ETAP Implementation of Mersen's Medium Voltage Controllable Fuse to Mitigate Arc Flash Incident Energy

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White Paper No.001.14 - 2016

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Abstract: This white paper provides a comprehensive discussion of the modeling of Mersen's medium voltage controllable fuses (MVCF) in ETAP. Two simulation techniques and their incident energy mitigation benefits are presented. Some important considerations in system configuration, protective device co-ordination, and application are also included.

Key Words: Medium Voltage Controllable Fuse, Mitigation techniques, ETAP, Fuse protection, MVCF,

1 INTRODUCTION

The use of electrical fuses has been used in the industry to protect electrical system, people and equipment for over 150 years. Medium voltage fuses used for transformer primary protection have successfully fulfilled system protection concerns by isolating fault current from the equipment. Arc faults on the transformer or equipment supplied by the transformer may yield low current magnitudes (in particular with respect to the primary side of the transformer). Such low currents often cause long fuse clearing times. Some of these clearing times may exceed 2 seconds. The end result of such long clearing times is a high incident energy value (typically over 40 cal/cm²). Medium voltage controllable fuses can overcome some of these problems since they can be configured to maintain coordination and still operate in a relatively low clearing time when compared to conventional E-type fuses. The typical application of a MVCF device is to install a secondary current relay which controls the operation of controllable fuse actuator module which bypasses the current into a high speed current limiting fuse. There are two methods which may be used to model MVCF devices in ETAP.

1.1 Method 1: As an external relay interlocked to operate contactors.

1.2 Method 2: As a medium voltage current limiting fuse.

Either method can be used to simulate normal and maintenance mode of operation. Their advantages/disadvantages are discussed in the conclusion section later in this paper.

2 PRIMARY FUSE PROTECTION ISSUES

In this example, before presenting the implementation of the MVCF device in ETAP, a few application concepts need to be discussed first.

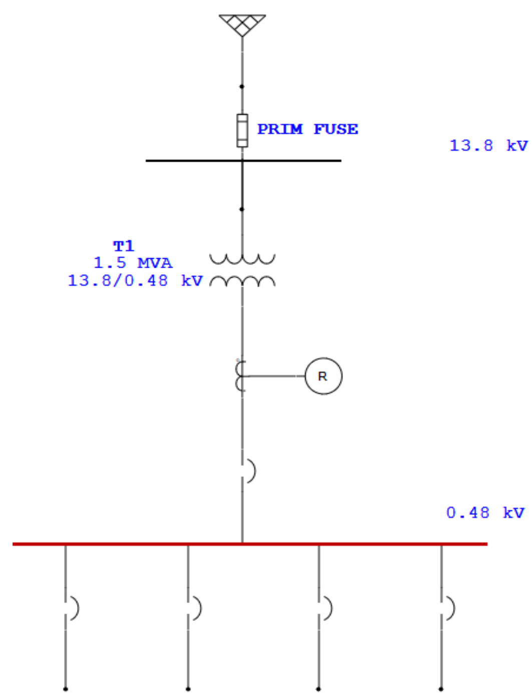

Figure 1: Switchgear with no MVCF.

The system described in Figure 1 shows a 480V switchgear where an incident energy calculation performed showed incident energy exceeding 40 cal/cm². The primary transformer protection is an E-rated fuse selected based on the transformer protection criteria.

Figure 2 shows the time current characteristic curve for the system of figure 1. It can be easily noted that for an arc fault anywhere in the secondary of the transformer and/or main protective device (optional in some designs) that the clearing time of the fuse will be in the seconds range. This is caused by the very inverse characteristic of the primary side fuse.

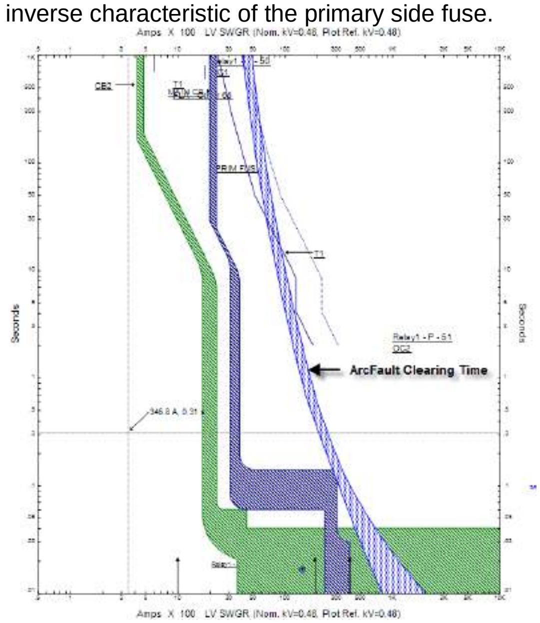

Figure 2 Time Current Curve for LV System

3 MVCF MODELLING TECHNIQUES

3.1 MVCF ETAP Implementation-Method I

The basic goal of the MVCF device is to mitigate incident energy and reduce equipment damage. Figure 3 shows the actual implementation and components needed to implement the MVCF. Figure 4 shows how these components would be modeled in ETAP by using a current transformer, overcurrent relay with multiple OC levels and a normally closed bypass switch. In figure 5, it can be observed that the 50P OC relay level is set to operate the bypass at the required time delay (for coordination with downstream devices). A 51P OC level is used to simulate the CLF fuse total clearing time.

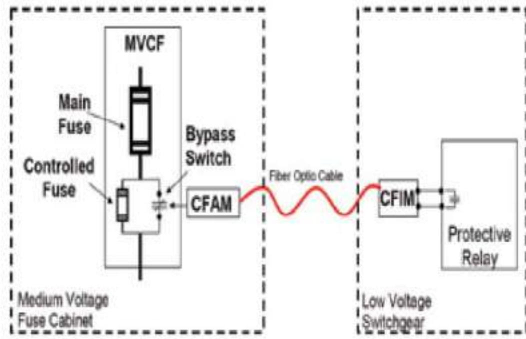

Figure 3: MVCF Diagram

The E-rated fuse is present and will protect the transformer against overload conditions and primary faults, but the MVCF device will operate much faster under short-circuit or arc fault conditions. Figure 5 showed the normal mode of operation which significantly reduces the incident energy level at the line side of the main switchgear breaker from 40+ to approximately 14 cal/cm^2.

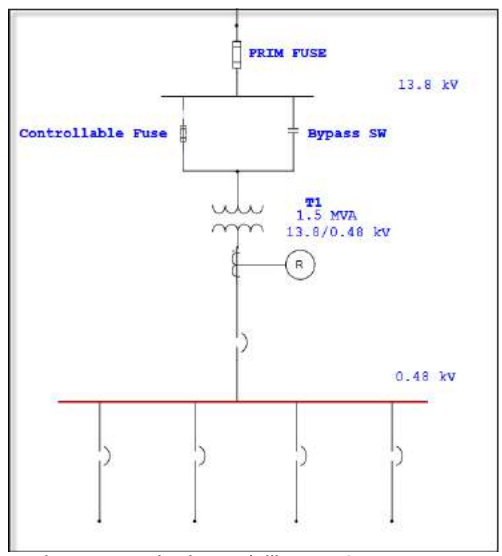

Figure 4: Method I-Modelling MVCF as an external relay in ETAP

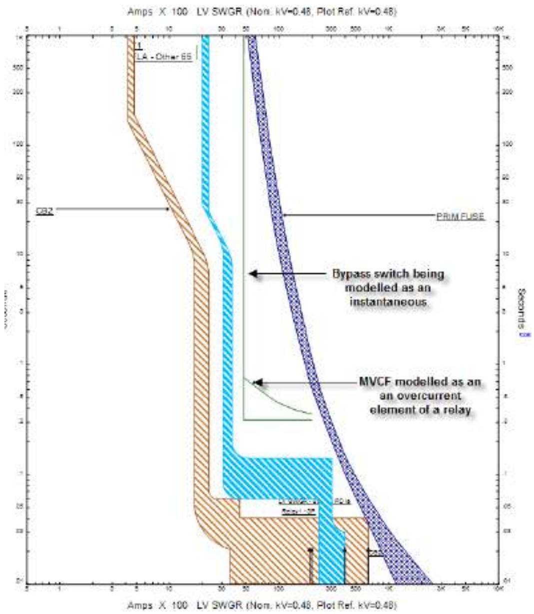

Figure 5: Time Current Curves of Controlled Fuse with 200 ms delay.

If further incident energy mitigation is required, a maintenance mode may also be implemented using the MVCF device. The maintenance mode can be modeled in ETAP by adjusting the instantaneous and overcurrent levels down to very low pickup values which are enabled only during energized work. The resultant incident energy is much lower (approximately 3 to 4 cal/cm^2). Of course, just like with any maintenance mode incident energy mitigation technique, coordination is compromised during the time energized work is taking place. Figure 6 shows the TCC of the same system with the maintenance mode enabled.

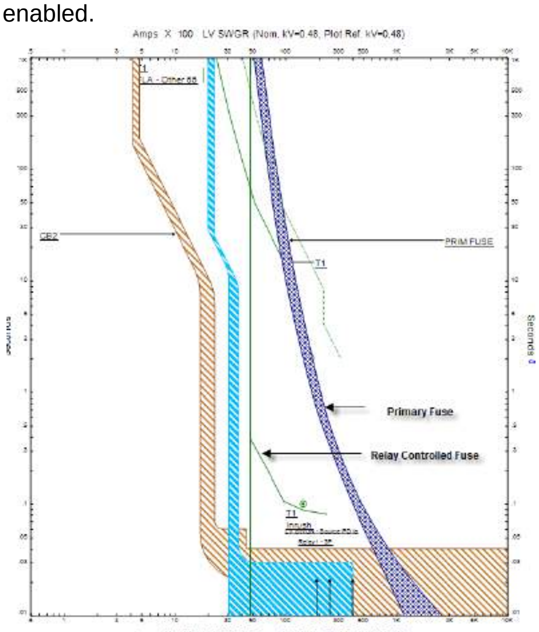

Figure 6: Method I :MVCF with Maintenance Mode

3.2 MVCF ETAP Implementation-Method II

In this approach, (Figure 7), the MVCF is modelled as an actual fuse and it is coordinated to isolate secondary side faults while continuing to provide coordination with downstream elements. It is modelled in such a manner that it will block any current below 100A and anything above 1000A will be cleared by the main fuse.

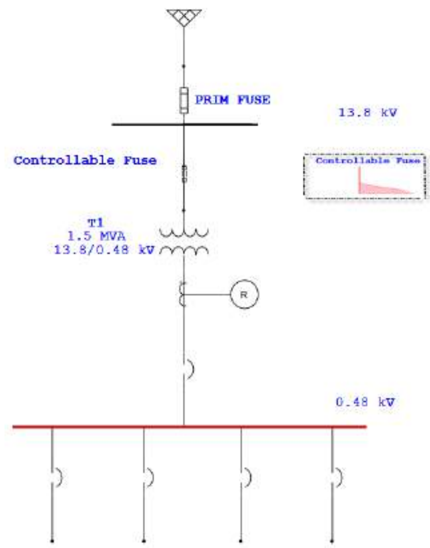

Figure 7: MVCF Implementation with Fuse Curves

Figure 8 shows how the MVCF device is modeled as a TCC fuse curve. There are no calculation differences expected from ETAP arc flash when modeling the device using method I or II.

The total clearing time of the fuse (upper fuse curve edge) is used by ETAP to calculate the total incident energy. The energy released at the line side of the main secondary protective device is still expected to be approximately 14 cal/cm^2 since both methods are equivalent.

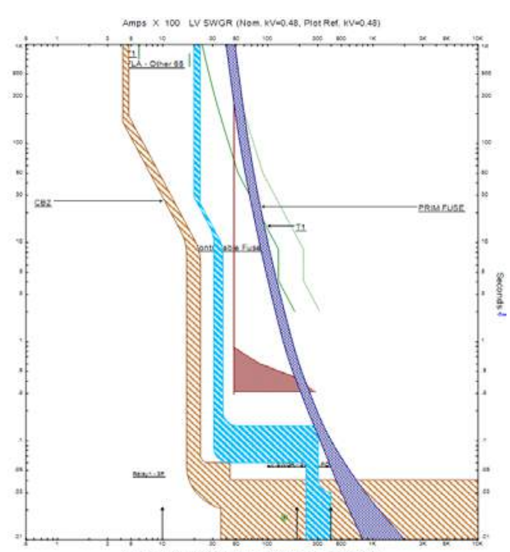

Figure 8: Method II- MVCF Fuse TCC

Similar to method I, to implement maintenance mode, a second fuse curve can be activated by means of the ETAP revision tool. The revision tool allows the selection of an infinite number of TCC curves for the same device. Figure 9 shows the MVCF curve activated in an ETAP revision. This is a nice feature which allows the simulation of this device without having to insert a third fuse into the diagram.

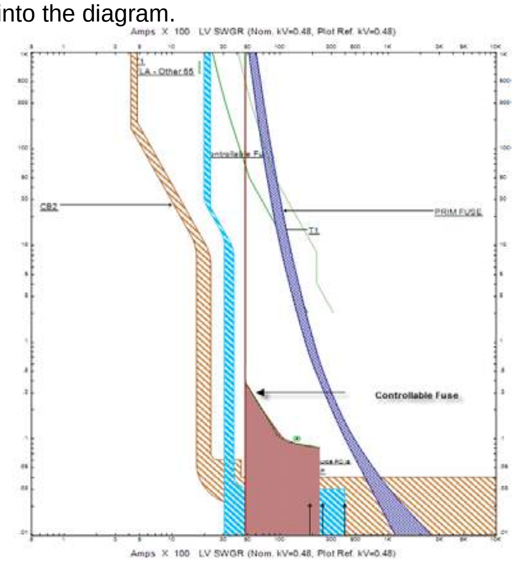

Figure 9: Method II :MVCF Maintenance Mode – Fuse TCC Implementation

In both methods, switching to maintenance mode removes the additional coordination time delay but effectively reduces the incident energy to 3 to 4 cal/cm^2.

4 PERFORMANCE ANALYSIS

Several arc flash simulations were used to evaluate the performance of the MVCF. This section presents a quick comparison of the incident energy mitigation benefits when applying the MVCF under two configurations (normal and with maintenance mode enabled). Note no difference is expected in the results of table 1 when implementing the MVCF device in ETAP using either method I or II.

Table 1: Comparison of Incident Energy Results

Equipment Configuration	I.E. (cal/cm^2)
E-RATED FUSE (No MVCF)	~40 +
MVCF – NORMAL (Method I or II)	~14
MVCF – MAINT. (Method I or II)	1~2

5 CONCLUSION

Mersen's medium voltage controllable fuse can be effectively simulated in ETAP using two methods. Both methods yields the same results but have slightly different application advantages in ETAP.

Method I advantages are:

ETAP Sequence of Operation (both for short-circuit and arc flash simulations) can graphically simulate the operation of the bypass switch and fuse. This provides rich graphical instructional simulation of the actual MVCF operation.

Another advantage is that no multiple sizes or elements need to be entered. Relays in ETAP can easily be adjusted to different delays and pickup values. Both normal and maintenance modes can be simulated with the same device.

Only disadvantage may be the more complex modeling requirements of an adjustable relay with multiple OC levels (50/51 OC levels).

Method II advantages are:

Simpler to model. Data entry of points to represent the MVCF is far simpler than that of modeling the relay.

Disadvantages are that for each adjustment, a new fuse size needs to be created in the library. The same is true for normal and maintenance modes. At least two different fuse curves are needed in the library to model both modes. For different sizes and continuous current ratings, the number of elements in the library may be significant.

6 REFERENCES

The following documents were consulted during the creation of this white paper:

[1] IEEE Standard 242, "IEEE Buff Book, IEEE-1986"

[2] Mohla, D.C; Driscoll, T.; Hamer, P.S---- "Mitigating electric shock and arc flash energy — a total system approach for personnel and equipment protection".

[3] Mersen Tech topic Arc Flash Note 7 issue 1---- "Using a Medium Voltage Controllable Fuse to mitigate arc flash energies on low voltage switch gear"

[4] IEEE Standard C37.46, "Standard for High-Voltage expulsion and Current-Limiting Type Power Class Fuses.

7 Authors

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8 Appendix A- ETAP Model Setup

Sample MVCF implementation model and library files used are attached with this paper.

http://etap.com/quality-assurance/documentation/MVCFMersen.zip