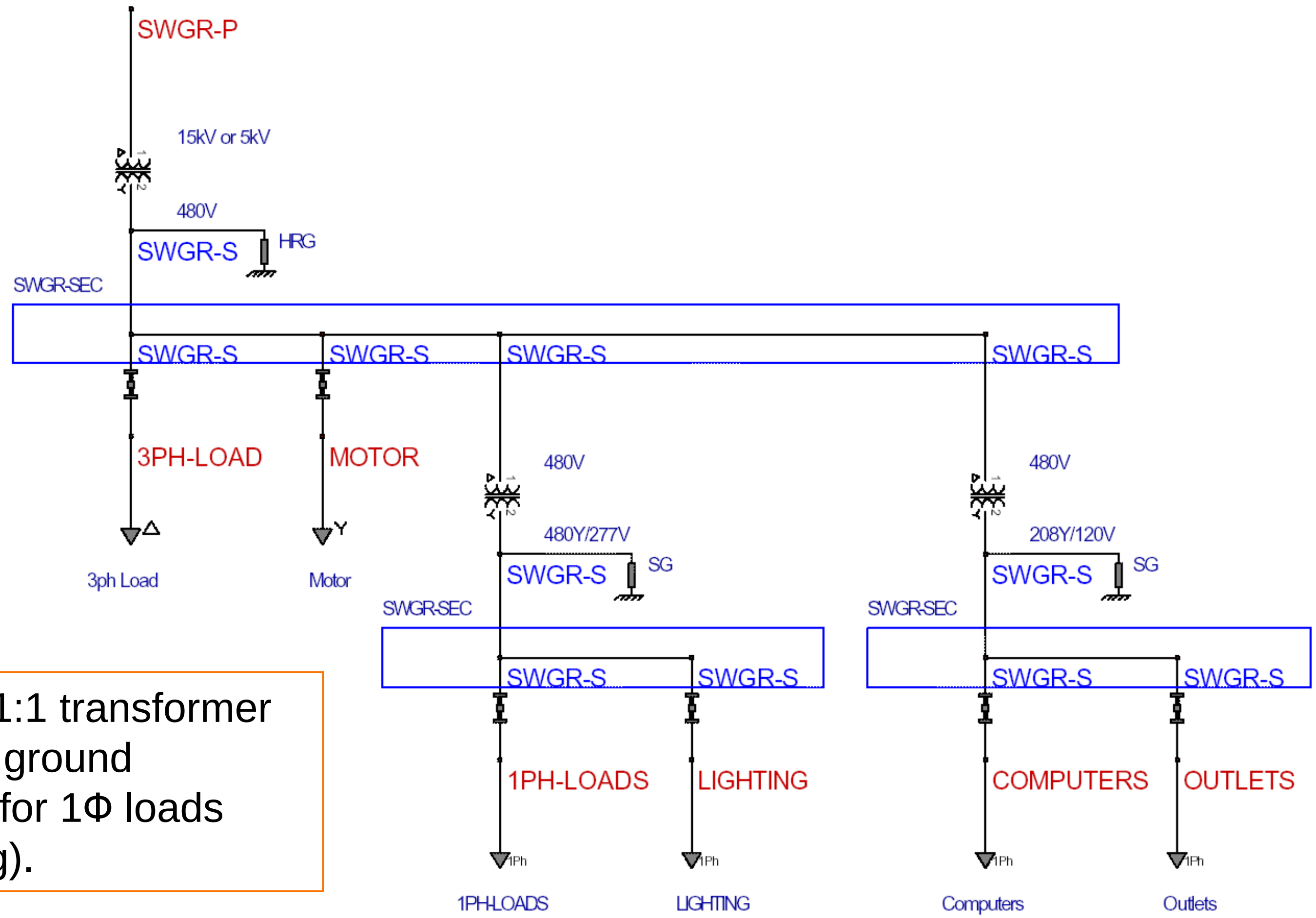
- (2) Ground detectors are installed on the system.

- (3) **Line-to-neutral loads are not served.**

Lower Incident Energy



Add small 1:1 transformer and solidly ground secondary for 1Φ loads (i.e. lighting).

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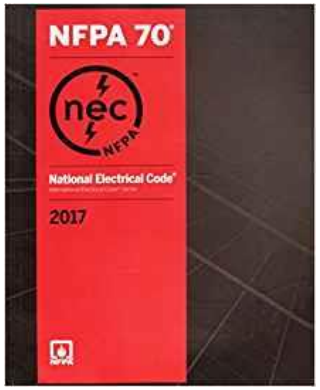
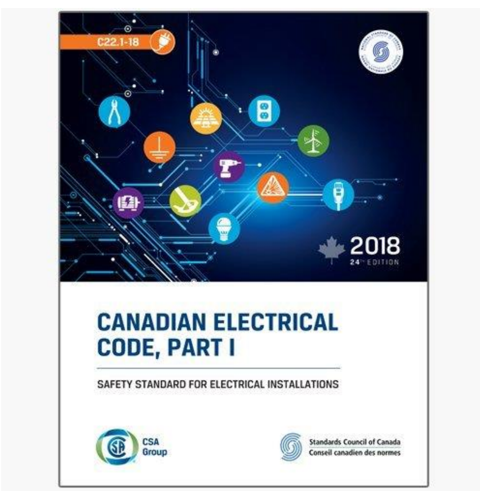
Reliability

No Unscheduled Downtime



250-36



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(2) Ground detectors are installed on the system.

(3) Line-to-neutral loads are not served.

10-302

5) On detection of a ground fault on the ungrounded conductors, an impedance grounded system shall be permitted to remain energized if

a) the system is operating at 5 kV or less;

b) the system serves no neutral loads;

c) the ground fault current is controlled at 10 A or less; and

d) the impedance grounding device is rated for continuous use.

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Manual High Resistance Grounding Fault Detection

- Normal resistor for 480V system with ground fault limited to 5A
  277V/ 5A= 55.4 ohms

- A device to reduce the value of the resistor to 27.7 ohms 40 times a minute.
  Current = 277/27 = 10A

- A clamp on ammeter places around the cables (or conduit) with the ground fault will fluctuate between 5A and 10A 40 times a minute

Effect on System Due to a Second Ground Fault

- A second fault on the system (supplied by the same transformer) will result in a phase to phase ground fault.
- This will result in tripping of one of the two circuits
- Arc Flash energy will increase
- Safety and Reliability are enhanced if two faults on the same system are prevented

Methods to Prevent Two Faults on the Same System

- 1. **Maintenance practices to detect and repair the first ground fault quickly**
  Not always possible due to various conditions
- 2. **Trip the feeder in the event of a first fault**
  instant or time selective feeder isolation
- *3.* **Detect and automatically isolate the second fault of lower priority or impact**

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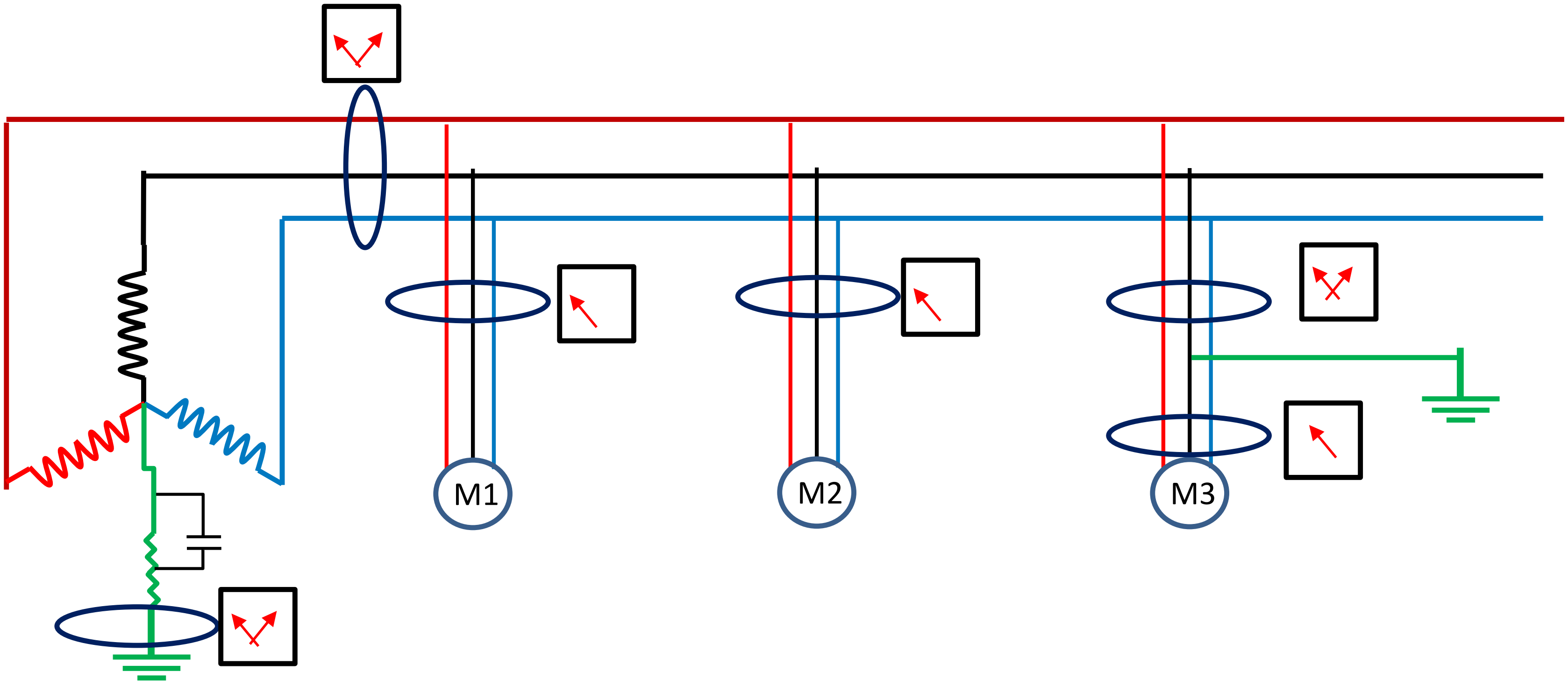
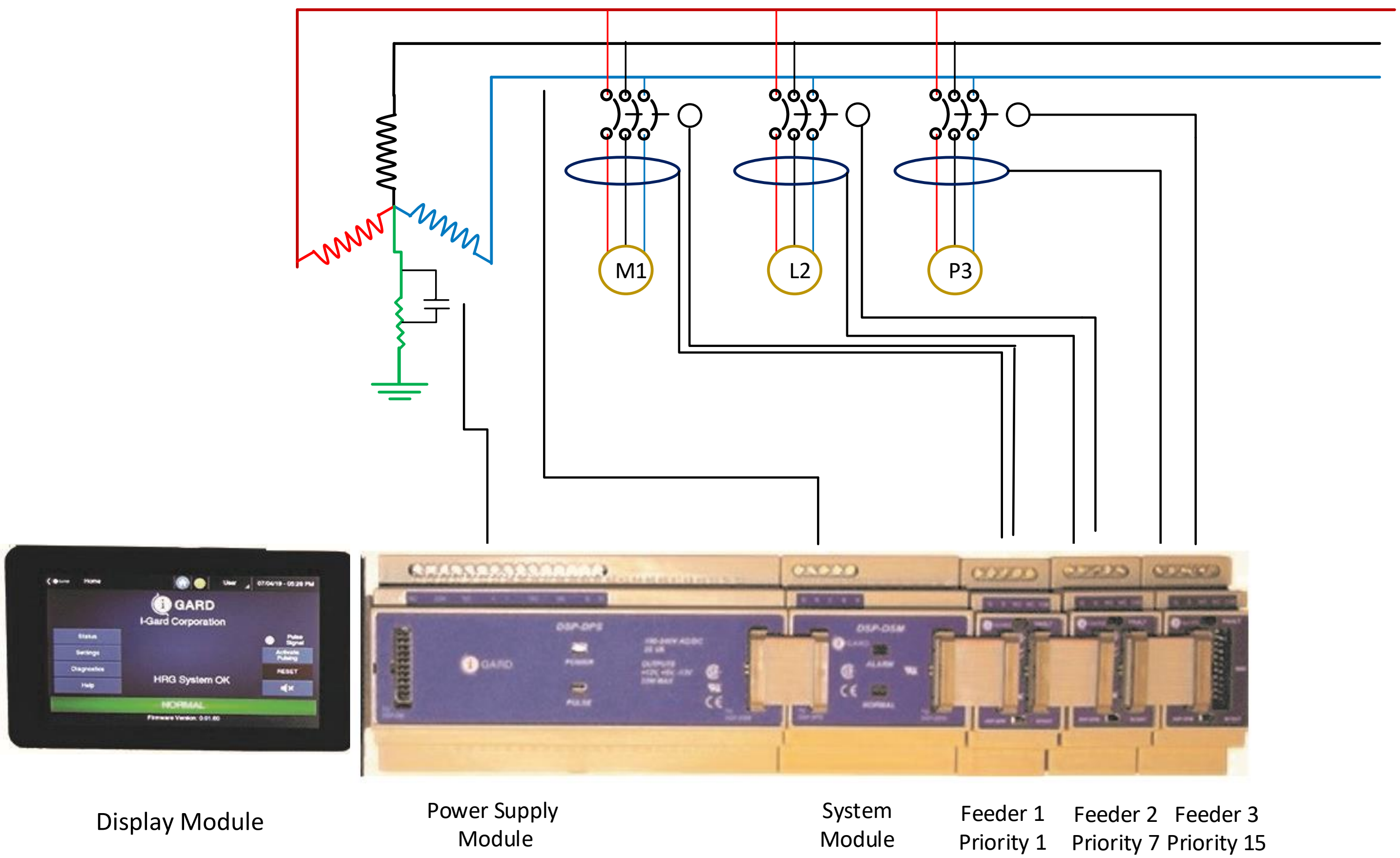


Advanced High Resistance Grounding

SIFT



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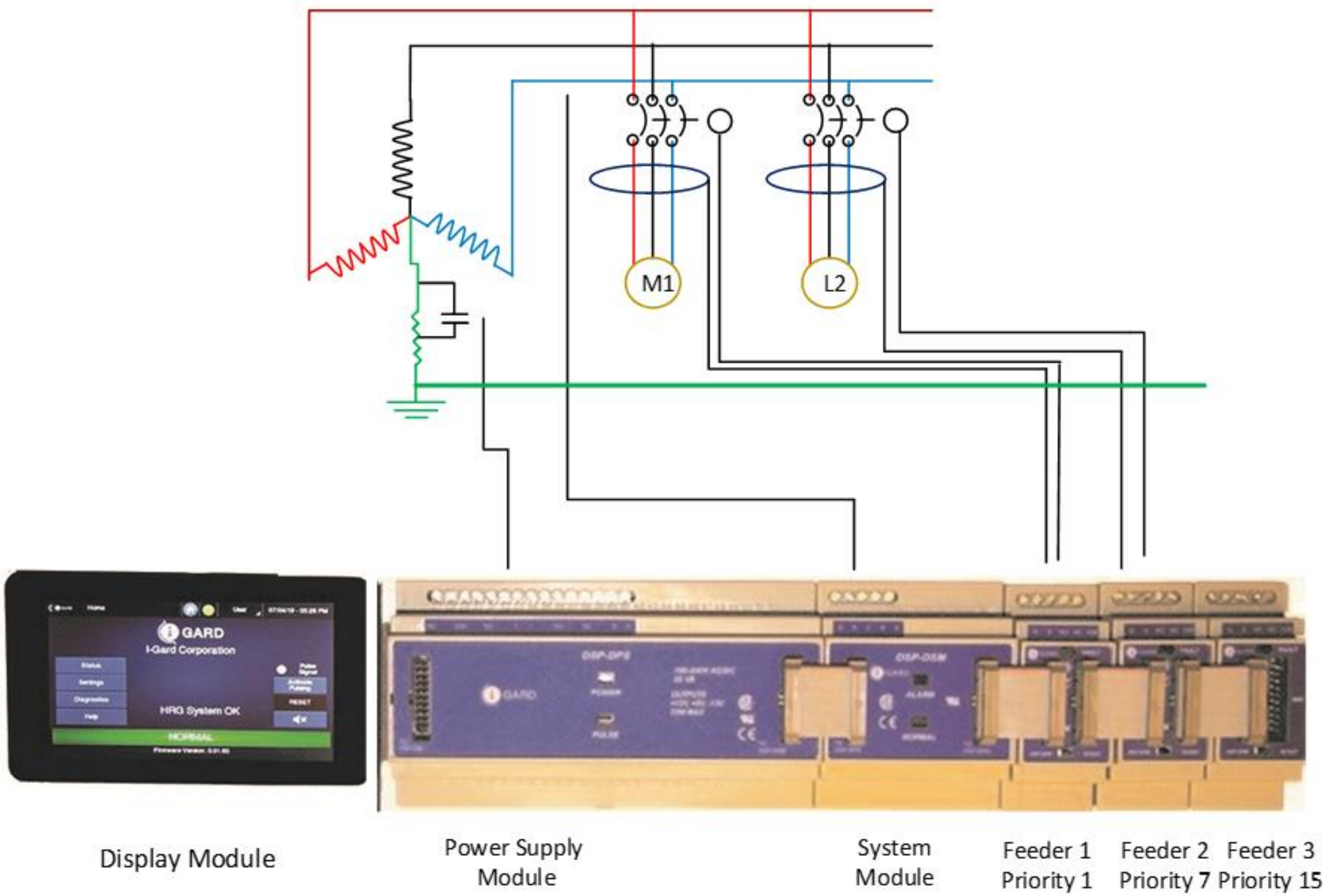
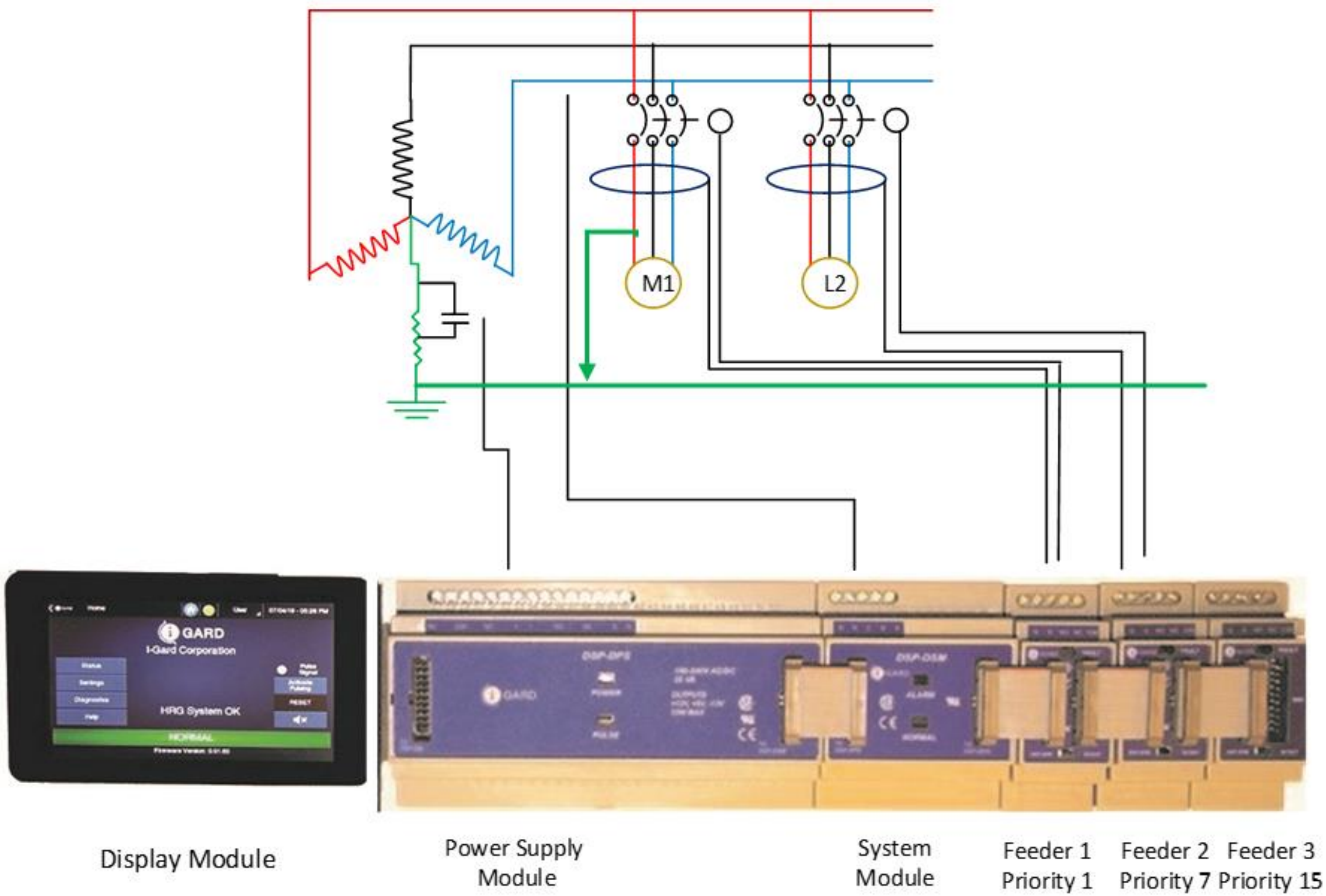
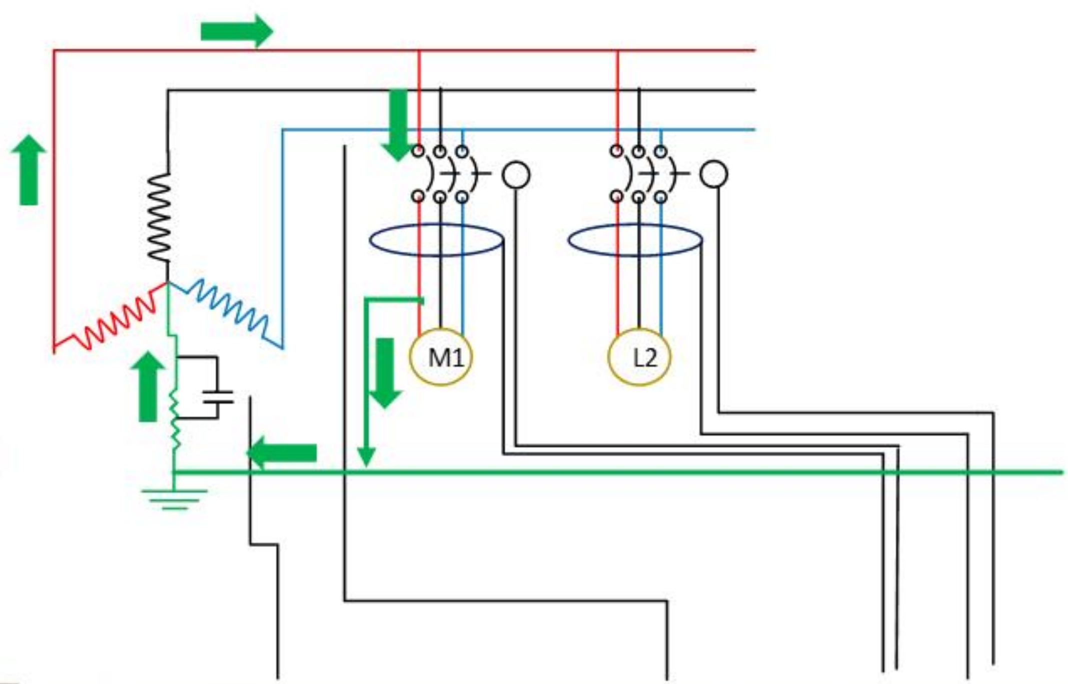



M1
L2
Display Module
Power Supply Module
System Module
Feeder 1 Priority 1
Feeder 2 Priority 7
Feeder 3 Priority 15

A Phase Faulted

I_F=5A



Display Module

Power Supply Module

System Module

Feeder 1 Priority 1

Feeder 2 Priority 7

Feeder 3 Priority 15

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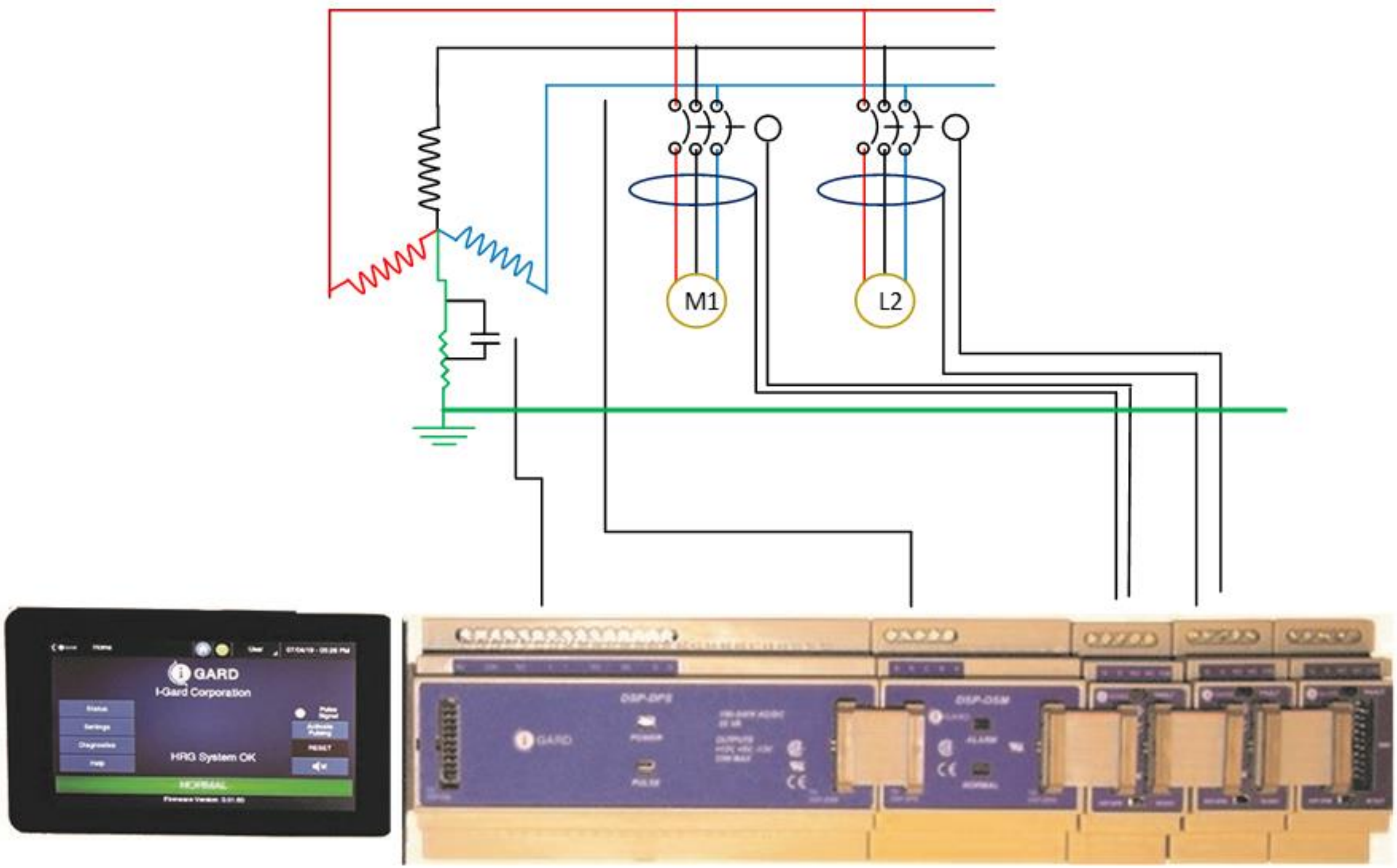
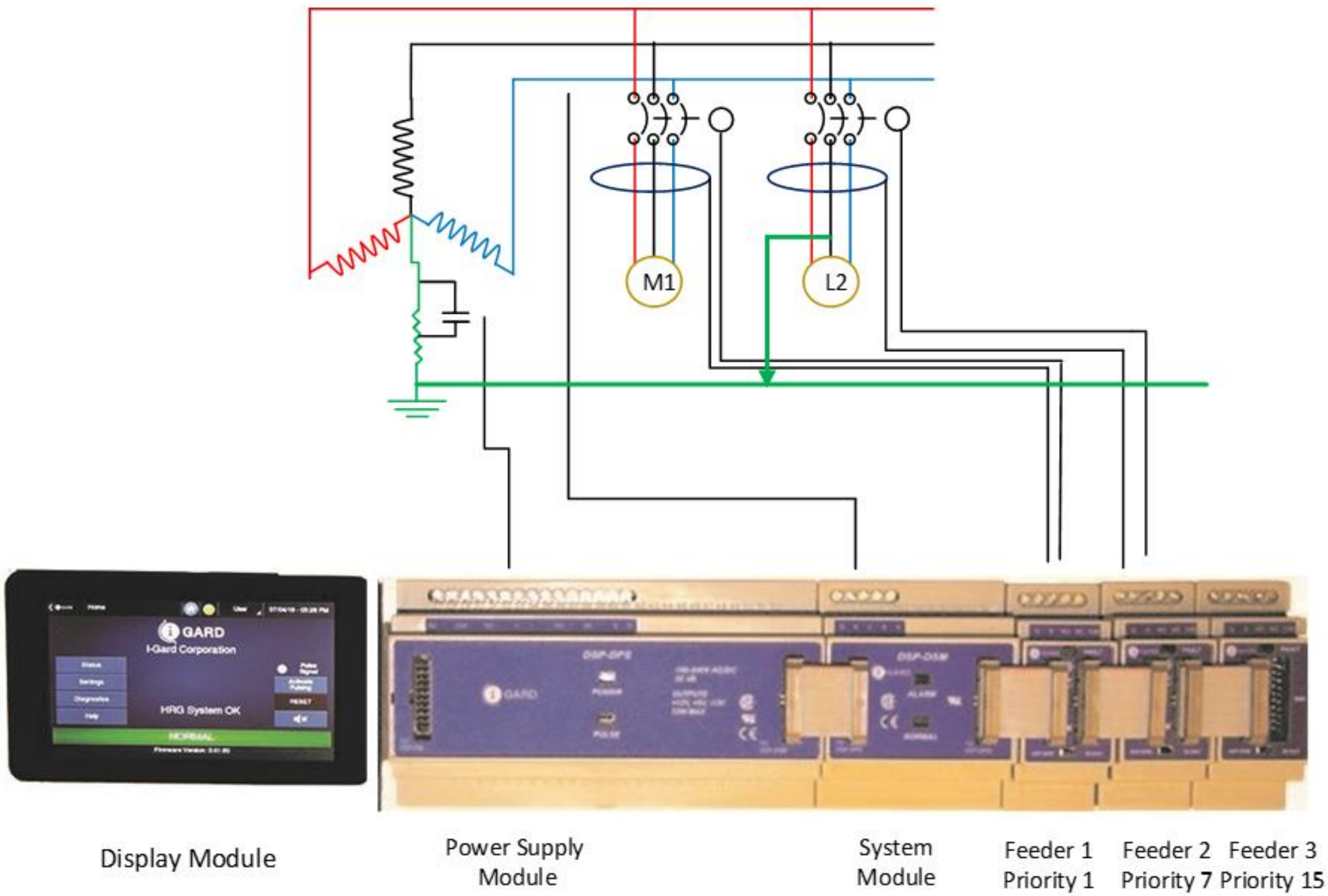
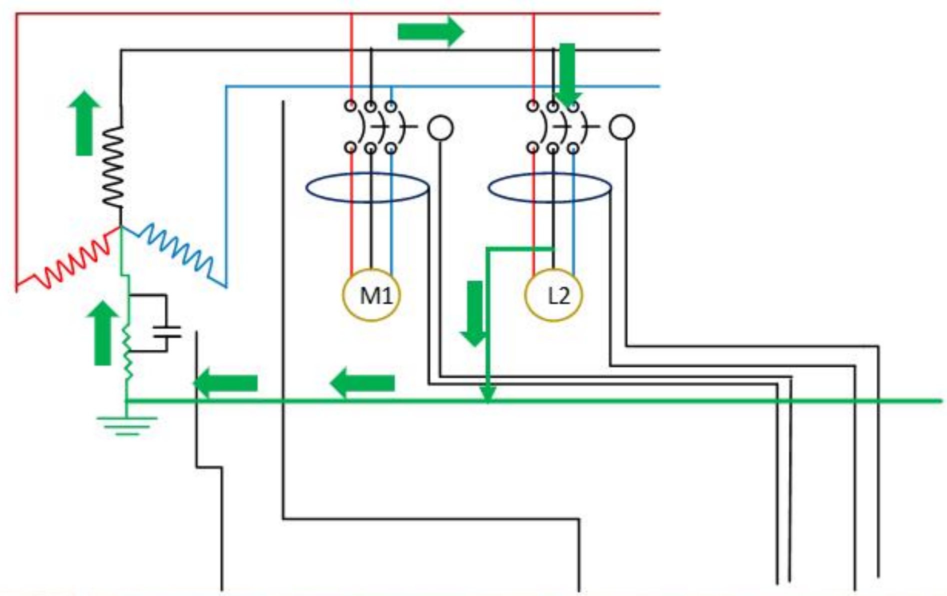



M1
L2
Display Module
Power Supply
Module
System
Module
Feeder 1
Priority 1
Feeder 2
Priority 7
Feeder 3
Priority 15



B Phase Faulted

I_F=5A

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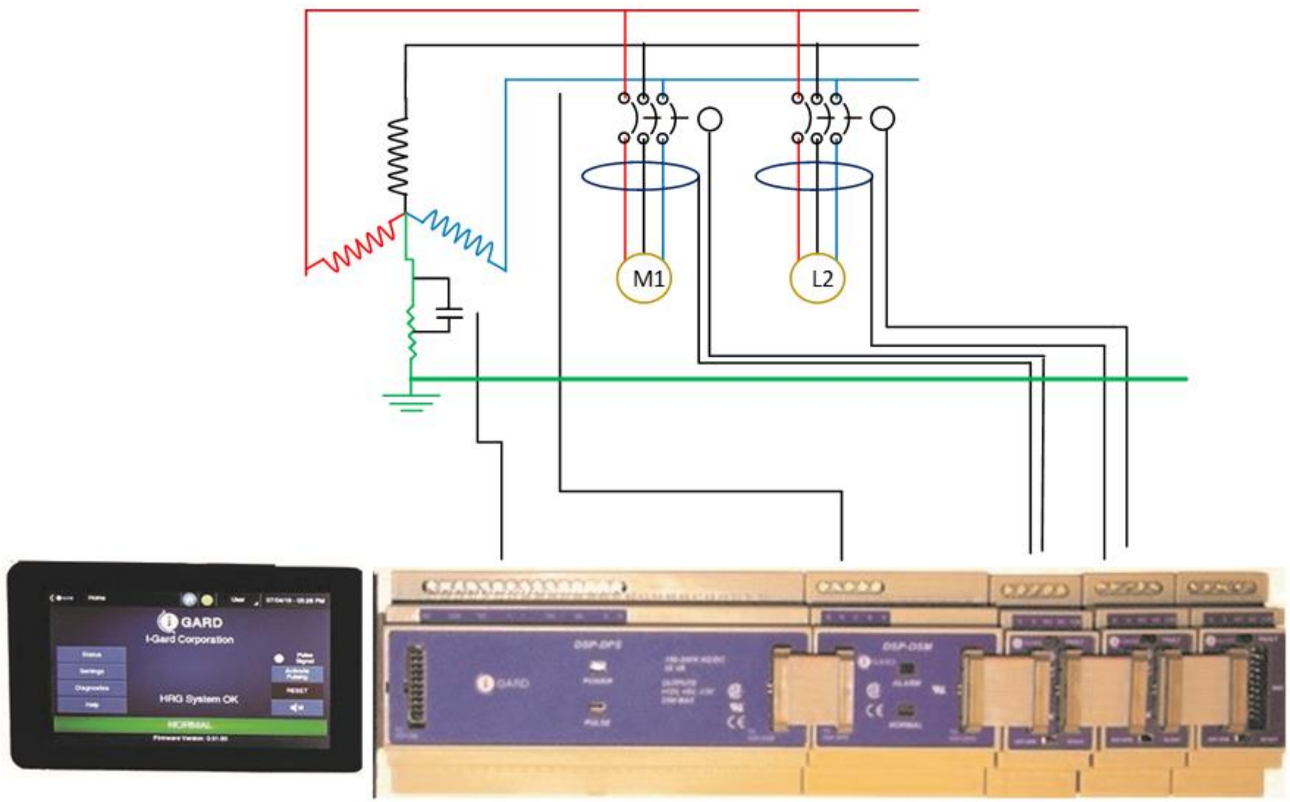

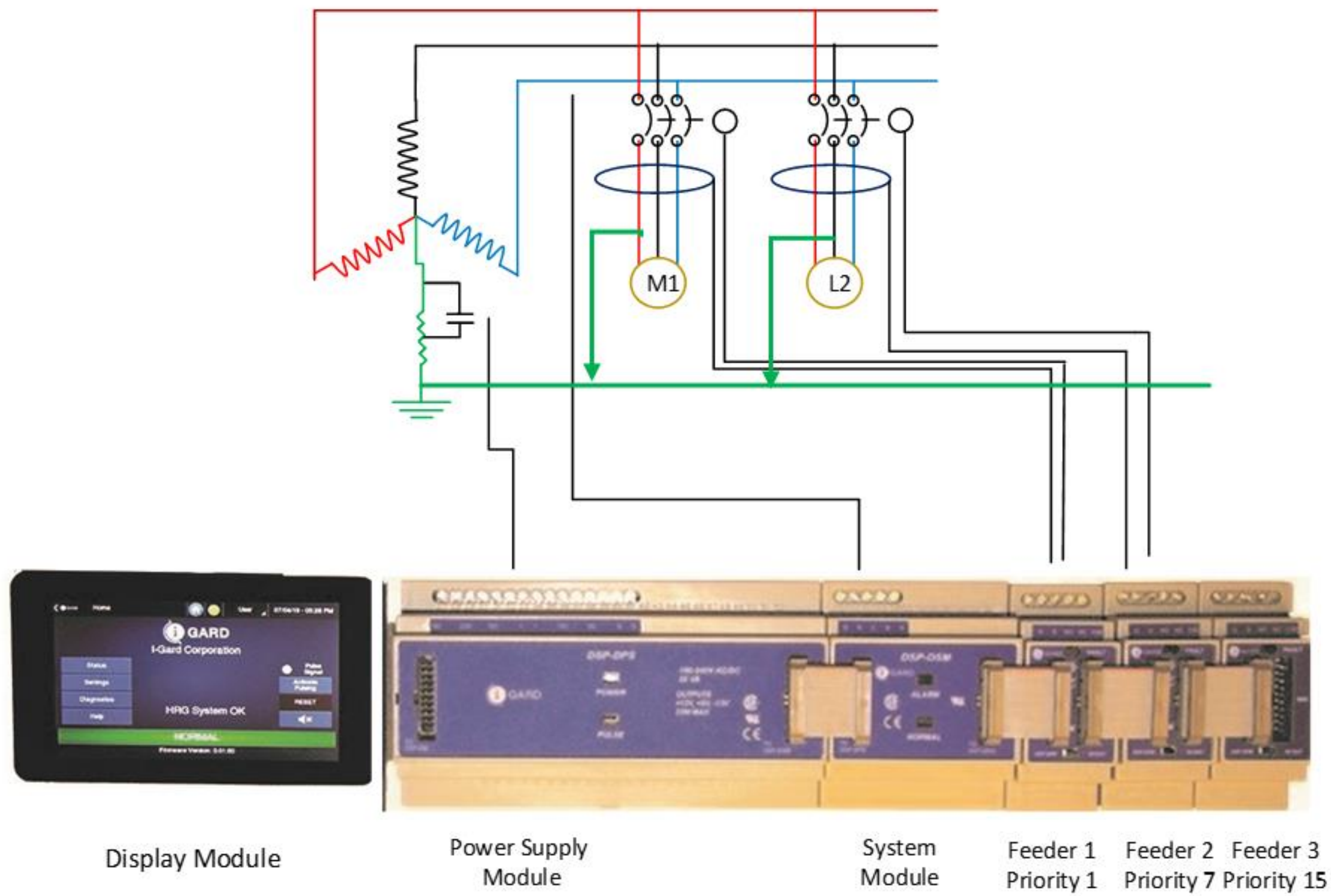
M1
L2
GARD
I-Gard Corporation
HRG System OK
NORMAL
Display Module
Power Supply Module
System Module
Feeder 1 Priority 1
Feeder 2 Priority 7
Feeder 3 Priority 15

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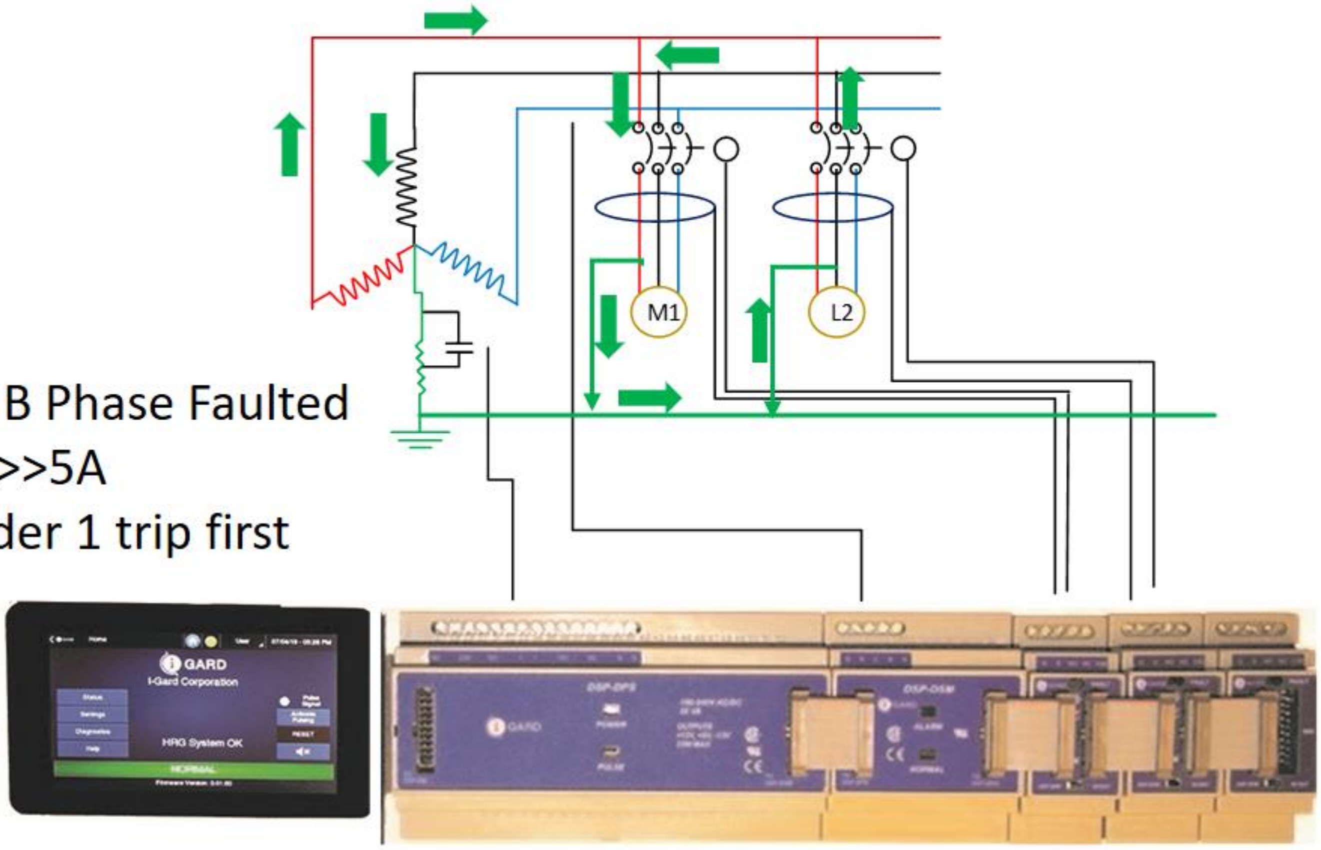
A & B Phase Faulted

I_F=>>>5A

Feeder 1 trip first



Display Module

Power Supply Module

System Module

Feeder 1 Priority 1

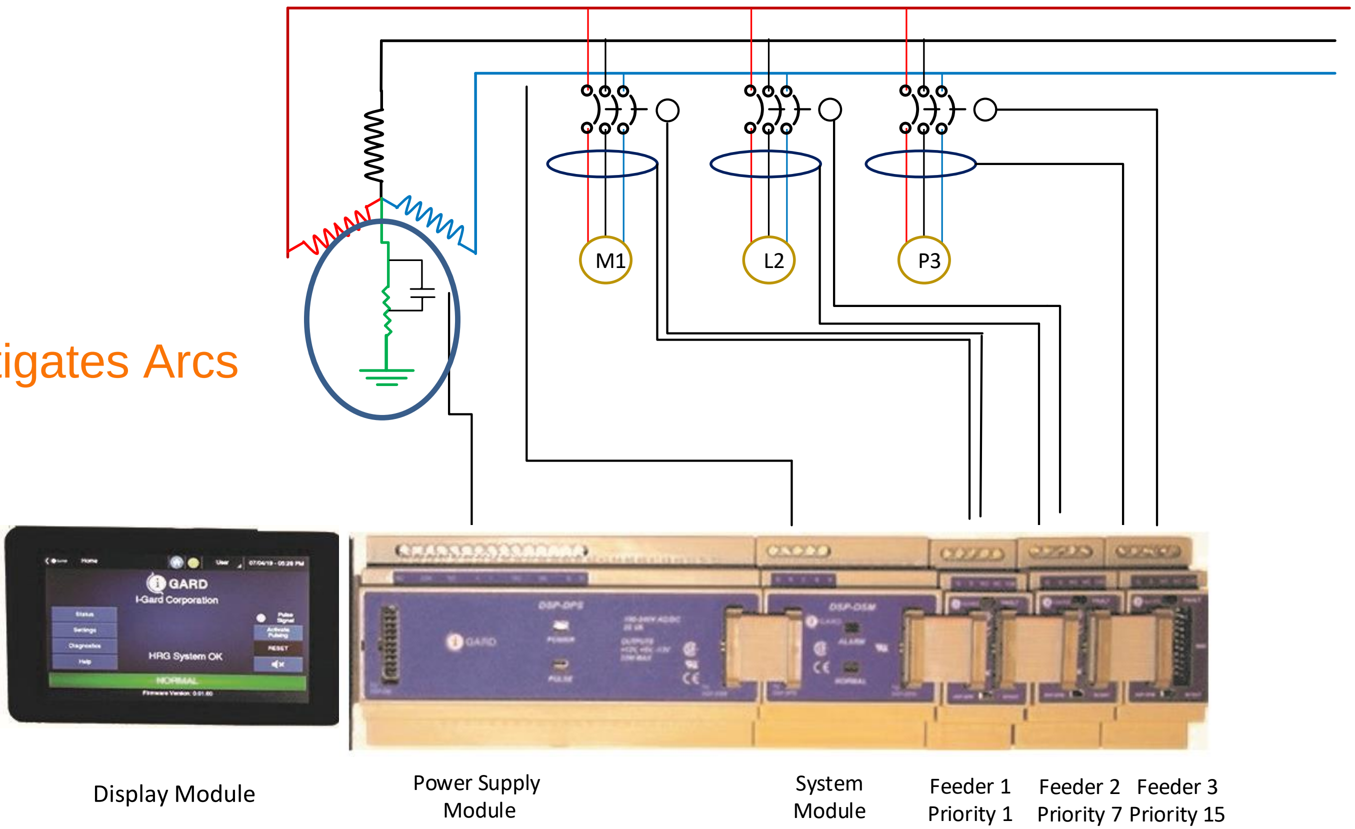
Feeder 2 Priority 7

Feeder 3 Priority 15

Advanced High Resistance Grounding

MITIGATE **95-98%** of arc flash incidents

Resistor Mitigates Arcs

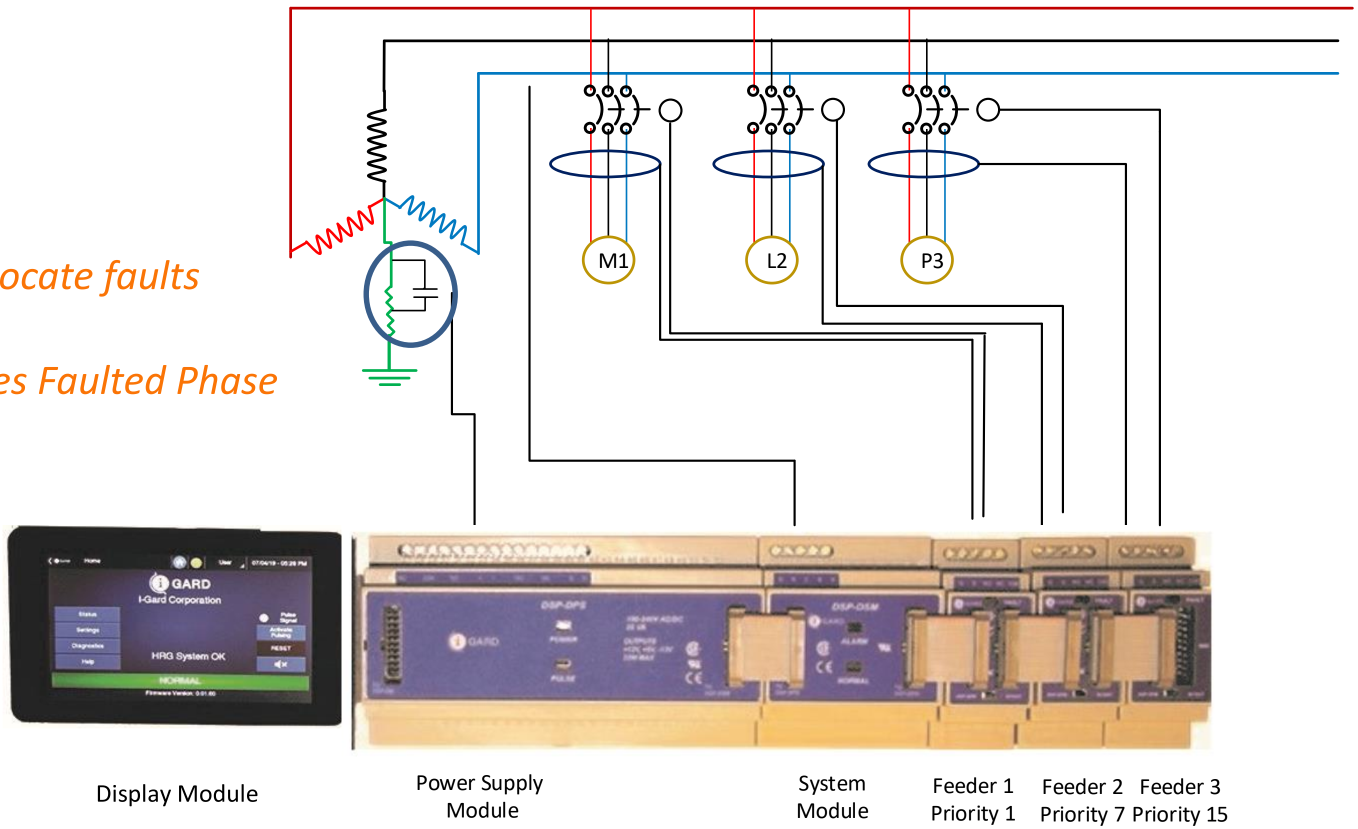


Advanced High Resistance Grounding

ASSISTED fault location

Pulsing Helps locate faults

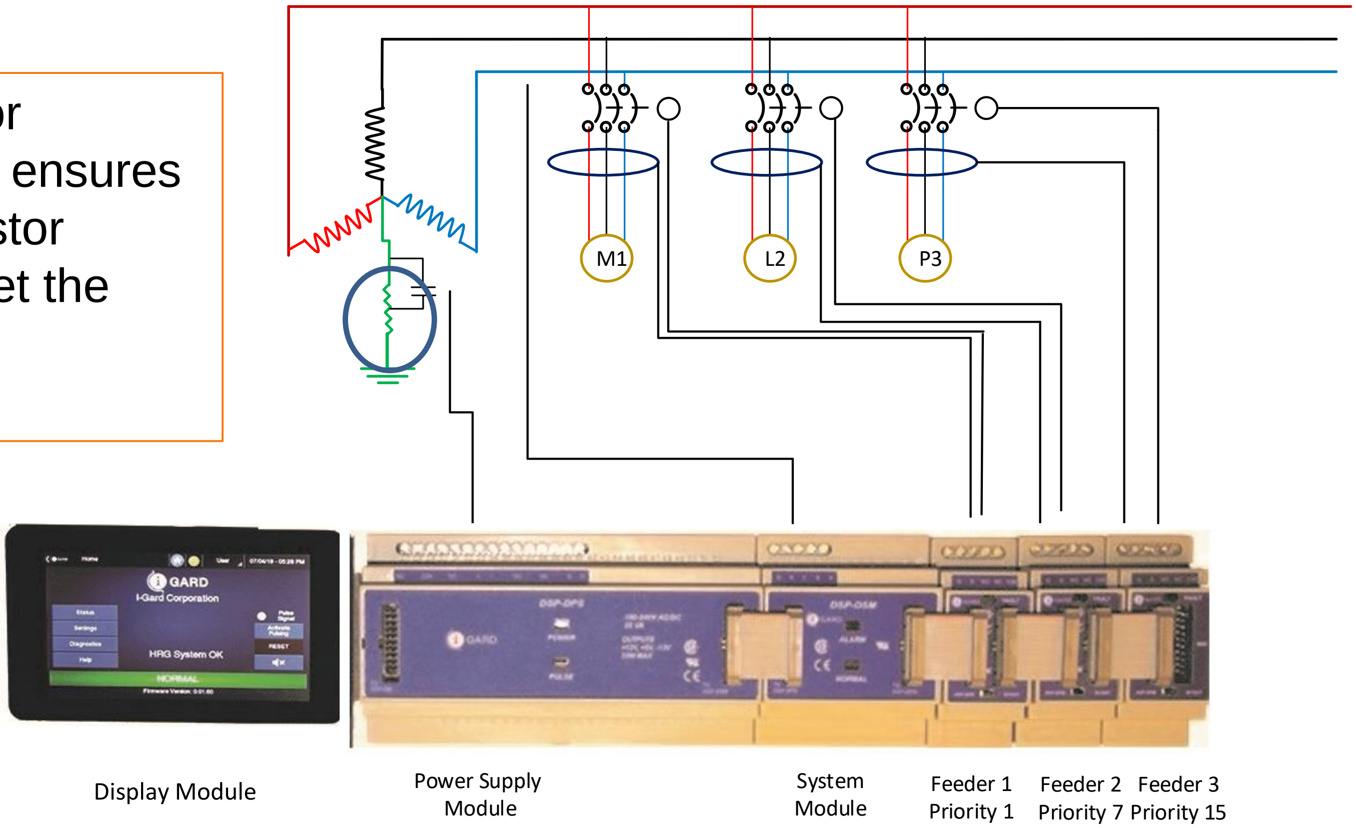
Display Indicates Faulted Phase And Feeder



Advanced High Resistance Grounding

RESISTOR-integrity monitoring

Optional Resistor Integrity Monitor ensures neutral and resistor continuity to meet the new CSA code Requirement



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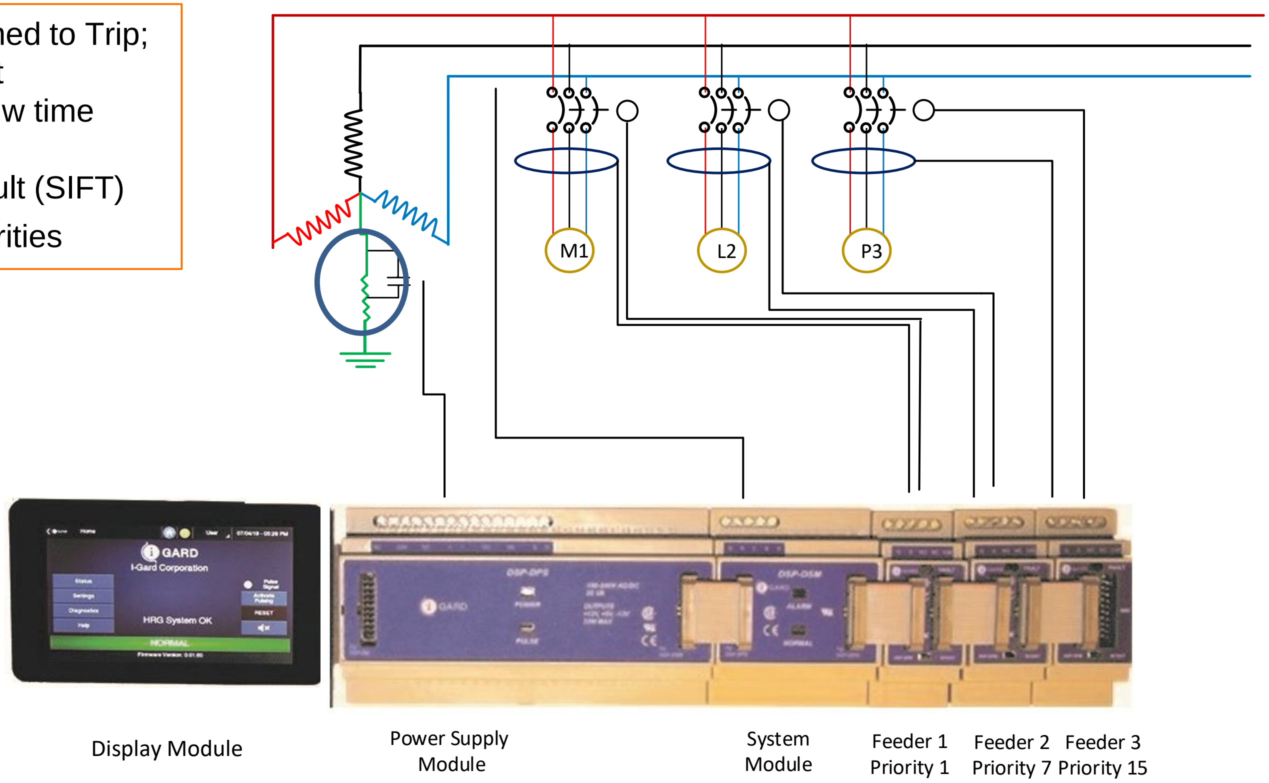
Advanced High Resistance Grounding

TIME-selective feeder isolation

Can be programmed to Trip;
1) On first Fault
2) On first fault w time delay (SIFT)
3) On Second Fault (SIFT)

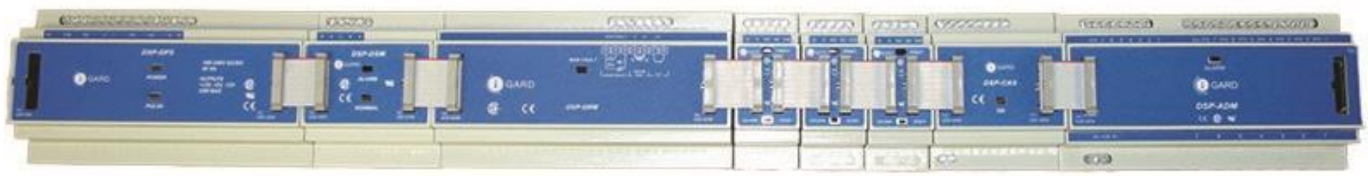
16 unique priorities



Advanced HRG Technology

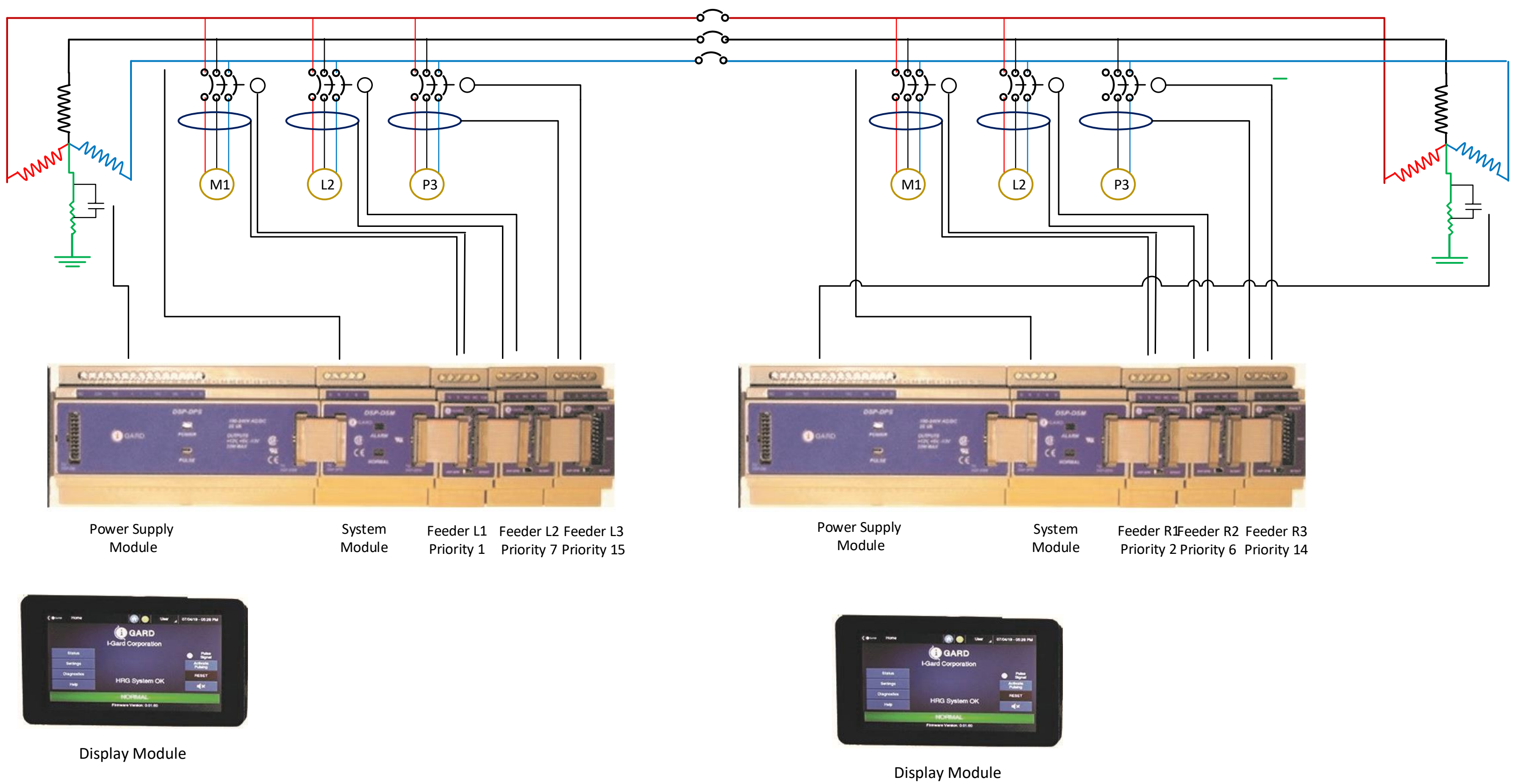
- SENTINEL HRG using the DSP OHMNI Relay system
- The only SMART HRG

- Selective instantaneous feeder trip (SIFT) – 2nd fault
- Mitigate 95-98% of arc flash incidents - on 1st phase to ground fault
- Assisted fault location
- Resistor-integrity monitoring
- Time-selective feeder isolation



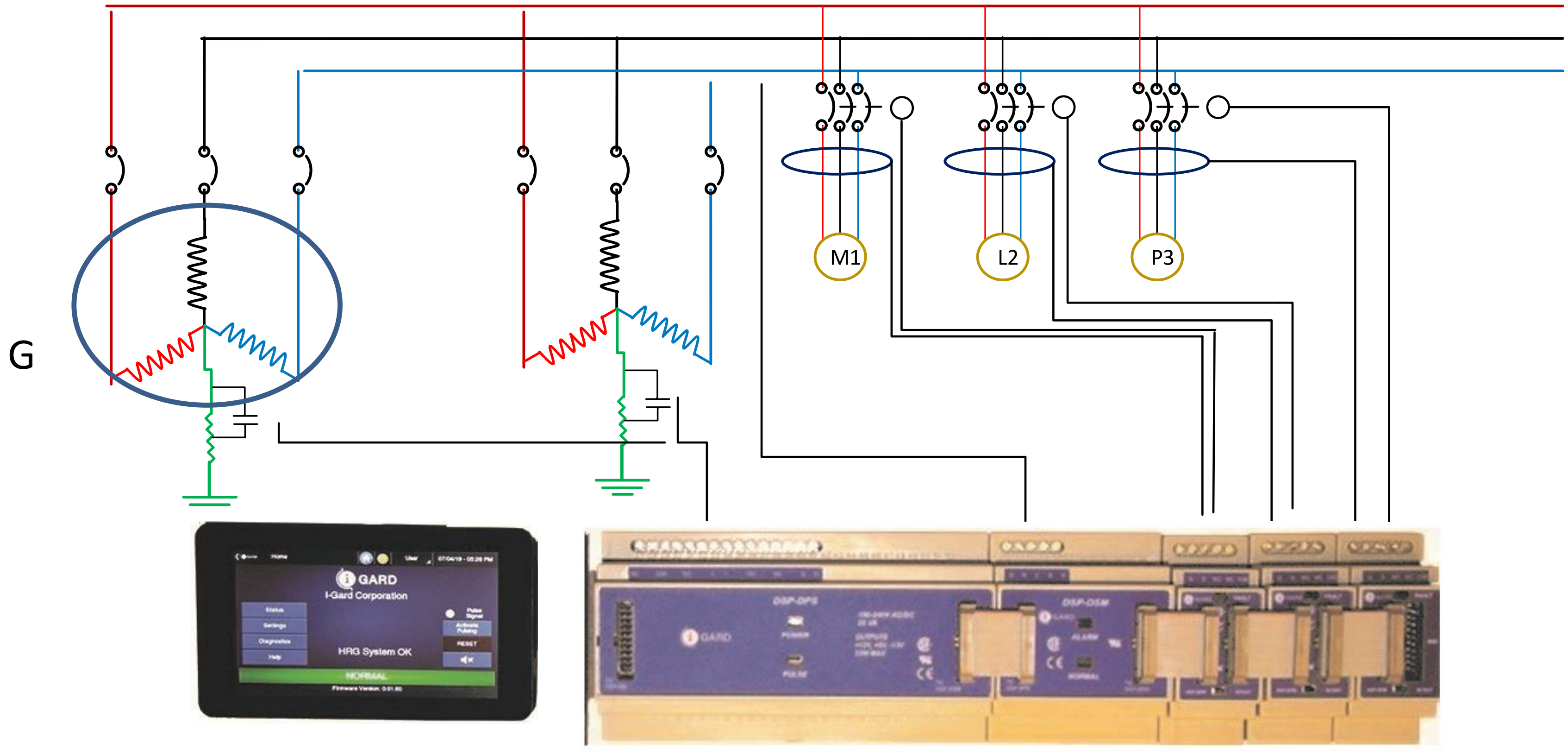
Main-Tie-Main

Designed facilitates Use with Selective Source



Typical Data Center Design

Designed facilitates Use with Selective Source



Display Module

Power Supply Module

System Module

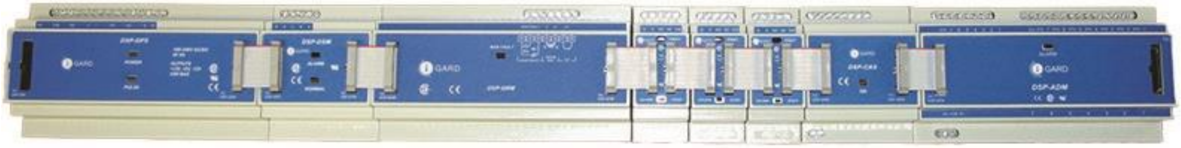
Feeder L1 Priority 1

Feeder L2 Priority 7

Feeder L3 Priority 15

Optional Arc Flash Module

- Ability to offer lower Incident Energy with New Arc Flash Module in case of phase to phase fault
- Will issue isolation command in < 1 ms on light only
- system protection for arc flash



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Economics

Item Initial Costs	Solidly Grounded	HRG
Neutral from Xfmr to Switchgear	12,500	0
Adder for Neutral Conductor	3,500	0
“G” Function of LSIG	5,000	0
HRG	0	7,500
Isolation transformer for lighting	0	1000

Exclusive of Labor $12,500 savings for HRG over solidly grounded systems

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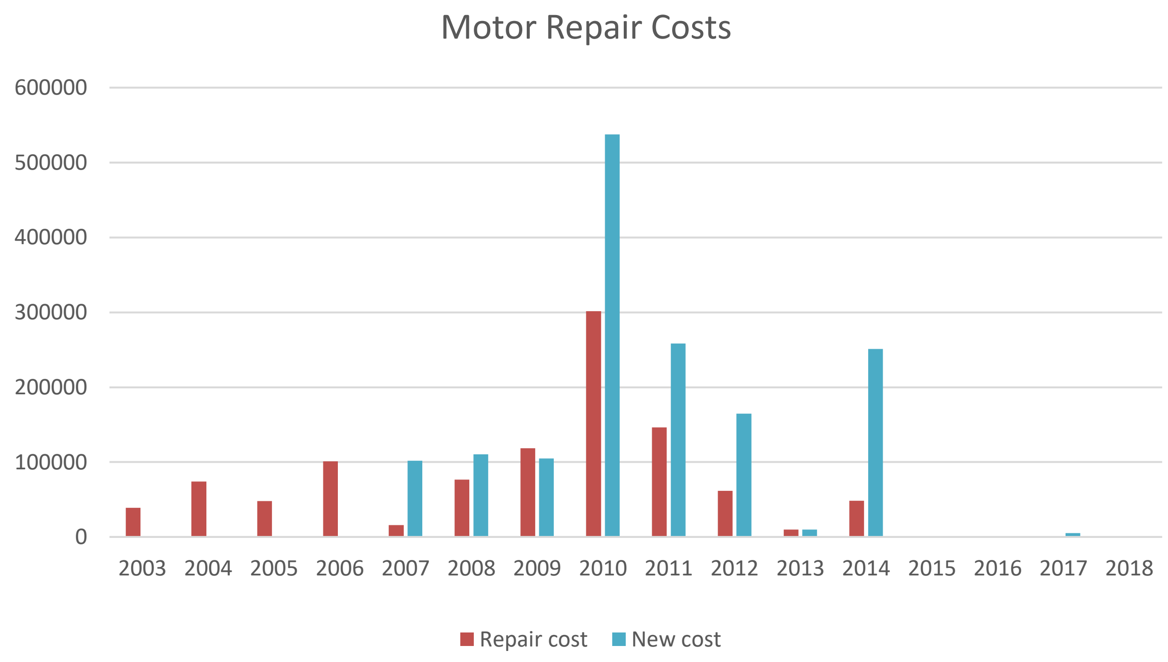
Outage Costs

Sector	Hourly Interruption Costs($)
Automotive	15,000
Food and Beverage	16,000
Plastics and Moulding	7,600
Pulp and Paper	14,000
Ticket Reservations	72,000
Data Centers	474,000
Hospitals	$$$$$$$

Motor Repair cost

Reduction in repair cost after HRG installation



Project completed in 2015

2012 & 2014 costs on solidly grounded systems only

More than 100 transformers changed from Solidly grounded to HRG Starting in 2012 and completed in 2015

3 Reasons to Consider the Change

- Risk management and mitigation of electrical hazards including arc flash and shock.
- Increased process reliability through the reduction in unscheduled process outages
- Lower operational costs through reduction in equipment repair costs and more effective utilization of maintenance resources.