Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amps (F.L.A.) from

$$3Ø\text{ Transformer}\qquad I_{F.L.A.} = \frac{kVA \times 1000}{E_{L\text{-}L} \times 1.732}$$

$$1Ø\text{ Transformer}\qquad I_{F.L.A.} = \frac{kVA \times 1000}{E_{L\text{-}L}}$$

either the nameplate, the following formulas or Table 1:

$$\text{Multiplier} = \frac{100}{{}^{*}\%\,Z_{\text{transformer}}}$$

Step 2. Find the transformer multiplier. See Notes 1 and 2

*** Note 1.** Get %Z from nameplate or Table 1. Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is increased on the primary until full load current flows in the secondary. This applied voltage divided by the rated primary voltage (times 100) is the impedance of the transformer.

Example: For a 480 Volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is 9.6/480 = .02 = 2%Z.

*** Note 2.** In addition, UL 1561 listed transformers 25kVA and larger have a ± 10% impedance tolerance. Short circuit amps can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by .9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Step 3. Determine by formula or Table 1 the transformer let-through short-circuit current. See Notes 3 and 4.

$$I_{S.C.} = \text{Transformer}_{F.L.A.} \times \text{Multiplier}$$

Note 3. Utility voltages may vary ±10% for power and ±5.8% for 120 Volt lighting services. Therefore, for highest short circuit conditions, multiply values as calculated in step 3 by 1.1 or 1.058 respectively. To find the lower end worst case, multiply results in step 3 by .9 or .942 respectively.

Note 4. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor.

3Ø Faults

$$f = \frac{1.732 \times L \times I_{3Ø}}{C \times n \times E_{L\text{-}L}}$$

1Ø Line-to-Line (L-L) Faults
See Note 5 & Table 3

$$f = \frac{2 \times L \times I_{L\text{-}L}}{C \times n \times E_{L\text{-}L}}$$

1Ø Line-to-Neutral (L-N) Faults
See Note 5 & Table 3

$$f = \frac{2 \times L \times I_{L\text{-}N}^{\dagger}}{C \times n \times E_{L\text{-}N}}$$

Where:

L = length (feet) of conductor to the fault.
C = constant from Table 4 of "C" values for conductors and Table 5 of "C" values for busway.
n = Number of conductors per phase (adjusts C value for parallel runs)
I = Available short-circuit current in amperes at beginning of circuit.
E = Voltage of circuit.

† Note 5. The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L\text{-}N} = 1.5 \times I_{L\text{-}L}$ at Transformer Terminals.

At some distance from the terminals, depending upon wire size, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on change in turns ratio between primary and secondary, infinite source available, zero feet from terminals of transformer, and 1.2 x %X and 1.5 x %R for L-N vs. L-L resistance and reactance values. Begin L-N calculations at transformer secondary terminals, then proceed point-to-point.

Step 5. Calculate "M" (multiplier) or take from Table 2.

$$M = \frac{1}{1+f}$$

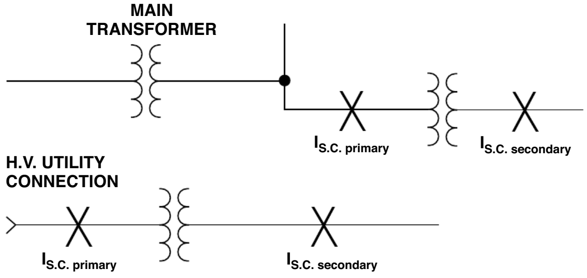
Step 6. Calculate the available short circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

$$I_{S.C.\,sym.\,RMS} = I_{S.C.} \times M$$

Step 6A. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Calculation of Short-Circuit Currents When Primary Available Short-Circuit Current is Known

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



Step A. Calculate the "f" factor ($I_{S.C.\ primary}$ known)

3Ø Transformer
($I_{S.C.\ primary}$ and
$I_{S.C.\ secondary}$ are
3Ø fault values)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times 1.73\ (\%Z)}{100{,}000 \times kVA_{\ transformer}}$$

1Ø Transformer
($I_{S.C.\ primary}$ and
$I_{S.C.\ secondary}$ are
1Ø fault values:
$I_{S.C.\ secondary}$ is L-L)

$$f = \frac{I_{S.C.\ primary} \times V_{primary} \times (\%Z)}{100{,}000 \times kVA_{\ transformer}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1+f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\ secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\ primary}$$

Three-Phase Short Circuits

System A

Available Utility
Infinite Assumption

1500 KVA Transformer
480V, 3Ø, 3.5%Z,
3.45% X, 0.56%R

$I_{f.l.}$=1804A

25' - 500kcmil Cu
3 Single Conductors
6 Per Phase
Magnetic Conduit

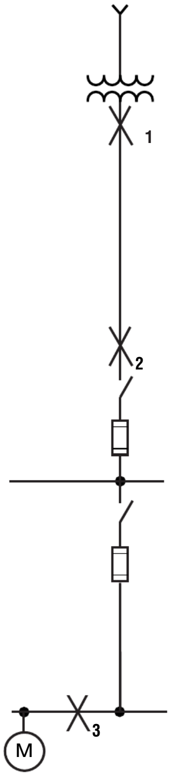
2000A Switch
KRP-C 2000SP Fuse

400A Switch
LPS-RK-400SP Fuse

50' - 500 kcmil Cu
3 Single Conductors
Magnetic Conduit

Motor Contribution*

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{1500 \times 1000}{480 \times 1.732} = 1804.3A$

Step 2. Multipler $\frac{100}{3.5 \times 0.9^{\dagger}} = 31.746$

Step 3. $I_{s.c.} = 1804.3 \times 31.746 = 57{,}279A$
$I_{s.c.\ motor\ contribution^{**}} = 4 \times 1804.3 = 7217A$
$I_{total\ s.c.\ sym\ RMS} = 57{,}279 + 7217 = 64{,}496A$

Fault X_2

Step 4. $f = \frac{1.732 \times 25 \times 57{,}279}{22{,}185 \times 6 \times 480} = 0.0388$

Step 5. $M = \frac{1}{1 + 0.0388} = 0.9626$

Step 6. $I_{s.c.\ sym\ RMS} = 57{,}279 \times 0.9626 = 55{,}137A$
$I_{s.c.\ motor\ contribution^{**}} = 4 \times 1804.3 = 7217A$
$I_{total\ s.c.\ sym\ RMS} = 55{,}137 + 7217 = 62{,}354A$

Fault X_3

Step 4. $f = \frac{1.732 \times 50 \times 55{,}137}{22{,}185 \times 1 \times 480} = 0.4484$

Step 5. $M = \frac{1}{1 + 0.4483} = 0.6904$

Step 6. $I_{s.c.\ sym\ RMS} = 55{,}137 \times 0.6904 = 38{,}067A$
$I_{s.c.\ motor\ contribution^{**}} = 4 \times 1804.3 = 7217A$
$I_{total\ s.c.\ sym\ RMS\ (X_3)} = 38{,}067 + 7217 = 45{,}284A$

*See note 4 on page 240.
**Assumes 100% motor load. If 50% of this load was from motors. $I_{s.c.\ motor\ contrib.} = 4 \times 1804 \times 0.5 = 3{,}608A$
† See note 2 on page 240

System B

Available Utility
Infinite Assumption

1000 KVA Transformer
480V, 3Ø, 3.5%Z,

$I_{f.l.}$=1203A

30' - 500kcmil Cu
3 Single Conductors
4 Per Phase
PVC Conduit

1600A Switch

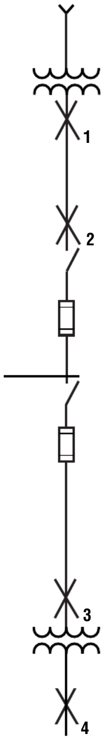
KRP-C 1500SP Fuse

400A Switch
LPS-RK-350SP Fuse

20' - 2/0 Cu
3 Single Conductors
2 Per Phase
PVC Conduit

225 KVA Transformer
208V, 3Ø
1.2%Z

One-Line Diagram



Fault X_1

Step 1. $I_{s.c.} = \frac{1000 \times 1000}{480 \times 1.732} = 1202.8A$

Step 2. Multipler $= \frac{100}{3.5 \times 0.9^{\dagger}} = 31.746$

Step 3. $I_{s.c.} = 1202.8 \times 31.746 = 38{,}184A$

Fault X_2

Step 4. $f = \frac{1.732 \times 30 \times 38{,}184}{26{,}706 \times 4 \times 480} = 0.0387$

Step 5. $M = \frac{1}{1 + 0.0387} = 0.9627$

Step 6. $I_{s.c.\ sym\ RMS} = 38{,}184 \times 0.9627 = 36{,}761A$

This example assumes no motor contribution.

Fault X_3

Step 4. $f = \frac{1.732 \times 20 \times 36{,}761}{2 \times 11{,}424 \times 480} = 0.1161$

Step 5. $M = \frac{1}{1 + 0.1161} = 0.8960$

Step 6. $I_{s.c.\ sym\ RMS} = 36{,}761 \times 0.8960 = 32{,}937A$

Fault X_4

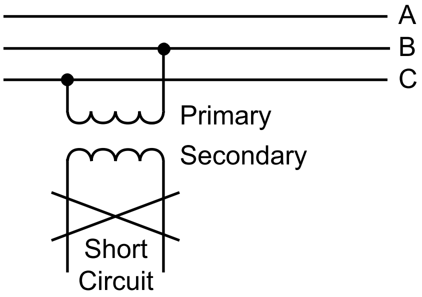
Step A. $f = \frac{32{,}937 \times 480 \times 1.732 \times (1.2 \times 0.9)}{100{,}000 \times 225} = 1.3144$

Step B. $M = \frac{1}{1 + 1.3144} = 0.4321$

Step C. $I_{s.c.\ sym\ RMS} = \frac{480 \times 0.4321 \times 32{,}937}{208} = 32{,}842A$

Single-Phase Short Circuits

Short circuit calculations on a single-phase center tapped transformer system require a slightly different procedure than 3Ø faults on 3Ø systems.



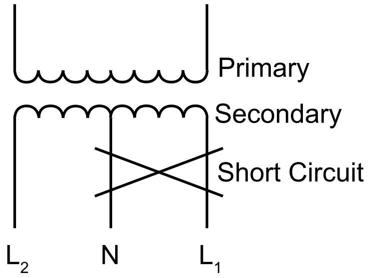
1. It is necessary that the proper impedance be used to represent the primary system. For 3Ø fault calculations, a single primary conductor impedance is used from the source to the transformer connection. This is compensated for in the 3Ø short circuit formula by multiplying the single conductor or single-phase impedance by 1.73.

   However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.

2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

   The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

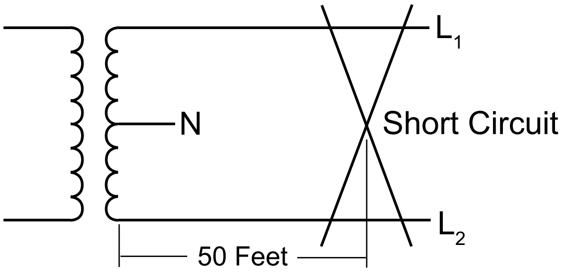
   - 1.5 times full winding %R on full winding basis.
   - 1.2 times full winding %X on full winding basis.



Note: %R and %X multipliers given in “Impedance Data for Single Phase Transformers” Table may be used, however, calculations must be adjusted to indicate transformer kVA/2.

3. The impedance of the cable and two-pole switches on the system must be considered “both-ways” since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.

   The calculations on the following pages illustrate 1Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.



Note in these examples:

a. The multiplier of 2 for some electrical components to account for the single-phase fault current flow,

b. The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation, and

Single-Phase Short Circuits

System A

Available Utility
Infinite Assumption

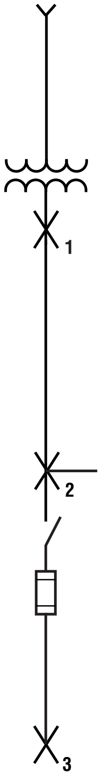
75KVA, 1Ø Transformer.
1.22%X, 0.68%R
1.40%Z
120/240V

25' - 500kcml Cu
Magnetic Conduit
3 Single Conductors

400A Switch
LPN-RK-400SP Fuse

50' - 3 AWG Cu
Magnetic Conduit
3 Single Conductors

One-Line Diagram



Line-to-Line (L-L) Fault

Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multipler} = \frac{100}{1.4 \times 0.9^{\dagger}} = 79.37$

Step 3. $I_{s.c.\ (L\text{-}L)} = 312.5 \times 79.37 = 24{,}802A$

Fault X_2

Step 4. $f = \frac{2 \times 25 \times 24{,}802}{22{,}185 \times 1 \times 240} = 0.2329$

Step 5. $M = \frac{1}{1 + 0.2329} = 0.8111$

Step 6. $I_{s.c.\ (L\text{-}L)\ (X_2)} = 24{,}802 \times 0.8111 = 20{,}116$

Fault X_3

Step 4. $f = \frac{2 \times 50 \times 20{,}116}{4774 \times 1 \times 240} = 1.7557$

Step 5. $M = \frac{1}{1 + 1.7557} = 0.3629$

Step 6. $I_{s.c.\ (L\text{-}L)\ (X_3)} = 20{,}116 \times 0.3629 = 7{,}300A$

† In addition, UL 1561 listed transformers 25kVA and larger have a ± 10% impedance tolerance. Short circuit amps can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by 0.9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Line-to-Neutral (L-N) Fault

Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multipler} = \frac{100}{1.4 \times 0.9^{\dagger}} = 79.37$

Step 3*. $I_{s.c.\ (L\text{-}N)} = 24{,}802 \times 1.5 = 37{,}202A$

Fault X_2

Step 4. $f = \frac{2 \times 25 \times 37{,}202}{22{,}185 \times 1 \times 120} = 0.6987$

Step 5. $M = \frac{1}{1 + 0.6987} = 0.5887$

Step 6*. $I_{s.c.\ (L\text{-}N)\ (X_2)} = 37{,}202 \times 0.5887 = 21{,}900A$

Fault X_3

Step 4. $f = \frac{2 \times 50 \times 21{,}900^{**}}{4774 \times 1 \times 120} = 3.8323$

Step 5. $M = \frac{1}{1 + 3.823} = 0.2073$

Step 6*. $I_{s.c.\ (L\text{-}N)\ (X_3)} = 21{,}900 \times 0.2073 = 4{,}540A$

* Note 5. The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L\text{-}N} = 1.5 \times I_{L\text{-}L}$ at Transformer Terminals.

**Assumes the neutral conductor and the line conductor are the same size.

Impedance & Reactance Data

Transformers

Table 1. Short-Circuit Currents Available from Various Size Transformers

(Based upon actual field nameplate data or from utility transformer worst case impedance)

Voltage and Phase	kVA	Full Load Amps	% Impedance†† (Nameplate)	Short Circuit Amps†
120/240 1 ph.*	25	104	1.5	12175
	37.5	156	1.5	18018
	50	208	1.5	23706
	75	313	1.5	34639
	100	417	1.6	42472
	167	696	1.6	66644
120/208 3 ph.**	45	125	1.0	13879
	75	208	1.0	23132
	112.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
277/480 3 ph.**	75	90	1.00	10035
	112.5	135	1.00	15053
	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

* Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 KVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/R ratio = 3.

** Three-phase short-circuit currents based on "infinite" primary.

†† UL listed transformers 25 KVA or greater have a ± 10% impedance tolerance. Short-circuit amps shown in Table 1 reflect –10% condition. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

† Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% greater available short-circuit currents than as shown in Table 1.

Table 2. "M" (Multiplier)

$$M = \frac{1}{1 + f}$$

f	M	f	M	f	M
0.01	0.99	0.50	0.67	7.00	0.13
0.02	0.98	0.60	0.63	8.00	0.11
0.03	0.97	0.70	0.59	9.00	0.10
0.04	0.96	0.80	0.55	10.00	0.09
0.05	0.95	0.90	0.53	15.00	0.06
0.06	0.94	1.00	0.50	20.00	0.05
0.07	0.93	1.20	0.45	30.00	0.03
0.08	0.93	1.50	0.40	40.00	0.02
0.09	0.92	1.75	0.36	50.00	0.02
0.10	0.91	2.00	0.33	60.00	0.02
0.15	0.87	2.50	0.29	70.00	0.01
0.20	0.83	3.00	0.25	80.00	0.01
0.25	0.80	3.50	0.22	90.00	0.01
0.30	0.77	4.00	0.20	100.00	0.01
0.35	0.74	5.00	0.17		
0.40	0.71	6.00	0.14		

Impedance Data for Single-Phase Transformers

kVA 1Ø	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

* National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

** Based on rated current of the winding (one–half nameplate kVA divided by secondary line-to-neutral voltage).

Note: UL Listed transformers 25 kVA and greater have a ± 10% tolerance on their impedance nameplate.

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Impedance Data for Single-Phase and Three-Phase Transformers-Supplement†

kVA 1Ø	kVA 3Ø	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
	75	1.11	1.5
	150	1.07	1.5
	225	1.12	1.5
	300	1.11	1.5
333	—	1.9	4.7
	500	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: UL Listed transformers 25kVA and greater have a ±10% tolerance on their impedance nameplate.

Table 3.
Various Types of Short -Circuit Currents as a Percent of Three Phase Bolted Faults (Typical).

Three Phase Bolted Fault	100%
Line-to-Line Bolted Fault	87%
Line-to-Ground Bolted Fault	25-125%* (Use 100% near transformer, 50% otherwise)
Line-to-Neutral Bolted Fault	25-125% (Use 100% near tansformer, 50% otherwise)
Three Phase Arcing Fault	89% (maximum)
Line-to-Line Arcing Fault	74% (maximum)
Line-to-Ground Arcing Fault (minimum)	38% (minimum)

*Typically much lower but can actually exceed the Three Phase Bolted Fault if it is near the transformer terminals. Will normally be between 25% to 125% of three phase bolted fault value.

Conductors & Busways "C" Values

Table 4. "C" Values for Conductors

AWG or kcmil	Three Single Conductors Conduit						Three-Conductor Cable Conduit					
	Steel			Nonmagnetic			Steel			Nonmagnetic		
	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV	600V	5kV	15kV
Copper												
14	389	-	-	389	-	-	389	-	-	389	-	-
12	617	-	-	617	-	-	617	-	-	617	-	-
10	981	-	-	982	-	-	982	-	-	982	-	-
8	1557	1551	-	1559	1555	-	1559	1557	-	1560	1558	-
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053
2/0	10755	10062	9390	11424	10878	10319	11245	11045	10500	11703	11529	11053
3/0	12844	11804	11022	13923	13048	12360	13656	13333	12613	14410	14119	13462
4/0	15082	13606	12543	16673	15351	14347	16392	15890	14813	17483	17020	16013
250	16483	14925	13644	18594	17121	15866	18311	17851	16466	19779	19352	18001
300	18177	16293	14769	20868	18975	17409	20617	20052	18319	22525	21938	20163
350	19704	17385	15678	22737	20526	18672	22646	21914	19821	24904	24126	21982
400	20566	18235	16366	24297	21786	19731	24253	23372	21042	26916	26044	23518
500	22185	19172	17492	26706	23277	21330	26980	25449	23126	30096	28712	25916
600	22965	20567	17962	28033	25204	22097	28752	27975	24897	32154	31258	27766
750	24137	21387	18889	29735	26453	23408	31051	30024	26933	34605	33315	29735
1,000	25278	22539	19923	31491	28083	24887	33864	32689	29320	37197	35749	31959
Aluminum												
14	237	-	-	237	-	-	237	-	-	237	-	-
12	376	-	-	376	-	-	376	-	-	376	-	-
10	599	-	-	599	-	-	599	-	-	599	-	-
8	951	950	-	952	951	-	952	951	-	952	952	-
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977
4/0	10741	10167	9700	11174	10749	10387	11185	11022	10642	11409	11277	10969
250	12122	11460	10849	12862	12343	11847	12797	12636	12115	13236	13106	12661
300	13910	13009	12193	14923	14183	13492	14917	14698	13973	15495	15300	14659
350	15484	14280	13288	16813	15858	14955	16795	16490	15541	17635	17352	16501
400	16671	15355	14188	18506	17321	16234	18462	18064	16921	19588	19244	18154
500	18756	16828	15657	21391	19503	18315	21395	20607	19314	23018	22381	20978
600	20093	18428	16484	23451	21718	19635	23633	23196	21349	25708	25244	23295
750	21766	19685	17686	25976	23702	21437	26432	25790	23750	29036	28262	25976
1,000	23478	21235	19006	28779	26109	23482	29865	29049	26608	32938	31920	29135

Note: These values are equal to one over the impedance per foot and based upon resistance and reactance values found in IEEE Std 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commerical Buildings & IEEE Std 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 KV & 15 KV are from the Gray Book only (Values for 14-10 AWG at 5 kV and 14-8 AWG at 15 kV are not available and values for 3 AWG have been approximated).

Table 5. "C" Values for Busway

Ampacity	Busway				
	Plug-In	Feeder		High Impedance	
	Copper	Aluminum	Copper	Aluminum	Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.

Ratings of Conductors and Tables to Determine Volt Loss

With larger loads on new installations, it is extremely important to consider volt loss, otherwise some very unsatisfactory problems are likely to be encountered.

The actual conductor used must also meet the other sizing requirements such a full-load current, ambient temperature, number in a raceway, etc.

How to Figure Volt Loss

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps) by the *figure* shown in table for the kind of current and the size of wire to be used, by one over the number of conductors per phase.

Then, put a decimal point in front of the last 6 digits–you have the *volt loss* to be expected on that circuit.

Example – 6 AWG copper wire, one per phase, in 180 feet of steel conduit–3 phase, 40 amp load at 80% power factor.

Multiply feet by amperes: 180 x 40 = 7200
Multiply this number by number from table for 6 AWG wire three-phase at 80% power factor: 7200 x 745† = 5364000
Multiply by $\frac{1}{\#/\text{phase}}$ x 5364000 = $\frac{1}{1}$ x 5364000 = 5364000
Place decimal point 6 places to left:
This gives volt loss to be expected: 5.364V

(For a 240V circuit the % voltage drop is $\frac{5.364}{240}$ x 100 or 2.23%).

Table A and B take into consideration *reactance on AC circuits* as well as resistance of the wire.

Remember on short runs to check to see that the size and type of wire indicated has sufficient ampacity.

How to Select Size of Wire

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps), by one over the number of conductors per phase.

Divide that figure into the permissible *volt loss* multiplied by 1,000,000.

Example – Copper in 180 feet of steel conduit–3 phase, 40 amp load at 80% power factor–maximum volt loss permitted from local code equals 5.5 volts.
Multiply feet by amperes by $\frac{1}{\#/\text{phase}}$ 180 x 40 x $\frac{1}{1}$ = 7200.
Divide permissible volt loss multiplied by 1,000,000 by this number: $\frac{5.5 \times 1{,}000{,}000}{7200}$ = 764.

Look under the column in Table A and B applying to the type of current and power factor for the value nearest, but not above your result – you have the size of wire needed.

Select number from Table A, three-phase at 80% power factor, that is nearest but not greater than 764. This number is 745 which indicates the size of wire needed: 6 AWG.

Line-to-Neutral

For line to neutral voltage drop on a 3 phase system, divide the three phase value by 1.73. For line to neutral voltage drop on a single phase system, divide single phase value by 2.

Open Wiring

The volt loss for open wiring installations depends on the separation between conductors. The volt loss is approximately equal to that for conductors in non-magnetic conduit.

Installation in Conduit, Cable or Raceway

NEC® Tables 310.15(B)(16) through 310.15(B)(19) give allowable ampacities (current-carrying capacities) for not more than three current carrying conductors in a conduit, cable, or raceway. Where the number of current carrying conductors exceeds three the allowable ampacity of each conductor must be reduced as shown in the following tables:

Installation in Conduit, Cable or Raceway per 310.15(B)(2)(a)

The Number of Conductors In One Conduit, Raceway Or Cable	Percentage of Values In Tables 310.16 And 310.18
4 to 6	80%
7 to 9	70%
10 to 20	50%
21 to 30	45%
31 to 40	40%
41 and over	35%

Conditions Causing Higher Volt Loss

The voltage loss is increased when a conductor is operated at a higher temperature because the resistance increases.

Room Temperature Affects Ratings

The ampacities (carrying capacities) of conductors are based on a room temperature of either 30°C or 40ºC. For derating based upon 30ºC ambient, if room temperature is higher, the ampacities are reduced by using the following multipliers; (for 0-2000 volt, insulated conductors not more than 3 conductors in raceway or direct buried, Table 310.15(B)(2)(a)). For room temperatures based upon a 40ºC ambient, see Table 310.15(B)(2)(b).

Room Temperature Affects Ratings

Room		Ampacity Multiplier		
Temperature	TW	THW, THWN	THHN, XHHW*	
°C	°F	(60°C Wire)	(75°C Wire)	(90°C Wire)
31-35	87-95	.91	.94	.96
36-40	96-104	.82	.88	.91
41-45	105-113	.71	.82	.87
46-50	114-122	.58	.75	.82
51-55	123-131	.41	.67	.76
56-60	132-140	–	.58	.71
61-70	141-158	–	.33	.58
71-80	159-176	–	–	.41

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† Value from Table A

Table A — Copper Conductors — Ratings & Volt Loss†

Conduit	Wire Size	Ampacity			Direct Current	Volt Loss (See explanation prior page.)									
		Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)		Three-Phase (60 Cycle, Lagging Power Factor.)					Single-Phase (60 Cycle, Lagging Power Factor.)				
						100%	90%	80%	70%	60%	100%	90%	80%	70%	60%
Steel Conduit	14	20*	20*	25*	6140	5369	4887	4371	3848	3322	6200	5643	5047	4444	3836
	12	25*	25*	30*	3860	3464	3169	2841	2508	2172	4000	3659	3281	2897	2508
	10	30	35*	40*	2420	2078	1918	1728	1532	1334	2400	2214	1995	1769	1540
	8	40	50	55	1528	1350	1264	1148	1026	900	1560	1460	1326	1184	1040
	6	55	65	75	982	848	812	745	673	597	980	937	860	777	690
	4	70	85	95	616	536	528	491	450	405	620	610	568	519	468
	3	85	100	110	490	433	434	407	376	341	500	501	470	434	394
	2	95	115	130	388	346	354	336	312	286	400	409	388	361	331
	1	110	130	150	308	277	292	280	264	245	320	337	324	305	283
	0	125	150	170	244	207	228	223	213	200	240	263	258	246	232
	00	145	175	195	193	173	196	194	188	178	200	227	224	217	206
	000	165	200	225	153	136	162	163	160	154	158	187	188	184	178
	0000	195	230	260	122	109	136	140	139	136	126	157	162	161	157
	250	215	255	290	103	93	123	128	129	128	108	142	148	149	148
	300	240	285	320	86	77	108	115	117	117	90	125	133	135	135
	350	260	310	350	73	67	98	106	109	109	78	113	122	126	126
	400	280	335	380	64	60	91	99	103	104	70	105	114	118	120
	500	320	380	430	52	50	81	90	94	96	58	94	104	109	111
	600	335	420	475	43	43	75	84	89	92	50	86	97	103	106
	750	400	475	535	34	36	68	78	84	88	42	79	91	97	102
	1000	455	545	615	26	31	62	72	78	82	36	72	84	90	95
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	14	20*	20*	25*	6140	5369	4876	4355	3830	3301	6200	5630	5029	4422	3812
	12	25*	25*	30*	3464	3464	3158	2827	2491	2153	4000	3647	3264	2877	2486
	10	30	35*	40*	2420	2078	1908	1714	1516	1316	2400	2203	1980	1751	1520
	8	40	50	55	1528	1350	1255	1134	1010	882	1560	1449	1310	1166	1019
	6	55	65	75	982	848	802	731	657	579	980	926	845	758	669
	4	70	85	95	616	536	519	479	435	388	620	599	553	502	448
	3	85	100	110	470	433	425	395	361	324	500	490	456	417	375
	2	95	115	130	388	329	330	310	286	259	380	381	358	330	300
	1	110	130	150	308	259	268	255	238	219	300	310	295	275	253
	0	125	150	170	244	207	220	212	199	185	240	254	244	230	214
	00	145	175	195	193	173	188	183	174	163	200	217	211	201	188
	000	165	200	225	153	133	151	150	145	138	154	175	173	167	159
	0000	195	230	260	122	107	127	128	125	121	124	147	148	145	140
	250	215	255	290	103	90	112	114	113	110	104	129	132	131	128
	300	240	285	320	86	76	99	103	104	102	88	114	119	120	118
	350	260	310	350	73	65	89	94	95	94	76	103	108	110	109
	400	280	335	380	64	57	81	87	89	89	66	94	100	103	103
	500	320	380	430	52	46	71	77	80	82	54	82	90	93	94
	600	335	420	475	43	39	65	72	76	77	46	75	83	87	90
	750	400	475	535	34	32	58	65	70	72	38	67	76	80	83
	1000	455	545	615	26	25	51	59	63	66	30	59	68	73	77

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

Table B — Aluminum Conductors — Ratings & Volt Loss†

Conduit	Wire Size	Ampacity			Direct Current	Volt Loss (See explanation two pages prior.)									
		Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)		Three-Phase (60 Cycle, Lagging Power Factor.)					Single-Phase (60 Cycle, Lagging Power Factor.)				
						100%	90%	80%	70%	60%	100%	90%	80%	70%	60%
Steel Conduit	12	20*	20*	25*	6360	5542	5039	4504	3963	3419	6400	5819	5201	4577	3948
	10	25	30*	35*	4000	3464	3165	2836	2502	2165	4000	3654	3275	2889	2500
	8	30	40	45	2520	2251	2075	1868	1656	1441	2600	2396	2158	1912	1663
	6	40	50	60	1616	1402	1310	1188	1061	930	1620	1513	1372	1225	1074
	4	55	65	75	1016	883	840	769	692	613	1020	970	888	799	708
	3	65	75	85	796	692	668	615	557	497	800	771	710	644	574
	2	75	90	100	638	554	541	502	458	411	640	625	580	529	475
	1	85	100	115	506	433	432	405	373	338	500	499	468	431	391
	0	100	120	135	402	346	353	334	310	284	400	407	386	358	328
	00	115	135	150	318	277	290	277	260	241	320	335	320	301	278
	000	130	155	175	259	225	241	234	221	207	260	279	270	256	239
	0000	150	180	205	200	173	194	191	184	174	200	224	221	212	201
	250	170	205	230	169	148	173	173	168	161	172	200	200	194	186
	300	190	230	255	141	124	150	152	150	145	144	174	176	173	168
	350	210	250	280	121	109	135	139	138	134	126	156	160	159	155
	400	225	270	305	106	95	122	127	127	125	110	141	146	146	144
	500	260	310	350	85	77	106	112	113	113	90	122	129	131	130
	600	285	340	385	71	65	95	102	105	106	76	110	118	121	122
	750	320	385	435	56	53	84	92	96	98	62	97	107	111	114
	1000	375	445	500	42	43	73	82	87	89	50	85	95	100	103
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	12	20*	20*	25*	6360	5542	5029	4490	3946	3400	6400	5807	5184	4557	3926
	10	25	30*	35*	4000	3464	3155	2823	2486	2147	4000	3643	3260	2871	2480
	8	30	40	45	2520	2251	2065	1855	1640	1423	2600	2385	2142	1894	1643
	6	40	50	60	1616	1402	1301	1175	1045	912	1620	1502	1357	1206	1053
	4	55	65	75	1016	883	831	756	677	596	1020	959	873	782	668
	3	65	75	85	796	692	659	603	543	480	800	760	696	627	555
	2	75	90	100	638	554	532	490	443	394	640	615	566	512	456
	1	85	100	115	506	433	424	394	360	323	500	490	455	415	373
	0	100	120	135	402	346	344	322	296	268	400	398	372	342	310
	00	115	135	150	318	277	281	266	247	225	320	325	307	285	260
	000	130	155	175	252	225	234	223	209	193	260	270	258	241	223
	0000	150	180	205	200	173	186	181	171	160	200	215	209	198	185
	250	170	205	230	169	147	163	160	153	145	170	188	185	177	167
	300	190	230	255	141	122	141	140	136	130	142	163	162	157	150
	350	210	250	280	121	105	125	125	123	118	122	144	145	142	137
	400	225	270	305	106	93	114	116	114	111	108	132	134	132	128
	500	260	310	350	85	74	96	100	100	98	86	111	115	115	114
	600	285	340	385	71	62	85	90	91	91	72	98	104	106	105
	750	320	385	435	56	50	73	79	82	82	58	85	92	94	95
	1000	375	445	500	42	39	63	70	73	75	46	73	81	85	86

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

Common Electrical Terminology

Ohm
The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one amp to flow under a pressure of one volt.

Ohm's Law
The relationship between voltage, current, and resistance, expressed by the equation E = IR, where E is the voltage in volts, I is the current in amps, and R is the resistance in ohms.

One Time Fuses
Generic term used to describe a Class H nonrenewable cartridge fuse, with a single element.

Overcurrent
A condition which exists on an electrical circuit when the normal load current is exceeded. Overcurrents take on two separate characteristics – overloads and short-circuits.

Overload
Can be classified as an overcurrent which exceeds the normal full load current of a circuit. Also characteristic of this type of overcurrent is that it does not leave the normal current carrying path of the circuit – that is, it flows from the source, through the conductors, through the load, back through the conductors, to the source again.

Peak Let-Through Current, Ip
The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Renewable Fuse (600V & below)
A fuse in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards.

Resistive Load
An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS Current
The RMS (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

Semiconductor Fuses
Fuses used to protect solid-state devices. See "High Speed Fuses."

Short-Circuit
Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit – it takes a "short cut" around the load and back to the source.

Short-Circuit Current Rating
The maximum short-circuit current an electrical component can sustain without the occurrence of excessive damage when protected with an overcurrent protective device.

Single-Phasing
That condition which occurs when one phase of a three-phase system opens, either in a low voltage (secondary) or high voltage (primary) distribution system. Primary or secondary single-phasing can be caused by any number of events. This condition results in unbalanced currents in polyphase motors and unless protective measures are taken, causes overheating and failure.

Threshold Current
The symmetrical RMS available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off of a peak let-through chart where the fuse curve intersects the A - B line. A threshold ratio is the relationship of the threshold current to the fuse's continuous current rating.

Time-Delay Fuse
A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Voltage Rating
The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an overcurrent. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.

Withstand Rating
The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage.

Electrical Formulas

To Find	Single-Phase	Two-Phase	Three-Phase	Direct Current
Amperes when kVA is known	$\frac{\text{kVA} \quad 1000}{\text{E}}$	$\frac{\text{kVA} \quad 1000}{\text{E} \quad 2}$	$\frac{\text{kVA} \quad 1000}{\text{E} \quad 1.73}$	Not Applicable
Amperes when horsepower is known	$\frac{\text{HP} \quad 746}{\text{E} \quad \%\text{ eff.} \quad \text{pf}}$	$\frac{\text{HP} \quad 746}{\text{E} \quad 2 \quad \%\text{ eff.} \quad \text{pf}}$	$\frac{\text{HP} \quad 746}{\text{E} \quad 1.73 \quad \%\text{ eff.} \quad \text{pf}}$	$\frac{\text{HP} \quad 746}{\text{E} \quad \%\text{ eff.}}$
Amperes when kilowatts are known	$\frac{\text{kW} \quad 1000}{\text{E} \quad \text{pf}}$	$\frac{\text{kW} \quad 1000}{\text{E} \quad 2\text{ pf}}$	$\frac{\text{kW} \quad 1000}{\text{E} \quad 1.73 \quad \text{pf}}$	$\frac{\text{kW} \quad 1000}{\text{E}}$
Kilowatts	$\frac{\text{I} \quad \text{E} \quad \text{pf}}{1000}$	$\frac{\text{I} \quad \text{E} \quad 2 \quad \text{pf}}{1000}$	$\frac{\text{I} \quad \text{E} \quad 1.73 \quad \text{pf}}{1000}$	$\frac{\text{I} \quad \text{E}}{1000}$
Kilovolt-Amperes	$\frac{\text{I} \quad \text{E}}{1000}$	$\frac{\text{I} \quad \text{E} \quad 2}{1000}$	$\frac{\text{I} \quad \text{E} \quad 1.73}{1000}$	Not Applicable
Horsepower	$\frac{\text{I} \quad \text{E} \ \%\text{ eff.} \quad \text{pf}}{746}$	$\frac{\text{I} \quad \text{E} \quad 2 \quad \%\text{ eff.} \quad \text{pf}}{746}$	$\frac{\text{I} \quad \text{E} \quad 1.73 \quad \%\text{ eff.} \quad \text{pf}}{746}$	$\frac{\text{I} \quad \text{E} \quad \%\text{ eff.}}{746}$
Watts	$\text{E} \quad \text{I} \quad \text{pf}$	$\text{I} \quad \text{E} \quad 2 \quad \text{pf}$	$\text{I} \quad \text{E} \quad 1.73 \quad \text{pf}$	$\text{E} \quad \text{I}$

$$\text{Energy Efficiency} = \frac{\text{Load Horsepower} \quad 746}{\text{Load Input kVA} \quad 1000}$$

$$\text{Power Factor} = \text{pf} = \frac{\text{Power Consumed}}{\text{Apparent Power}} = \frac{\text{W}}{\text{VA}} \text{ or } \frac{\text{kW}}{\text{kVA}} = \cos\theta$$

I = Amperes
E = Volts
kW = Kilowatts
kVA = Kilovolt-Amperes
HP = Horsepower
% eff. = Percent Efficiency
pf = Power Factor