Basler APPLICATION Notes

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Arc Flash: Helping Electric Utilities Manage NESC 410.A.3 "Flame Retardant Clothing Requirement"

The 2007 revision of the IEEE National Electrical Safety Code (NESC) requires all electric utilities to perform Arc-Flash assessments to determine when "flame retardant clothing" is required. Specifically, the rule change states:

> "*Effective as of January 1, 2009, the employer shall ensure that an assessment is performed to determine potential exposure to an electric arc for employees who work on or near energized parts or equipment. If the assessment determines a potential employee exposure greater than 2cal/cm2 exists, the employer shall require employees to wear clothing or a clothing system that has an effective arc rating not less than the anticipated level of arc energy.*"

Further, the effective arc rating of clothing or a clothing system (defined in NESC 410.A.3) to be worn at voltages 1000V and above shall be determined using Tables 410-1 and 410-2 or by performing an arc hazard analysis.

Changes to the IEEE NESC were made specifically to address arc flash hazard requirements at voltage levels normally associated with Electric Utilities. To avoid OSHA citations and expensive liability lawsuits, it may be best to do a complete Arc-Flash hazard assessment on electrical equipment where employees are likely to be exposed, as industrials have learned in the last 10 years. NESC revisions still leave some areas open to interpretation.

Calculating potential Arc-Flash energies, and how to select PPE (personal protection equipment) for arc ratings between 12 and 40 cal/cm2 are two examples (Tables 410-1 and 2 only go up to 12 cal/cm2). At this point, the only national standard that defines required PPE up to 40 cal/cm2 is NFPA 70E. Also, IEEE 1584 only defines arc flash calculation methods up to 15kV, but most utilities have higher equipment voltage ratings. For voltages higher than 15kV, the utility is referred to the "Lee Equations". There are also commercially available software tools for performing calculations based on the Lee equations (Ralph Lee "The Other Electrical Hazard: Electric Arc Blast Burns" paper 1980s).

What it is "Arc Flash"

Arc Flash is the rapid release of heat and light energy caused by the electrical breakdown of, and subsequent electrical discharge through, an electrical insulator such as air, i.e. a rapid release of energy due to an arcing short circuit between two or more adjacent conductors. The cause of the short may burn away during the initial flash, in which case the arcing fault is sustained by highly-conductive plasma. The plasma will conduct as much energy as is available and is only limited by the impedance of the arc. Electrocution is, therefore, not the primary concern when assessing arc flash energy as the blast of hot gasses and shrapnel can cause severe injury and also lead to "fall" injuries.

ARC FLASH Solution

Historical Perspective

Arc flash protection first became an issue of serious study in the early 1980s when an article written by Ralph Lee appeared in IEEE Transactions on Industry Applications Titled: "The Other Electrical Hazard: Electric Arc Blast Burns". This paper convinced industrial and petrochemical companies that too many workers were receiving burn injuries from arc flash incidents. Mr. Lee also was the first to develop formulae for estimating the amount of arc energy (incident energy produced by electrical arcs) and his equations are still included in IEEE Standard 1584 today.

OSHA requested NFPA create a standard to address worker safety, which resulted in NFPA70E in 1995 including the appearance Arc Flash as a "recognized hazard". Arc Flash is recognized by OSHA as a potential cause of serious injury and death among electrical workers and references NFPA70E in defining Arc-Flash and the personal protective equipment (PPE) that employees working on or near energized equipment must wear to protect against this hazard.

Minimizing Impact of Arc Flash

First and foremost, electrical equipment should be worked in a de-energized state whenever possible. Also, personnel involved with removing electrical equipment from service, such as circuit breakers and disconnect switches, should remain outside the Flash Protection Boundary at all times. This is often accomplished with remote switching techniques. In situations where this is not practical, minimizing the impact of arc flash by reducing arc duration is essential for safe and effective work practices.

Typical protection coordination studies depend on time and magnitude of fault current to provide coordination between upstream and downstream devices.

However, for arc flash conditions time is the enemy and, the longer a fault persists, the higher the incident energy becomes. A low fault current event allowed to persist could have more Arc Energy (incident energy) than a high magnitude fault current that clears quickly. Protection strategies that reduce clearing times for arc flash conditions greatly reduce the incident energy and the overall impact of the event. One method for reducing arc duration is to force the feeder breaker protection to miscoordinate during the short period of time that personnel are within the Flash Protection Boundary. Increasing the sensitivity of the instantaneous (50) pickup setting at the substation feeder breaker will allow the circuit to trip in the fastest possible time while electrical workers are working downstream. Remember, the goal of this program is to give the workers maximum protection and reduce the amount of arc flash clothing they will need to wear.

Methods to Determine Arc-Flash Energy

NESC 410 provides tables for determining protective clothing systems but arc flash calculations provide a more precise method and should be used whenever possible. Incident energy is based on arcing fault current, duration of the arc, and distance from the arc. By reducing arc duration the incident energy can be reduced significantly. A short-circuit study is needed to determine the fault current at the location in question. While an all inclusive protective device coordination study may not be necessary, the device settings in question will be required to determine the arc duration. This information along with the arc flash distance can then be fed into a program like SKM or Arc Pro to determine the appropriate arc-flash energy. This method may require more time but will prove to be more accurate than using the tables.

Protection Coordination

A typical radial distribution feeder protected with multifunction or single function overcurrent relaying would be comprised of 50 and 51 phase and ground overcurrent elements, 50 being the instantaneous overcurrent element and 51 being the time overcurrent element. See Figure 1. These relay systems or single function relays are located in the substation, on the feeder circuit breaker. Other protective devices such as reclosers, sectionalizers, and fuses are used out on the circuit. Circuit reclosers (not to be confused with the 79 function) monitor current and may include fast and slow time curves for fault clearing; sectionalizers count (fault by me) and open after a predetermined number of counts while the circuit is dead; fuses protect for overloads and faults. The 50 and 51 elements of the overcurrent relaying at the substation must be set to coordinate with the circuit protection devices so all work in concert to limit the amount of the feeder removed from service (number of customers taken out of service) for a given fault condition and location.

If there is a feeder fault on the substation side of the circuit recloser and within the 50 "reach" setting, time coordination is not an issue, and the instantaneous element (50) results in fast fault clearing (no intentional time delay). The 50 element trips the circuit breaker at

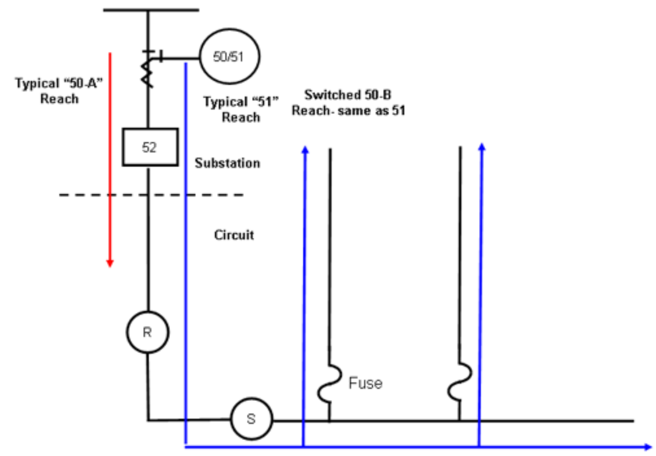

Figure 1: Typical Distribution Feeder Protection Coordination

the substation and the entire feeder is out of service (all lights are out). If the fault was a ¼ mile beyond the recloser, protection elements in the recloser, and fuses beyond, should operate and isolate the fault while maintaining the load between the substation and recloser (some lights are still on). However some utilities use "fuse saving" schemes that allow the 50 to overreach the recloser for one operation and then is defeated. The 51 element of the feeder relay at the substation normally is set to see faults at the end of the circuit (depends on load and other factors); therefore, it provides timed backup protection for nearly all circuit faults, i.e. if a line recloser or fuse fails to clear a fault, the 51 element at the substation eventually will trip the substation circuit breaker and isolate the fault.

Relative to arc flash mitigation, the key point is how much of the circuit is covered (protected) by the high speed 50 instantaneous overcurrent element and how much is covered by the 51 time overcurrent element. As discussed, the 50 is typically set short of the first circuit fault clearing device (3-phase circuit recloser). Also typical, the first recloser is relatively close to the substation in percentage of overall circuit length. As an example, assume the recloser is located in the first 15 to 20% of overall circuit length. Therefore, with the 50 set short of the recloser, at best only 15 to 20% of the circuit has high speed fault detection. If a line crew is performing "hot" work at 30% of the total line length and the circuit is properly coordinated, more than likely the crew is in a time delay tripping (51) portion of the circuit.

This is the essence of the arc flash issue; how quickly can the fault be detected and cleared. The breaker clearing time is fixed, but the longer it takes to detect a fault, the greater the arc energy at the contact point. The arc energy level is what determines required personal protective clothing, or whether the circuit can even be worked when hot.

Basler Product Options for Reducing Arc Energy

BE1-50/51B-235

Basler Electric has several options available to reduce incident energy by reducing the relays' operate time. Multiple settings groups are standard in all Basler communicating multifunction relays.

When maintenance crews work on a circuit or plan to be within the Flash Protection Boundary, the relay can be switched to a "maintenance" setting group, which has a very sensitive instantaneous pickup setting (50) that allows for high-speed tripping over the entire length of the circuit. Setting groups can be changed with a local maintenance switch or via remote communications. This is intentional miscoordination, but only for the short period of time that personnel are within the Flash Protection Boundary, at which time the most important thing is their safety. With the low set instantaneous element armed, it doesn't matter what part of the circuit personnel are working, they are always covered by high speed protection (50) which lowers (mitigates) arc energy when compared to time delay tripping (51). Again, the breaker operate time is fixed and cannot be improved by protective relay choice. See Figure 2.

BE1-50/51B-237

For legacy feeder applications using GE-IAC and ABB-CO electromechanical relays, the same coordination option as found in the multifunction products is available with Basler BE1-50/51B-235 and -237 "plug and play" relays. These are direct replacements (no wiring changes) for the electromechanical product, and each has a 51 time overcurrent and two 50 instantaneous overcurrent elements (50-A and 50-B). The 50-A has a 2-99 Amp pickup range in 1 Amp steps (high set) and the 50-B has a 1-15.9 Amp pickup range in 0.1 Amp steps (low set). See Figure 3.

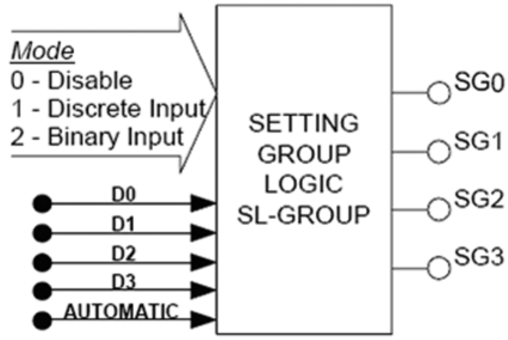

Figure 2: Setting Group Control Logic Block

Before maintenance crews begin work on an energized circuit, the substation circuit breaker automatic reclosing function (79) is disabled. This prevents automatic reclosing of the circuit while the crews are working on the circuit.

Similarly, the second instantaneous element (50-B) of Basler plug and play products manually is switched (43) into the protection scheme at the substation. The 50-B minimum pickup typically is set below the 51 pickup providing sensitive "high speed fault detection" for the entire circuit. Yes, this does cause a coordination problem, but only for the short period of time the line crew is working on or near the hot circuit, at which time the most important thing is their safety. With the low set instantaneous element in the circuit, it doesn't matter what part of the circuit the crew is working, they are always covered by high speed "detection" that lowers (mitigates) arc flash energy when compared to time delay tripping (51). Again, the breaker operate time is fixed and cannot be improved by protective relay choice.

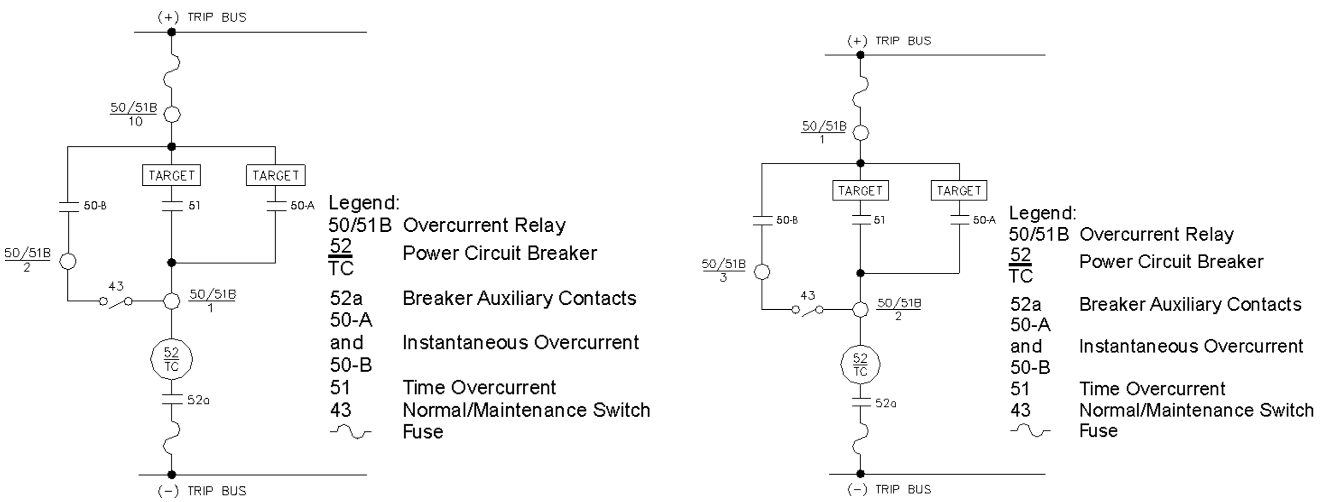

Figure 3: Basler Product Options for Reducing Arc Flash Energy:
Lef t - BE1-50/51B-235 (CO Replacement) Right - BE1-50/51B-237 (IAC Replacement)

Example

By adding a second instantaneous unit when personnel are working on the circuit, the relay trip time can be significantly reduced and, thus, the arc flash energy.

For the example in Figure 4, we have a 1200 amp arcing fault. If the second instantaneous element were enabled, the trip time will be reduced from 42 cycles to 5 cycles plus breaker opening time. This is a 88% reduction in time and equates to arc-flash energy being reduced from 17 cal/cm2 down to 4 cal/cm2. This is a significant reduction and certainly will have an impact on the protective clothing required by the worker.

More Information

You can access information on the entire BE1 numerical protection system family at http://www.basler.com. For more information on Basler BE1-50/51B family of relays, download Bulletin UHK.

You also can call 618-654-2341 for information on Basler products.

For further information on arc flash applications, refer to:

- OSHA CFR 29, Part 1910 Subpart S
- NEC 110.16 - 2008
- NFPA 70E - 2004
- IEEE Std. 1584 - 2002 (with 2004 Amendment)
- IEEE Std. C2-2007 (National Electrical Safety Code) specifically 410.A.3

IEEE 1584-2002 (with the 2004 Amendment) was created to develop a standard for quantifying the dangers associated with arc flash, and in 2007, NESC 410.A.3 identified arc flash as a "recognized hazard" establishing guidelines and a compliance timetable for power generating utilities.

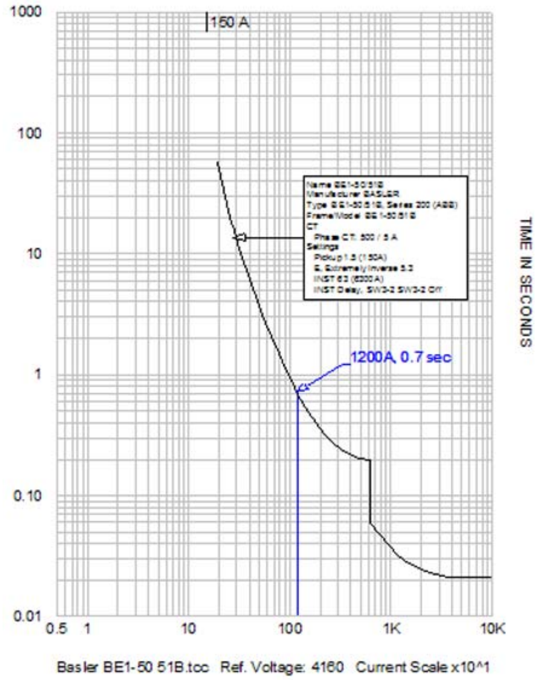

Figure 4: High Speed Fault Detection

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