Engineering Dependable Protection - Part II
"Selective Coordination of Overcurrent Protective Devices"

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Selective Coordination

Engineering
Dependable
Protection
For An
Electrical
Distribution
System

Bulletin EDP-2
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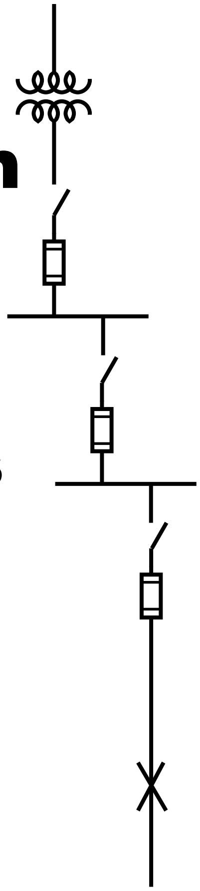
Part 2

Selective Coordination Of Overcurrent Protective Devices For Low Voltage Systems



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Basic Considerations of Selective Coordination

Engineering Dependable Protection

Part I has provided a simple method to calculate short-circuit currents that occur in electrical systems. With this information, selective coordination studies of the systems can be performed in order to prevent **blackouts.**

What Is Selective Coordination?

Today, more than ever, one of the most important parts of any installation - whether it is an office building, an industrial plant, a theater, a high-rise apartment or a hospital - is the electrical distribution system. Nothing will stop all activity, paralyze production, inconvenience and disconcert people and possibly cause a panic more effectively than a major power failure.

ISOLATION of a faulted circuit from the remainder of the installation is MANDATORY in today's modern electrical systems. Power BLACKOUTS CANNOT be tolerated.

It is not enough to select protective devices based solely on their ability to carry the system load current and interrupt the maximum fault current at their respective levels. A properly engineered system will allow ONLY the protective device nearest the fault to open, leaving the remainder of the system undisturbed and preserving continuity of service.

We may then define selective coordination as "THE ACT OF ISOLATING A FAULTED CIRCUIT FROM THE REMAINDER OF THE ELECTRICAL SYSTEM, THEREBY ELIMINATING UNNECESSARY POWER OUTAGES. THE FAULTED CIRCUIT IS ISOLATED BY THE SELECTIVE OPERATION OF ONLY THAT OVERCURRENT PROTECTIVE DEVICE CLOSEST TO THE OVERCURRENT CONDITION."

Figures 1 and 2 illustrate a non-selective system and a selectively coordinated system, respectively.

Popular Methods of Performing a Selective Coordination Study

Currently two methods are most often used to perform a coordination study:

1. Overlays of Time-Current Curves, which utilize a light table and manufacturers' published data, then hand plot on log-log paper.

2. Computer programs that utilize a PC and allow the designer to select time current curves published by manufacturers and transfer to a plotter or printer, following proper selections.

This text will apply to both methods.

Non-Selective Coordination Resulting in a Blackout

A fault on a branch circuit opens protective devices "D", "C" and "B". The entire power supply to the building is completely shut down. This non-selective operation is normally due to a medium to high level short circuit. This fault may be L-L, L-G, or 3 phase bolted in nature.

It is also possible that non-selective OPENING could be due to overload conditions on the branch circuit.

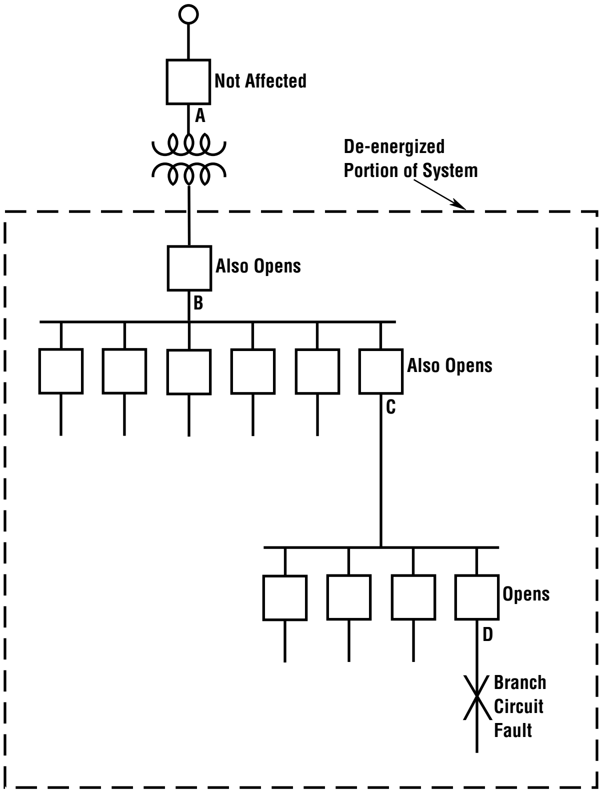


Figure 1

Selective Coordination

A fault on a branch circuit opens protective device " D" only. Since A, B and C are not disturbed, the remainder of the electrical system is still energized.

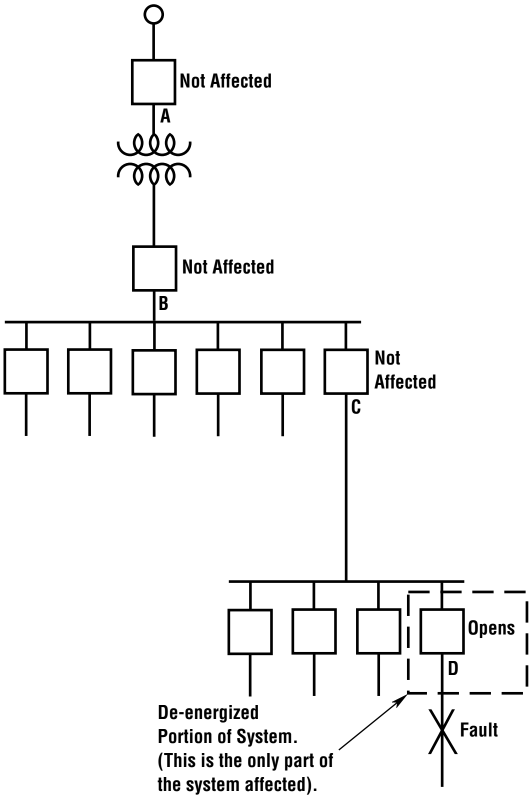


Figure 2

Selective Coordination –

Reading Time-Current Curves

Overloads and Low Level Fault Currents

This information is presented as an aid to understanding time-current characteristic curves of fuses and circuit breakers, and will discuss the major considerations in properly applying electrical protective devices. A thorough understanding of time-current characteristic curves of overcurrent protective devices is essential to provide a Selectively Coordinated System.

It should be noted that the study of time-current curves indicates performance during overload and low level fault conditions. The performance of overcurrent devices that operate under medium to high level fault conditions are not reflected on standard curves. Other engineering methods must be utilized.

Fuse Curves

Figure 3 illustrates the time-current characteristic curves for two sizes of time-delay, dual-element fuses in series, as depicted in the one-line diagram in Figure 3a. The horizontal axis of the graph represents the RMS symmetrical current in amperes. The vertical axis represents the time, in seconds, until the fault occurs .

For example: Assume an available fault current level of 1000 amperes RMS symmetrical on the load side of the 100 ampere fuse. To determine the time it would take this fault current to open the two fuses, first find 1000 amperes on the horizontal axis (Point A), follow the dotted line vertically to the intersection of the total clear curve of the 100 ampere time-delay dual-element fuse (Point B) and the minimum melt curve of the 400 ampere time-delay dual-element fuse (Point C). Then, horizontally from both intersection points, follow the dotted lines to Points D and E. At 1.75 seconds, Point D represents the maximum time the 100 ampere time-delay dual-element fuse will take to open the 1000 ampere fault. At 88 seconds, Point E represents the minimum time at which the 400 ampere time-delay dual-element fuse could open this available fault current. Thus, selective operation is assured.

The two fuse curves can be examined by the same procedure at various current levels along the horizontal axis (for example, see Points F and G at the 2000 ampere fault level). It can be determined that the two fuses are selectively coordinated, since the 100 ampere time-delay dual-element fuse will open before the 400 ampere time-delay dual-element fuse can melt.

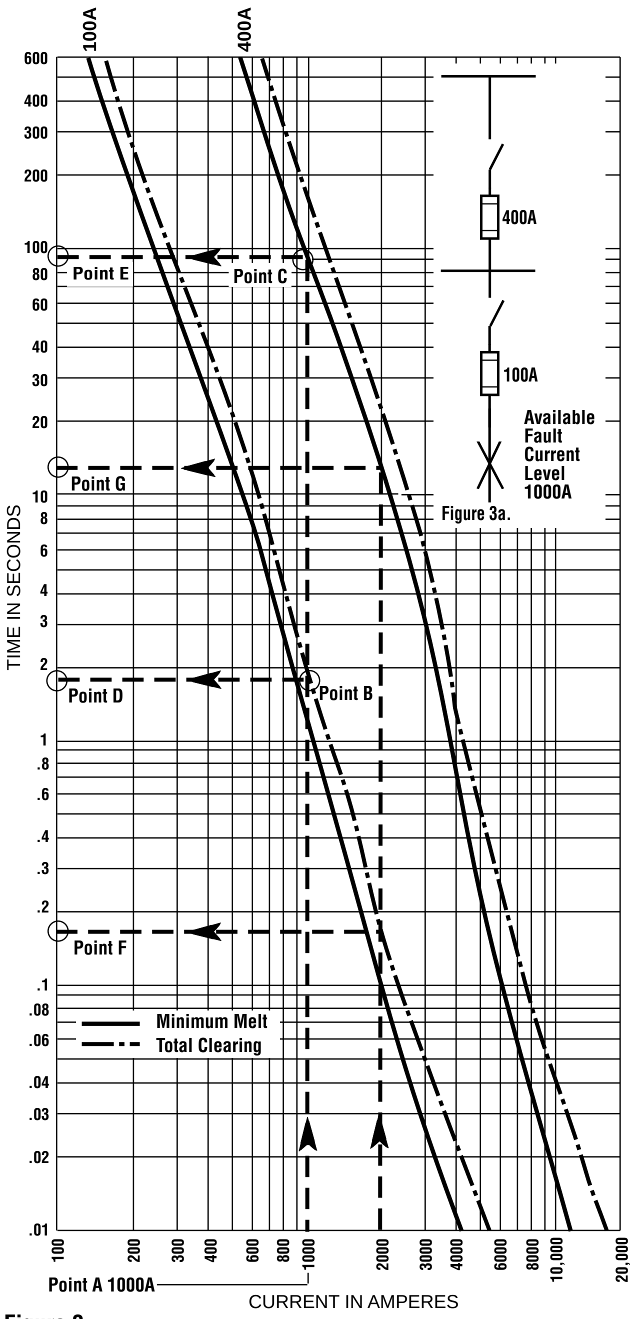


Figure 3

Reading Time-Current Curves

Circuit Breaker Curves

Figure 4 illustrates a typical thermal magnetic molded case circuit breaker curve with an overload region and an instantaneous trip region (two instantaneous trip settings are shown). Circuit breaker time-current characteristic curves are read similar to fuse curves. The horizontal axis represents the current, and the vertical axis represents the time at which the breaker interrupts the circuit.

When using molded case circuit breakers of this type, there are four basic curve considerations that must be understood. These are:

1.Overload Region
2.Instantaneous Region
3.Unlatching Time
4.Interrupting Rating

1. Overload Region - The opening of a molded case circuit breaker in the overload region (see Figure 4) is generally accomplished by a thermal element, while a magnetic coil is generally used on power breakers. Electronic sensing breakers will utilize CT's. As can be seen, the overload region has a wide tolerance band, which means the breaker should open within that area for a particular overload current.

2. Instantaneous Region - The instantaneous trip setting indicates the multiple of the full load rating at which the circuit breaker will open as quickly as possible. The instantaneous region is represented in Figure 4 and is shown to be adjustable from 5x to 10x the breaker rating. When the breaker coil senses an overcurrent in the instantaneous region, it releases the latch which holds the contacts closed.

In Figure 4, the unlatching time is represented by the curve labeled "average unlatching time for instantaneous tripping". After unlatching, the overcurrent is not halted until the breaker contacts are mechanically separated and the arc is extinguished. Consequently, the final overcurrent termination can vary over a wide range of time, as is indicated by the wide band between the unlatching time curve and the maximum interrupting time curve in Figure 4.

The instantaneous trip setting for larger molded case and power breakers can usually be adjusted by an external dial. Figure 4 shows two instantaneous trip settings for a 400 amp breaker. The instantaneous trip region, drawn with the solid line, represents an I.T. = 5x, or five times 400 amperes = 2000 amperes. At this setting, the circuit breaker will trip instantaneously on currents of approximately 2000 amperes or more. The ± 25% band represents the area in which it is uncertain whether the overload trip or the instantaneous trip will operate to clear the overcurrent.

The dashed portion of Figure 4 represents the same 400 ampere breaker with an I.T. = 10x, or 10 times 400 amperes = 4000 amperes. At this setting the overload trip will operate up to approximately 4000 amperes (±10%). Overcurrents greater than 4000 amperes (±10%) would be cleared by the instantaneous trip.

3. Unlatching Times - As explained above, the unlatching time indicates the point at which the breaker senses an overcurrent in the instantaneous region and releases the latch holding the contacts. However, the fault current continues to flow through the breaker and the circuit to the point of fault until the contacts can physically separate and extinguish the arc. Once the unlatching mechanism has sensed an overcurrent and unlatched, the circuit breaker will open. The final interruption of the current represented on the breaker curve in the instantaneous region occurs after unlatching, but within the maximum interruption time.

The relatively long delay between unlatching and the actual interruption of the overcurrent in the instantaneous region is the primary reason that molded case breakers are very difficult to coordinate. This is an inherent problem since the breaking of current is accomplished by mechanical means.

4. Interrupting Rating - The interrupting rating of a circuit breaker is a critical factor concerning protection and safety. The interrupting rating of a circuit breaker is the maximum fault current the breaker has been tested to interrupt in accordance with testing laboratory standards. Fault currents in excess of the interrupting rating can result in destruction of the breaker and equipment and possible injury to personnel. In other words, when the fault level exceeds the circuit breaker interrupting rating, the circuit breaker is no longer a protective device.

Looking at Figure 10, the interrupting ratings at 480 volts are 14,000 amperes for the 90 ampere breaker and 30,000 amperes for the 400 ampere breaker. The interrupting ratings on circuit breakers vary according to breaker type and voltage level.

When drawing circuit breaker time-current curves, determine the proper interrupting rating from the manufacturer's literature and represent this interrupting rating on the drawing by a vertical line at the right end of the curve.

Reading Time-Current Curves

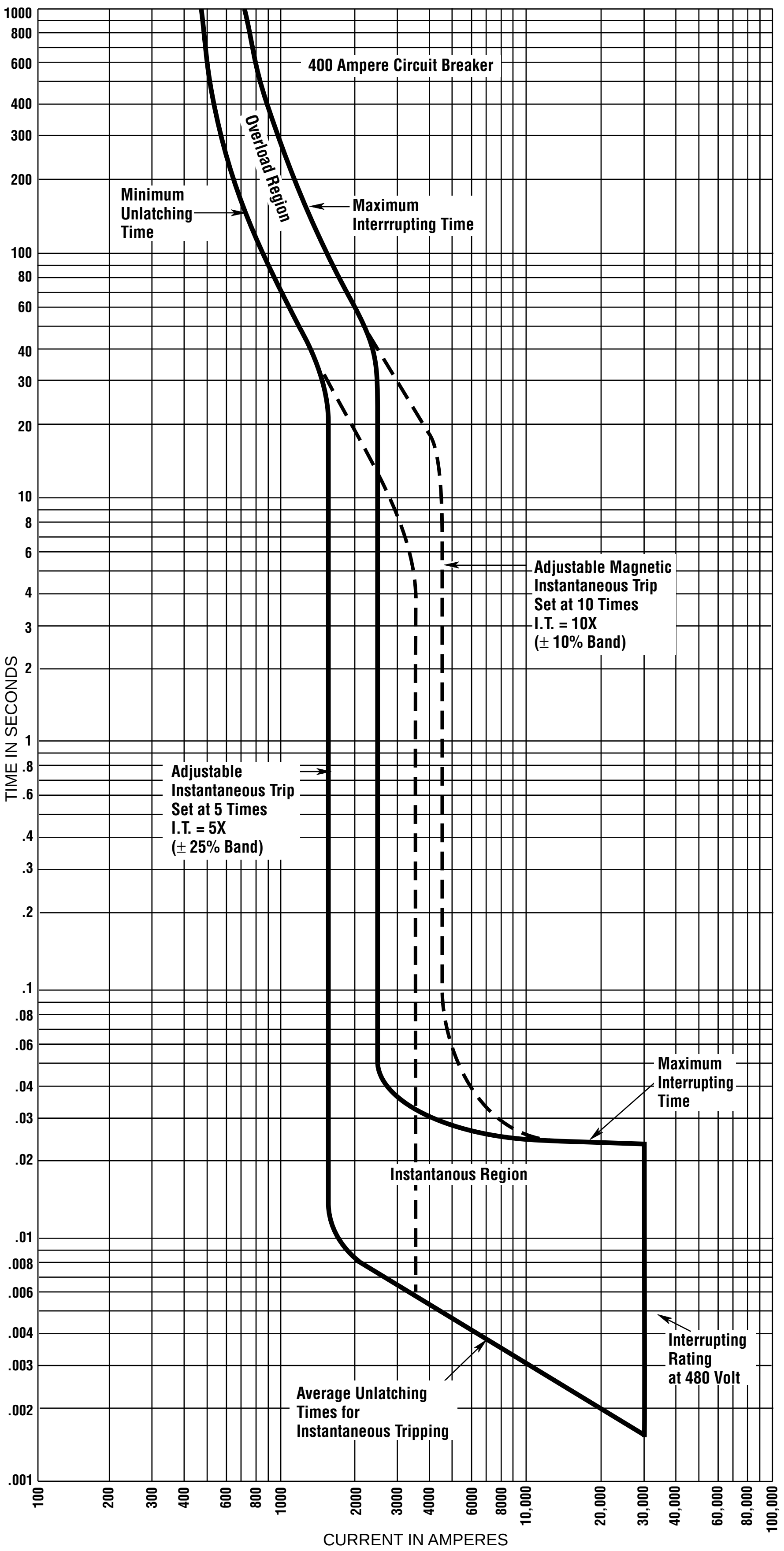


Figure 4. Typical Circuit Breaker Time-Current Characteristic Curve

Average Unlatching Times Breaker Tripping Magnetically

Current in RMS Amps	Time in Seconds
5,000	.0045
10,000	.0029
15,000	.0024
20,000	.0020
25,000	.0017

Interrupting Rating

RMS Sym.	Amps
240V	42,000
480V	30,000
600V	22,000

Reading Time-Current Curves

5. Short Time Delay And Instantaneous Override - Circuit breaker short-time-delay (STD) mechanisms allow an intentional delay to be installed on Low Voltage Power Circuit Breakers (Figure 5). Short-time-delays allow the fault current to flow for several cycles, which subjects the electrical equipment being protected to unnecessarily high mechanical and thermal stress. Most equipment ratings, such as short-circuit ratings for bus duct and switchboard bus, do not apply when short-time-delay settings are employed. The use of short-time-delay settings on circuit breakers requires the system equipment to be reinforced to withstand the available fault current for the duration of the short-time-delay. Ignoring equipment ratings in relation to the protective device opening time and let-thru characteristics can be disastrous.

An Insulated Case Circuit Breaker (ICCB) may also be equipped with short-time-delay. However, ICCB's will have a built-in override mechanism (Figure 6). This is called the instantaneous override function, and will override the STD for medium to high level faults. This override may "kick in" for faults as low as 12x the breaker's ampere rating. This can result in non-selective tripping of the breaker and load side breakers where overlaps occur. This can be seen in the example given in Figure 7. As the overlap suggests, for any fault condition greater than 21,000 amperes, both devices will open, causing a blackout.

Note: Choosing overcurrent protective devices strictly on the basis of voltage, current, and interrupting rating **will not** assure component protection from short-circuit currents. The interrupting rating of a protective device pertains **only** to that device and has absolutely no bearing on its ability to protect connected downstream components. High interrupting rated electro-mechanical overcurrent protective devices, such as circuit breakers, especially those that are not current-limiting, may not be capable of protecting wire, cable or other components within the higher short-circuit ranges. Quite often, the component is completely destroyed under short-circuit conditions while the protective device is opening the faulted circuit.

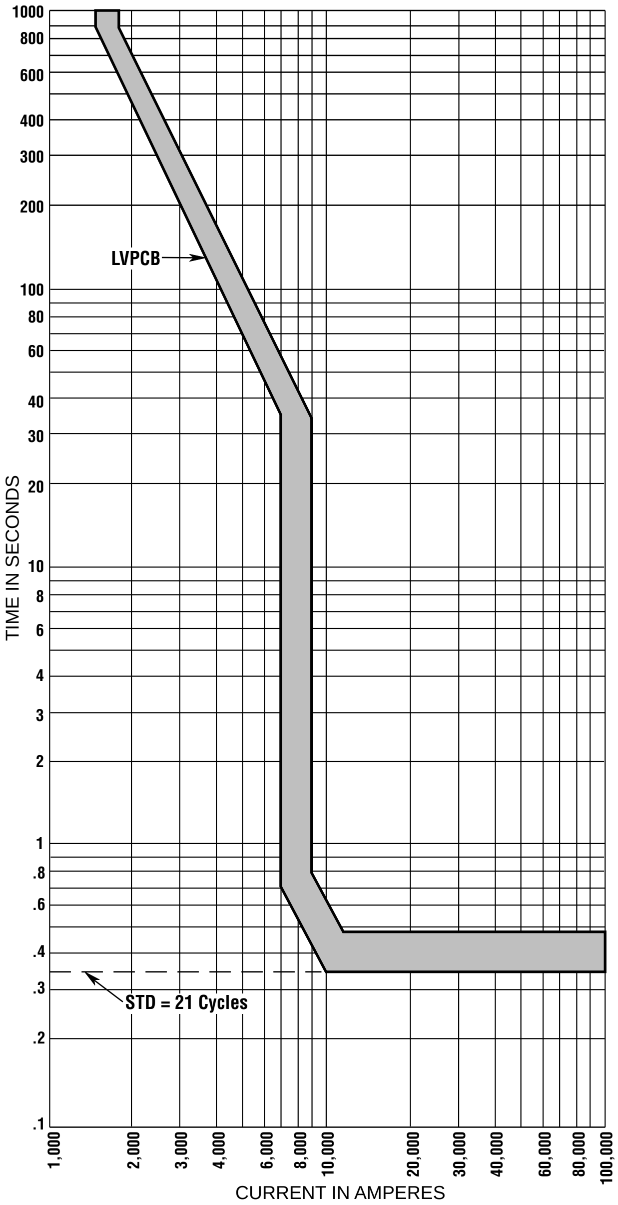


Figure 5

Reading Time-Current Curves

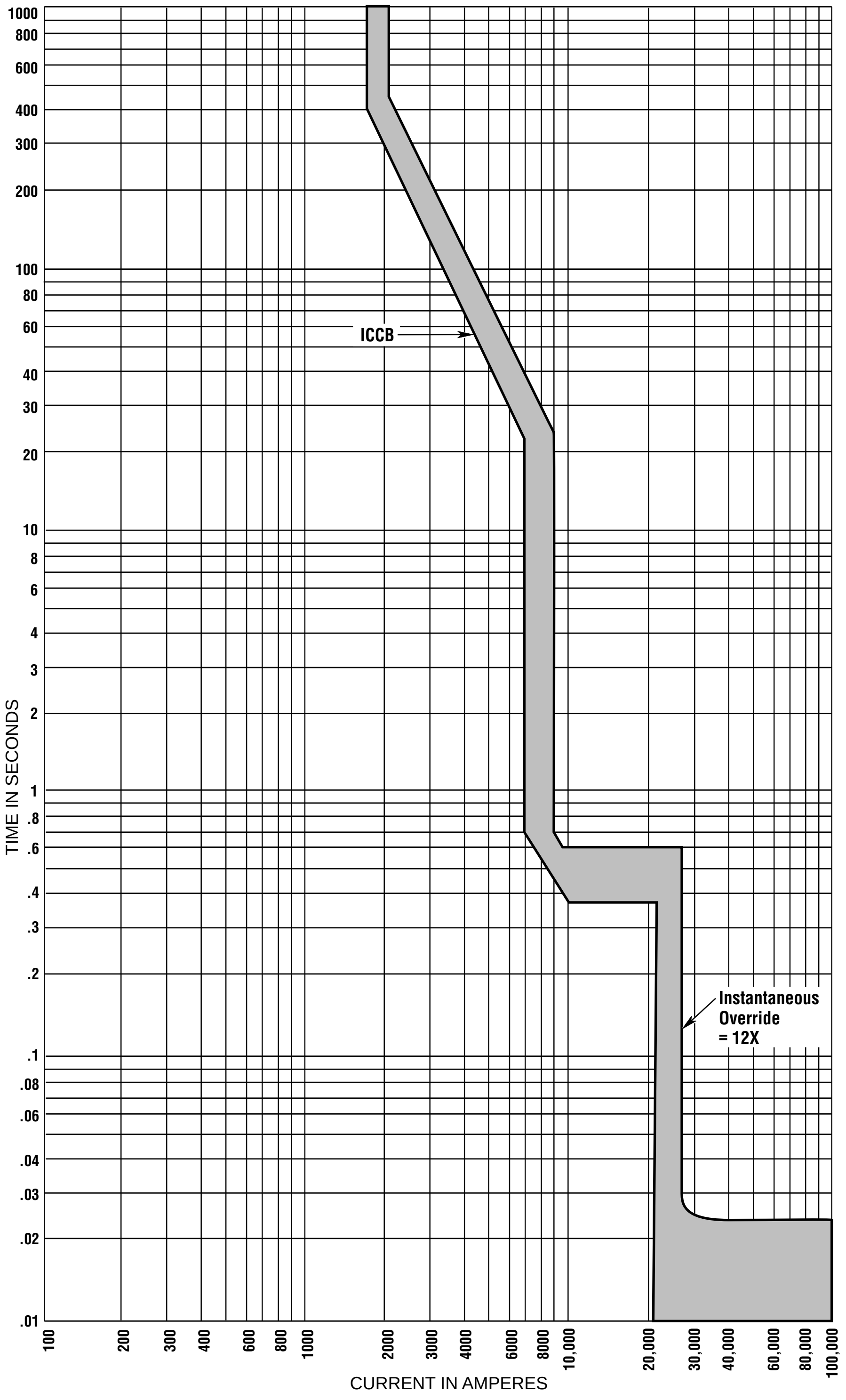


Figure 6

Reading Time-Current Curves

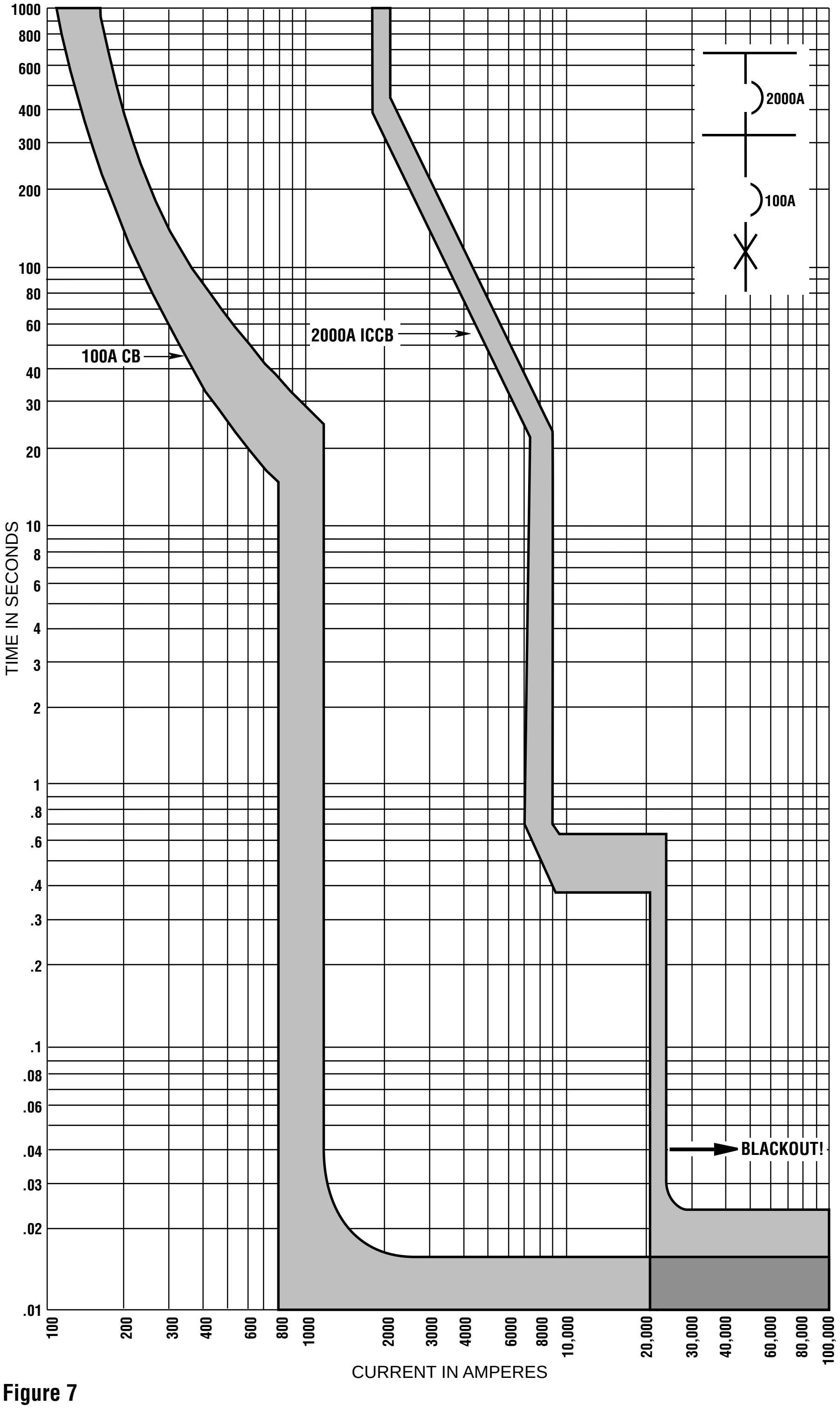


Figure 7

Selective Coordination –

Current Limiting Fuses

Medium to High Level Fault Currents

Figure 8 shows that the available short-circuit current will reach a peak value of I_p during the first half cycle unless a protective device limits the peak fault current to a value less than I_p. A current-limiting fuse will reduce the available peak current to less than I_p, namely I'_p, and will clear the fault in approximately one-half cycle or less. Note that t_c is the total clearing time of the fuse, t_m the melting time and t_a the arcing time of the fuse. Where high values of fault current are available, the sub-cycle region becomes the most critical region for selective operation of current-limiting fuses.

The area under the current curves indicates the energy let-thru. If no protective device were present, or if mechanical type overcurrent devices with opening times of one-half cycle or longer were present, the full available short-circuit energy would be delivered to the system. The amount of energy delivered is directly proportionate to the square of the current. So we can see how important it is to have fuses which can limit the current being delivered to the system to a value less than the available current. The amount of energy being produced in the circuit while the fuse is clearing is called the total clearing energy and is equal to the melting energy plus the arcing energy.

Selectivity between two fuses operating under short-circuit conditions exists when the total clearing energy of the load side fuse is less than the melting energy of the line side fuse (See Figure 9).

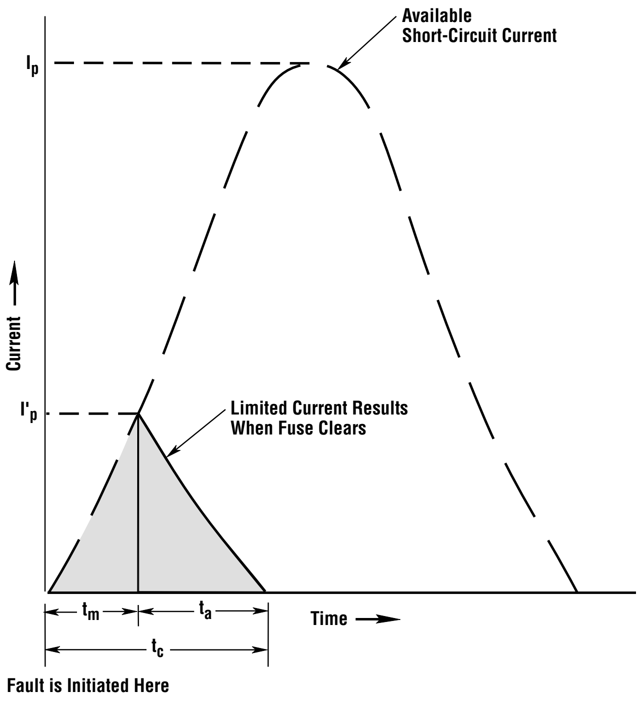


Figure 8

An engineering tool has been developed to aid in the proper selection of fuses for selective coordination. This Selectivity Ratio Guide (SRG) is shown below.

*Selectivity Ratio Guide (Line-Side to Load-Side) for Blackout Prevention

Circuit					Load-Side Fuse									
	Current Rating				601-6000A	601-4000A	0-600A			601-6000A	0-600A	0-1200A	0-600A	0-60A
		Type			Time-Delay	Time-Delay	Dual-Element Time-Delay			Fast-Acting	Fast-Acting			Time-Delay
			Trade Name &		LOW-PEAK	LIMITRON	LOW-PEAK		FUSETRON	LIMITRON	LIMITRON	T-TRON	LIMITRON	SC
			Class		(L)	(L)	(RK1)	(J)**	(RK5)	(L)	(RK1)	(T)	(J)	(G)
				Buss Symbol	**KRP-CSP**	**KLU**	**LPN-RKSP** **LPS-RKSP**	**LPJSP**	**FRN-R** **FRS-R**	**KTU**	**KTN-R** **KTS-R**	**JJN** **JJS**	**JKS**	**SC**
Line-Side Fuse	601 to 6000A	Time-Delay	LOW-PEAK (L)	**KRP-CSP**	2:1	2.5:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
	601 to 4000A	Time-Delay	LIMITRON (L)	**KLU**	2:1	2:1	2:1	2:1	4:1	2:1	2:1	2:1	2:1	N/A
	0 to 600A	Dual Ele-ment	LOW-PEAK (RK1)	**LPN-RKSP** **LPS-RKSP**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
			(J)	**LPJSP****	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
			FUSETRON (RK5)	**FRN-R** **FRS-R**	–	–	1.5:1	1.5:1	2:1	–	1.5:1	1.5:1	1.5:1	1.5:1
	601 to 6000A	Fast-Acting	LIMITRON (L)	**KTU**	2:1	2.5:1	2:1	2:1	6:1	2:1	2:1	2:1	2:1	N/A
	0 to 600A		LIMITRON (RK1)	**KTN-R** **KTS-R**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
	0 to 1200A		T-TRON (T)	**JJN** **JJS**	–	–	3:1	3:1	8:1	–	3:1	3:1	3:1	4:1
	0 to 600A		LIMITRON (J)	**JKS**	–	–	2:1	2:1	8:1	–	3:1	3:1	3:1	4:1
	0 to 60A	Time-Delay	SC (G)	**SC**	–	–	3:1	3:1	4:1	–	2:1	2:1	2:1	2:1

* **Note:** At some values of fault current, specified ratios may be lowered to permit closer fuse sizing. Plot fuse curves or consult with Bussmann.
General Notes: Ratios given in this Table apply only to Buss fuses. When fuses are within the same case size, consult Bussmann.
** Consult Bussmann for latest LPJSP ratios.

As an example, refer to Figure 9 and the SRG for Low Peak fuses. The SRG suggests that the minimum ratio between line side and load side fuse should be at least 2:1. The one-line illustrated in Figure 9 shows Low Peak fuses KRP-C1000SP feeding a LPS-RK200SP. The ratio of ampere ratings is 5:1 (1000:200) which indicates coordination between these fuses. Continuing further into the system the LPS-RK-200SP feeds a LPJ60SP. This ratio of ampere ratings is 3.33:1 (200:60), which also indicates a selectively coordinated system.

Current Limiting Fuses

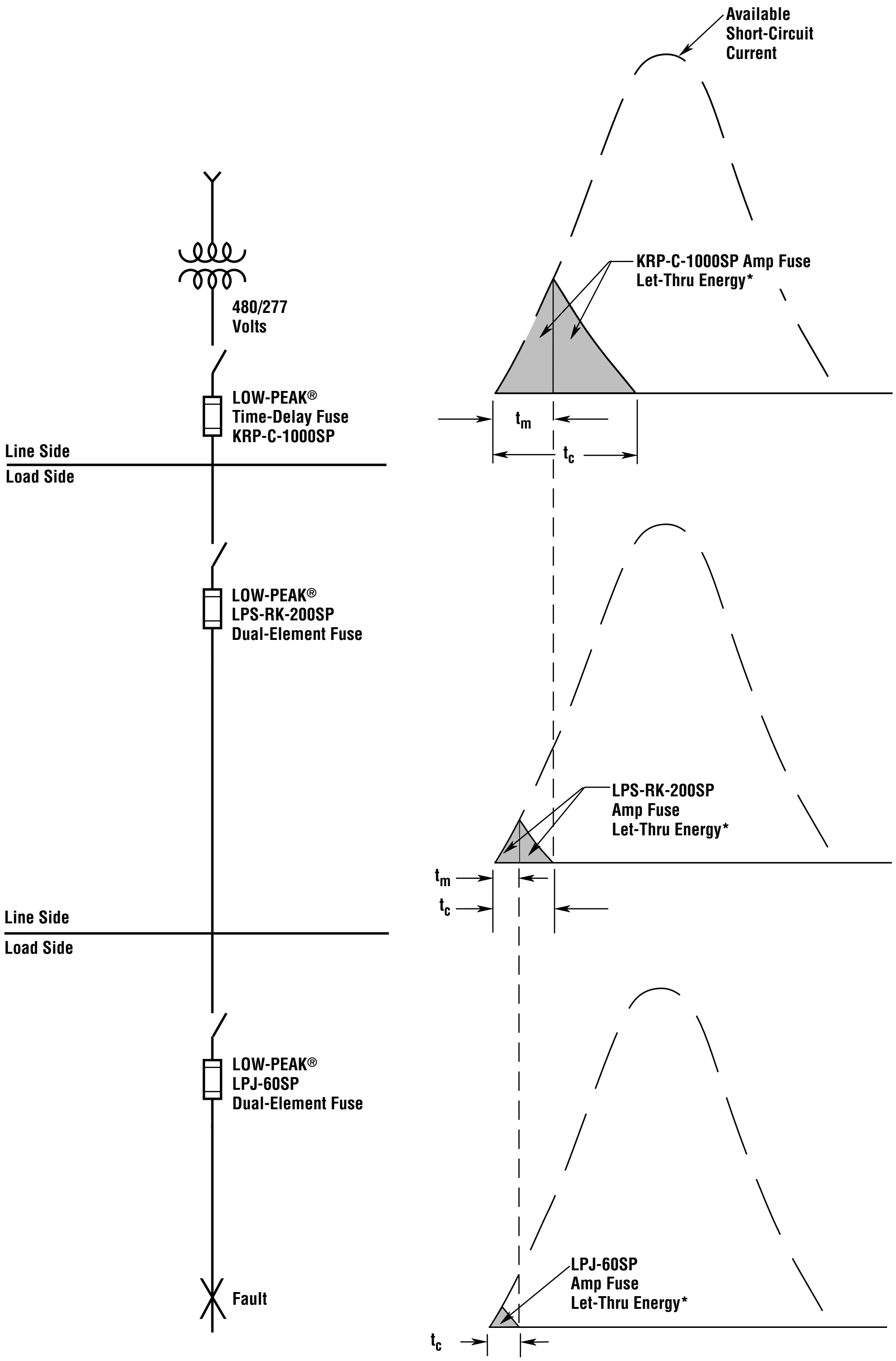


Figure 9

Requirements for selectivity—Total clearing energy of load side fuse is less than melting energy of line side fuse.

*Area under the curves indicates let-thru energy.

Circuit Breakers

Medium to High Level Fault Currents

Figure 10 illustrates a 400 ampere circuit breaker ahead of a 90 ampere breaker. Any fault above 1500 amperes on the load side of the 90 ampere breaker will open both breakers. The 90 ampere breaker will generally unlatch before the 400 ampere breaker. However, before the 90 ampere breaker can separate its contacts and clear the fault current, the 400 ampere breaker has unlatched and also will open.

Assume a 4000 ampere short circuit exists on the load side of the 90 ampere circuit breaker. The sequence of events would be as follows:

1. The 90 ampere breaker will unlatch (Point A) and free the breaker mechanism to start the actual opening process.

2. The 400 ampere breaker will unlatch (Point B) and it, too, would begin the opening process. Once a breaker unlatches, it will open. At the unlatching point, the process is irreversible.

3. At Point C, the 90 ampere breaker will have completely interrupted the fault current.

4. At Point D, the 400 ampere breaker also will have completely opened the circuit.

Consequently, this is a **non-selective** system, causing a complete blackout to the load protected by the 400 ampere breaker.

As printed by one circuit breaker manufacturer, "One should not overlook the fact that when a high fault current occurs on a circuit having several circuit breakers in series, the instantaneous trip on all breakers may operate. Therefore, in cases where several breakers are in series, the larger upstream breaker may start to unlatch before the smaller downstream breaker has cleared the fault. This means that for faults in this range, a main breaker may open when it would be desirable for only the feeder breaker to open."

Circuit Breakers

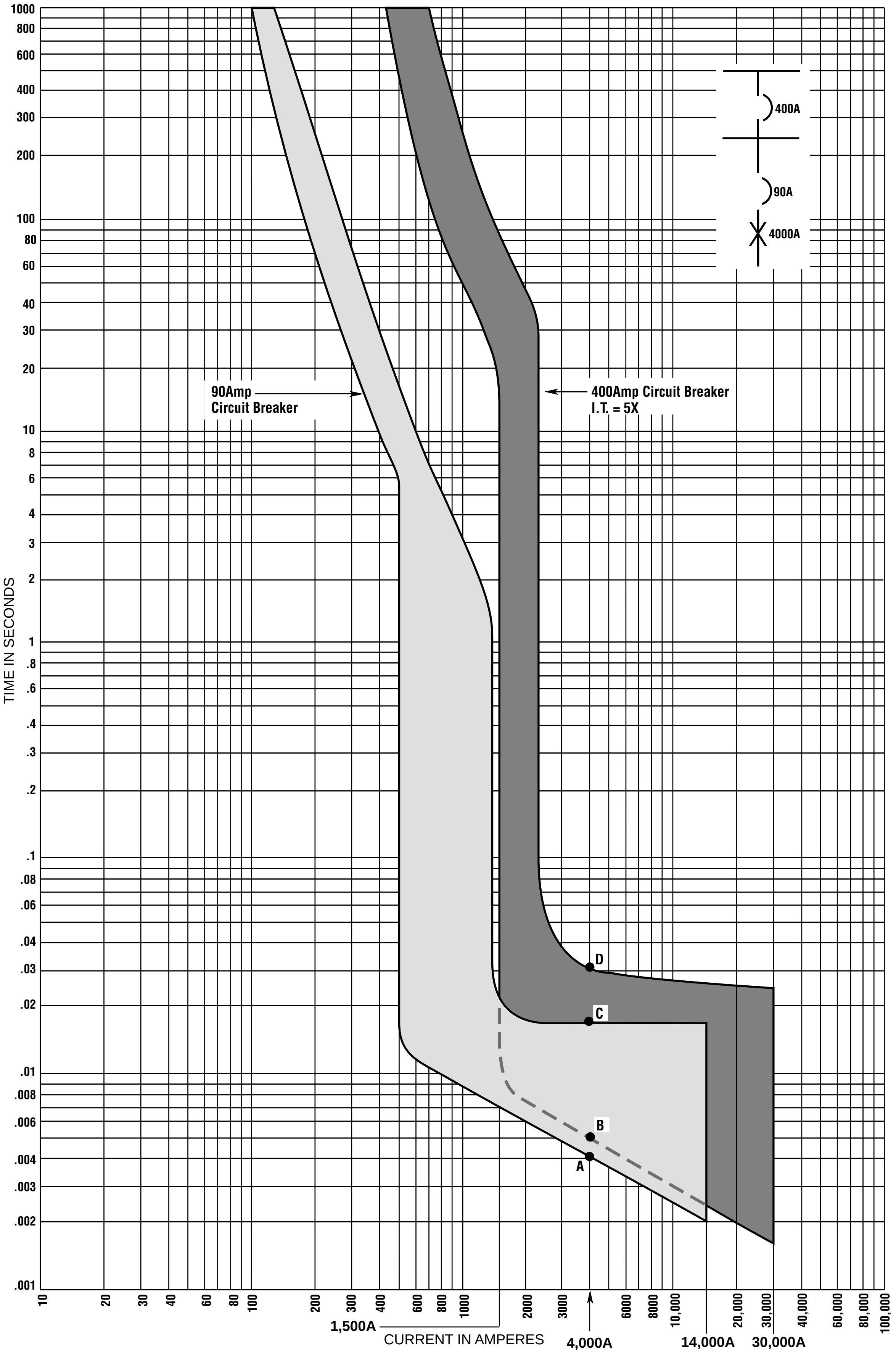


Figure 10

Selective Coordination Study –

Recommended Procedures

The following steps are recommended when conducting a selective coordination study.

1. One-Line Diagram

Obtain the electrical system one-line diagram that identifies important system components, as given below.

a. Transformers

Obtain the following data for protection and coordination information of transformers:

- KVA rating
- Inrush points
- Primary and secondary connections
- Impedance
- Damage curves
- Primary and secondary voltages
- Liquid or dry type

b. Conductors - Check phase, neutral, and equipment grounding. The one-line diagram should include information such as:

- Conductor size
- Number of conductors per phase
- Material (copper or aluminum)
- Insulation
- Conduit (magnetic or non-magnetic)

From this information, short circuit withstand curves can be developed. This provides information on how overcurrent devices will protect conductors from overload **and** short circuit damage.

c. Motors

The system one-line diagram should include motor information such as:

- Full load currents
- Horsepower
- Voltage
- Type of starting characteristic
  (across the line, etc.)
- Type of overload relay
  (Class 10, 20, 30)

Overload protection of the motor and motor circuit can be determined from this data.

d. Fuse Characteristics

Fuse Types/Classes should be identified on the one-line diagram.

e. Circuit Breaker Characteristics

Circuit Breaker Types should be identified on the one-line diagram.

f. Relay Characteristics

Relay Types should be identified on the one-line diagram.

2. Short Circuit Study

Perform a short circuit analysis, calculating maximum available short circuit currents at critical points in the distribution system (such as transformers, main switchgear, panelboards, motor control centers, load centers, and large motors and generators.) (Reference: Bussmann Bulletin, Engineering Dependable Protection - EDPI.)

3. Helpful Hints

a. Determine the Ampere Scale Selection. It is most convenient to place the time current curves in the center of the log-log paper. This is accomplished by multiplying or dividing the ampere scale by a factor of 10.

b. Determine the Reference (Base) Voltage. The best reference voltage is the voltage level at which most of the devices being studied fall. (On most low voltage industrial and commercial studies, the reference voltage will be 208, 240, or 480 volts). Devices at other voltage levels will be shifted by a multiplier based on the transformer turn ratio. The best reference voltage will require the least amount of manipulation. Modern computer programs will automatically make these adjustments when the voltage levels of devices are identified by the input data.

c. Commencing the Analysis. The starting point can be determined by the designer. Typically, studies begin with the main circuit devices and work down through the feeders and branches. (Right to left on your log-log paper.)

d. Multiple Branches. If many branches are taken off one feeder, and the branch loads are similar, the largest rated branch circuit should be checked for coordination with upstream devices. If the largest branch will coordinate, and the branch devices are similar, they generally will coordinate as well. (The designer may wish to verify other areas of protection on those branches, conductors, etc.)

e. Don't Overcrowd the Study. Many computer generated studies will allow a maximum of ten device characteristics per page.

f. One-Line Diagram. A one-line diagram of the study should be drawn for future reference.

Examples of Selective Coordination Studies

The following pages will analyze in detail the system shown in Figure 11. It is understood that a short circuit study has been completed, and all devices have adequate interrupting ratings. A Selective Coordination Analysis is the next step.

This simple radial system will involve three separate time current curve studies, applicable to the three feeder/branches shown.

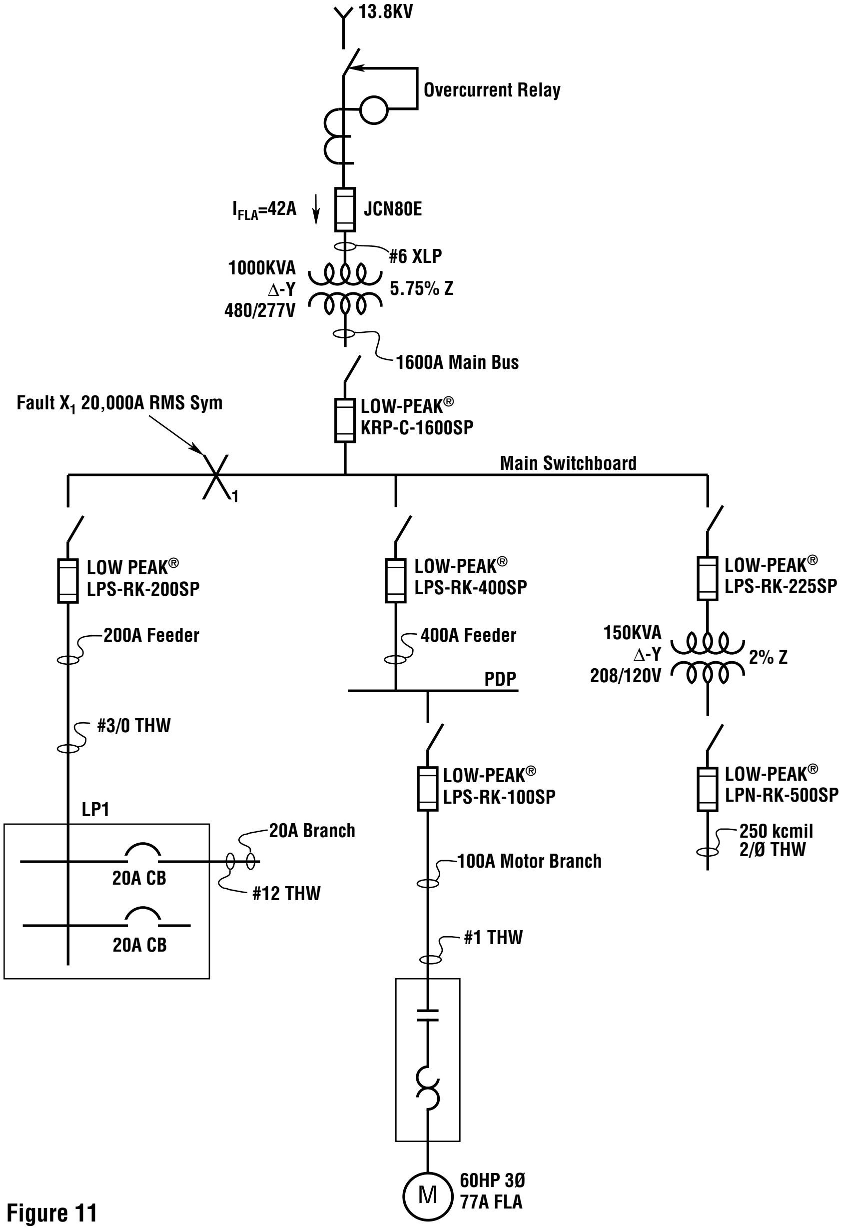


Figure 11

Example –

Time Current Curve #1 (TCC1)

Notes:

1. TCC1 includes the primary fuse, secondary main fuse, 200 ampere feeder fuse, and 20 ampere branch circuit breaker from LP1.

2. Analysis will begin at the main devices and proceed down through the system.

3. Reference (base) voltage will be 480 volts, arbitrarily chosen since most of the devices are at this level.

4. Selective coordination between the feeder and branch circuit is not attainable for faults above 2500 amperes that occur on the 20 amp branch circuit, from LP1. Notice the overlap of the 200 ampere fuse and 20 ampere circuit breaker.

5. The required minimum ratio of 2:1 is easily met between the KRP-C-1600SP and the LPS-RK-200SP.

Device ID	**Description**	**Comments**
①	1000KVA XFMR Inrush Point	12 x FLA @ .1 Seconds
②	1000KVA XFMR Damage Curves	5.75%Z, liquid filled (Footnote 1) (Footnote 2)
③	JCN 80E	E-Rated Fuse
④	#6 Conductor Damage Curve	Copper, XLP Insulation
⑤	Medium Voltage Relay	Needed for XFMR Primary Overload Protection
⑥	KRP-C-1600SP	Class L Fuse
⑪	LPS-RK-200SP	Class RK1 Fuse
⑫	3/0 Conductor Damage Curve	Copper THW Insulation
⑬	20A CB	Thermal Magnetic Circuit Breaker
⑭	#12 Conductor Damage Curve	Copper THW Insulation

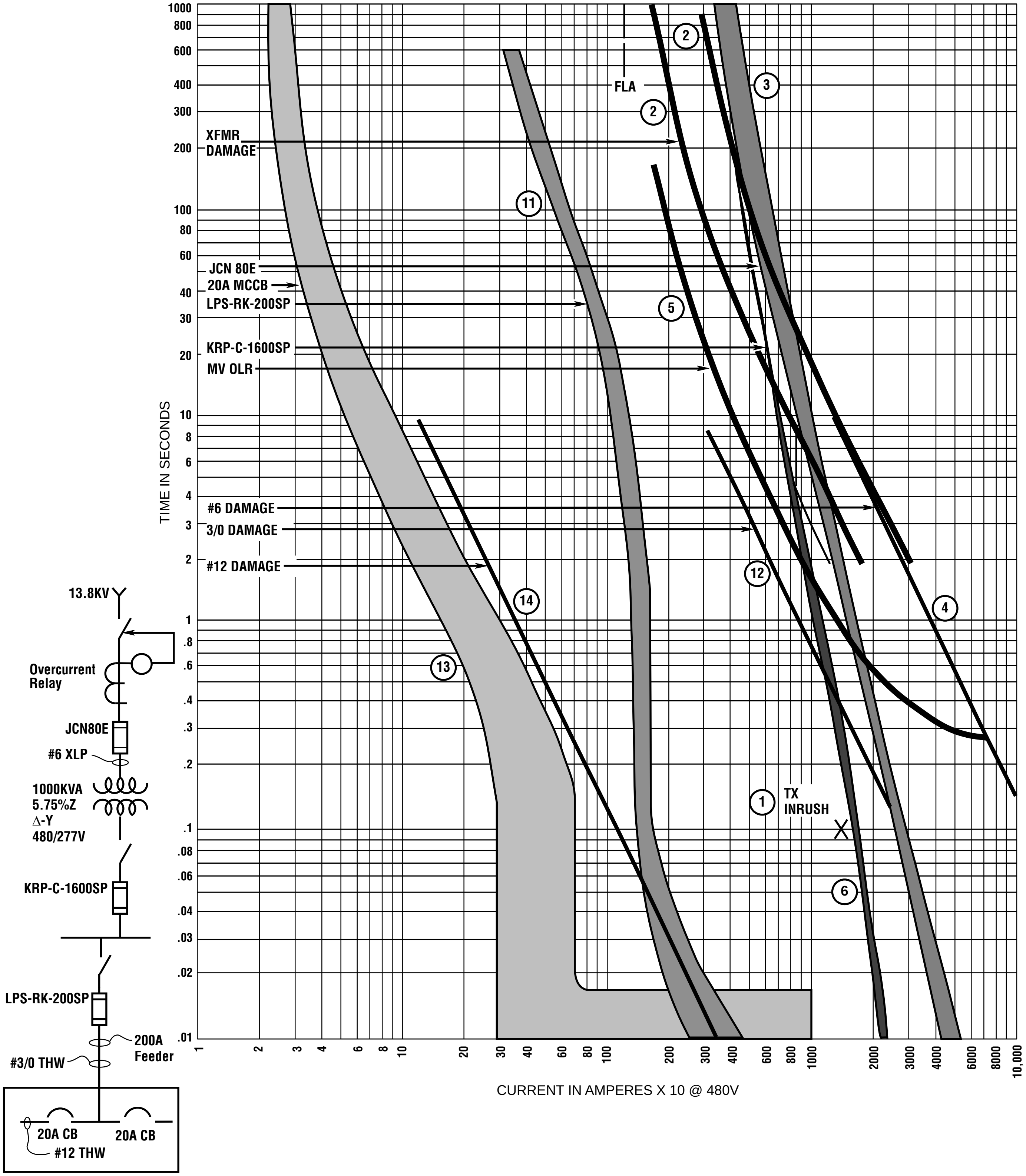
Footnote 1: Transformer damage curves indicate when it will be damaged, thermally and/or mechanically, under overcurrent conditions.

Transformer impedance, as well as primary and secondary connections, and type, all will determine their damage characteristics.

Footnote 2: A Δ-Y transformer connection requires a 15% shift, to the right, of the L-L thermal damage curve. This is due to a L-L secondary fault condition, which will cause 1.0 p.u. to flow through one primary phase, and .866 p.u. through the two faulted secondary phases. (These currents are p.u. of 3-phase fault current.)

Example –

Time Current Curve #1 (TCC1)



Example –

Time Current Curve #2 (TCC2)

Notes:

1. TCC2 includes the primary fuse, secondary main fuse, 400 ampere feeder fuse, 100 ampere motor branch fuse, 77 ampere motor and overload relaying.

2. Analysis will begin at the main devices and proceed down through the system.

3. Reference (base) voltage will be 480 volts, arbitrarily chosen since most of the devices are at this level.

Device ID	Description	Comment
①	1000KVA XFMR Inrush Point	12 x FLA @ .1 seconds
②	1000KVA XFMR Damage Curves	5.75%Z, liquid filled (Footnote 1) (Footnote 2)
③	JCN 80E	E-Rated Fuse
④	#6 Conductor Damage Curve	Copper, XLP Insulation
⑤	Medium Voltage Relay	Needed for XFMR Primary Overload Protection
⑥	KRP-C-1600SP	Class L Fuse
㉑	LPS-RK-100SP	Class RK1 Fuse
㉒	Motor Starting Curve	Across the Line Start
㉓	Motor Overload Relay	Class 10
㉔	Motor Stall Point	Part of a Motor Damage Curve
㉕	#1 Conductor Damage Curve	Copper THW Insulation

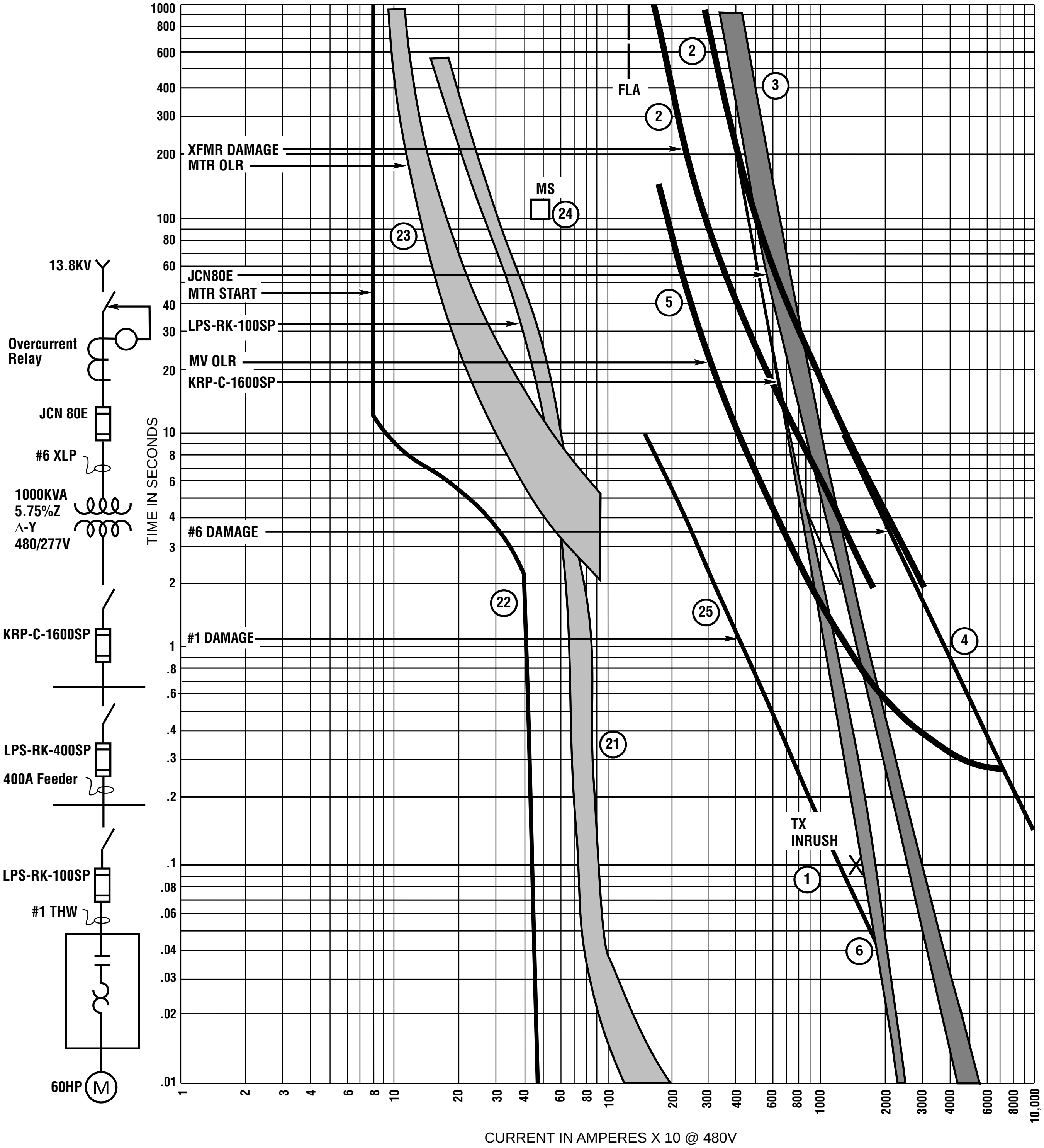
Footnote 1: Transformer damage curves indicate when it will be damaged, thermally and/or mechanically, under overcurrent conditions.

Transformer impedance, as well as primary and secondary connections, and type, all will determine their damage characteristics.

Footnote 2: A Δ-Y transformer connection requires a 15% shift, to the right, of the L-L thermal damage curve. This is due to a L-L secondary fault condition, which will cause 1.0 p.u. to flow through one primary phase, and .866 p.u. through the two faulted secondary phases. (These currents are p.u. of 3-phase fault current.)

Example –

Time Current Curve #2 (TCC2)



Example –

Time Current Curve #3 (TCC3)

Notes:

1. TCC3 includes the primary fuse, secondary main fuse, 225 ampere feeder/transformer primary and secondary fuses.

2. Analysis will begin at the main devices and proceed down through the system.

3. Reference (base) voltage will be 480 volts, arbitrarily chosen since most of the devices are at this level.

4. Relative to the 225 ampere feeder, coordination between primary and secondary fuses is not attainable, noted by overlap of curves.

5. Overload and short circuit protection for the 150 KVA transformer is afforded by the LPS-RK-225SP fuse.

Device ID	**Description**	**Comment**
①	1000KVA XFMR Inrush Point	12 x FLA @ .1 seconds
②	1000KVA XFMR Damage Curves	5.75%Z, liquid filled (Footnote 1) (Footnote 2)
③	JCN 80E	E-Rated Fuse
④	#6 Conductor Damage Curve	Copper, XLP Insulation
⑤	Medium Voltage Relay	Needed for XFMR Primary Overload Protection
⑥	KRP-C-1600SP	Class L Fuse
㉛	LPS-RK-225SP	Class RK1 Fuse
㉜	150 KVA XFMR Inrush Point	12 x FLA @.1 Seconds
㉝	150 KVA XFMR Damage Curves	2.00% Dry Type (Footnote 3)
㉞	LPN-RK-500SP	Class RK1 Fuse
㉟	2-250kcmil Conductors Damage Curve	Copper THW Insulation

Footnote 1: Transformer damage curves indicate when it will be damaged, thermally and/or mechanically, under overcurrent conditions.

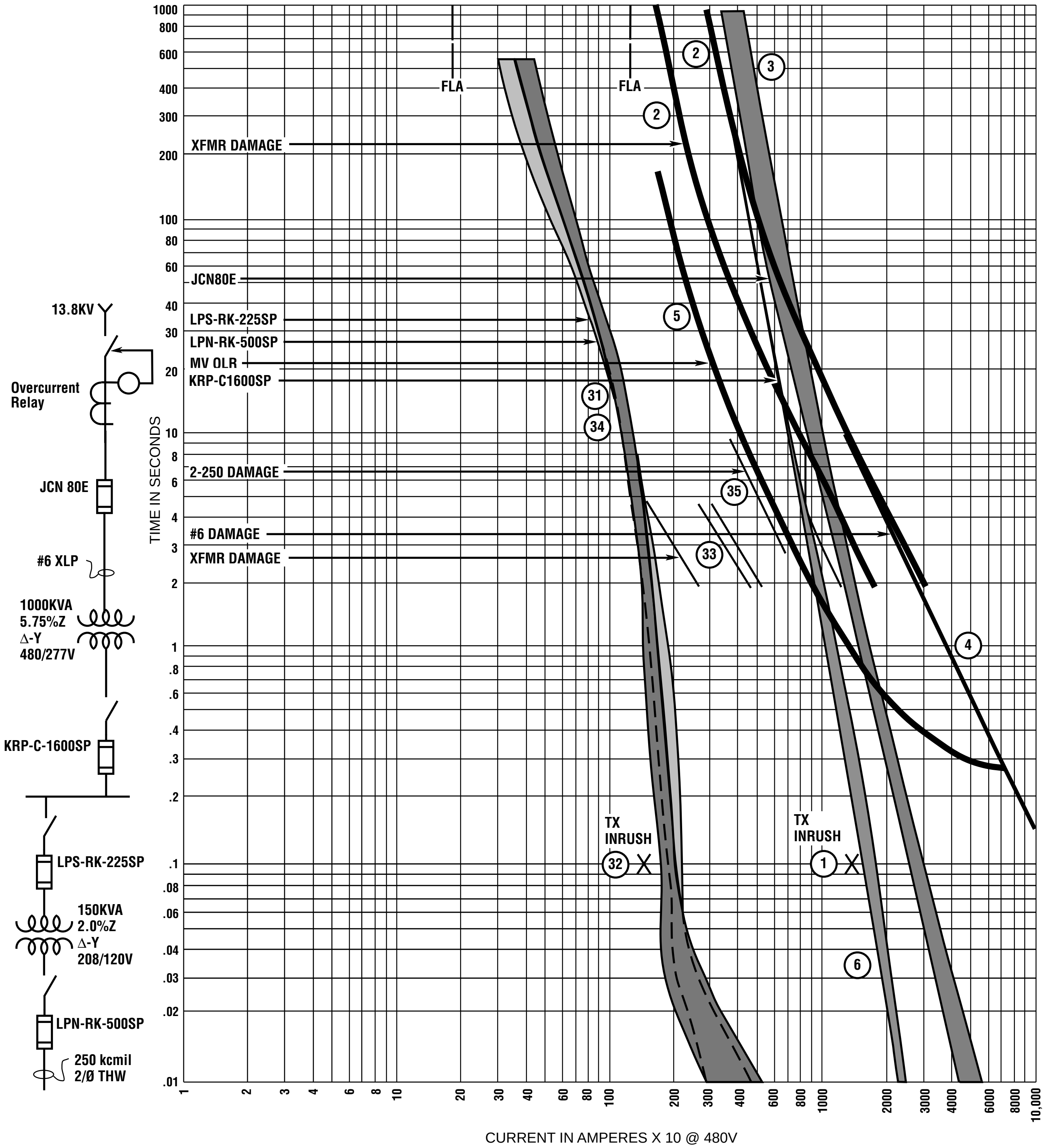
Transformer impedance, as well as primary and secondary connections, and type, all will determine their damage characteristics.

Footnote 2: A Δ-Y transformer connection requires a 15% shift, to the right, of the L-L thermal damage curve. This is due to a L-L secondary fault condition, which will cause 1.0 p.u. to flow through one primary phase, and .866 p.u. through the two faulted secondary phases. (These currents are p.u. of 3-phase fault current.)

Footnote 3: Damage curves for a small KVA (<500KVA) transformer, illustrate thermal damage characteristics for Δ-Y connected. From right to left, these reflect damage characteristics, for a line-line fault, 3Ø fault, and L-G fault condition.

Example –

Time Current Curve #3 (TCC3)



Conclusions

Unnecessary power OUTAGES, such as the BLACKOUTS we so often experience, can be stopped by isolating a faulted circuit from the remainder of the system through the proper selection of MODERN CURRENT-LIMITING FUSES.

Time-Delay type current-limiting fuses can be sized close to the load current and still hold motor-starting currents or other harmless transients, thereby ELIMINATING nuisance OUTAGES.

The SELECTIVITY GUIDE on page 10 may be used for an easy check on fuse selectivity regardless of the short-circuit current levels involved. Where medium and high voltage primary fuses are involved, the time-current characteristic curves of the fuses in question should be plotted on standard NEMA log-log graph paper for proper study.

The time saved by using the SELECTIVITY GUIDE will allow the electrical systems designer to pursue other areas for improved systems design.