

Arc Flash Protection

Electrical Reliability Services



Arc Flash Hazard

- What is it?
- What Can Cause it?
- Why Should You Care?
- Why are We Now Paying Attention?
- What are the Risks?
- How do you Reduce Your Risks?
- What are the Benefits?
- When Should You Act?
- Electrical Reliability Services Can Help

What is an Arc Flash?

An arc flash is highly concentrated **radiant thermal energy** released in a fraction of a second. It is the **result of an arcing fault** when current flows through the air between phase conductors or phase conductors to ground.

What Can Cause an Arc Flash?

- Human error (dropped tool, pulling conductor, racking a breaker, etc.) – 80% of incidents
- Loose connections
- Frayed insulation
- Conductors touching from the magnetic force of a short circuit
- Contaminants in the air
- Small animals (e.g. birds, rodents, snakes)

Why Should You Care?



Blast Damage!!!

- Temperatures up to 35,000°F (Burned!)
- Extreme heat causes copper to expand 67,000 times from solid to vapor- pressure (Slammed!)
- Flying shrapnel at over 700 mph (Shot!)
- The potential results:
 - Ruptured eardrums/damaged vision
 - Severe burns and fall injuries
 - Surrounding equipment damaged or destroyed
 - Facility shutdown

Why are We Now Paying Attention?

- The Danger has increased
- Exposure to arc flash hazards has steadily increased as a result of higher system voltages and available fault current
- Larger loads, higher service voltage, on-site generation, medium voltage equipment
- Energy utilization increased 13 times from 1949 to 2002 to over 3450 billion KWH (excluding co-generation)

Why are We Now Paying Attention?

- We operate differently (increasing risk)
- Continuous manufacturing or operations facilities (e.g. batch processors, datacenters, water/waste water, hospitals) cannot be economically shut down for service. Competing in global economy
- Some electrical testing can only be done when equipment is energized (e.g. on-line partial discharge, infrared scan)
- Energized equipment can be the safer alternative (e.g. air handling equipment in hazardous areas)

Why are We Now Paying Attention?

- Industry and government are more proactive
- Better analysis tools to assess the risk and better equipment and clothing for protection
- Tougher and more comprehensive regulations that keep up with the state of the art in knowledge and safety solutions (e.g. NEC, OSHA, NFPA70E, IEEE, ANSI)

What are Your Risks?

- Compliance – Failure to meet NEC code can delay project startup. OSHA safety violations can result in significant fines
- Injury/Death – Yourself, your coworkers, outside contractors and other third parties. 5-10 arc flash incidents happen every day
- Equipment damage – Costly to repair or replace
- Plant shutdown – Reduced productivity, lost revenues, lost customers, lost jobs
- Liability – Lawsuits, higher insurance premiums, out of pocket costs if self insured – a single incident can easily run in excess of \$10M! (**\$15.75M per 1999 EPRI study**)

These are Just Some of Your Risks!!!



How Do You Reduce Your Risks?

- Identify and Quantify the Hazard
- Train personnel to assess the hazard and to protect themselves with proper clothing, tools and procedures when working on energized equipment
- Make safe operating practice a part of the culture through ongoing training, documentation and skills assessment

Quantify the Shock Hazard

- The voltage level defines the magnitude of the shock hazard
- It is a constant at a given location
- The insulated personal protective equipment must meet or exceed the quantified shock hazard



Quantify the Arc Flash Hazard

- Incident (thermal) energy expressed as calories/cm² defines the magnitude of the arc flash hazard
- The protective PPE must meet or exceed the quantified burn hazard
- Changes in the system configuration will likely change the incident energy value

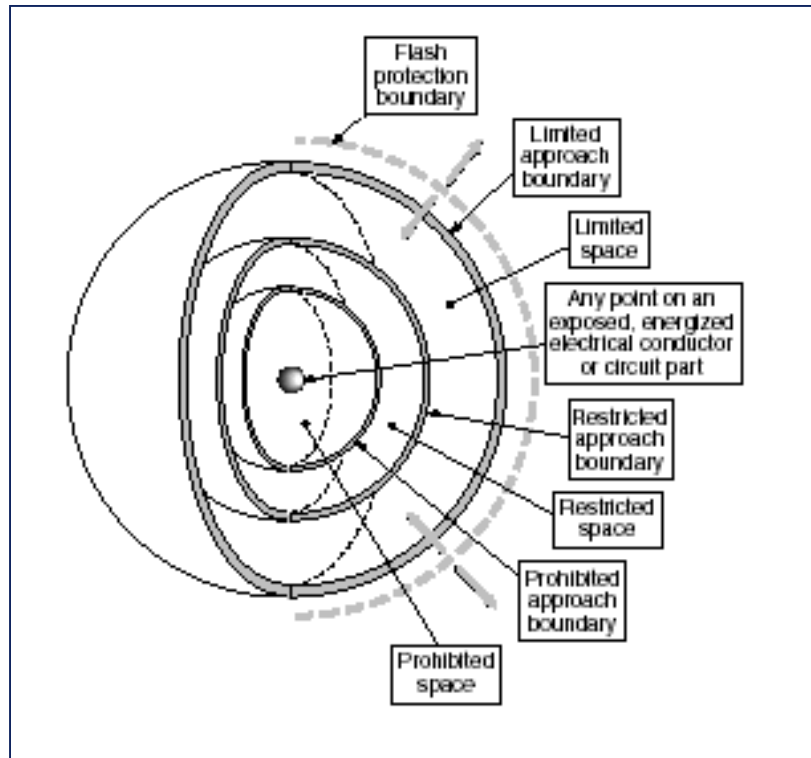


Communicate the Hazard (Labeling)

| | | | |
|---|--|--|---------|
|  | WARNING |  | |
| Arc Flash and Shock Hazard Appropriate PPE Required | | | |
| 6.0 feet | Flash Hazard Boundary | | |
| 9.2 cal/cm² | Flash Hazard at 18 inches | | |
| Class 2 | FR Clothing over Non FR Clothing, Hardhat, Arc Rated Faceshield, Leather Work Boots Class 00 Gloves | | |
| 480 VAC | Shock Hazard when Cover is removed | | |
| 42 Inches | Limited Approach Boundary | | |
| 12 Inches | Restricted Approach Boundary | | |
| 1 Inches | Prohibited Approach Boundary | | |
| Location: 480V Location | | | |
|  | Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888 | | |
| Job#: | 30xxxxx | Prepared: 5/19/05 | By: CSI |
| Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements | | | |

| | | | |
|---|--|---|---------|
|  | DANGER |  | |
| NO PPE AVAILABLE ENERGIZED WORK PROHIBITED | | | |
| 17.8 feet | Flash Hazard Boundary | | |
| 46.1 cal/cm² | Flash Hazard at 18 inches | | |
| DANGER | NO SAFE PPE AVAILABLE | | |
| | Class 00 Gloves | | |
| 480 VAC | Shock Hazard when Cover is removed | | |
| 42 Inches | Limited Approach Boundary | | |
| 12 Inches | Restricted Approach Boundary | | |
| 1 Inches | Prohibited Approach Boundary | | |
| Location: 480V Switchgear | | | |
|  | Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888 | | |
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Properly Interpret the Data (NPFA70E)



Boundaries

- **FLASH HAZARD (1.2 cal/cm²)** – Appropriate PPE required. Can be within or outside of Limited Approach!
- **LIMITED APPROACH** – Qualified personnel only
- **RESTRICTED APPROACH** – Detailed work plan & PPE required
- **PROHIBITED APPROACH** – Considered making contact! Detailed work plan, specialized training, risk analysis & PPE required

| SYSTEM VOLTAGE | FLASH HAZARD | LIMITED APPROACH | RESTRICTED APPROACH | PROHIBITED APPROACH |
|----------------|----------------|------------------|---------------------|---------------------|
| 208V | ANALYSIS REQ'D | 42" | AVOID CONTACT | AVOID CONTACT |
| 480V | ANALYSIS REQ'D | 42" | 12" | 1" |
| 5kV | ANALYSIS REQ'D | 60" | 26" | 7" |
| 15kV | ANALYSIS REQ'D | 60" | 26" | 7" |

PPE Example From NFPA 70E-2004

| Hazard/Risk Category | Typical Protective Clothing Systems | Required Minimum Arc Rating of PPE (cal/cm ²) |
|----------------------|---|---|
| 0 | Non-melting, flammable materials (natural or treated materials with at least 4.5 oz/yd ²) | N/A (1.2) |
| 1 | FR pants and FR shirt, or FR coverall | 4 |
| 2 | Cotton Underware, plus FR shirt and FR pants | 8 |
| 3 | Cotton Underware, plus FR shirt and FR pants and FR coverall | 25 |
| 4 | Cotton Underware, plus FR shirt and FR pants and multiplayer flash suit | 40 |

Prohibited work above 40 cal/cm²

Understand the Limitations

The threshold of a second degree burn is 1.2 Cal/cm². anything more may cause a 3rd degree burn (considered permanent damage)



Where do the Numbers Come From?

- Voltage is inherent in the design of the equipment and is included on the nameplate – a constant
- Incident energy is a function of the equipment's location/protection within an electrical system. It must be calculated. You can't pre-label the equipment with quantified information
- Requires an arc flash system analysis – **If you want to protect personnel, equipment and revenues, the data must be up to date and accurate**

Perform an Arc Flash System Analysis

- Performed by a qualified engineer using methods described in IEEE Standard 1584-2002 “Standard Method for Determining Incident Energy” - Nov 2002
- IE calculations take into account bolted fault current, clearing time, equipment type, grounding and construction over a range of voltages
- Should be performed at any facility with a 480V or higher electrical system and a 240V system served by a 125 kVA transformer and larger.
- Included in latest NFPA 70E, 2004 Edition

Requirements for an Arc Flash Analysis

- Up to date system one-line diagram (NFPA 70E)
- Conductor size, types, and lengths
- Electric utility source information
- Current short-circuit/coordination study
- Validated protective device types and settings
- Data collection to update the system one-line, short-circuit and coordination studies, protective device types and setting verification can be provided if not available

What Does an Analysis Provide?

- Report summary provides analysis methodology, findings and recommendations
- Input data for utility source, equipment and cables **documents your electrical system** (table)
- Available fault current at each equipment locations with comparison to equipment rating (table) – **avoids failure of underrated equipment**
- Overcurrent device settings “as found” and “as recommended” (table) - **balances selective coordination with incident energy level mitigation**

Arc Flash Mitigation

- Locations where incident energy is either prohibited or above the available PPE
- Mitigation (Reduce the IE level) Options
 - Reduce arcing current (e.g. current limiting fuses, breakers or reactors)
 - Increase working distance (e.g. hot stick, remote racking)
 - Reduce clearing time (e.g. relay settings)

What Does an Analysis Provide?

Incident energy level (cal/cm²) for each equipment location and recommended PPE

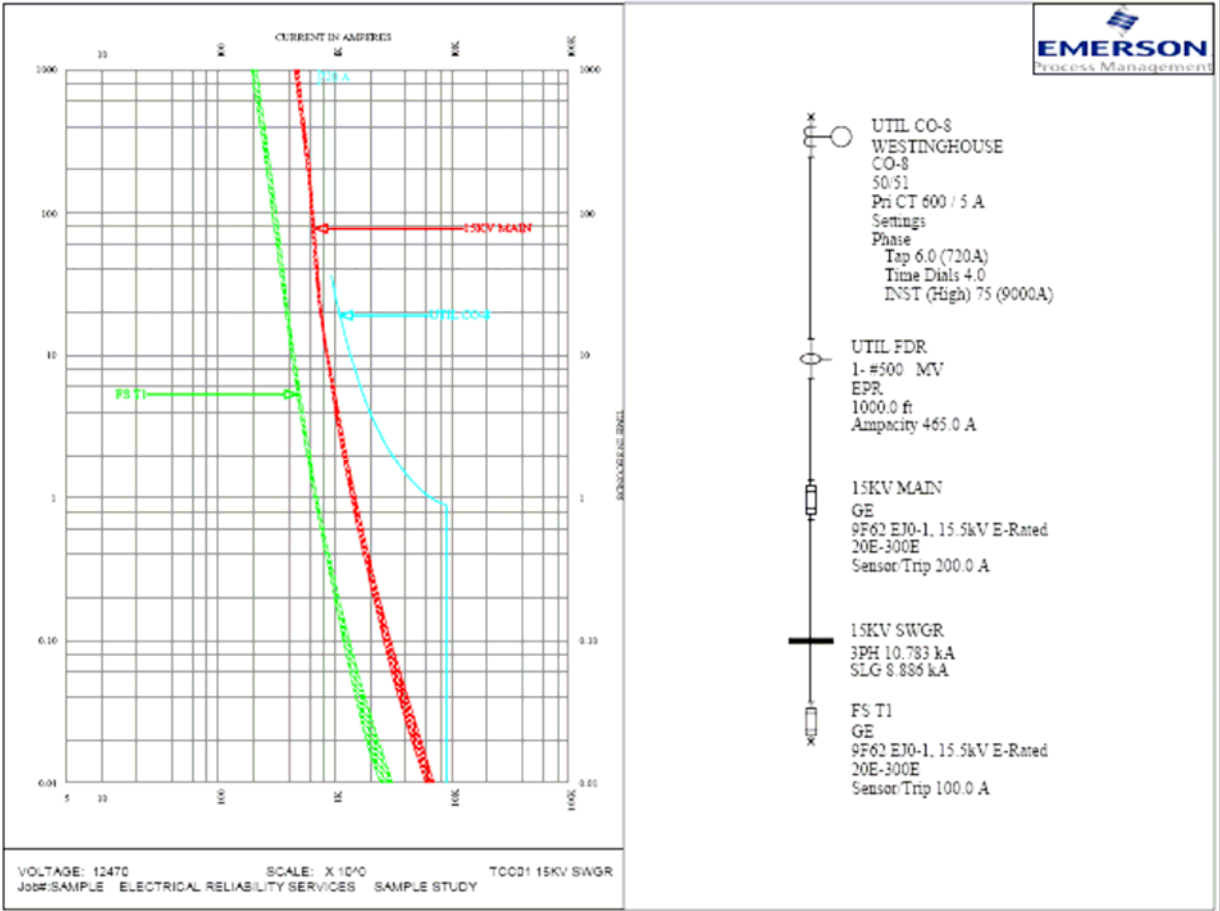
Arc Flash Evaluation IEEE 1584-2004a Bus Report (80% Cleared Fault Threshold, Include Ind. Motors for 5.0 Cycles), mis-coordination not checked

| | Bus Name | Protective Device Name | Bus kV | Bus Bolted Fault (kA) | Prot Dev Bolted Fault (kA) | Prot Dev Arcing Fault (kA) | Trip/ Delay Time (sec.) | Breaker Opening Time (sec.) | Ground | Equip Type | Gap (mm) | Arc Flash Boundary (In) | Working Distance (In) | Incident Energy (cal/cm ²) | Required Protective FR Clothing Category |
|---|---|------------------------|--------|-----------------------|----------------------------|----------------------------|-------------------------|-----------------------------|--------|------------|----------|-------------------------|-----------------------|--|--|
| 1 | 15KV SWGR | 15KV MAIN | 12.5 | 10.78 | 10.78 | 10.45 | 0.01 | 0.000 | Yes | SWG | 153 | 3 | 36 | 0.13 | Category 0 |
| 2 | DSB | DSB MAIN | 0.208 | 5.24 | 5.24 | 2.76 | 2 | 0.000 | Yes | PNL | 25 | 89 | 18 | 16.5 | Category 3 (19) |
| 3 | MSB | MSB MAIN | 0.48 | 30.20 | 30.20 | 16.85 | 0.47 | 0.000 | Yes | PNL | 25 | 121 | 18 | 27.4 | Category 4 |
| 4 | Category 0: Untreated Cotton | | | | | | | | | | | | | | (19) - Max Arcing Duration Reached |
| 5 | Category 1: FR Shirt & Pants | | | | | | | | | | | | | | |
| 6 | Category 2: Cotton Underwear + FR Shirt & Pants | | | | | | | | | | | | | | |
| 7 | Category 3: Cotton Underwear + FR Shirt & Pant + FR Coverall | | | | | | | | | | | | | | |
| 8 | Category 4: Cotton Underwear + FR Shirt & Pant + Multi Layer Flash Suit | | | | | | | | | | | | | | IEEE 1584-2004a Bus Report (80% Cleared Fault Threshold, Include Ind. Motors for 5.0 Cycles), mis-coordination not checked |

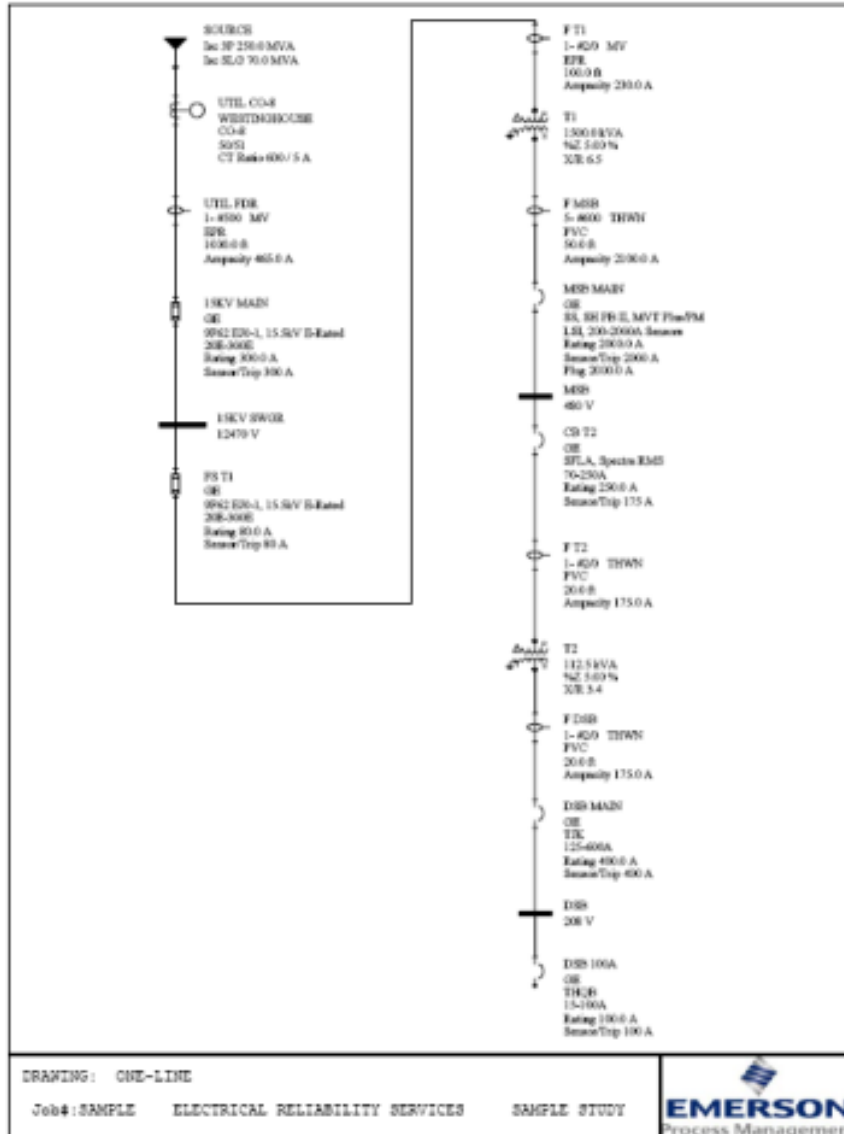


What Does an Analysis Provide?

Overcurrent device coordination curves



What Does an Analysis Provide?









Complete single line diagram of the system analyzed



What Does an Analysis Provide?

Label output ready for printing and placement on equipment

| | | |
|--|---|------------------|
|  WARNING  | | |
| Arc Flash and Shock Hazard | | |
| Appropriate PPE Required | | |
| 121 inch | Flash Hazard Boundary | |
| 27.4 cal/cm² | Flash Hazard at 18 inches | |
| Category 4 | Cotton Underwear + FR Shirt & Pant + Multi Layer Flash Suit | |
| 480 VAC | Shock Hazard when cover is removed | |
| 00 | Glove Class | |
| 42 inch | Limited Approach (Fixed Circuit) | |
| 12 inch | Restricted Approach | |
| 1 inch | Prohibited Approach | |
| Bus: MSB Prot: MSB MAIN | | |
|  Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888 | | |
| Job#:SAMPLE | Prepared on: | October 24, 2005 |
| Warning: Changes in equipment settings or system configuration will invalidate the calculated values and PPE requirements | | |

| | | |
|--|--|------------------|
|  WARNING  | | |
| Arc Flash and Shock Hazard | | |
| Appropriate PPE Required | | |
| 89 inch | Flash Hazard Boundary | |
| 16.5 cal/cm² | Flash Hazard at 18 inches | |
| Category 3 | Cotton Underwear + FR Shirt & Pant + FR Coverall | |
| 208 VAC | Shock Hazard when cover is removed | |
| 00 | Glove Class | |
| 42 inch | Limited Approach (Fixed Circuit) | |
| 0 inch | Restricted Approach | |
| 0 inch | Prohibited Approach | |
| Bus: DSB Prot: DSB MAIN | | |
|  Electrical Reliability Services, Inc. 3150-B East Birch Street Brea, California 92821 (714)961-2888 | | |
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Personal Protective Equipment (Apparel)

- Meet ASTM F1505 fire retardant standards
- Include ATPV rating (cal/ cm²) per ASTM 1959-2002
- Comfort/wear/wash
- Several materials types available from multiple manufacturers
- Review PPE ratings and equipment labeling together
- OSHA mandates the use of fabrics that don't increase the burn hazard (CFR 29, 1910.269(l)(6)(iii))



Train Personnel & Document Results

- It's a requirement of OSHA 29CFR1910
- Provide basic training in electrical safety, interpretation of safety data, use of protective equipment and procedures
- Incorporate arc flash analysis results into your companies safety documentation and plan
- Assess and document the skills of personnel working on energized equipment

What's the Latest with Standards?

- **NEC (Article 110.16 2002 & 2005)**
 - Requires marking of the highest voltage and presence of an arc flash hazard. Note refers to NFPA 70E for assistance in quantifying specific arc flash protection goals
- **OSHA (29CFR 1910)**
 - 29 CFR 1910 requires certified hazard assessment, selection of appropriate PPE, training, proficiency and retraining of employees
 - References NFPA 70E in Subpart S Appendix A
- **NFPA 70E**
 - Officially an ANSI standard in February 2004
 - De facto standard that ensures OSHA compliance
 - Mandatory inclusion in OSHA imminent (hearings 3/6/06)

Benefits of an Arc Flash Hazard Program

- Protect the health and safety of your most valuable asset – **employees!!**
- Maximize productivity, revenues and profit by minimizing facility shutdown due to human error or equipment malfunction/damage
- Avoid regulatory compliance penalties.
1910.132 - three of top 25 OSHA violations
- Reduce your self insurance costs or avoid increased premiums from your insurer (**human error can cause equipment failure and revenue loss**)

When Should You Act?

- The risk and your exposure have increased
- The tools and resources are available to help you implement a complete solution
- Ignorance is not a legal or regulatory defense against negligence and liability
- It only takes one event to.....
- Regulatory requirements are tougher and imminently mandatory
- There is no better time than now to take action

Electrical Reliability Services Can Help

- [NETA Certified Technicians](#) - We don't just collect data. Your system is more than just a single line. We understand the impact of the physical facility layout on an accurate incident energy study that protects your employees and how to assess the ability of your protective devices to perform their critical function
- [Registered Professional Engineers](#) – Optimizing a facility electrical system takes more than just a computer program or reading a table. Years of applied power system study experience provides you with the best design solution for your facility performance and safety

Electrical Reliability Services Can Help

- [Training & Consulting](#) – It's not a sideline! It's a business with dedicated resources to effectively educate or advise your employees and document the necessary procedures to operate safely
- [Nationwide Experience](#) - Our extensive experience in a variety of applications and industries provides you with an ongoing “best practice” solution for your company's safety and performance
- [Nationwide Resources](#) – Our arc flash solution package is available for implementation at a single facility or for a nationwide corporate initiative
- [One Stop Shopping](#) – A single point of contact to implement your arc flash hazard safety program can give you peace of mind for safety and compliance

A Complete Arc Flash Protection Solution

- Review/update facility one-line diagram; Short Circuit and Coordination Study + IE Study
- Verify protective equipment settings and operation
- Develop/install arc flash warning labels
- Determine procedures and authorizations
- Determine minimum PPE requirements and classifications
- Integrate information into facility safety policies
- Provide training to workforce in order to fully understand policies, procedures, and protective labels

Arc Flash Hazard Solutions Web Site

- <http://www.ers.assetweb.com>
- Select “Arc Flash Resources”
- 1-877-468-6384

