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Selective Trip Coordination with Modern Molded Case Circuit Breakers

Electrical System Design.
The electrical distribution system designer must consider many factors and make many choices. The overriding consideration of electrical design must always be safety. Other critical design principles must include providing adequate voltage and current to serve anticipated loads, providing overcurrent protective devices that will limit system damage under foreseeable fault conditions, and providing protective devices that have the capability of limiting the extent and duration of service interruptions. However, safety must take precedence over economics, equipment damage, and service continuity.

Limiting equipment damage can best be achieved by selecting overcurrent protective devices that have the lowest possible trip characteristics, i.e. the lowest ampacity fuse or the circuit breaker with the lowest possible current pickup and fastest time settings. Best protection is achieved with settings that are just above the load requirements for continuous and inrush current.

The best service continuity can be achieved by selecting overcurrent protective devices that have the highest possible trip characteristics, i.e. the largest fuse that is allowed or the circuit breaker that has the highest current pickup and the longest possible time settings.

These are to some degree opposing goals but fortunately modern technology provides an array of system protective devices and techniques that allow a good balance between protection and coordination, while assuring that safety always comes first.

ANSI/IEEE Standard 242, also known as the Buff Book, offers good advice on power system protection and selective trip coordination to achieve service continuity. Chapter 1 in general addresses the first principles of system design and paragraph 1.1.2, “Equipment Damage Versus Service Continuity” discusses specific design philosophies. Poor design choices can seriously compromise system protection and selective trip coordination.

NEC Selective Trip Coordination.
The National Electrical Code (NEC) Article 100, defines selective coordination as localizing an overcurrent condition - by implication accomplished by tripping the local device, to restrict outages to the circuit affected. The upstream devices remain closed and continue supplying power to all other circuits. The 2005 NEC has requirements for selective trip coordination in Article 620.62 for Elevators, and new requirements in 700.27 for Emergency Systems, and 701.18 for Legally Required Standby Systems.

Overlaying circuit breaker time-current trip curves is the typical method of determining selective trip coordination between two circuit breakers in series in power distribution systems. This method has been used for many years and has proven effective. However, there is some uncertainty in the region of instantaneous tripping due mainly to the very conservative approach to showing the characteristics of the molded case circuit breaker (MCCB) in this region. The typical breaker time-current trip curve does not fully account for the current limiting effects exhibited in most MCCBs, especially small ampacity frame devices. In order to truly determine trip coordination other methods must be used to supplement the overlay method. One method is to actually test the breakers under full short circuit currents, another is to compare the peak current let-through values of the downstream breaker to the minimum instantaneous current trip value of the upstream breaker. The minimum instantaneous current trip value may be somewhat higher at very short time periods than the instantaneous pick-up line drawn on a trip curve, again due to the conservative approach of manufacturer published curves.

The following Selective Trip Coordination Table shows the maximum values of short circuit current, at the downstream breaker, that will allow selective trip coordination between the two Siemens breakers. The values shown are the result of consideration of both methods mentioned above. As further industry experience in this area becomes available and further testing is conducted, updates to the table will be published. Please contact you Siemens representative for the latest information.

The following steps will assure the best use of the Selective Trip Coordination Table:

1. Conduct a short circuit study to determine the available fault current values at each level of the system where coordination is critical. This allows the most cost effective selection of breakers to achieve the necessary selective trip coordination. A higher available fault current value will necessitate a larger and more expensive upstream circuit breaker. Accurate short circuit current will also mean more accurate arc-flash energy calculations.

2. Trip coordination is assured up to the value shown in the “Branch Coordination Level” column. A short circuit study will be the best source of the maximum available fault current to be compared to the current value shown in this field. Selective trip coordination is assured where the maximum available fault current value is less than this “Branch Coordination Level”. Faults occurring at the maximum calculated values are very rare so this is a conservative approach. The system designer may elect to consider other factors to balance the needs of system protection and coordination at various anticipated levels of current.

If the branch available fault current is not known, the main breaker maximum available fault current value may be used. This is a very conservative approach and may result in the least cost effective solution. For many systems the distribution transformer let-through value will provide a conservative available fault current for this use. The published data for the transformer should be consulted.

In many cases the minimum frame MCCB will only coordinate at relatively low levels of fault current. If the level of selective coordination between the two circuit breakers initially selected is insufficient for the available fault current at that point in the system, the tables may be used to find an alternate upstream circuit breaker that will allow a higher level of coordination. This will usually involve a larger frame size or different type of circuit breaker such as an insulated case or power breaker. The table is ordered from lower to higher coordination current levels so that by moving down the table it is possible to find an upstream breaker that will deliver a higher level of selective coordination.

Selective Trip Coordination Table

TABLE NOTES:

1. Coordination is assured up to the value of current shown in the "Branch Coordination Level" field.
2. If the available fault current at the branch is unknown, coordination is assured when the available fault current at the main is less than or equal to the value shown in the "Branch Coordination Level" field.
3. If the main breaker has an Instantaneous setting it must be set at maximum, branch Instantaneous generally set near minimum.
4. Coordination in the thermal range is also achieved. Electronic trip units must be adjusted for Long Time and Instantaneous functions (also Short Time if so equipped). As shipped, factory settings are minimum. Curves may touch or show slight overlap in the thermal region without compromising coordination.

Breaker Type Key:

Breaker types shown in the table except as shown below.
'ED' includes the following types: ED4, ED6, HED4
'FD' includes the following types: FXD6-A, FD6-A, FD6, HFD6, HFXD6
'JD' includes the following types: JXD2-A, JXD6-A, JD6-A, JD6, JXD6, HJD6-A, HJD6, HJXD6-A, HJXD6
'LD' includes the following types: LXD6-A, LD6-A, LD6, LXD6, HLXD6-A, HLD6-A, HLD6, HLXD6
'LMD' includes the following types: LMD6, LMXD6
'MD' includes the following types: MD6, MXD6

240Vac

Main Amps	Main Breaker	Branch Coordination Level	1, 2, and 3 Pole Branch Breakers
100A	ED4, ED6 100A	1kA	15-60A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH
	FD 175A	1.5kA	15-80A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH
			15-70A ED
250A	FD 250A JD 250A	3kA	15-100A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH 15-125A ED
			70-150A FD
400A	JD 400A LD 400A	10kA	15-70A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH
		8kA	80-100A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH
		3.6kA	15-125 ED
			70-250A FD
			200-250A JD
	SLD6-A 600/400A	10kA	15-100A BL, BLH, BLF, BLHF, BAF, BAFH, QP, QPH, QF, QFH, QAF, QAFH
		6.4kA	15-125 ED
			70-250A FD
			200-300A JD, LD
	SBS1200/400A LS Trip	30kA	15-125A NGB, NGG
		25kA	15-125A ED
			70-250A FD
			200-250A JD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH

		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	SBS2000/400A LS Trip	42kA	15-125A NGB, NGB
		35kA	15-125A ED
			70-250A FD
			200-250A JD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 800/400A FS1 Class L LS Trip	65kA	15-125A NGB, NGG 15-125 ED
			70-250A FD
			200-250A JD, LD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
600A	600A LD LMXD6, LMD6 MXD6, MD6	18kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
		5.4kA	15-125 ED
			70-250A FD
			200-300A JD, LD
	SLD6-A 600A	18kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
		6.4kA	15-125 ED
			70-250A FD
			200-300A JD, LD
	SMD6 800/600A	22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF 15-125 ED
			70-250A FD
			200-300A JD, LD
	SBS1200/600A LS Trip	30kA	15-125A NGB, NGG
		25kA	15-125A ED
			70-250A FD
			200-300A JD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	SBS2000/600A LS Trip	42kA	15-125A NGB, NGG
		35kA	15-125A ED
			70-250A FD
			200-300A JD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 800/600A FS1 Class L LS Trip	65kA	15-125A NGB, NGG 15-125 ED4
			70-250A FD
			200-300A JD, LD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 800/600A FS2 Class L	85kA	15-125 HED4
			70-250A HFD6, HFXD6

	LS Trip		200-300A HJD6-A, HJDX6-A, HLD6-A, HLXD6-A
		65kA	15-125A ED4, ED6, NGB, NGG
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, BAFH, QP, QF, QAF
800A	800A LMXD6, LMD6 MXD6, MD6 MG 800A	22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
		7.2kA	15-125 ED
			70-250A FD
			200-400A JD, LD
	SMD6 800A	22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
	NG 1200/800A	10kA	15-100A BL, BLF, BAF, QP, QF, QAF 15-125 ED
			70-250A FD
			200-400A JD, LD 300-600A SLD6-A
	SBS1200/800A LS Trip	30kA	15-125A NGB, NGG
		25kA	15-125A ED
			70-250A FD
			200-400A JD 300-600A SLD6-A
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	SBS2000/800A LS Trip	42kA	15-125A NGB, NGG
		35kA	15-125A ED
			70-250A FD
			200-400A JD 300-600A SLD6-A
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 800/800A FS1 Class L LS Trip	65kA	15-125A NGB, NGG 15-125 ED
			70-250A FD
			200-400A JD
			250-500A LD 300-600A SLD6-A
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 800/800A FS2 Class L LS Trip	85kA	15-125 HED4
			70-250A HFD6, HFXD6
			200-400A HJD6-A, HJDX6-A, HLD6-A, HLXD6-A
			250-450A HLD6-A, HLXD6-A
			300-600A SHLD6-A
		65kA	15-125A NGB, NGG
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
1200A	1200A NXD6, ND6	18kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
		9kA	15-125 ED

			70-250A FD
			200-400A JD
			450-600A LD 500-700A LMD 600-800A SMD6
	SND 1200A NG 1200A	22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF 15-125 ED
			70-250A FD
			200-400A JD 450-600A LD 500-700 LMD 500-600A MD 600-800A SMD6
	SBS1200/1200A LS Trip	30kA	15-125A NGB, NGG
		25kA	15-125A ED
			70-250A FD
			200-400A JD 450-600A LD 500-700 LMD 500-600A MD 600-800A SMD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	SBS2000/1200A LS Trip	42kA	15-125A NGB, NGG
		35kA	15-125A ED
			70-250A FD
			200-400A JD 450-600A LD 500-700 LMD 500-600A MD 600-800A SMD6
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 1200/1200A FS1 Class L LS Trip	65kA	15-125A NGB, NGG
			15-125 ED
			70-250A FD
			200-400A JD
			450-600A LD
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF
	WL 1200/1200A FS2 Class L LS Trip	85kA	15-125 HED4
			70-250A HFD6, HFXD6
			200-400A HJD6-A, HJDX6-A, HLD6-A, HLXD6-A
			250-450A HLD6-A, HLXD6-A
		65kA	15-125A NGB, NGG
		22kA	15-100A BLH, BLHF, BAFH, QPH, QFH, QAFH
		10kA	15-100A BL, BLF, BAF, QP, QF, QAF