Siemens Dynamic Arc Flash Reduction System and its application in motor control centers

The risk of Arc Flash is a growing concern within the electrical equipment community and among both designers and workers. Current research shows that up to 80% of reported electrical injuries are caused by an electrical arc[1]. This fact has spawned new requirements and standards in governing documents, such as in NFPA 70E and the NEC, which address the safety of workers, on and around energized electrical equipment. Prior to the development of these standards, Siemens understood the importance of mitigating arc flash risk for its customers. This led Siemens to develop the innovative Dynamic Arc Flash Sentry (DAS). This paper will explore the capabilities of the Dynamic Arc Flash Sentry, investigate an example case, and show the benefits of this technology in motor control centers.

Siemens strongly recommends that all systems be de-energized when personnel are working on electrical equipment. However, in some circumstances qualified professionals may need to access and work near energized equipment. For example, many troubleshooting operations, or work on critical applications, require that power remain on to complete the task. This is where many accidents occur and the risks and effects of an arc flash are the greatest. The Dynamic Arc Flash Sentry system is designed to greatly reduce the risk of arc flash while maintaining efficiency of the loads on the motor control center. These loads could include motor inrush currents, and normal variance in motor operating amperage.

Siemens Dynamic Arc Flash Sentry Technology uses a dual function setting of the ETU776 electronic trip unit when housed in the Siemens WL power circuit breaker. The trip unit has two complete and independent set of parameters (A and B), that allow the operator to switch back and forth from a normal operating mode to a personnel protective mode. It should be noted that the parameters A and B can be assigned to either the normal operating mode or personnel protective mode. By setting the personnel protective mode to parameter A and the normal operating mode to parameter B, a fail-safe is created because the system will default to DAS-active in the event the DAS wiring is broken. However, throughout this paper, normal operating mode will refer to parameter A and personnel protective mode will refer to parameter B. The personnel protective mode (Parameter B) reduces the instantaneous trip setting of the WL main circuit breaker. By reducing the instantaneous region, the trip timing of the system is controlled, and can be reduced to clear a fault much sooner than the original operating time. This decreases the amount of energy available in an arc flash, making the area surrounding the motor control center less susceptible to an arc flash event.

Let's look at an example of how the DAS can function to increase safety and help mitigate the risks associated with arc flash. We will use a sample system that is based on an actual application in the field. This example was set up with aid from ESA and their EasyPower software[2] tool to help create the motor control center layout and calculate the associated arc flash energies. Figure 1 shows a typical motor control center with a Siemens WL as a main circuit breaker and numerous feeder circuit breakers controlling different functions including motors, panels and other loads.

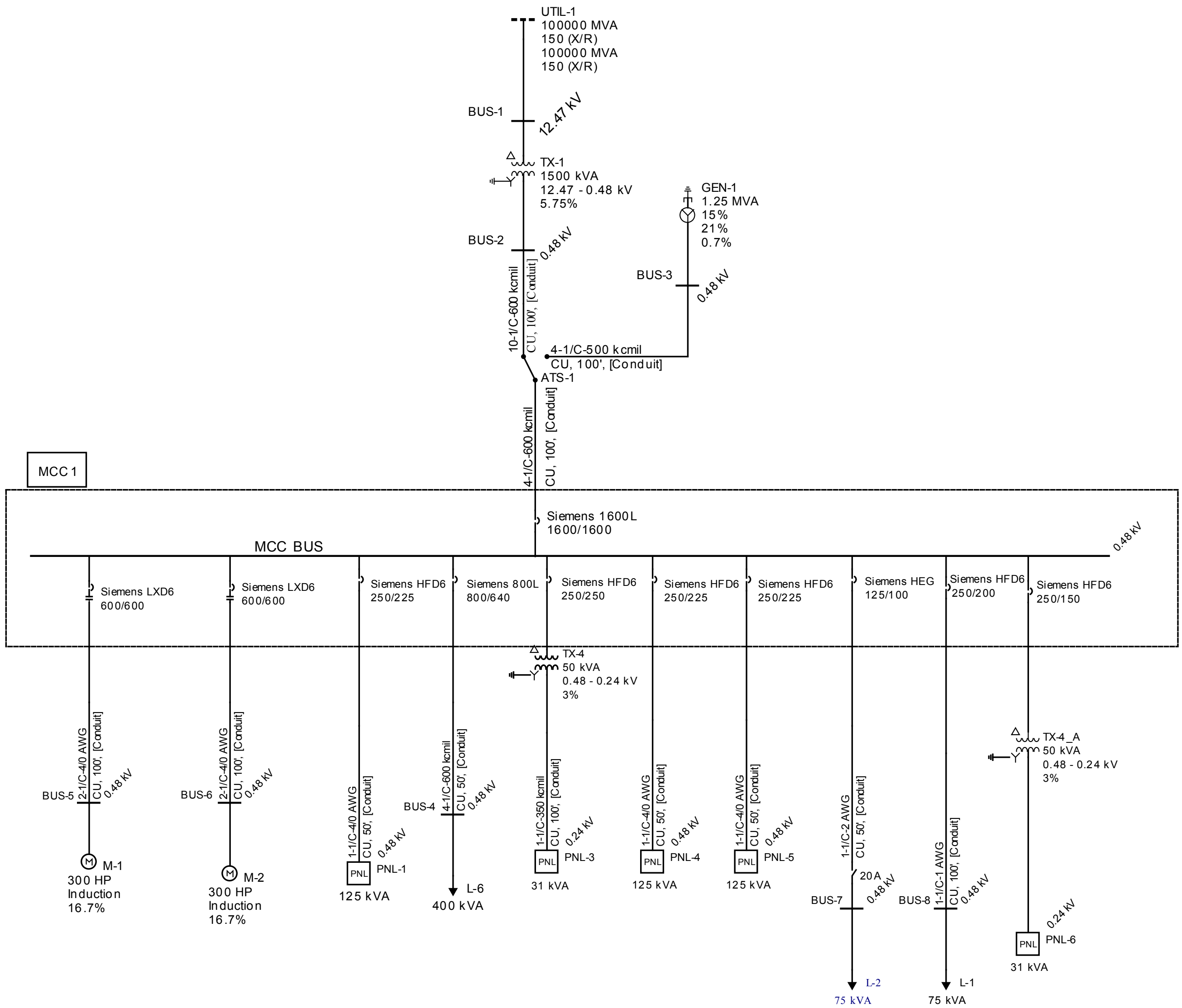

Figure 1 – MCC Example One-line Diagram

Note: The 1600A main circuit breaker of the example is in an isolated section respective to the rest of the MCC. The incident energy for this section will be as calculated using the upstream protective device and not the levels shown for the MCC bus.

This MCC configuration will serve as the basis for this example. To properly coordinate the circuit breakers controlled in the MCC with the main circuit breaker upstream, it is appropriate to analyze the time current curve (TCC) to see the trip parameters for long time, short time, and instantaneous trips. Typically in a motor control center, as with MCC1 in Figure 1, there are numerous operating devices present. The resulting TCC for this motor control center would be cluttered and virtually unreadable. For this example, we selected the three most relevant devices to display, that will affect the coordination of the upstream circuit breaker. Figure 2 shows the TCCs of four devices: a 600A Siemens combination motor starter with a 600A Siemens LXD6 circuit breaker, a 250A Siemens HFD6 circuit breaker, an 800A Siemens WL800L, and the main device a 1600A Siemens WL1600.

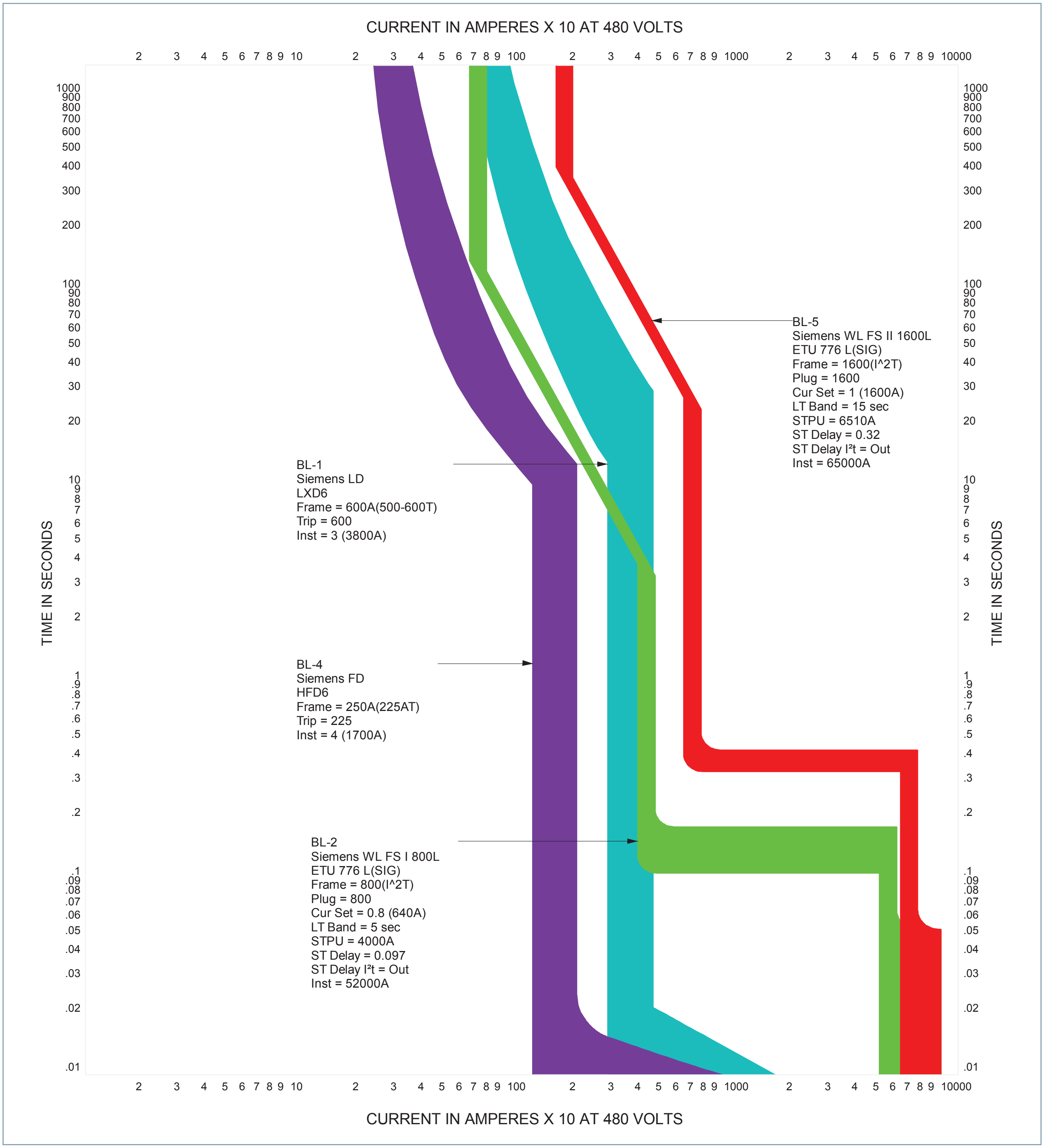

Figure 2 – TCC of Parameter A – Normal Operating Mode

As you can see in Figure 2, the WL circuit breaker is selectively coordinated with the devices downstream from it. The WL main circuit breaker will instantaneously trip within 50 milliseconds at 65 kA. The next step is to determine the arc-flash boundary and proper personal protective equipment (PPE) needed. There are two methods to determine this. The first method is the incident energy analysis method based on IEEE 1584 calculations, which are used to determine the arc-flash boundary and incident energy exposure. Based on the incident energy exposure, the correct PPE can be determined using Table H.3(b) in NFPA 70E, shown below as Table 1.

The second method is the arc flash PPE categories method. Table 130.7(C)(15)(A)(b) or Table 130.7(C)(15)(B) in NFPA 70E can be used to determine the PPE category and arc-flash boundary required for work on certain equipment. Table 130.7(C)(16) can then be used to determine the specific PPE required for each PPE category.

It is important to note that either, but not both, methods can be used on the same piece of equipment. For example, the incident energy cannot be calculated and then used to select a PPE category from Table 130.7(C)(16).

Table 1 below from NFPA70E 2015 edition shows the PPE required for each PPE risk category.

Incident Energy Exposure	Protective Clothing & PPE
≤ 1.2 cal/cm²	
Protective clothing, nonmelting (in accordance with ASTM F 1506) or untreated natural fiber	Shirt (long sleeve) and pants (long) or coverall
Other PPE	Face shield for projectile protection (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors (AN)
> 1.2 to 12 cal/cm²	
Arc-rated clothing and equipment with an arc rating equal to or greater than the determined incident energy	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall or arc flash suit (SR) Arc-rated face shield and arc-rated balaclava or arc flash suit hood (SR) Arc-rated jacket, parka, or rainwear (AN)
Other PPE	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection Heavy-duty leather gloves or rubber insulating gloves with leather protectors Leather footwear
> 12 cal/cm²	
Arc-rated clothing and equipment with an arc rating equal to or greater than the determined incident energy	Arc-rated long-sleeve shirt and arc-rated pants or arc-rated coverall or arc flash suit (SR) Arc-rated arc flash suit hood Arc-rated gloves Arc-rated jacket, parka, or rainwear (AN)
Other PPE	Hard hat Arc-rated hard hat liner (AN) Safety glasses or safety goggles (SR) Hearing protection Arc-rated gloves or rubber insulating gloves with leather protectors (SR) Leather footwear

Table 1 - Guidance on Selection of Arc-Rated Clothing and Other PPE from Table H.3(b), NFPA 70E 2015

Notes:

AS: As needed [in addition to the protective clothing and PPE required by 130.5(C)(1)]

SR: Selection of one group is required by 130.5(C)(1)

Figure 3 shows the conditions that appear at the MCC when a fault is sent to the bus in MCC1. Using the incident energy analysis method, the incident energy is calculated to be 24.4 cal/cm^2. Table H.3(b) can then be used to determine the PPE required to work on this MCC.

As the PPE requirements increase, the material can become increasingly bulky and hot, leading to uncomfortable work conditions for any personnel. Additionally, operators wearing arc flash suits have to be specially trained, and periodically re-certified to wear the equipment. Figure 3 also shows that the arc flash boundary is 112.7 inches away from the MCC in every direction. To have personnel working on or around this electrical equipment can be extremely hazardous.

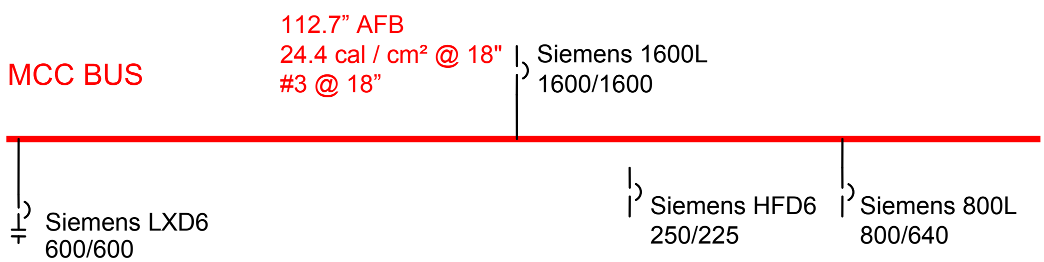

Figure 3 – Arc Flash in Parameter A

So how can we resolve this problem? There are two significant solutions to this problem, which can be used either independently, or jointly, to provide redundancy. The first alternative is to reduce the incident arc energy of the system, as discussed in this document. The second alternative is the **tiastar™ Arc Resistant Motor Control Center**, as described in its own White Paper.

The first alternative, reducing the incident arc energy of the system, is done by reducing the clearing time of the fault, which results in a safer environment. This solution lies in the patented Siemens Dynamic Arc Flash Sentry Technology.

Instead of working under these conditions, the DAS allows the flexibility for the worker to switch from the normal operating settings of Parameter A, to the lower arc flash energy settings of Parameter B. The goal is that when any person is working on or near this equipment, the system will be set to Parameter B. This is made possible by the dual protection capability of the ETU776 trip unit previously mentioned. So, lowering the instantaneous trip settings of the WL circuit breaker ensures that the time it takes for an electric fault to clear will be decreased, providing a safer working environment. Let's look at the second part of the example.

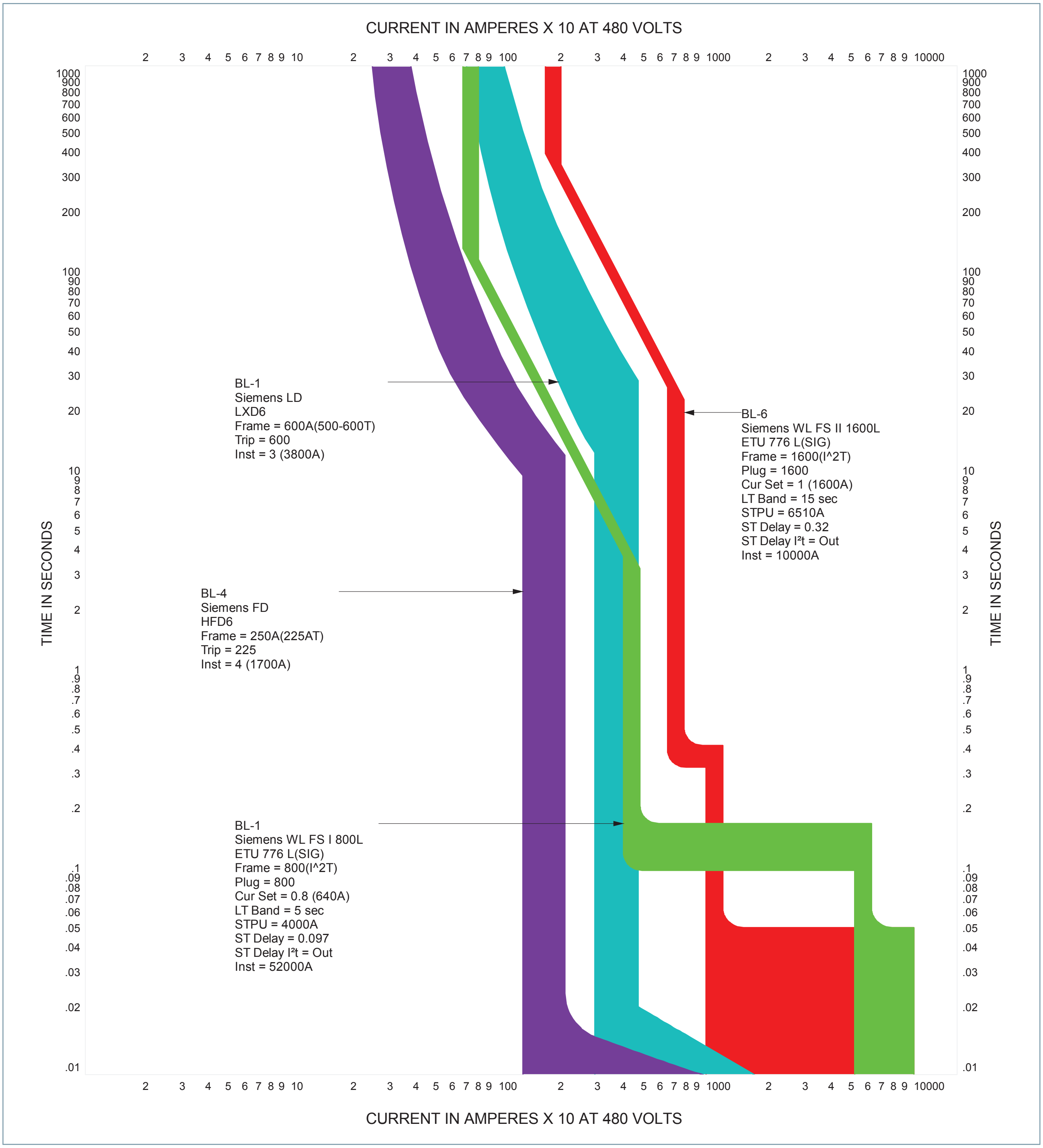

Figure 4 – TCC of Parameter B – Enhanced Safety Mode

When switching from Parameter A to Parameter B, each of the settings is kept the same in the motor control center, except the instantaneous trip setting of the WL main circuit breaker. The TCC for Parameter B is displayed in Figure 4. As can be seen, the WL main overlaps the WL feeder circuit breaker in the instantaneous region, which was lowered to 10kA, while the other regions remain coordinated appropriately. This provides another example of the flexibility of the ETU 776 trip unit in the Dynamic Arc Flash system.

This system allows the user to alter the trip delay settings, as well as long time, short time, and instantaneous pickup of the ETU 776 trip unit. However, these changes are not required and can be kept the same for simplicity reasons. In this example, only the instantaneous pickup was reduced between Parameter A and B, keeping all other trip unit and main circuit breaker settings the same. When an electrical fault is applied to the MCC1 bus in Parameter B, the difference can be seen.

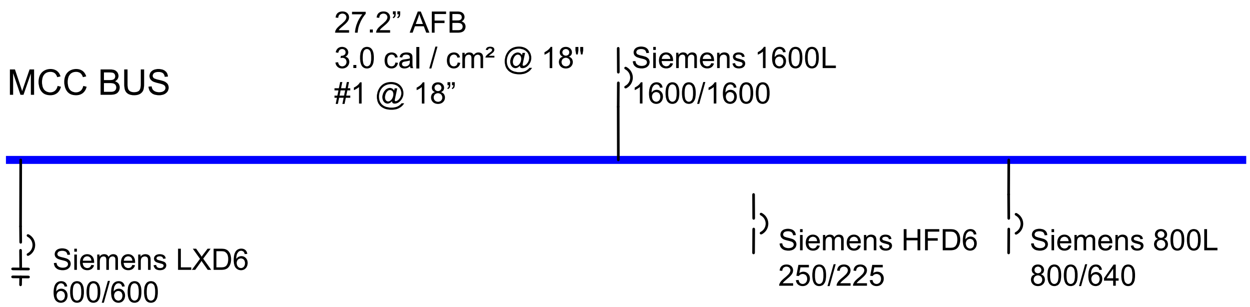

Figure 5 – Arc Flash in Parameter B

The results of the arc flash hazard analysis show that the incident energy has been reduced to 3.0 cal/cm^2, which is over an 8 times reduction in energy.

Based on the incident energy analysis method, this also significantly reduces the amount of PPE required by Table H.3(b).

Now let's compare the TCCs from Parameter A and B when they are side by side, as shown in Figure 6. This clearly shows that the only parameter that is changed is the main WL circuit breaker, with the instantaneous pickup being reduced. This greatly reduces the incident energy of a potential arc flash and creates a safer environment.

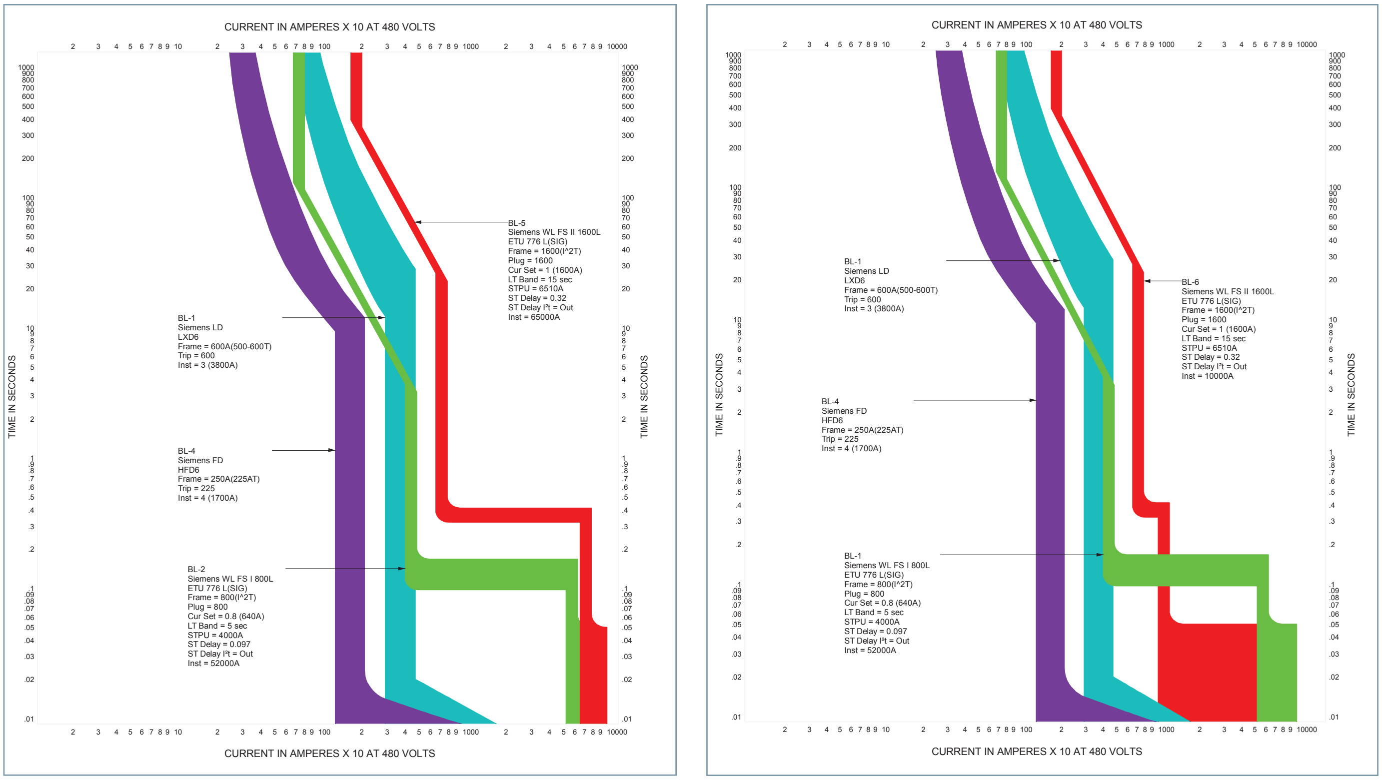

Figure 6 – Parameter A and Parameter B comparison

By switching from Parameter A to B, the DAS allows a temporary overlapping of the main circuit breaker with a feeder circuit breaker. However, to fully understand this situation, there are two main points to consider. First, to maintain a reliable system and avoid nuisance tripping due to normal operating currents in Parameter B, inrush currents must be taken into account. In this example, a 1500kVA transformer with a 480V secondary side and 5.75% impedance has a typical full load current of around 1.8kA. For the 300 HP motor running in our example, the full load amperage is 361 amps, which gives a typical inrush current of around 4700 amps.[3] With a peak inrush current lasting less than one second, this value is still well below the instantaneous pickup of the main circuit breaker at 10kA. Even with multiple devices and other loads running, a very high current spike would need to exist in order to trip the main. The reality is: if the system is designed correctly, compromising of the coordination which causes issues such as nuisance tripping should be extremely limited. In addition, the trade off that is being made with a worker standing in front of an energized motor control center should be worth this concession.

This leads to the second and more realistic point of understanding the temporary overlap of the main circuit breaker with a feeder circuit breaker. Parameter B does present an overlap of coordination; however the intent of this system is to create a significantly safer environment when the equipment is energized. Safety should be the primary concern in the unique and unusual situation in which the equipment cannot be de-energized. To address this issue, the DAS provides the flexibility of the full range of settings to create a safer environment for workers. In this way, the DAS system provides a unique solution for the industry.

The Dynamic Arc Flash Sentry has been available in low voltage switchgear for some time. It is available in Siemens Arc Resistant Motor Control Centers. This technology can also be employed in Siemens switchboards and busway. Siemens is listening to its customers and meeting the highest industry standards. By offering a system that has the flexibility to actually reduce the amount of arc flash incident energy without forcing customers to choose reliability over safety, the Dynamic Arc Flash System is addressing the difficult challenges related to electrical worker safety.

References:

[1] National Technology Transfer, Inc. NFPA 70E/ Arc Flash: Electrical Safety. Edition 3.1.

[2] EasyPower Software. ESA.

[3] "Inrush Current of Standard and High Efficiency Motors." Siemens Industry Automation and Drive Technologies, Service & Support. www.automation.siemens.com.

[4] IEEE Std 1584 -2002.

[5] NFPA 70E: Standard for Electrical Safety in the Workplace. 2015 Edition.

[6] "Dynamic Arc-Flash Sentry" by Ray Clark. Siemens Technical Journal.

Siemens Industry, Inc.
5300 Triangle Parkway
Norcross, GA 30092

1-800-964-4114
www.usa.siemens.com/mcc

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