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Ground Fault Protection on Solidly Grounded 480-Volt Systems

Ground fault protection on solidly grounded 480-volt systems is a trade-off between clearing a fault quickly to minimize damage and maximize safety vs. avoiding unnecessary trips that may adversely affect production. This topic is discussed in detail in the IEEE Buff Book (ANSI/IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems) and the IEEE Red Book (ANSI/IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants). The purpose of this technical note is to summarize the criteria for determining the appropriate ground fault protection and to give an example of its application based on the noted references and on experience.

The criteria to be used in determining the appropriate ground fault protection on solidly grounded 480-volt systems are summarized as follows:

1. The National Electrical Code (NEC) section 230-95 requires that ground-fault protection be applied "... for each service disconnecting means rated 1000 amperes or more". In addition, "the maximum setting of the ground-fault protection shall be 1200 amperes, and the maximum time delay shall be one second for ground-fault currents equal to or greater than 3000 amperes".

2. It is generally good practice to set the ground relay delay time to at least 0.1 seconds to avoid spurious trips due to events other than ground faults. When ground-fault protection is applied only on the 480-volt main, a 0.2 to 0.3 second minimum delay time will allow the down-line devices to clear for high-magnitude faults.

3. To minimize damage at the faulted area and to maximize safety, the settings should be as low and as fast as possible. For mains and feeders, the settings for ground fault protection are generally in the range of 10% to 100% of the circuit trip rating or fuse rating.

4. In many cases, a ground-fault device provides protection for a large number of down-line devices that are in series. An example of this is when there is ground fault detection on the main overcurrent protective device only. In this case, it is desirable to set the ground fault relay above the largest downline device, protecting a single piece of equipment. (For example, it is undesirable for the failure of a 100 hp motor to cause a 480 volt, 3000 amp main protective device to trip.)

5. When relays are used on devices in series, it is desirable to maintain a 0.3 to the 0.4-second margin between device curves at the maximum fault current to account for relay tolerances and breaker operating times. If the device characteristics involve minimum and maximum curves, which include all tolerances and operating times, it is only necessary that the plotted curves do not intersect to ensure coordination.

For mains rated at 2000 amps and above, criteria 1, 2, and 3 would typically result in settings at or between the two curves shown in Figure 1.

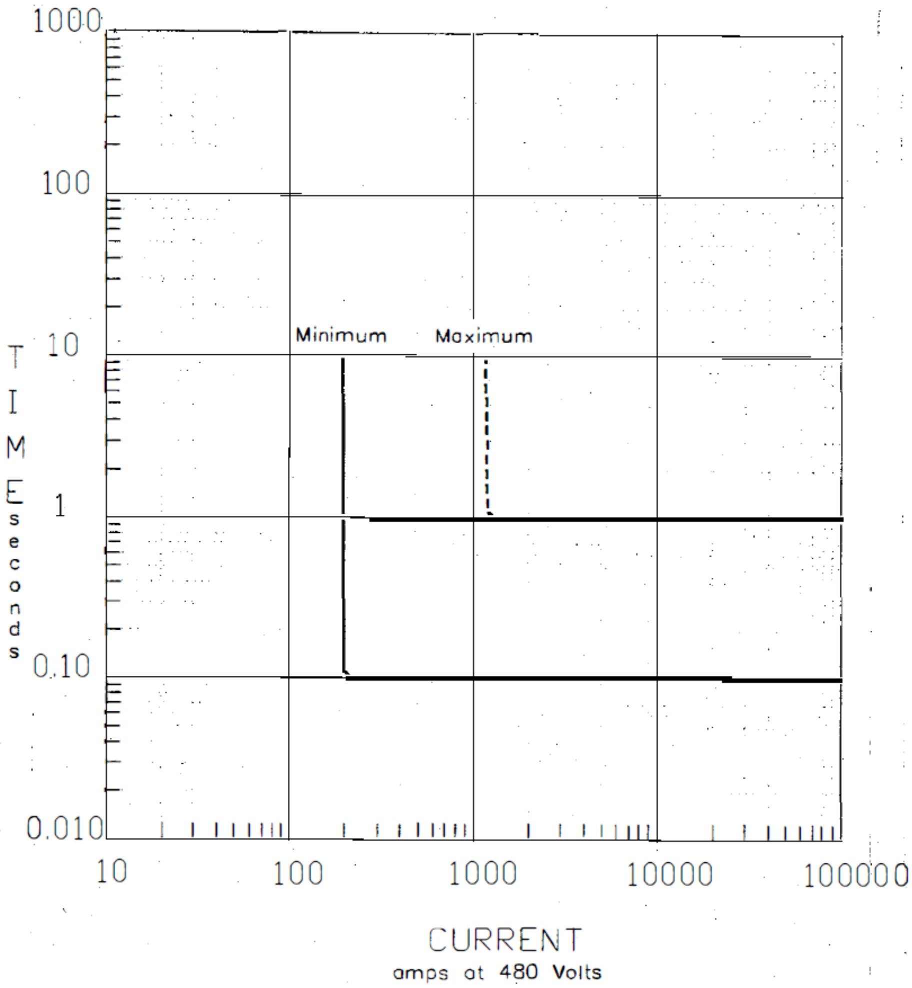

Figure1 – Ground Fault Setting Limits for 2000 A Main

With regard to criteria 3, how much damage is acceptable is not an easy question to answer. The Buff book gives some information which is plotted in Figures 2A and 2B. Figure 2A illustrates possible tolerable damage levels for a 100 amp bus and a 4000 amp bus. On the other hand, some technical articles have suggested equating arcing fault damage to kW cycles, suggesting limits in the range of 1,800 to 10,000 kW cycles, as illustrated in Figure 2B. Although this is not an exact science, these two sets of curves give some indication of the goals one could set for tolerable damage levels as well as the effect of current magnitude and time on the amount of damage that results. (For reference, the curves in Figure 2A are a function of $I^{1.5}t$, whereas the curves in Figure 2B are a function of $I^{1.0}t$.)

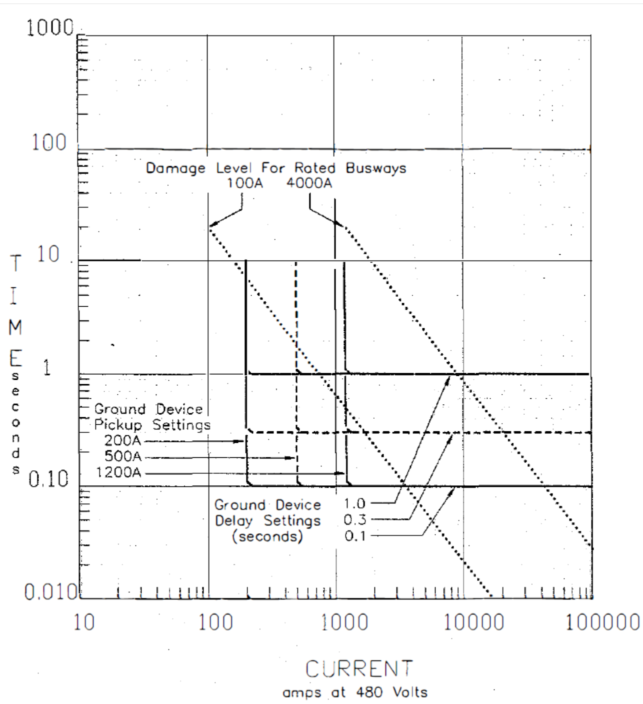

Figure 2A – Ground Fault Settings Versus Busway Damage Levels

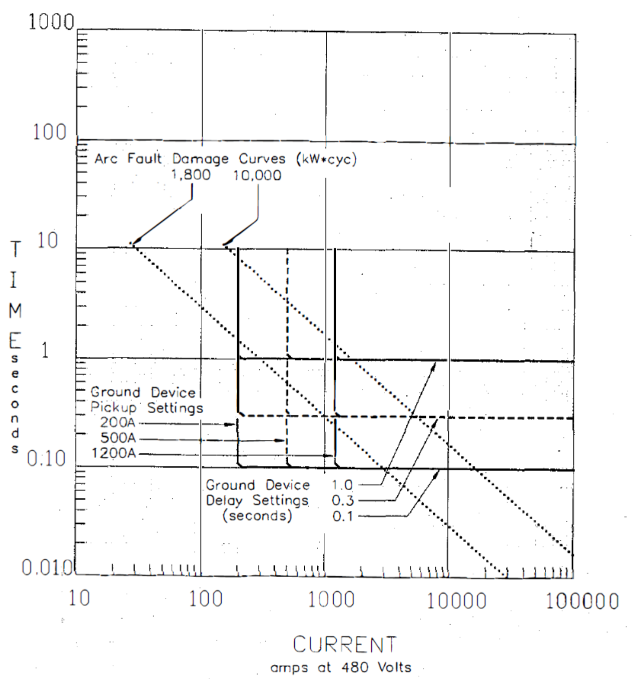

Figure 2B – Ground Fault Settings Versus Arc Fault Damage Levels

In Figure 3, potential ground fault relay settings are shown with main fuses rated 2000, 3000, and 4000 amps. For ground faults, the relay will result in much faster clearing and less damage than if the fuses were depended upon entirely to clear low-magnitude faults. The same relay curves are shown in Figure 4 for down-line fuses. It is possible that up to 200 amp fuses can be coordinated with the main ground fault relay when it is set at its maximum. Even if the time delay at 1200 amps is reduced from 1.0 seconds to .3 seconds, the area of overlap between the fuse and the ground relay is very small, and the damage due to a fault above the 200-amp fuse is reduced by 70%.

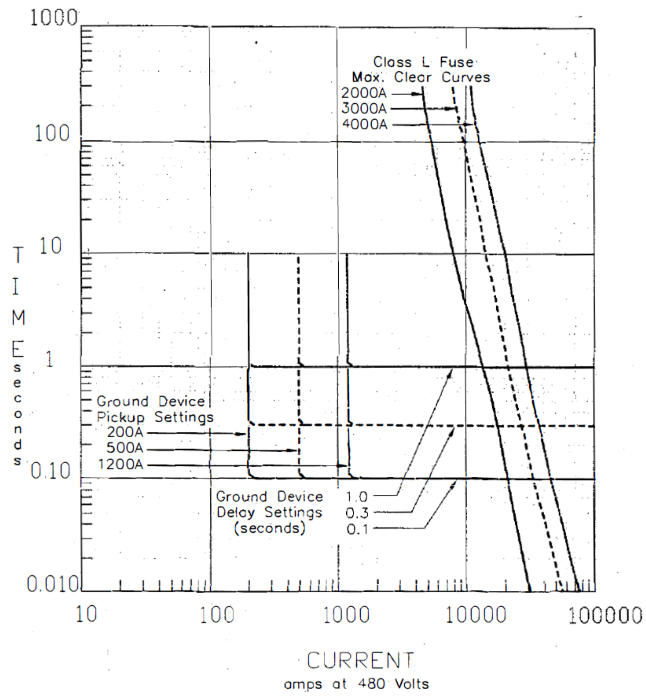

Figure 3 – Ground Fault Settings Versus Typical Mains Fusing

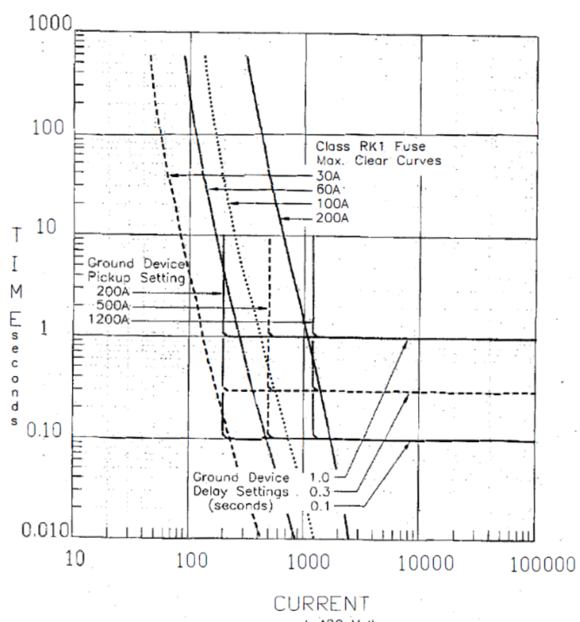

Figure 4 – Ground Fault Settings Versus Typical Branch Fusing

An example of a fused system with ground fault protection on the main is shown in Figure 5. In this example, the ground relay is set at 1200 amps with a .3-second delay. The logic for these ground fault settings is as follows:

1. The .3 second delay will help to avoid any spurious trips due to events other than faults, allow the fuses to coordinate for high-magnitude faults, and allow low-magnitude ground faults to be tripped quickly.

2. The 1200 amp pick-up will nearly result in full coordination with downline fuses up to 200 amps in rating. Devices with ratings above 200 amps could also coordinate with the main ground fault relay by having their own ground fault protection.

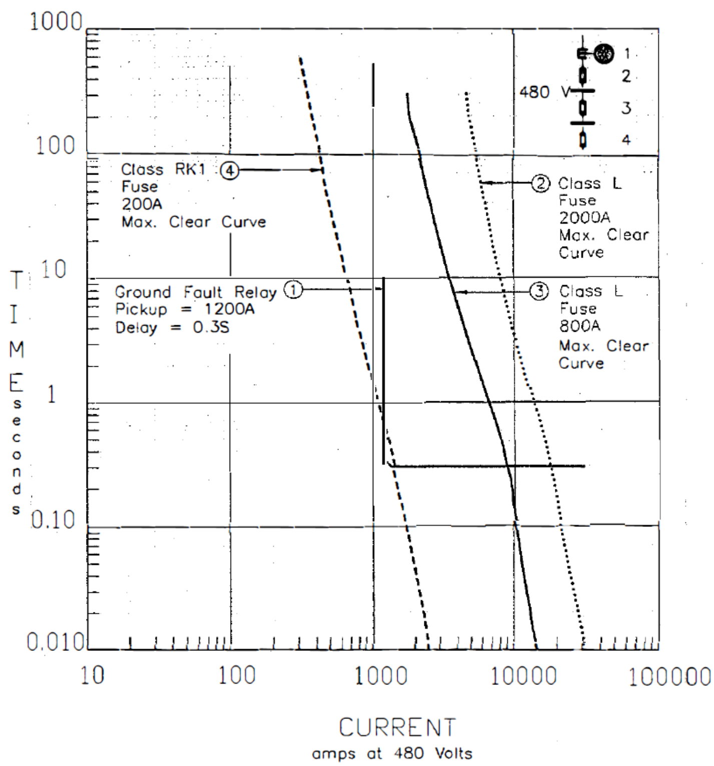

Figure 5 – Fused Main and Feeders, Ground Protection on Main Only

The criteria and the concepts presented in this technical note can be used in all types of overcurrent protection schemes, including circuit breakers with and without zone interlocking.