New standardized approach to arc flash protection

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1. ABSTRACT

Arcing characteristics and arcing faults have been extensively researched historically and more so in recent years. Numerous papers have been written on the subject. The increased level of knowledge has led to more stringent safety regulations to be put in place especially in North-America. This paper will only briefly summarize the common characteristics and risk factors related to arc flash incidents. The main emphasize of the paper is regarding implementation of the very fast acting arc protection based on arc light detection and current supervision. The evolution of the technology from 1980’s to present is discussed. The paper describes the benefits of new method of standard arc schemes.

2. ARC FAULT CHARACTERISTICS

Arcing faults release large amounts of energy in the form of radiant heat, intense light, and high pressure waves. The temperature in an arcing fault reaches as high as 20,000° C. The rapid increase of temperature expands the volume of the air causing a pressure wave which in turn leads further to a potentially damaging sound wave as well. The extreme temperatures cause switchgear components to vaporize within milliseconds. High pressure leads to opening of switchgear doors, releasing extreme energy to exposed personnel, should they be in the area during the arcing fault. In addition to direct light, temperature and pressure effect other danger factors include release of toxic gases and burning shrapnel.

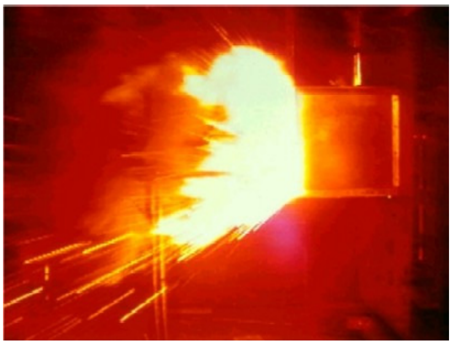


Figure 1: Arc flash events release large amounts of energy.

Arcing faults are typically caused by human errors resulting in equipment failures or aging equipment failing to operate according to specification. Some more common equipment failures are switchgear power cable connections and circuit breaker racking mechanisms. In some operational environments animals, such as rodents and snakes are known to cause arc faults when entering or nesting electrical equipment.

Many arc-flash faults start as single phase to ground fault and then develop into three phase faults. This is why an early detection of the arc fault and consequent fast fault isolation is critical. It is important to note that arcing currents are not the same as available full bolted fault currents due to varying fault impedance. In low-voltage applications arcing currents may be even less than half of the available bolted fault current. This should be considered when evaluating the protective devices clearing times as typically the lower current levels lead to extended clearing times and higher energy releases.

3. ARC FLASH PROTECTION BASED ON ARC LIGHT DETECTION

3.1. BENEFITS OF ARC FLASH PROTECTION BASED ON ARC LIGHT DETECTION

The main advantage of the light or light and current based arc protection system is the operation speed and sensitivity. As the current condition is utilized only as a second tripping criteria the phase overcurrent set-points can be set very sensitively, for example, 1.5 times the load current. Ground overcurrent can be set very sensitive as well. The protection zone is limited to internal arcing faults in the switchgear, and so there is no need to coordinate the protection, thus the tripping can be truly instantaneous resulting in detection and relay operate times of as low as 1-2ms. The total fault clearing time then depends on the type of circuit breaker(s) utilized to interrupt the fault feeding circuit. Arc protection systems are cost effective to implement if compared to traditional busbar differential schemes. It is also important to note that busbar differential protection zone may not include the critical cable terminations due to current transformer locations. Arc light detection and protection provide effective switchgear and busbar protection for both medium voltage and low voltage systems. This kind of arc protection system can be very easily retrofitted into existing power systems.

3.1. HISTORY OF ARC FLASH PROTECTION BASED OF ARC LIGHT DETECTION

The protective devices based on arc light sensors were first introduced in early eighties. The first devices utilized light sensitive arc sensors alone as the tripping criteria. Advances combined arc light and current sensing for the dual sensing method to further increase the reliability of the protection system. The drawback of the first combined systems was the additional operation time when current monitoring was utilized.

3.2. EVOLUTION OF ARC LIGHT DETECTION AND PROTECTION TECHNOLOGY

During the last decade the arc sensing and protection technology has been introduced to all continents and applied in all types of electrical power distribution systems ranging from electrical utility to traditional and renewable power generation, industrial, marine, off-shore, institutional and commercial applications in low and medium voltage switchgear and controlgear. At the same time manufacturers of these technologies have been enhancing products by adding more intelligence.

Operation times of dual sensing systems have been reduced to as low as 1-2ms, from arc detection to trip contact closure. Modern arc detection and protection systems contain full self-supervision capabilities in order to provide highest level of dependability by alarming of any erroneous conditions. Today's systems are capable of measuring both 3-phase currents and residual current along with arc light detection. The residual current detection is important in medium voltage low-resistance grounded systems where early arcing faults can be detected by combination of residual current and arc light detection. Both field data and laboratory experiments have shown that arcing currents in magnitudes of 250 Amps above 1000 Volts are enough to sustain an arcing fault. The combination of residual current and arc light detection can result in tripping action prior to fault escalating to phase to phase fault with resultant additional damage.

More selective and flexible programmable tripping scenarios have been added to arc detection and protection systems. Previously it has been a common practice to isolate the substation totally in case of an arcing faults, i.e. tripping the main feeding circuit breakers. Today's most complex systems require total selectivity limiting the effected zone to minimum in case of an arc fault.

Different kinds of arc light sensors have been introduced and more intelligence added to those. Arc light point sensors and fiber loop sensors are the most common types utilized. Arc sensors operating in high temperatures of up to 125℃ have been developed for environmentally harsh applications, such as wind-power generator winding protection. Different sensor sensitivity levels have been added as well. As an example, a known inherent function of opening an air magnetic circuit breaker during a fault could lead to nuisance tripping. This potential shortcoming was successfully solved by using less sensitive arc light sensors for air magnetic circuit breaker zones. Most modern arc light sensors can be also directed towards the possible fault locations making sensors less sensitive for inherent light released by opening of circuit breakers.

Sensor installation practices have been made simpler, a factor especially crucial in retrofitting arc sensors into existing switchgear. The most modern sensor types can be now connected in series instead of traditional radial star structure reducing the needed wiring significantly.

Figure 2: Modern arc light point sensors may be wired in series making the overall installation and wiring faster and more convenient. The most advanced sensors are able to monitor continuously even the photodiode element by integrated light pulse source. The light pulse also feedbacks users on the ready state of the sensor.

Different sensing elements such as pressure and lately even sound have been suggested as tripping or supervision criteria for arc faults. When combining different sensing types the reliability of the tripping scheme may possibly be enhanced. The drawback in using pressure related sensing is the time delay. Empirical data and laboratory experiments have proven that pressure rises in 5-7ms after the arc ignition and the sound wave results from oscillation of this same pressure. The reliability of the system based on pressure or sound is still to be proven; the pressure caused by closing doors and operating circuit breakers as well as sound of operating of circuit breakers could lead to false detection.

4. REDUCTION OF TOTAL ARCING TIME

4.1. CLEARING TIME

Trip times of dual sensing systems have been reduced to as low as 1ms, from arc detection to output trip signal. The importance of the total system operation time from arc detection to fault clearing needs to be emphasized taking into consideration circuit breakers' characteristics of interrupting the current flow only at zero crossings. This means a best case scenario of 8-10ms, depending on system frequency, fault current and circuit breaker specifications. All this needs to be considered as an additional time delay related to circuit breaker influence on clearing time. As an example, when comparing an arc protection system with trip times of 2ms to a system with 10ms trip times, one might simply assume 8ms difference in clearing time. But when considering the circuit breaker worst case scenario along with trip time difference we can conclude the worst case clearing difference between the two systems being actually much more and up to a full cycle depending on when the circuit breaker actually interrupts the fault current.

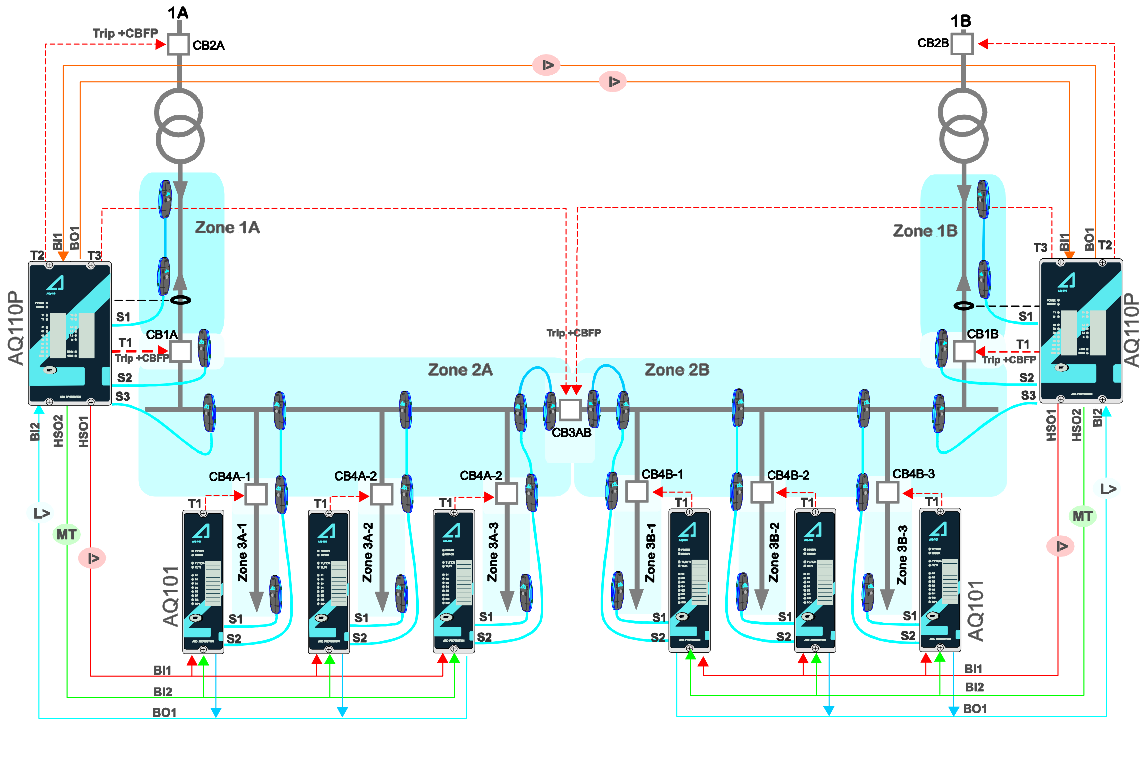
4.2. ARC QUENCHING SYSTEMS

Arc quenching systems were first introduced at 1990's. The main function of the arc quenching system is to facilitate faster arc fault elimination than use of circuit breakers allows considering the evident opening time of the circuit breaker; typically even the fastest circuit breakers require three cycles to open. As the pressure during the arcing fault builds up quickly, within the first ten milliseconds of the incident, even the fastest circuit breakers operating in three cycles are not fast enough to isolate the fault before pressure builds up.

Arc quenching systems are very fast acting devices, operating typically in approximately 5ms or less from arc detection in order to create a parallel low impedance path for the fault current thus extinguishing an arc before pressure builds up. Arc quenching systems have proven to be very efficient method of protection when utilized in conjunction with reliable arc protection and detection systems. When installing arc quenching system a particular attention must be paid to operating within the power system ratings.

5. STANDARD ARC SCHEMES

Standard arc schemes have been introduced to provide fully tested and documented arc protection systems for typical switchgear layouts. The added flexibility in arc detection and protection systems has led to situations where manufacturers have not been able to test all possible combinations of the protection scheme designed. This has caused complexity in setting-up, wiring and commissioning of the systems. The use of standard arc schemes guarantees a fully tested and standard wiring and setting for the protection scheme. Figure 2 illustrates a standard arc scheme layout for switchgear with two incoming circuit breakers and a tie breaker. Figure 3 represents the corresponding standard arc scheme wiring diagram and dip-switch settings.



Scheme IIa1.cdr

Figure 2: Example of standard arc scheme layout.

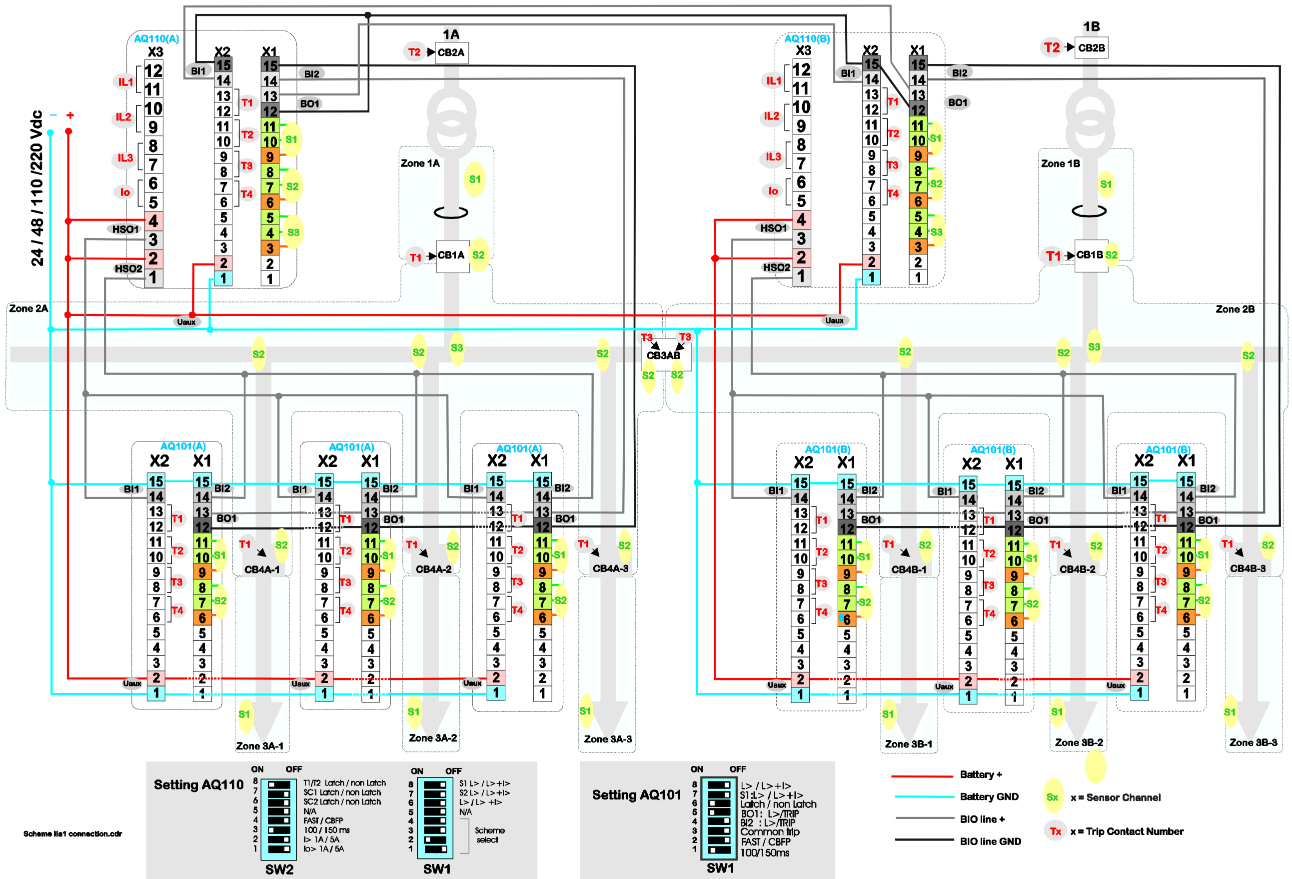


Figure 3: Example of standard arc scheme wiring diagram and dipswitch settings.

6. CONCLUSIONS

Arc flash is a widely researched and well known phenomena and it is becoming more prevalent in designing electrical power systems every day. Arc flash is known to cause potentially severe injuries to personnel and damage to electrical equipment leading to extended production outages. Arc flash protection using arc sensors sensitive to light and combination of arc light with current is a widely utilized and accepted protection principle. The dependability, applicability and operation time of the arc detection and protection systems has been evolving over the last decades. Arc quenching devices can be utilized in conjunction to arc detection and protection systems to minimize the pressure effect caused by an arcing fault. Use of standard, pre-build arc schemes offers users standard method of protection leading to direct cost savings and improved project timelines. The standard arc schemes provide greater reliability of the arc protection system in terms of manufacturer tested and documented solutions. The required application engineering time is reduced when applying standard wiring and setting practices. Standardization makes the commissioning of the systems more effective and reduces the after sales cost significantly. The modern arc protection and detection systems provide a solid solution for reducing energy released and damage to personnel and equipment in electrical power systems operating above 240VAC phase to phase.

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