# Implementation of an Arc Flash Reduction Maintenance Switch – A Case Study



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***Abstract*** - This paper presents a case study of an event that occurred in an industrial facility that resulted in an outage without extensive damage and no harm to employees due to proper use of arc flash reduction products and a safety program. The case in point will illustrate a design of a power distribution system that was approached with safety in mind as well as the safety program that complimented the design resulting in a much less severe event. Arc flash reduction solutions and techniques will be discussed, especially those that were used in this example. The safety program implemented at this facility will also be reviewed to illustrate the proper recipe for safety. This case illustrates how even working de-energized can present opportunities for accidents to occur that should be addressed through proper use of installed safety equipment coupled with the successful implementation of a safety program..

*Index Terms* — Arc Flash, ARMS, Maintenance

## I. INTRODUCTION

Arc flash events can be devistating to all involved on many different levels. With tthe proper safety plan and proper use of various technologies, arc flash events can be a thing of the past. There are many technologies on the market today that can help reduce the energy in a power distribtuion system in the case that a problem arises. This is a documented event that demonstrates the power of utilizing not only technologies but also the safety procedures that help ensure everyone’s safety on the job.

An arc flash requires time and current. The various technologies on the market seek to reduce one or the other or both of these components in the effort to reduce the energy released – hence mitigating the arc flash event.

## II. SAFETY PLANS AND PROCEDURES

### A. Project Preparation / Background

This project involved a major rework of a 480 volt distribution system which was supplied from a 1000kVA transformer. One of the first steps in this project, as per NFPA 70E Section 130.4(A) and 130.5(B), a shock and arc flash work hazard analysis was performed. This analysis found that a complex lockout and safe work permit was required for the last portion of the project which included the removal of a three conductor cable from the back of the 480 volt switchgear. This cable was removed from cable tray exiting the switchgear before work in the switchgear began. An Arc Flash Maintenance switch was identified to exist up stream of the 480 volt switchgear and was planned to be utilized for this project. The available energy without the maintenance switch and with the maintenance switch was 17.7 Cal/cm sq and 2.9 Cal/cm sq respectively. The PPE that was specified for this project included level 2 as the energy level was 2.9Cal/cmsq per the arc flash calculations. The available fault current at the 480 volt switchgear was 21,000 amps.

### B. Energized Work

The electrical contractor for this portion of the project, obtained the complex lockout and safe work permit and as per NFPA 70E section 120.2(D)(2), performed a project review to determine the necessary PPE that was required. The contractor also reviewed the switchgear installation to understand all aspects of the project and equipment that would be interfaced with. The energized cubicles and the maintenance switch were located. To proceed, the maintenance bypass switch, located on the switchgear, was placed in the on position and appropriate locks were put in place.

### C. Event

During the actual work of removing the 3 conductors, a rope was used as is typical with this type of project. The rope could not grab the conductors and would slip off of the cable which showed no signs of moving. The electrical contractor then employed a come along to assist in the removal as the come along could apply more force. The first conductor was successfully removed with this new tool. Upon removing the second conductor a small flash was observed below him. At this same instant the lights to the plant went out. The electrical contractor stopped his work and waited for the plant electricians to arrive not knowing what had just occurred.

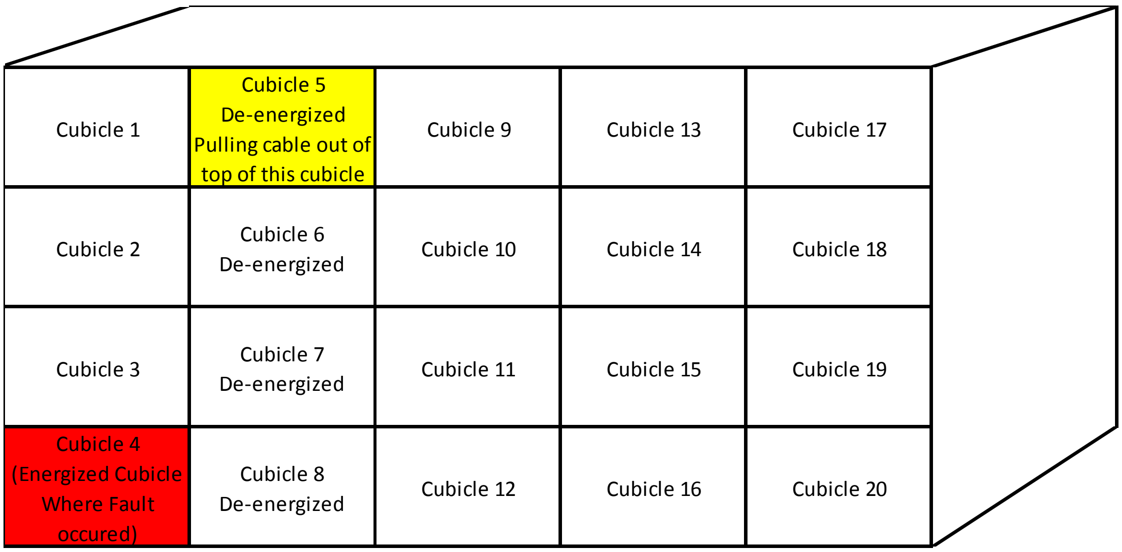


Figure 1: Cubicle arrangement depicting location of work relative to location of energized cubicle where the come along chain touched an energized terminal.

D. Post Event Analysis

The event caused the entire plant to shut down and stopped work on the project until an analysis could be completed. After the electrical contractor saw the flash of light, they stopped work and waited for the plant electricians.

The damage to the wall of the switchgear and come along tool was minimal. The chain of the come along had drifted below where the work was being performed and into an energized cubicle. (See Figure 1.) The chain touched an energized terminal and arced to ground when the chain touched metal in the non-energized cubicle just under where the electrician was working. After reviewing minimal damage (Figure 2) and completing the project while de-energized, the plant re-energized the switchgear. Total down time for the plant due to this event was minimal. No loss of equipment or injury to any employee was a result of this event.

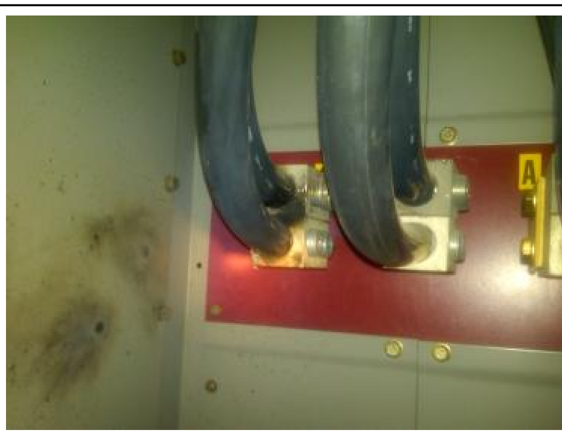

Figure 2: Small arcing results from event.

## III. EMPLOYED ARC FLASH REDUCTION TECHNIQUE

1) The Implemented Design

This system utilizes a design such that the arcflash reduction technology is separate from the instantaneious trip functionality with which we are most familiar. Instantaneous is defined as without intentional delay. The clearing time of the instantanious functionality of a circuit breaker, is determined by all that has to happen from the time the fault is detected to the time that the breaker clears the fault. There is not only an electronic functionality that takes time, there is also a physical action that must occur and it too takes time. The physical portion of fault clearing for a given breaker will stay the same but the electronics, how the trip unit detects and tells the breaker to trip, can be made such that the reaction time occurs faster under different circumstances.

Take the standard instantanious trip functionality for example. The electronics, the microprocessor, inside of the trip unit will have to sample the current that is flowing through the breaker, convert it to digital perform some logic/math to translate the received signal into a value that better represents current and then compare this value with the settings that were programmed by the engineer. This activity will take time to perform by the microprocessor and is represented in the trip curves that are used in coordination studies and arc flash studies. Any additional functions on the microprocessor will add to the time that it takes for a circuit breaker to trip. For example, if an additional function of zone selective interlocking (ZSI) was added, the microprocessor is being asked to perform additional functionality. ZSI works such that when an upstream circuit breaker detects a fault and receives indication that a downstream circuit breaker has also detected the fault, the upstream circuit breaker waits as per its programmed short delay time for the downstream circuit breaker to clear the fault. If this trip unit determines, during a fault, that the downstream breaker does not detect the fault, it will trip instantaniously. This instantious trip may not have the same clearing time as the standard instantanious because the microprocessor is doing more work before it determines that it must trip. There is no intentional delay, but the time to clear the fault for this ZSI functionality may be longer than your standard Instantaneous Trip clearing time.

The arc flash reduction technology used in this design works faster than the microprocessor driven instantanious functionality of the trip unit because it takes the microprocessor out of the picture and sends a trip signal based on analog circuitry. This is the same clearing time that you will get for the same breaker not in this arc flash reduction mode if you exceed what is called the instantanious override region of the Time Current Curve (TCC) curve. In this region of the curve, the breaker is simply trying to protect itself by removing the fault as fast as possible without waiting for a microprocessor to digest what it is seeing and tell the device to trip. Because this device acts so quickly, this has a very positive effect on the reduction of arcflash energy – very desirable if you are on the receiving end of that energy.

The reduction technology utilized in this application is designed to be put into action only during that period of time when work is being performed. The applicable switch for the project at hand was up stream of the equipment being worked on.

Table 2 below illustrates the impact that the technology employed here can have on the energy during a fault. Here, for a bolted fault current of 40kA, the arc flash incident energy is reduced from 10.7 cal/cm2 by approximately 80% to 2.2 cal/cm2 when the arc flash reduction maintenance switch is employed.

| Energy Reducing Maintenance Switch | Bolted Fault Current (kA) | Arcing Fault Current (kA) | Trip Delay Time (ms) | Incident Energy (cal/cm$^2$) |
|---|---|---|---|---|
| Inactive | 40 | 19.98 | 240 | 10.7 |
| Active | 40 | 19.98 | 50 | 2.23 |

Table 2 – Effect of an Energy-Reducing Maintenance Switching on Incident Arc Energy [10]

Figure 3 depicts what the arc flash reduction maintenance switch does to the TCC curve and offers more of a visual to facilitate a better understanding.

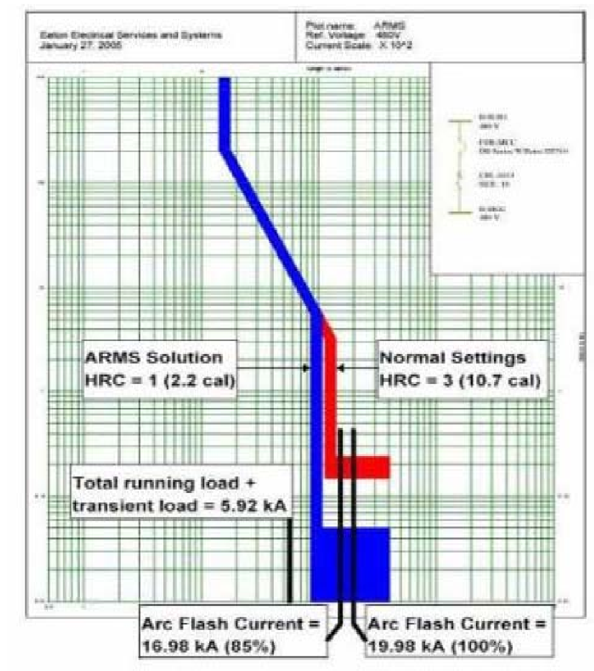


Figure 3 – Time-Current Curves showing Trip Time with Energy-Reducing Maintenance Switching [10].

## IV. CONCLUSIONS

System design, proper safety procedures and implementation lead to a successful avoidance of loss of property and lives that could have occurred in this event. Mistakes were indeed made, but did not result in a catastrophic event because procedures to utilize safety equipment, that was installed to reduce the energy in the distribution system should an event occur, were properly implemented before this project was begun.

The mistakes made by the electrical contractor in this case are good examples of what can occur during a project when events don't go as planned. In this case, due to the fact the anticipated method of removing the conductors was not working properly, a new tool was introduced (scope creep). When the plan was changed, the electrical contractor did not review the job before the tool was selected and utilized to remove the conductors. The tool should have been insulated as specified by the project plan. In this case, an un-insulated come along was used.

Even though a plant shut down was initiated by the safety equipment installed in the plant, a restart was able to be initiated due to the fact that damage was minimal.

## V. REFERENCES


[1] NFPA 70, 2011 *National Electrical Code*, Quincy, MA: NFPA.

[2] NFPA 70E, 2012 *Standard for Electrical Safety in the Workplace*, Quincy, MA: NFPA

[3] Christopher G. Walker, "*Arc Flash Energy Reduction Techniques Zone Selective Interlocking & Energy-Reducing Maintenance Switching*", Pulp and Paper Industry Technical Conference (PPIC) Conference Record: 2011


## VI. VITA

**Thomas A. Domitrovich (M'90)** Thomas A. Domitrovich is an Application Engineer for Eaton Corporation in Pittsburgh PA. Thomas began his career in 1990, after graduating from Gannon University in Erie PA with a Bachelor of Electrical Engineering (BEE), with Gilbert Commonwealth as an electrical engineer. Thomas has his Professional Engineering License and is a LEED Association Professional (LEED AP). Thomas has worked with electrical power systems from residential to large industrial and utilities. He is a member of the Institute of Electrical and Electronic Engineers (IEEE), involved with the National Electrical Manufacturer's Association (NEMA), the National Fire Protection Association (NFPA) and other industry organizations. Thomas is an Alternate member on NFPA 73 and has published industry articles as well as IEEE white papers.

**Kenneth White** received his BSEE from Rochester Institute of Technology. He is currently Principal Division Electrical Engineer, for Olin Chlor-Alaki and has thirty five years of experience in the chemical industry with various positions in Engineering, Maintenance and Management, primarily in the fields of power distribution, rectification and industrial controls.

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