Breaker Basics and New Technology

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Purpose

The purpose of this presentation is to briefly overview molded case circuit breakers, identify some common application errors, and to introduce some 'newer' concepts in breaker protection such as in home safety.

Circuit Breaker History

- First Developed at the request of Fire Inspection Authorities in the US in the 1920's to provide better protection against fires.
- These fires were caused by users of electrical power who were bridging plug fuses with pennies or replacing fuses with ratings too high for the wires installed.
- Modern breaker design was primarily made possible by the development of the arc chute by Dr. Slepian of Westinghouse.

Breaker Classifications

- MCCB – Molded Case Circuit Breaker
  - This presentation is primarily about MCCB's
- ICCB – Insulated Case Circuit Breaker
  - Same standard as MCCB's with some features found in LVPCB's
- LVPCB – Low Voltage Power Circuit Breaker

Marking and Terminology

Molded Case Circuit Breakers Marking and Terminology

- Voltage Rating
  - RMS AC voltage or DC Voltage at which the breaker is designed to operate.
  - Breaker voltage markings on MCCB's are significant and relate to the systems they may be used in.
    - "Straight ratings" – 600V, 480V, 240V
    - "Slash ratings" – 600Y/347V, 120/240V
- Current Rating
  - RMS AC current or DC current rating which the breaker will carry continuously in open air.

Molded Case Circuit Breakers Marking and Terminology

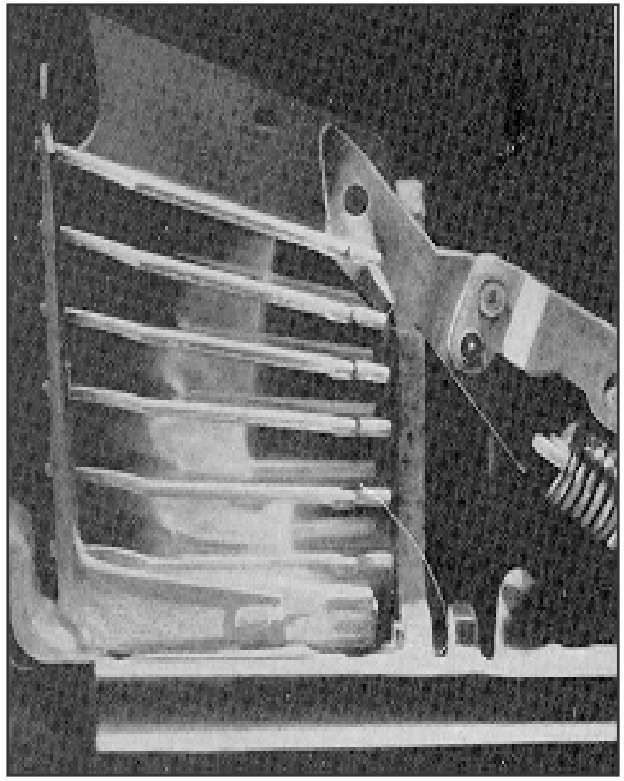
- Ambient Temperature
  - Temperature of the air surrounding the breaker itself
  - Not necessarily room temperature
- Interrupting Rating
  - Highest RMS symmetrical AC (or DC) current which a breaker is required to interrupt under specified test conditions.
- Switching Duty Rated
  - Breakers marked with SWD for breakers tested to switch florescent lighting loads on a regular basis.
- 100% Rated Breakers
  - Breakers must be marked specifically for 100% continuous operation in enclosures. All others are 80%.

Breaker Elements

Circuit Breaker Components

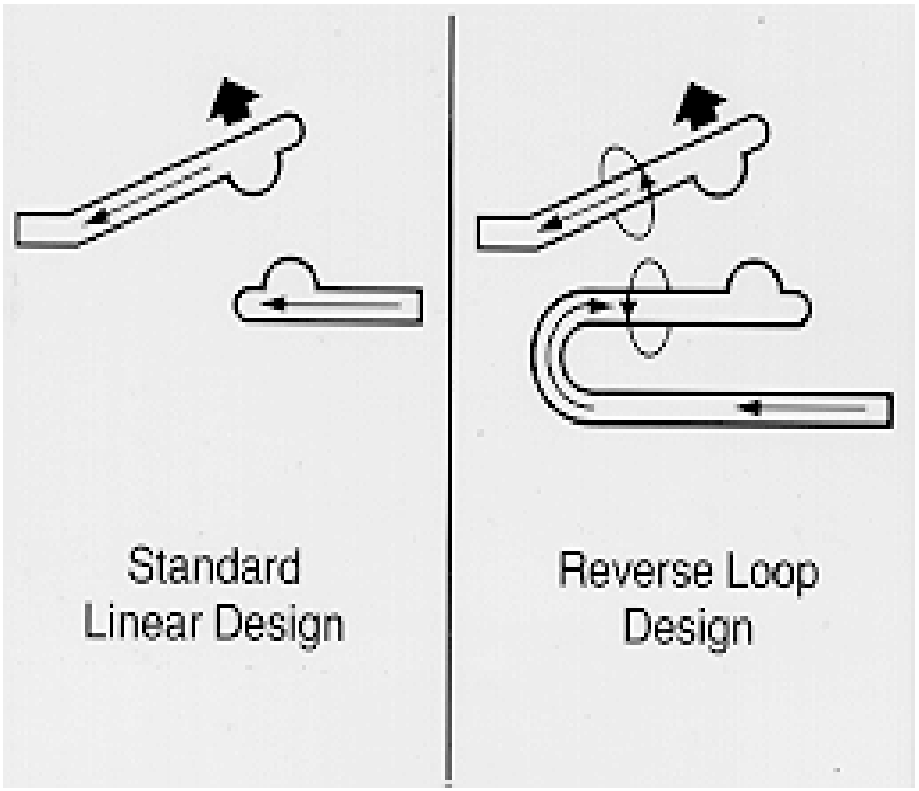
Arc Extinguisher / “Arc Chutes”

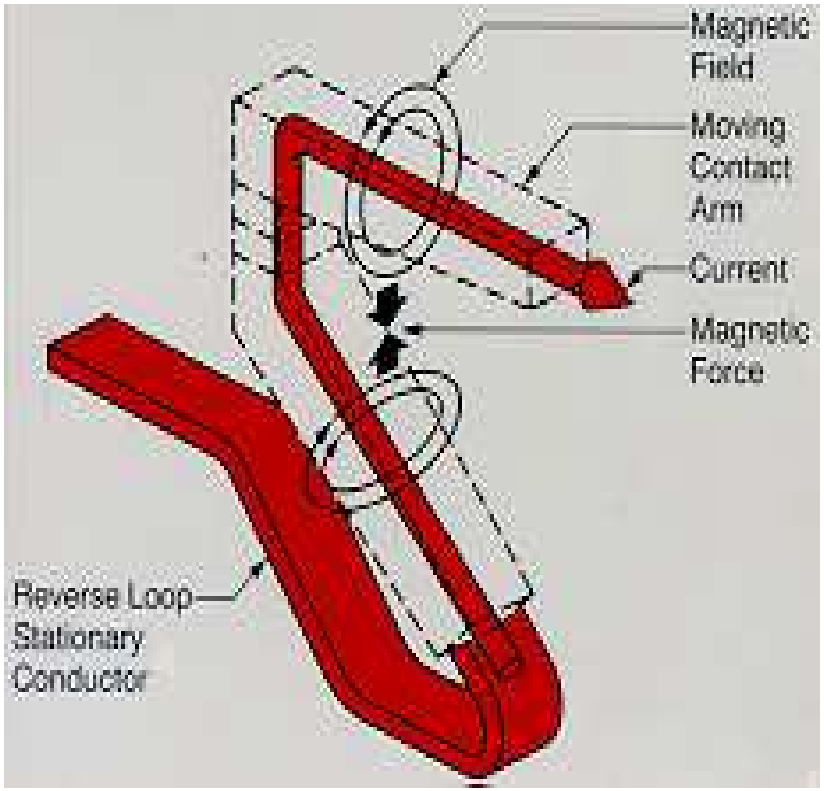
- Contact parting creates arc
- Magnetic field pulls arc into arc extinguisher
- Arc divided and cooled by steel plates
- Arc extinguishes, opening circuit



Circuit Breaker Components

Contact Assemblies





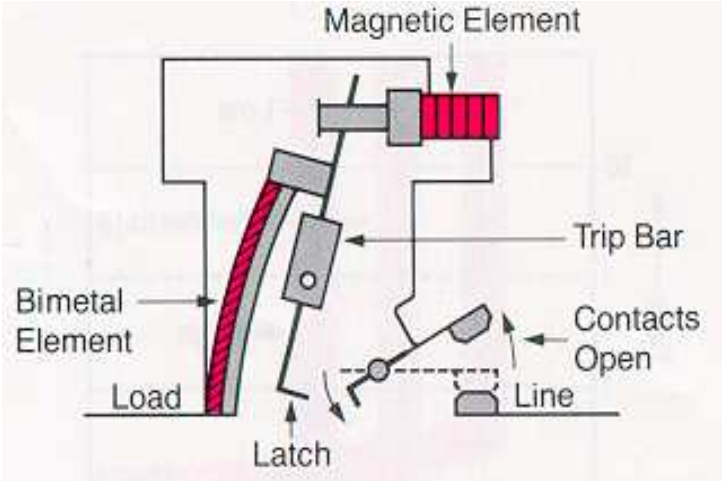
Circuit Breaker Components

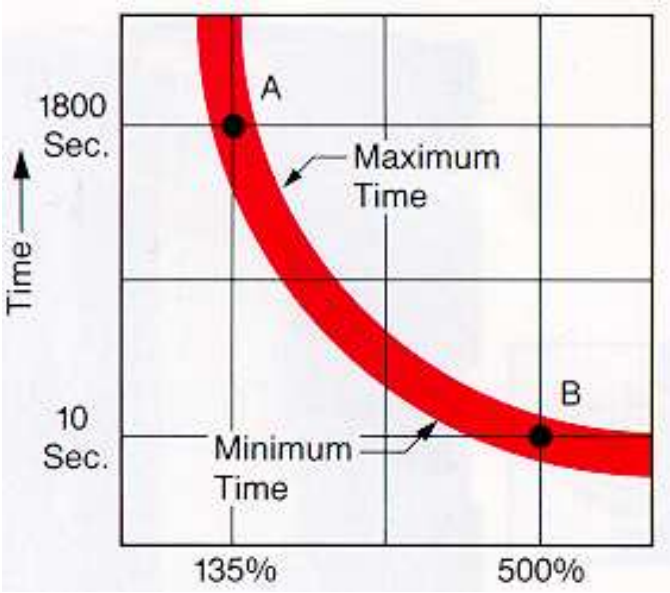
Overload Protection

- Bimetallic element
- Bimetal in series with connected cable
- Thermal “memory”

Circuit Breaker Components

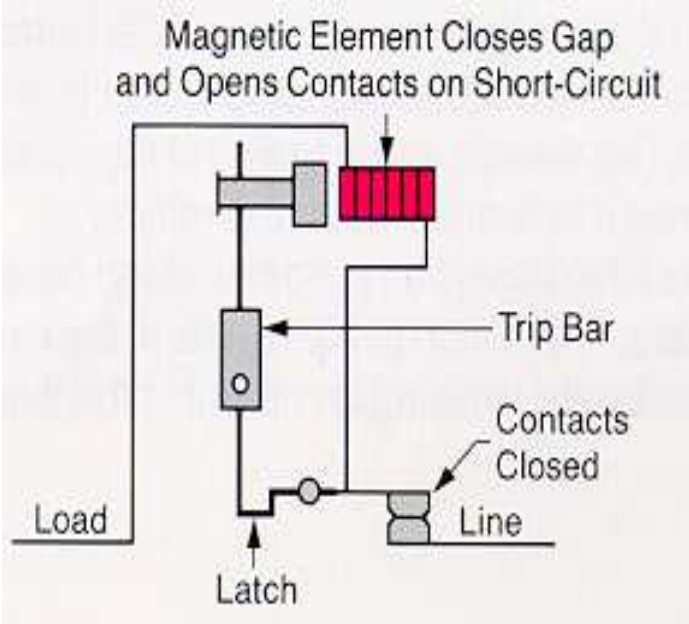
Overload Protection

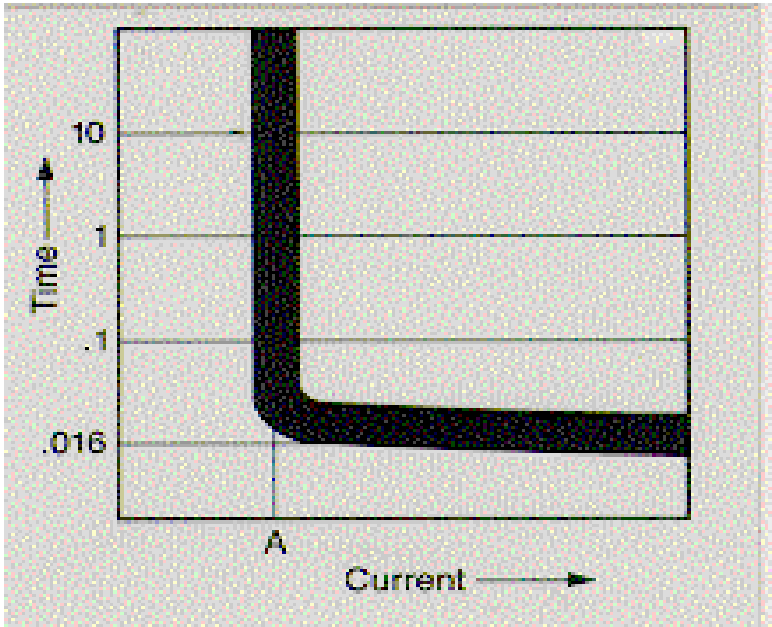




Circuit Breaker Components

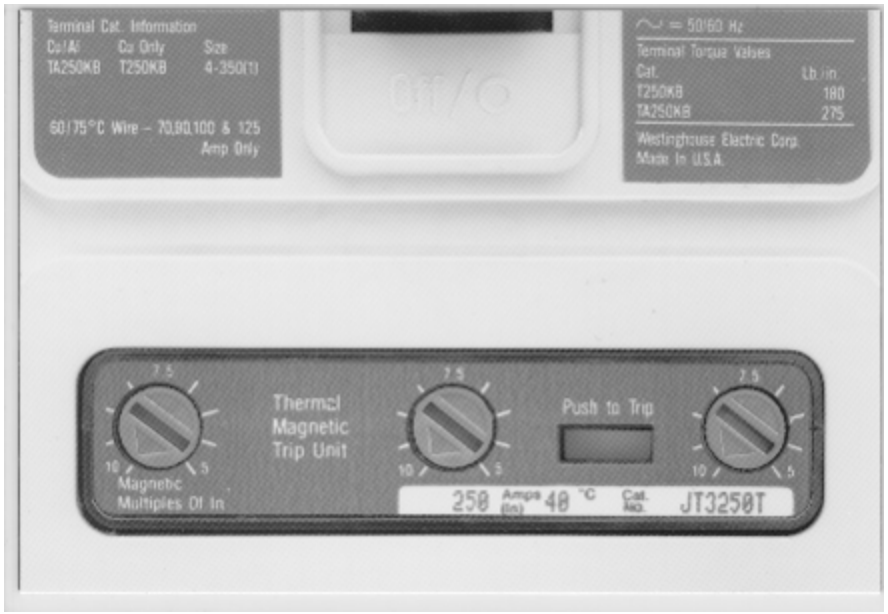
Short-Circuit Protection

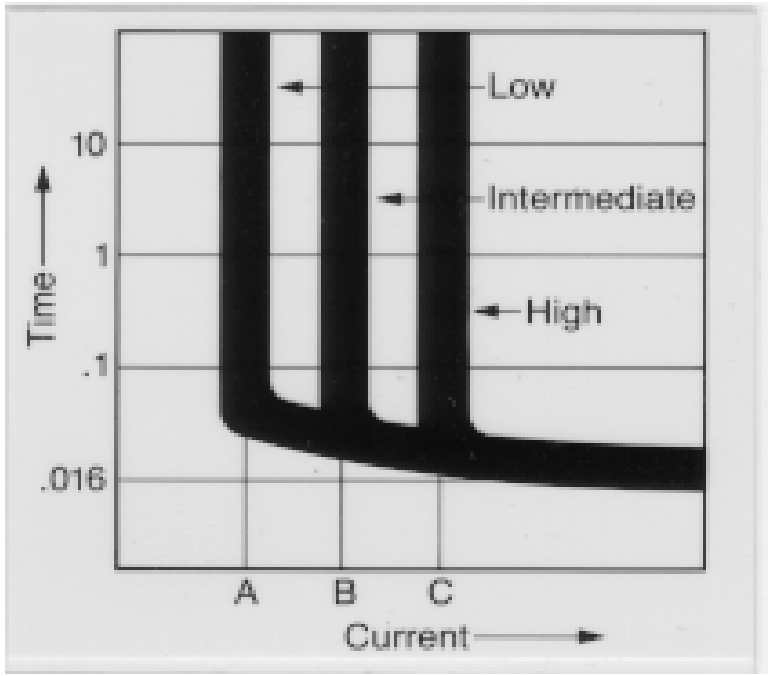




Circuit Breaker Components

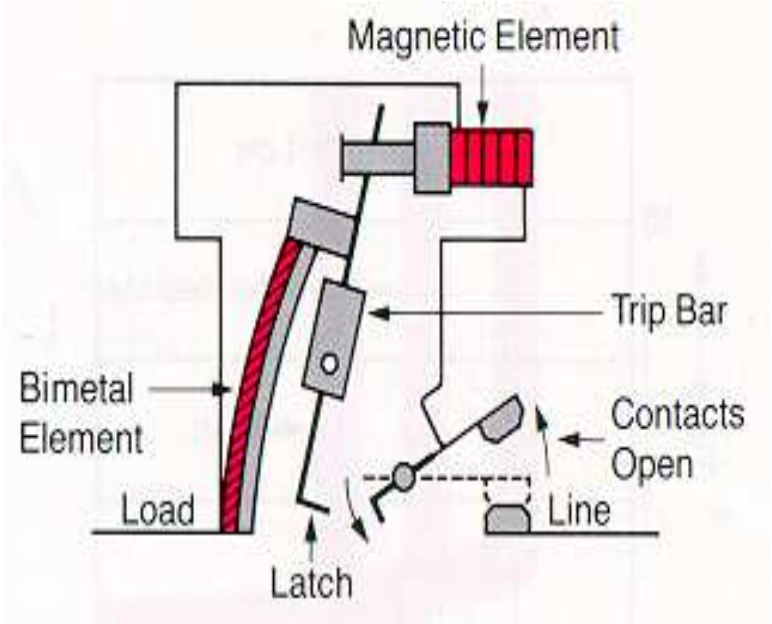
Short-Circuit Protection

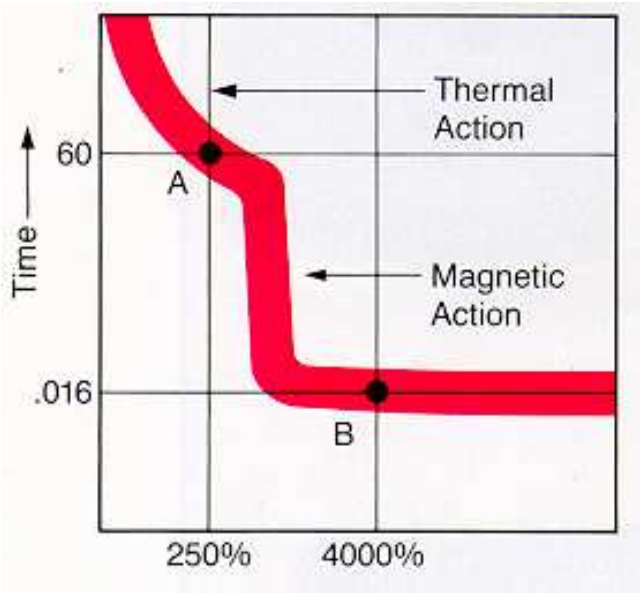




Circuit Breaker Components

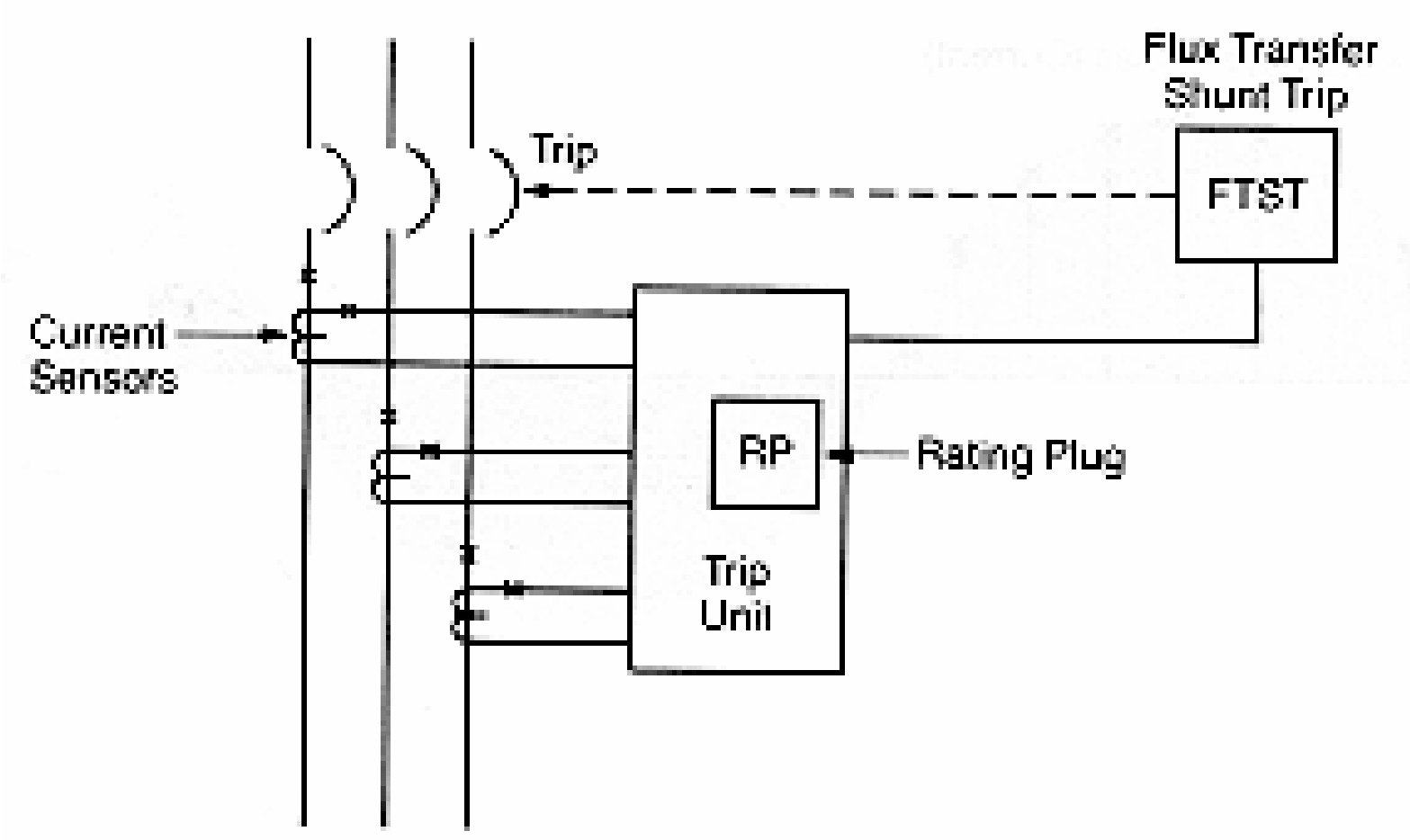
Thermal Magnetic Protection





Circuit Breaker Components

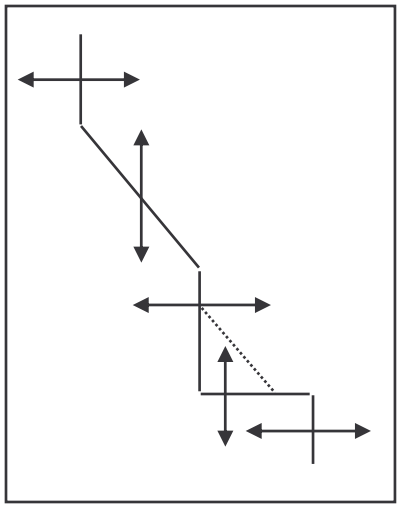
Electronic Circuit Breakers



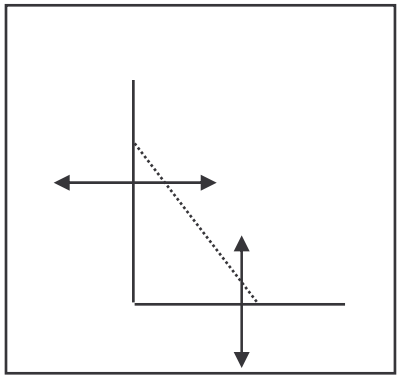
Circuit Breaker Components

Electronic Circuit Breakers

Thermal	**L**ong Time Pickup
	Long Time Delay Time
Magnetic	**S**hort Time Pickup
	Short Time Delay
	Instantaneous Pickup
Ground	**G**round Fault Pickup
	Ground Fault Delay



LSI



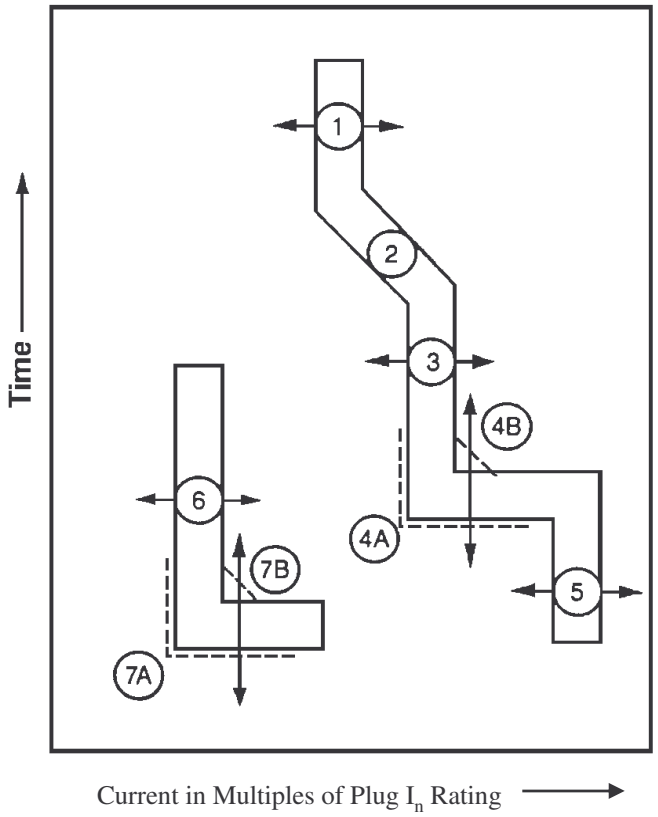
Ground

Electronic Trip Units

Trip Functions

Curve Shaping

The Basis for Coordination



THERMAL

1. Long Time Pickup (80%-160%)
2. Long Time Delay

MAGNETIC

3. Short Time Pickup (400% - 1000%)

4A. Short Time Delay Flat Response

4B. Short Time Delay I^2t Response (0.1-0.5s)

5. Instantaneous / Fixed Inst. Override ~~(500%-1500%)~~

GROUND FAULT

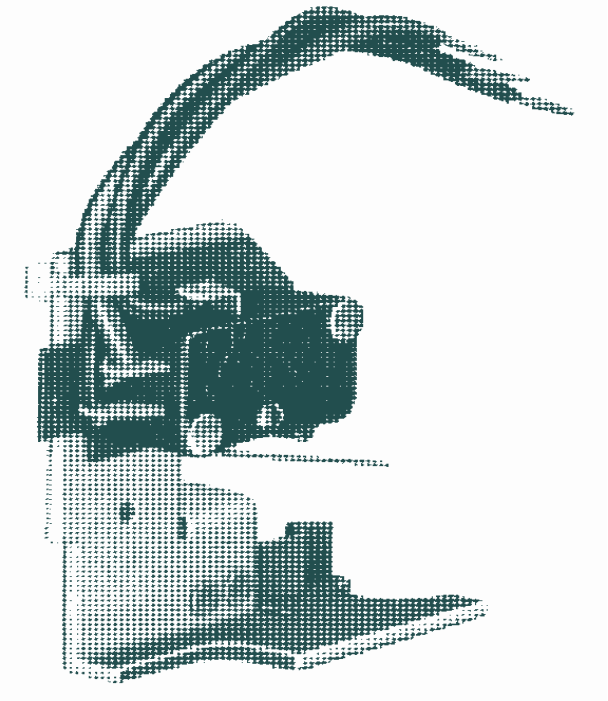
6. Ground Fault Pickup

7A. Ground Fault Delay Flat Response

7B. Ground Fault Delay I^2t Response

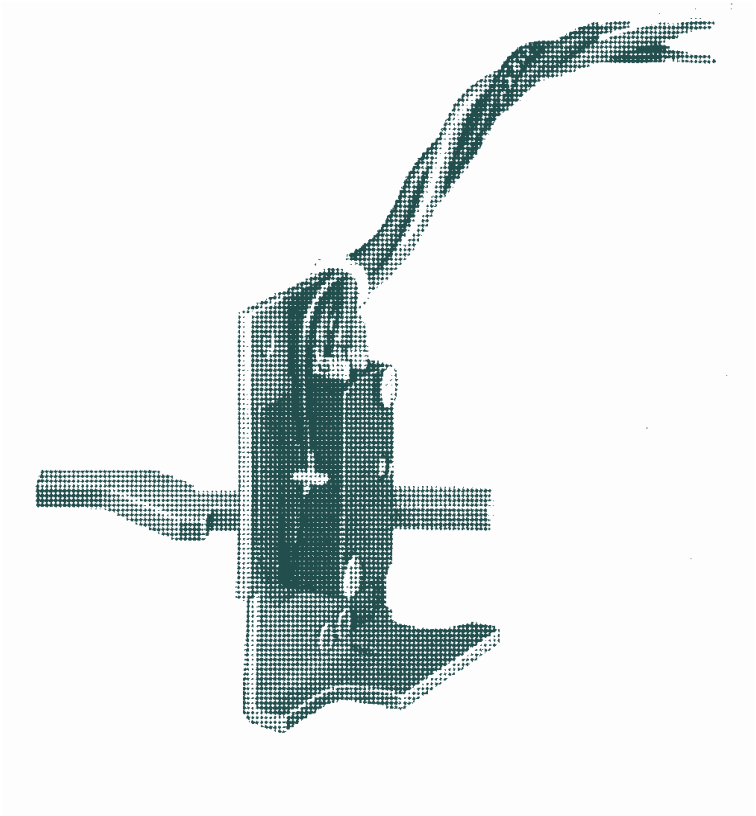
Auxiliary Switch

- Consists of contacts that are activated by the opening and closing of breaker.



Bell Alarm/Lockout Switch

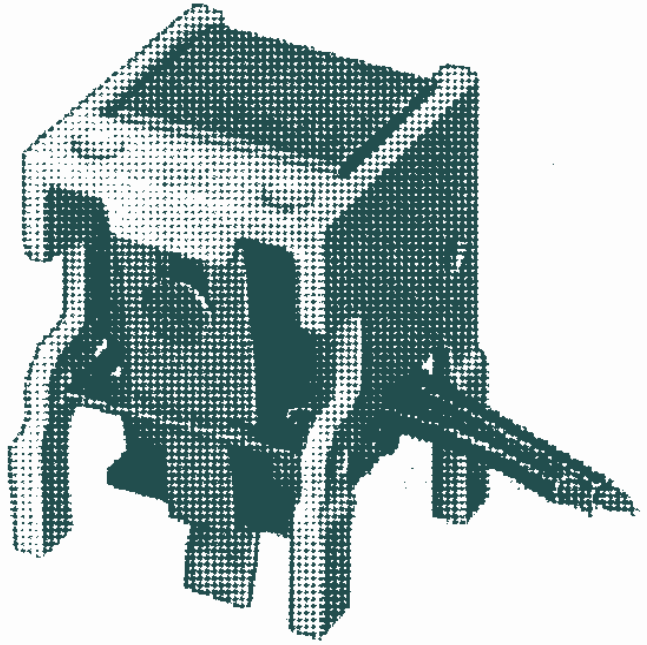
- Activated only when a breaker trips due to a fault.....not when breaker is turned manually off and on.



Shunt Trip

- Used to trip breaker from remote location
- Consists of a momentarily rated solenoid
- Must be energized by control power source

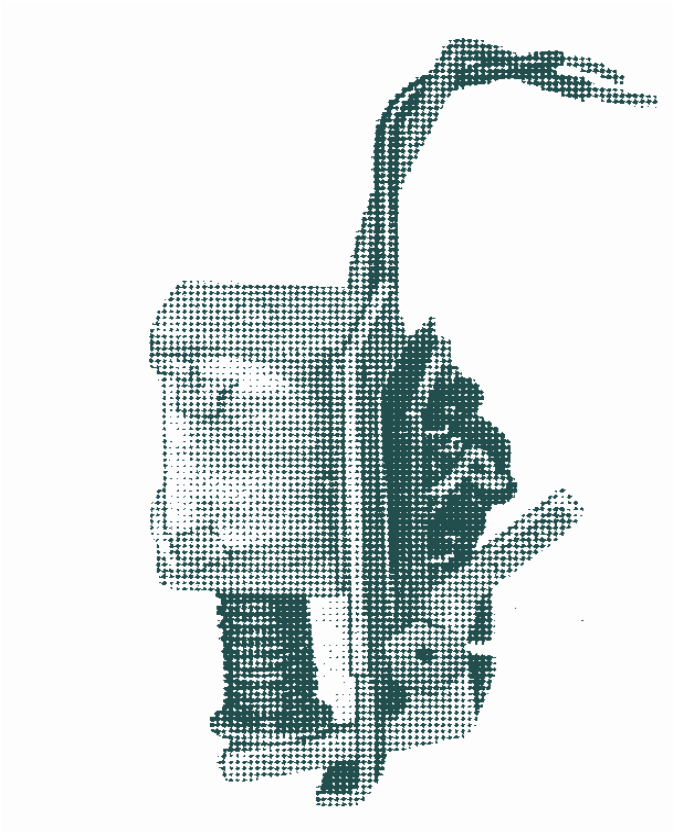
  Notes:
  - NOT to be used with maintained contacts.
  - NOT to be used as a circuit interlock.



Undervoltage Release

- Trips breaker when voltage falls below 35 to 70% of solenoid rating.
- Three types available:
  - automatic reset
  - handle reset
  - electric reset
- Breaker cannot be turned on until voltage returns to 85% of normal

  Note: NOT to be used as a circuit interlock



Standard Requirements

MCCB – Standard Requirements

- Tests covered by C22.2 No. 5.1
- US Manufacturers also comply to UL489
- Quick Overview of Tests:
  - 1.2 m of cable on load side of breaker – helps test wires for pull-out and to test for breakage of the MCCB case from stress
  - Calibration test
  - Required to interrupt a number of overload and fault conditions, be reset, and be put back into service.
  - Dielectric withstand test (2 x Rated Voltage + 1000V)
  - Fault test 2 operations: open and close-open
  - (optional) IER / Series Rating tests in rated enclosures

Unusual Operating Conditions

MCCB - Unusual Operating Conditions

- **High Ambient Temperatures > 40º** C
  - De-rate Thermal Magnetic Breakers Calibrated @ 40º C in accordance **with Manufacturer's Tables** (note: some electronic trip units do not require de-rating)
  - Some manufacturers have special use breakers suitable for 50C
  - "Rule of Thumb" from IEEE Std 1015-1997 "Blue Book" for MCCB's (assume T_1=T_2 = 90C):

$$I_2 = I_1\sqrt{(T_2 - A_2)/(T_1 - A_1)}$$

MCCB - Unusual Operating Conditions

- **Low Temperatures**

MCCB - Unusual Operating Conditions

- **Very Low Ambient Temperatures**
  - Ref: IEEE Standard 1015-1997 Blue Book MCCB and ICCB's –5C
  - Ratings from one manufacturer:
    - Environment Duty –20C -> 50C (CSA listed)
    - Typically –5C -> 40C
  - Change of grease required to perform at low temperatures represents a material change to the breaker.
  - Use of breakers below temperatures listed by the manufacturer may require special consideration, such as the use of a thermostat / space heater in the enclosure. Refer to manufacturer.

MCCB - Unusual Operating Conditions

- High X/R
  - Molded case breakers and Power Circuit Breakers are evaluated differently for X/R
  - If System X/R > Standard X/R, no de-rating is required.
  - Power Breakers are tested with X/R ratio of 6.6
  - MCCB's are tested with varying X/R :
    - Tested X/R varies from 6.6 to 1.75 depending on interrupting rating.
    - Can obtain multiplication factors for short circuit interrupting rating and ranges in IEEE Blue Book
- Harmonics
  - May affect the accuracy of "Peak Sensing" Electronic Trip Units / Relays. Modern protective relays that use RMS sensing typically do not have this issue.

MCCB - Unusual Operating Conditions

- **High Altitude > 6000 Ft**
  - **Dielectric is air, which is thinner at high altitude.**
  - **Affects both the Voltage and Current Rating.**
  - **IC usually unchanged if Voltage is de-rated.**
    - **One Manufacturer:**
      - **Typ. -3% V per 1000 ft over 6000 with IC remaining as published.**
      - **Typ. De-rate current equal to a 3C increase in Ambient per 1000 ft over 6000 (in addition to standard 80% de-rating)**
      - **Always use manufacturer tables.**

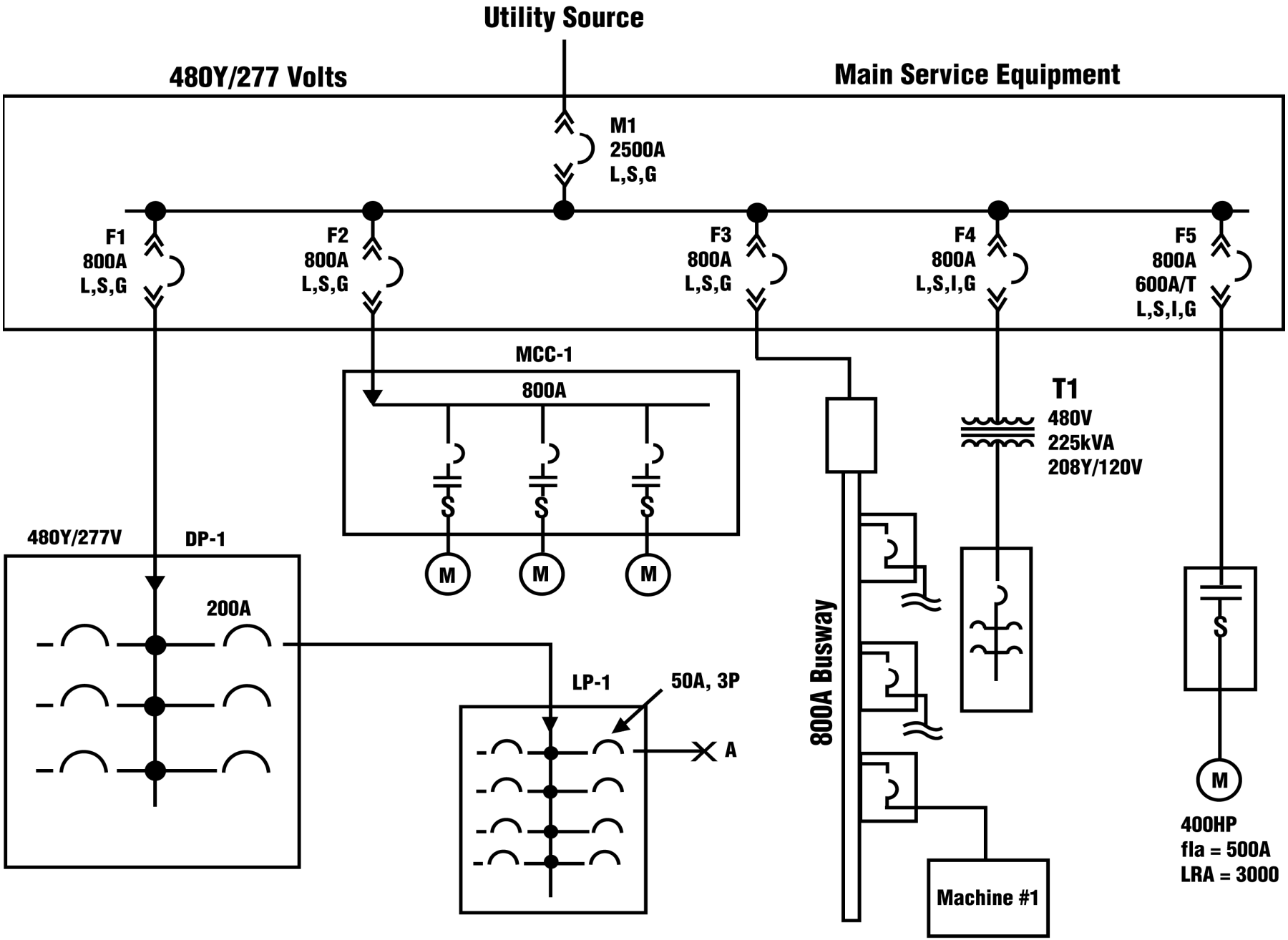
MCCB - Unusual Operating Conditions

- **Moisture**
  - **High Humidity is usually remedied by space heaters / thermostat to prevent condensation.**
  - **Incorrect installation of panel.**
  - **Sample – breaker from outdoor panel that was allowing water ingress.**

Common Errors

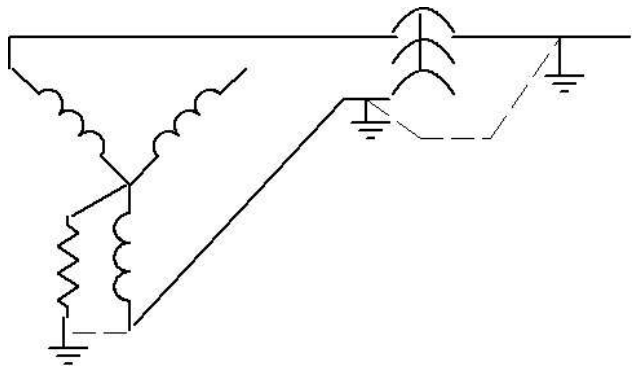
MCCB – Common Application Errors

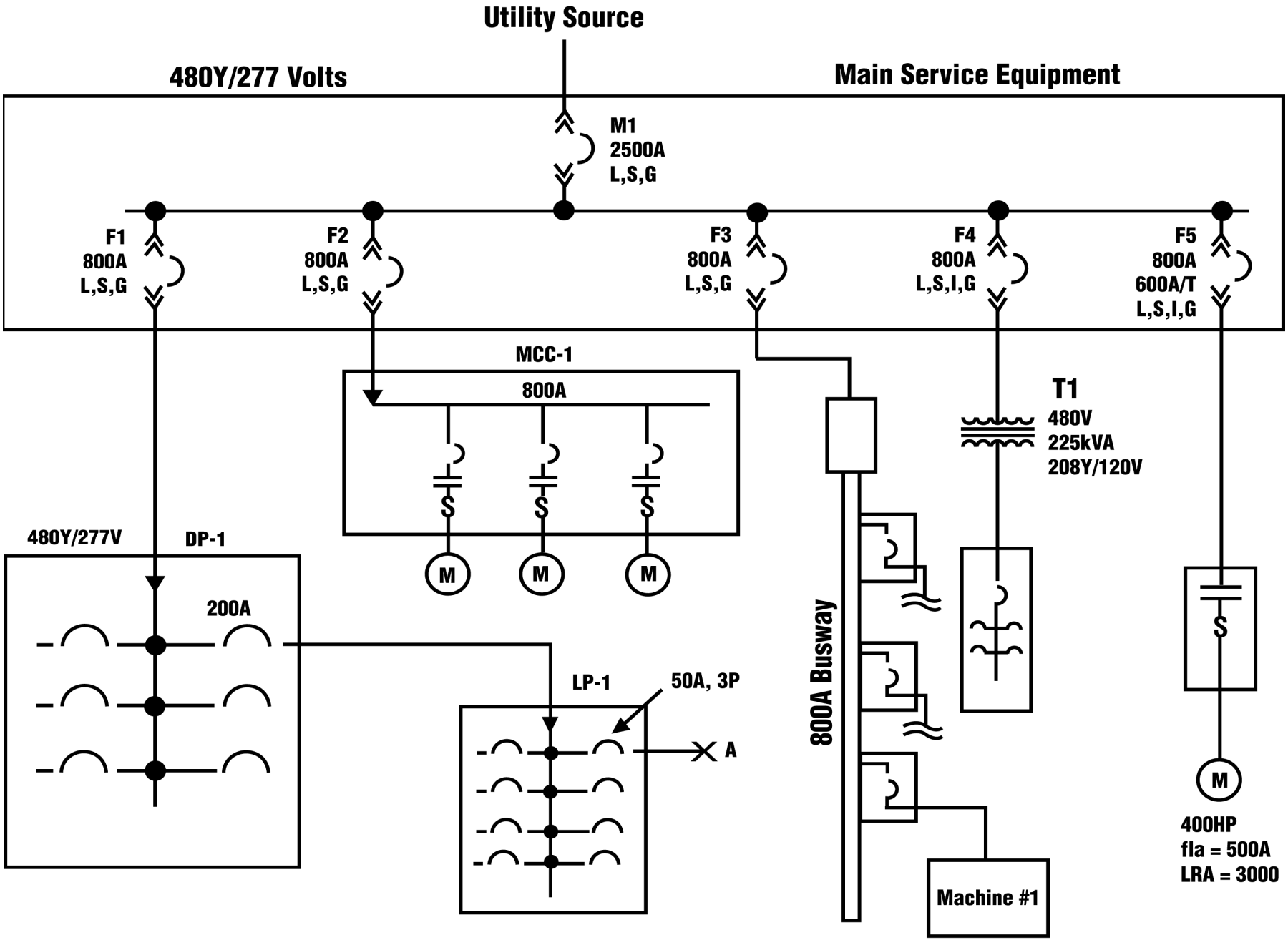
- **Incorrect Interrupting Rating**
  - **Fault study not completed.**
  - **Add breaker with one of lower interrupting rating.**
  - **Interrupting rating not de-rated for altitude > 6000 ft.**


Utility Source
480Y/277 Volts
Main Service Equipment
M1
2500A
L,S,G
F1
800A
L,S,G
F2
800A
L,S,G
F3
800A
L,S,G
F4
800A
L,S,I,G
F5
800A
600A/T
L,S,I,G
MCC-1
800A
M
M
M
T1
480V
225kVA
208Y/120V
480Y/277V
DP-1
200A
LP-1
50A, 3P
A
800A Busway
Machine #1
M
400HP
fla = 500A
LRA = 3000

MCCB – Common Application Errors

- **Incorrect Voltage Rating**
  - Consider the Y –Resistance grounded system below
  - Error is using breakers that are slash-rated ie: 347Y/600V vs straight-rated ie: 600V breakers
  - Further IEEE recommendations in Std. 141-1993 [B4]

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F5
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600A/T
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DP-1
200A
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50A, 3P
A
800A Busway
Machine #1
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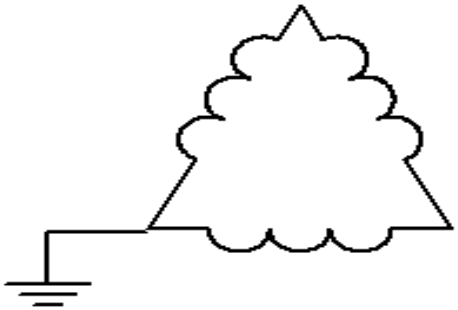
fla = 500A
LRA = 3000

MCCB – Common Application Errors

- **Incorrect Voltage Rating**
  - **Grounded B-phase system requires special attention.**
  - **A L-G fault, at full L-L voltage would be interrupted by a single pole of a MCCB. There is a single-pole test at L-L in C22.2 No 5.1, but at reduced interrupting rating.**
  - **UL listed breakers suitable for use will be marked "1ph-3ph", otherwise refer to manufacturer.**



MCCB – Common Application Errors

- **Incorrect current rating**
  - **Breakers, unless noted as “100% Rated” are 80% rated in enclosures.**
  - **May cause nuisance tripping.**

MCCB – Common Application Errors

- **Use of “Refurbished” molded case circuit breakers.**

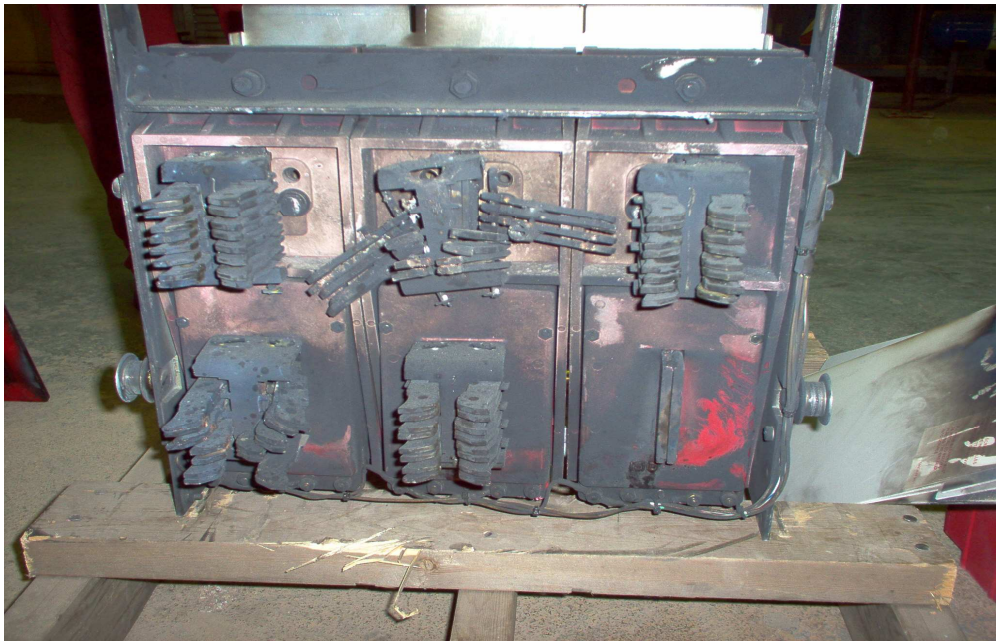
Better Protection

MCCB – Enhanced Protection Options

- **Breakers and Relaying**
  - **Only simple provisions (shunt trip, trip coil) are required to trip a breaker safely.**
  - **Allows many enhanced protection options via external or internal breaker relaying.**

MCCB – Enhanced Protection Options

- **Ground Fault Relaying**
  - **Ground faults are usually less than 38% of fault level and are extremely damaging to downstream equipment.**
  - **The faster these are cleared the damage is greatly reduced.**



“New” MCCB Technology / Advanced Applications

- **Series Ratings (IER)**

“New” MCCB Technology / Advanced Applications

- Selectively Coordinated Systems

Selectively Coordinated Systems

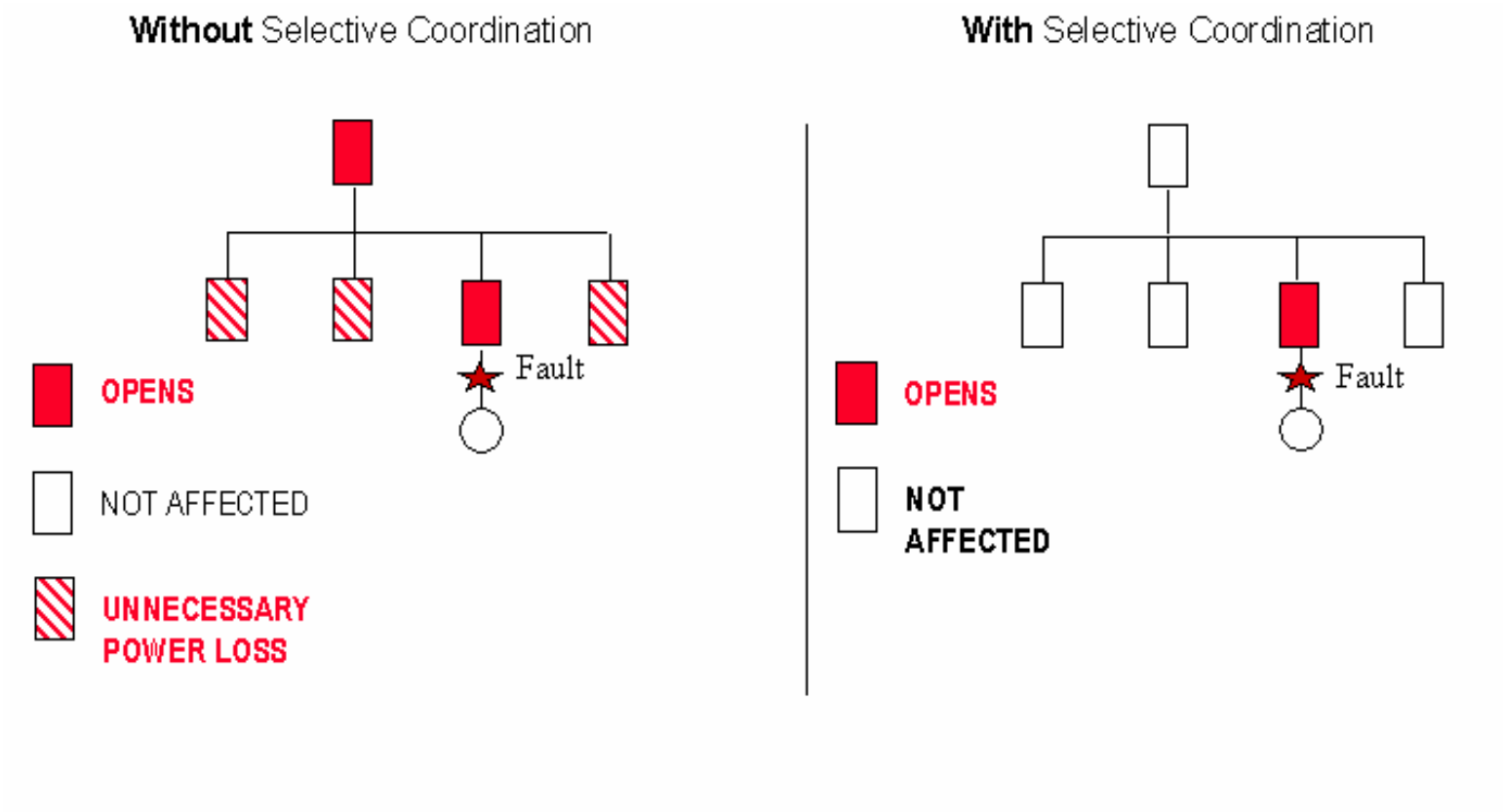
Zone selective interlocking is a means by which two or more selectively coordinated trip devices can communicate and alter their preset tripping mode to provide faster response time for upstream fault conditions. This allows the nearest upstream breaker from the faulted zone to clear the circuit in the shortest time possible and reduce the system damage level potential.

Selectively Coordinated Systems

LVPCB's with MCCB's

- Full discrimination
- Optimum continuity of service
- Short Time Delay - Allows the main breaker to remain closed for up to 30 cycles, **but**
  - Subjects equipment to high mechanical and thermal stresses
  - Higher equipment cost
  - Larger equipment size
  - Greater arc flash hazard risks
    - Short Time Delay

Co-Ordination Benefit Example 1 - Selective Co-Ordination



Zone Selective and Arc Flash

- **Unless a Low Voltage Power Circuit Breaker operates in the Instantaneous trip mode, the arc flash energy values will typically require Category 3 PPE or greater. The example on the next page illustrates this.**
- **Zone Selectively Interlocked Breakers provide significantly lower Arc Flash energy values:**

  Refer to your manufacturer for test data for arc flash using Selective Co-Ordination.
- **During maintenance it is usually recommended to temporarily adjust the Instantaneous and Ground Fault (if available) trip settings to their lowest value.**

Zone Selective Interlock Example

Without ZSI = 0.5 S:

43.7 Cal/cm²

Greater than Cat. 4 PPE

DANGER!

With ZSI = 0.08 S:

7.0 Cal/cm²

Cat. 2 PPE

FR Shirt & Pants

Home Safety

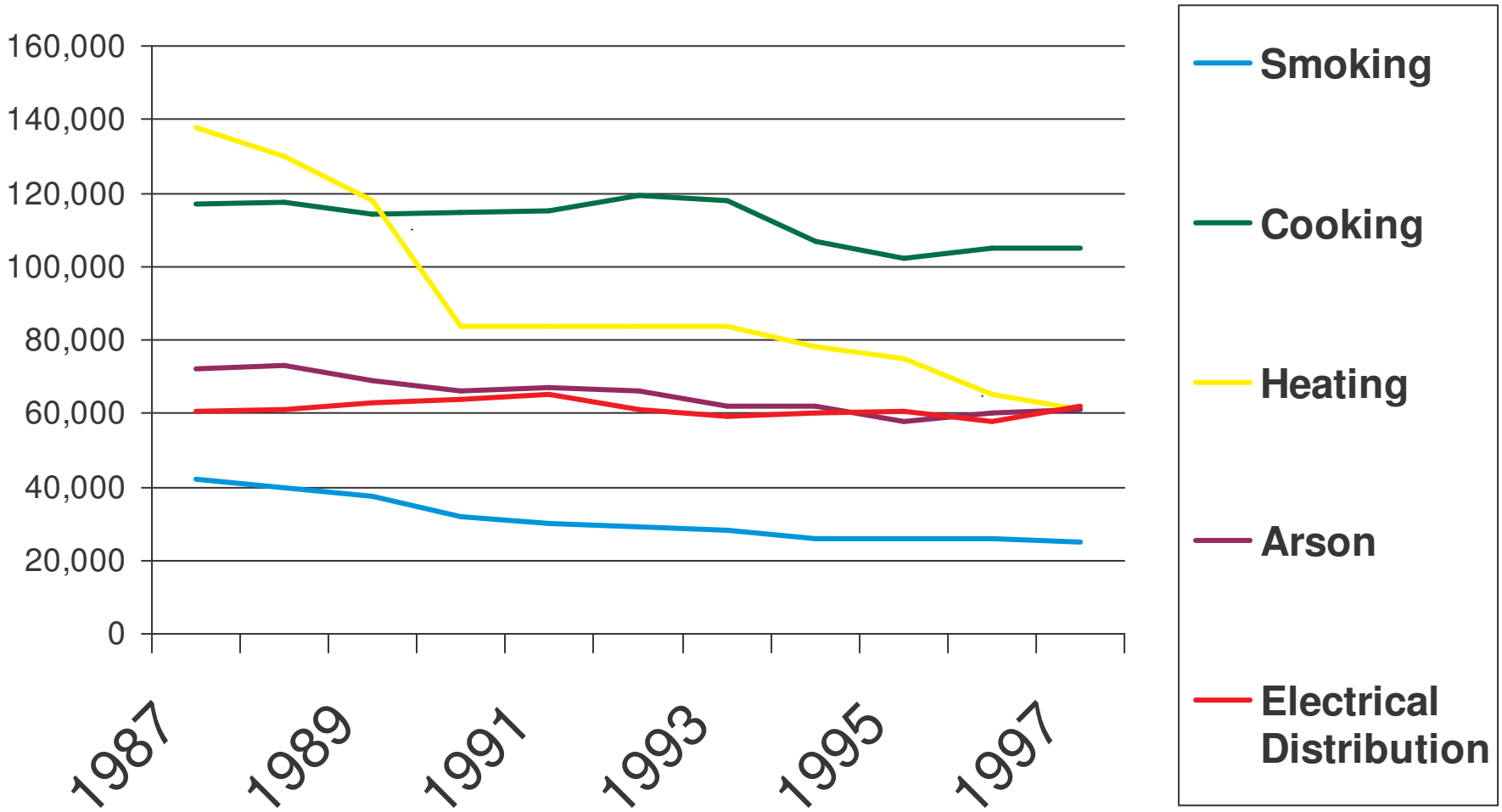
“New” MCCB Technology / Advanced Applications

- Arc Fault Circuit Interrupters – Home Safety

The CEC and AFCI

- **CEC**
  - **26-722(f): Branch circuits that supply receptacles installed in sleeping facilities of a dwelling unit shall be protected by an arc-fault circuit interrupter.**
  - **26-722(g): For the purposes of paragraph (f), an arc-fault circuit interrupter means a device intended to provide protection from the effects of arc-faults by recognizing characteristics unique to arcing and functioning to de-energize the circuit when an arc-fault is detected.**

Causes of Residential Fires

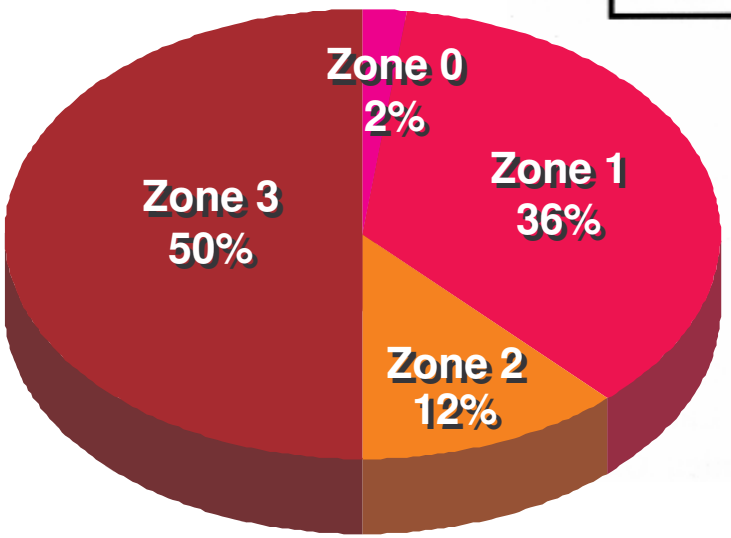


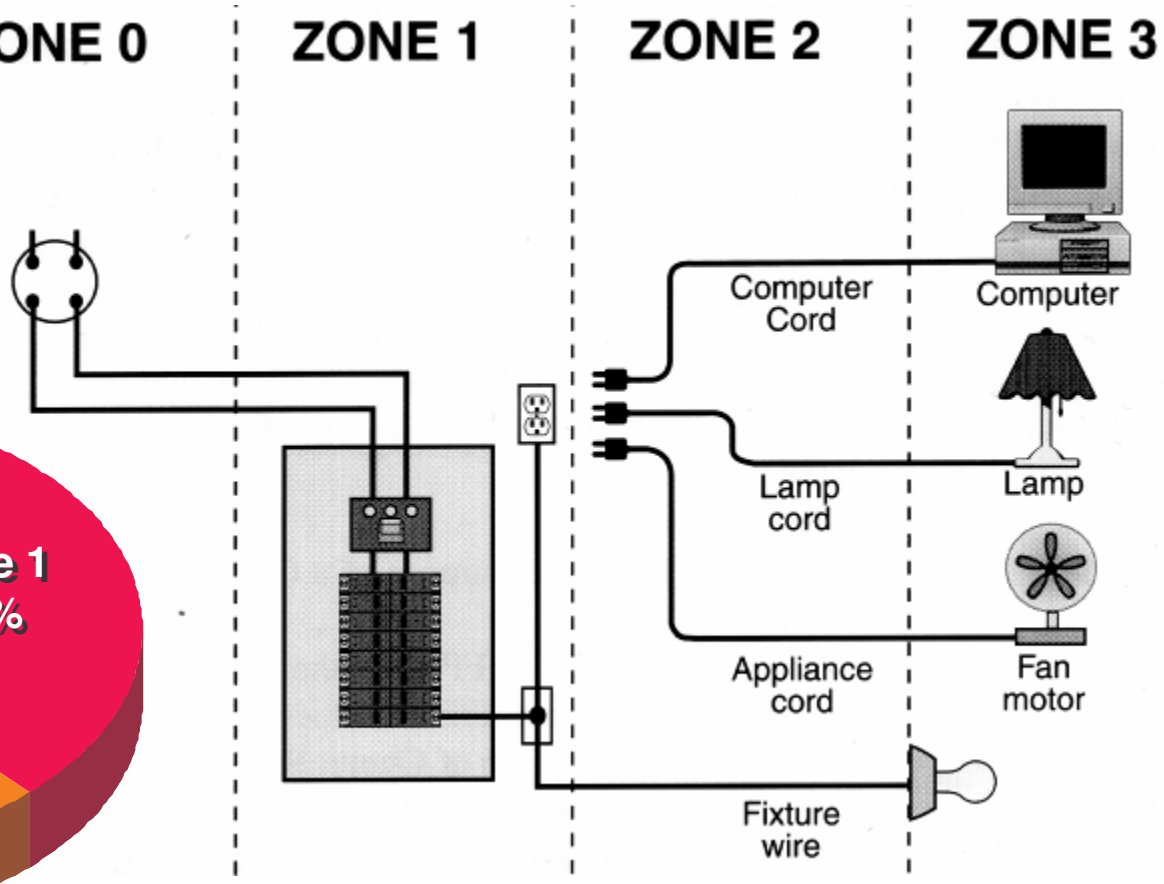
Source: NFPA

Where Do Electrical Fires Start?

- **Study conducted by NEMA task force**

Where Do Electrical Fires Start?

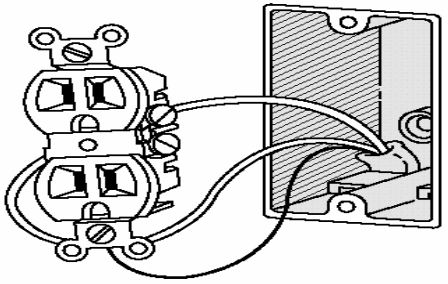




Why Do Electrical Fires Start?

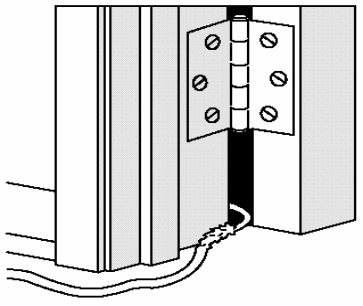
HAZARDOUS SITUATION

Arcing to ground can occur in a wall plug or switch that was not properly installed, or where connections become loose.



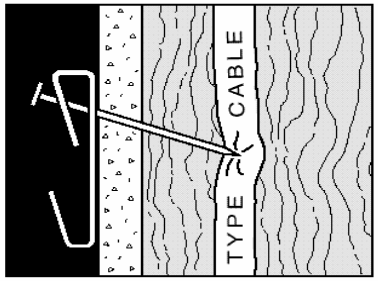
HAZARDOUS SITUATION

Cords that get caught in door jambs. The constant action of opening and closing can deteriorate the cable insulation, allowing arcing to occur.



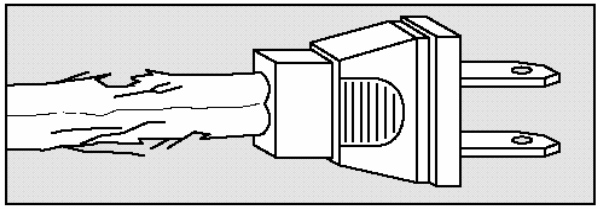
HAZARDOUS SITUATION

A nail from a picture hanger can break the insulation and cause arcing.



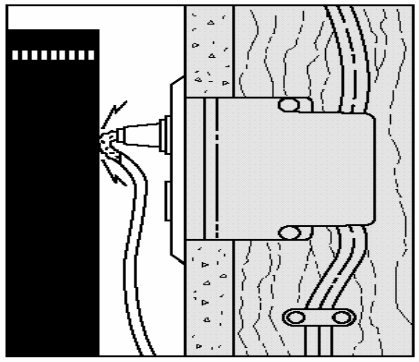
HAZARDOUS SITUATION

Damaged, abused or worn extension cords can pose an arcing situation.



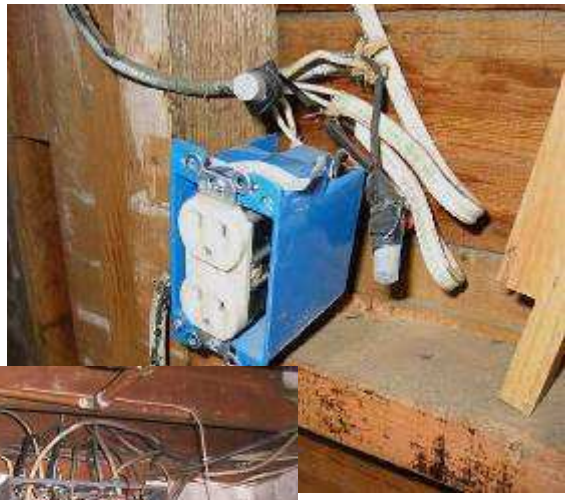
HAZARDOUS SITUATION

When furniture is pushed up against or rests on a cord - the deterioration of the insulation may be greatly increased. These damaged cords then become a potential condition for arcing.



Why Do Electrical Fires Start?

Homeowner Abuse:

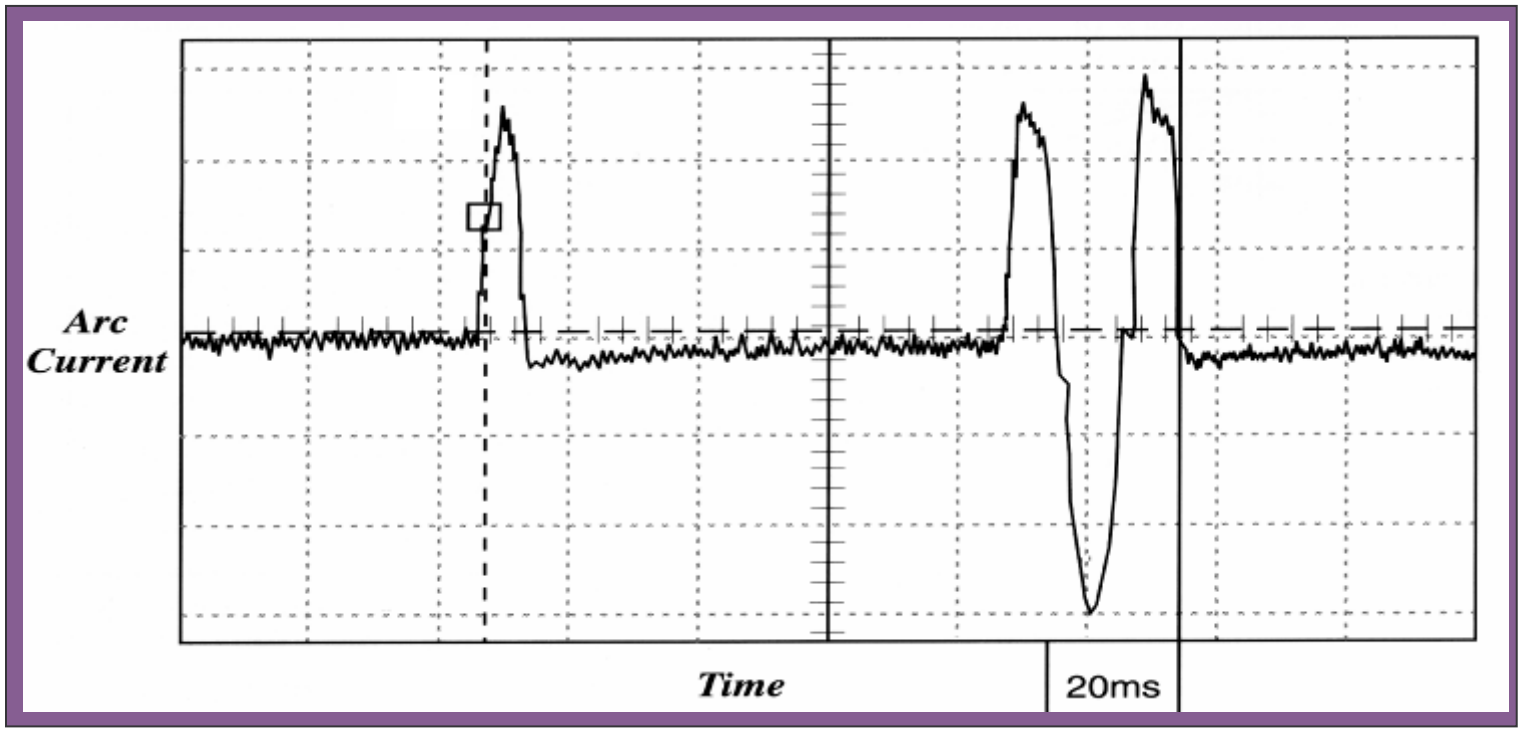



MAR 11 2001

Why didn't the Standard Breaker Trip?

- Current breakers offer three elements of protection
  - Thermal -
    - Protects wire from overheating due to low level current overloads - requires 3+ seconds of overcurrent to move the bimetal
  - Magnetic
    - Protects wire from high short circuit currents - utilizes an electromagnet
  - Ground Fault (optional)
    - Senses unbalanced line to neutral loads
    - 5mA and 30mA sensitivity

Typical Arc Current Waveform



Typical current waveforms observed when a carbon-steel blade cuts through 16 AWG SPT-2 cord. The available current is 100A.

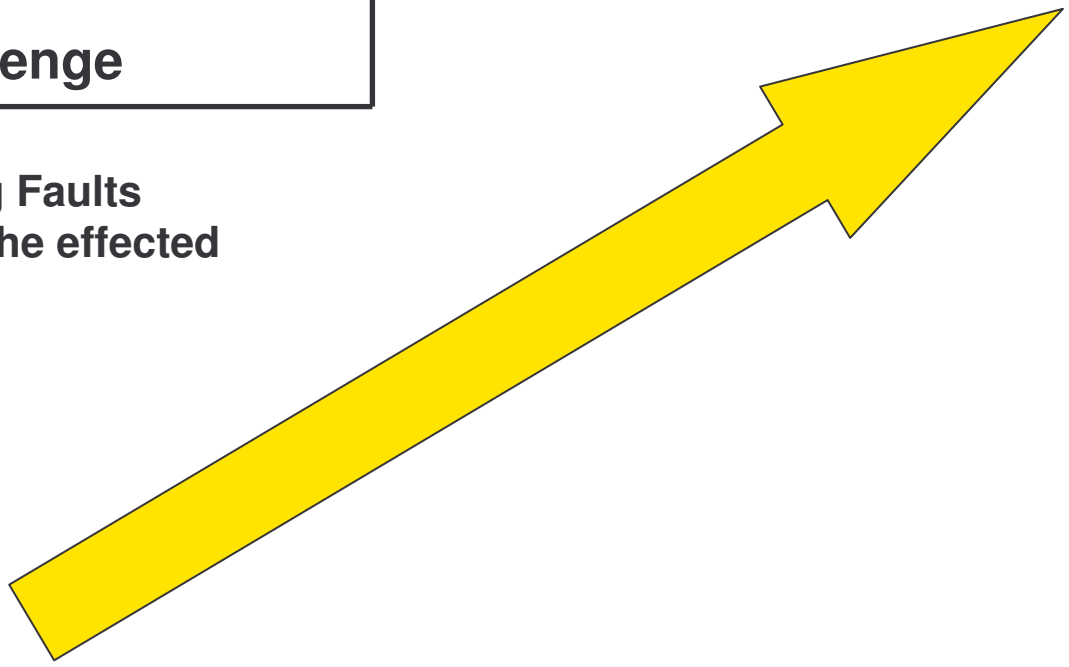
A Two Tier Challenge

Required Innovation

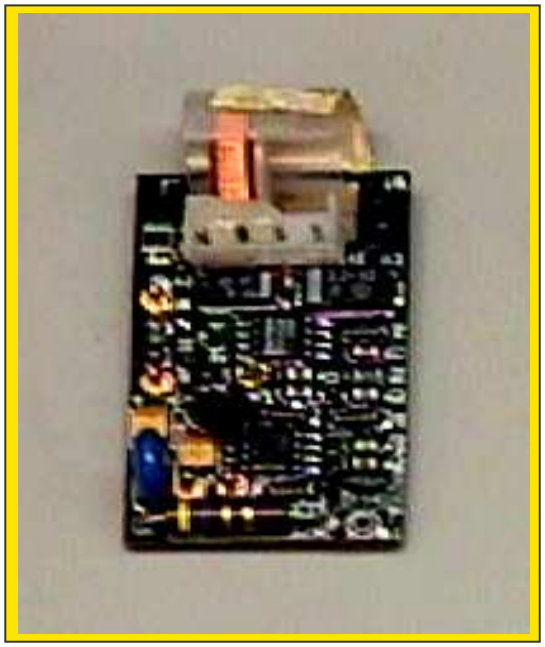
- Determine unsafe versus acceptable arcing
- Avoid unnecessary breaker tripping

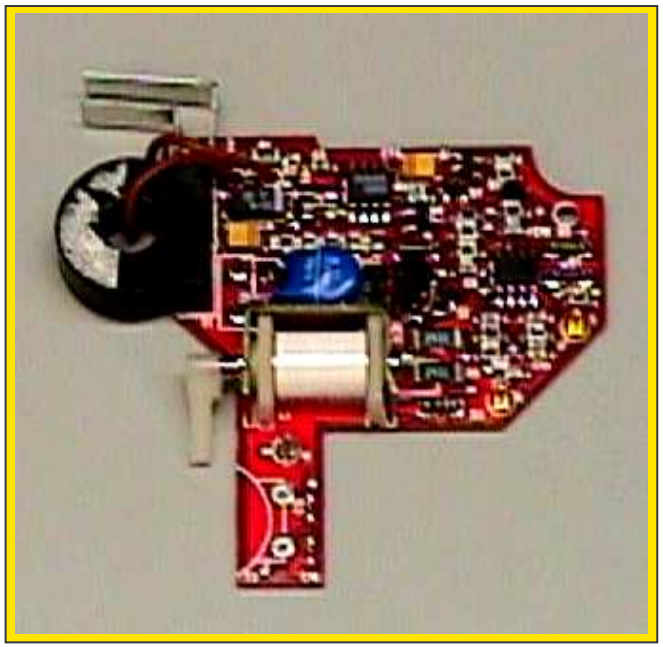
Technical Challenge

- Detect Arcing Faults
- De-energize the effected circuit



AFCI Electronics

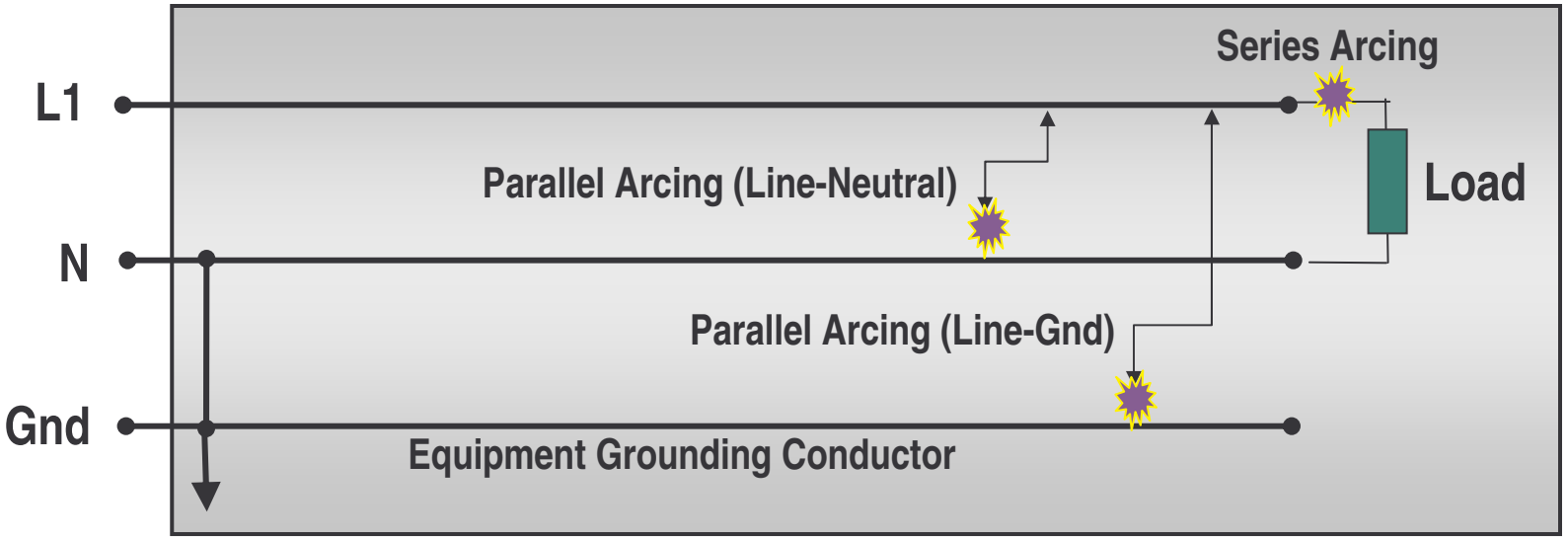




The challenge has been to design electronic circuitry that recognizes arc signatures.

Types of Arcing Faults

- Series Arc Fault (undetectable by other means)
- Parallel Arc Fault (undetectable by other means)
- Arcing Faults to Ground (also GFCI)



Arc Fault Demo

Questions?