CITY OF MADISON HEIGHTS
COMMUNITY DEVELOPMENT DEPARTMENT
BUILDING DIVISION

Available Short-Circuit Current

By Mike Holt, Published in EC&M Magazine

Available short-circuit current (SCA) is the current in amperes that is available at a given point in the electrical system. This available short current is first determined at the secondary terminals of the utility transformer. Thereafter the available short-circuit current is calculated at the terminals of the service equipment, branch circuit panel and branch circuit load.

The available short-circuit current is different at each point of the electrical system; it is highest at the utility transformer and lowest at the branch circuit load. The available short-circuit current is dependent on the impedance of the circuit, which increases downstream from the utility transformer. The greater the circuit impedance (utility transformer and the additive impedances of the circuit conductors) the lower the available short-circuit current.

Factors that impact the available short-circuit current at the utility transformer include the system voltage, the transformer kVA rating and it's impedance (as expressed in a percentage). Properties that impact the impedance of the circuit include the conductor material (copper versus aluminum), the conductor size, and it's length.

Author's Comment: The impedance of the circuit increases the further from the utility transformer, therefor the available short-circuit current is lower downstream from the utility transformer.

Interrupting Rating. Overcurrent protection devices such as circuit breakers and fuses are intended to interrupt the circuit and they must have an ampere interrupting rating (AIR) sufficient for the available short-circuit current in accordance with Sections 110-9 and 240-1. Unless marked otherwise, the ampere interrupting rating for branch-circuit circuit breakers is 5,000 ampere [240-83(c)] and 10,000 ampere for branch-circuit fuses [240-60(c)].

Extremely high values of current flow (caused by short-circuits or line-to-ground faults) produce tremendous destructive thermal and magnetic forces. If the circuit overcurrent protection device is not rated to interrupt the current at the available fault values, it could explode while attempting to clear the fault. Naturally this can cause serious injury, death as well as property damage.

Protection of Electrical Components. In addition to interrupting rating for overcurrent devices, electrical equipment, components, and circuit conductors must have a short-circuit current (withstand) rating that will permit the circuit overcurrent protective device to clear a fault without extensive damage to any of the components of the electrical system [110-9, 110-10, 250-2(d), 250-90, 250-96(a) and Table 250-122 Note].

If the available short-circuit current exceeds the equipment/conductor short-circuit current rating, then the thermal and magnetic forces can cause the equipment to explode and/or the circuit conductors as well as grounding conductors to vaporize. The only solution to the problem of excessive available fault current is to 1) Install equipment that has a higher short-circuit rating; or 2) Protect the components of the circuit by a current-limiting protection device such as a fast-clearing fuse, which can reduce the let-thru energy.

Circuit impedance and short circuit ratings are required per NEC 110.10

Short circuit calculations are needed for plan review for most non-residential projects with new or re-designed services. These calculations are usually done by the electrical designer on sealed plans.

AVAILABLE FAULT CURRENT INFORMATION NEEDED FOR
SHORT CIRCUIT CALCULATION

1. The transformer electrical information is found on the transformer or by contacting the power company. This information includes the voltage, phase configuration and KVA.

2. The contractor provides the wire size and material (al,cu), length of conductors and raceway material (metal or pvc).

These values are inserted into the calculator of choice. There are several web sites with free calculators.

THE FOLLOWING ATTACHMENTS ARE PROVIDED TO ASSIST YOU WITH CALCULATING THE AVAILABLE SHORT CIRCUIT CURRENT.

Transformer Impedances

The tables below list the current transformer impedances for Detroit Edison's power distribution transformers. This information is necessary for calculating available fault current.

Related links
Avoid winter construction fees
Overhead service
Underground service
Converting to underground
Transformer impedances

Single Phase Overhead Distribution Transformers

Dual Voltage 7.6kV X 4.8kV Primary Single Phase - 120/240

Size in kVA	% Impedance
15	1.6 - 3.0
25	1.6 - 3.0
50	1.6 - 3.0
100	1.6 - 3.0
167	1.8 - 3.0

Dual Voltage 7.6kV X 4.8kV Primary Single Phase - 277 VOLT

Size in kVA	% Impedance
50	1.6 - 3.0
100	1.6 - 3.0
167	1.8 - 3.0

Dual Voltage 7.6kV X 4.8kV Primary Single Phase - 120 VOLT

Size in kVA	% Impedance
15	1.6 - 3.0
25	1.6 - 3.0
50	1.6 - 3.0
100	1.6 - 3.0
167	1.8 - 3.0

7.6 kV Primary Single Phase - 7620/13,200Y - 120/240 VOLTS

Size in kVA	% Impedance
100	1.6 - 3.0
250	3.0 - 3.5

Isolation transformers 7620/13,200 - 4800/8320 VOLTS

Size in kVA	% Impedance
75	1.6 - 3.0
250	1.6 - 3.5
333	1.6 - 3.7
500	1.6 - 3.7

Pad Mounted, Dead Front, Single Phase, Distribution Transformers

13,200 Grd Y/7620 - 240/120 VOLTS

Size in kVA	% Impedance
25	1.5 - 2.75
50	1.5 - 2.5

100	1.5 - 2.5
167	1.8 - 3.0
250	3.0 - 3.4

Pad Mounted, Dead Front, Single Phase, Distribution Transformers

Dual Voltage 4800/8320Y X 13,200 GrdY/7620 - 240/120 VOLTS

Size in kVA	% Impedance
50	1.5 - 2.5
100	1.5 - 2.5
167	1.8 - 3.0

Pad Mounted, Dead Front, Three Phase, Distribution Transformers

13,200 GRD Y/7620 - 208/120 VOLTS

Size in kVA	% Impedance
150	1.6 - 2.5
300	1.6 - 2.5
500	1.8 - 3.5
750	5.75

13,200 GRD Y/7620 - 480/277 VOLTS

Size in kVA	% Impedance
150	1.6 - 2.5
300	1.6 - 2.5
500	1.8 - 3.5
750	5.75

4800 X 13,200 GRD Y/7620 - 208/120 VOLTS*

Size in kVA	% Impedance
75	1.6 - 2.5
150	1.6 - 2.5
300	1.6 - 2.5
500	1.8 - 3.5

4800 X 13,200 GRD Y/7620 - 240/120 VOLTS*

Size in kVA	% Impedance
300	1.6 - 2.5
500	1.8 - 3.5

4800 X 13,200 GRD Y/7620 - 480/277 VOLTS*

Size in kVA	% Impedance
75	1.6 - 2.5
150	1.6 - 2.5
300	1.6 - 2.5
500	1.8 - 3.5

Pad Mounted, Live Front, Three Phase, Distribution Transformers

4800 X 13,200 - 208/120 VOLTS

Size in kVA	% Impedance
750	5.75
1000	5.75
50	1.6 - 3.0

4800 X 13,200 - 480/277 VOLTS

Size in kVA	% Impedance

750	5.75
1000	5.75
1500	5.75

COOPER Bussmann

Introduction

Several sections of the National Electrical Code® relate to proper overcurrent protection. Safe and reliable application of overcurrent protective devices based on these sections mandate that a short circuit study and a selective coordination study be conducted. These sections include, among others:

- 110.9 Interrupting Rating
- 110.10 Component Protection
- 240.1 Conductor Protection
- 250.122 Equipment Grounding Conductor Protection
- Marked Short-Circuit Current Rating;
  - 230.82 (3) Meter Disconnect
  - 409.110 Industrial Control Panels
  - 440.4(B) Air Conditioning & Refrigeration Equipment
  - 670.3(A) Industrial Machinery
- Selective Coordination
  - 517.17 Health Care Facilities - Selective Coordination
  - 517.26 Essential Electrical Systems In Healthcare Systems
  - 620.62 Selective Coordination for Elevator Circuits
  - 700.27 Emergency Systems
  - 701.18 Legally Required Standby Systems

Compliance with these code sections can best be accomplished by conducting a short circuit study as a start to the analysis. The protection for an electrical system should not only be safe under all service conditions but, to insure continuity of service, it should be selectively coordinated as well. A coordinated system is one where only the faulted circuit is isolated without disturbing any other part of the system. Once the short circuit levels are determined, the engineer can specify proper interrupting rating requirements, selectively coordinate the system and provide component protection. See the various sections of this book for further information on each topic.

Low voltage fuses have their interrupting rating expressed in terms of the symmetrical component of short-circuit current. They are given an RMS symmetrical interrupting rating at a specific power factor. This means that the fuse can interrupt the asymmetrical current associated with this rating. Thus only the symmetrical component of short-circuit current need be considered to determine the necessary interrupting rating of a low voltage fuse. For listed low voltage fuses, interrupting rating equals its interrupting capacity.

Low voltage molded case circuit breakers also have their interrupting rating expressed in terms of RMS symmetrical amps at a specific power factor. However, it is necessary to determine a molded case circuit breaker's interrupting capacity in order to safely apply it. See the section Interrupting Rating vs. Interrupting Capacity in this book.

110.16 now requires arc-flash hazard warning labeling on certain equipment. A flash hazard analysis is required before a worker approaches electrical parts that have not been put into a safe work condition. To determine the incident energy and flash protection boundary for a flash hazard analysis the short-circuit current is typically the first step.

General Comments on Short Circuit Calculations

Sources of short-circuit current that are normally taken under consideration include:

- Utility Generation
- Local Generation
- Synchronous Motors
- Induction Motors
- Alternate Power Sources

Short circuit calculations should be done at all critical points in the system. These would include:

- Service Entrance
- Transfer Switches
- Panel Boards
- Load Centers
- Motor Control Centers
- Disconnects
- Motor Starters
- Motor Starters

Normally, short circuit studies involve calculating a bolted 3-phase fault condition. This can be characterized as all 3-phases "bolted" together to create a zero impedance connection. This establishes a "worst case" (highest current) condition that results in maximum three phase thermal and mechanical stress in the system. From this calculation, other types of fault conditions can be approximated. This "worst case" condition should be used for interrupting rating, component protection and selective coordination. However, in doing an arc-flash hazard analysis it is recommended to do the arc-flash hazard analysis at the highest bolted 3 phase short circuit condition and at the "minimum" bolted three-phase short circuit condition. There are several variables in a distribution system that affect calculated bolted 3-phase short-circuit currents. It is important to select the variable values applicable for the specific application analysis. In the Point-to-Point method presented in this section there are several adjustment factors given in Notes and footnotes that can be applied that will affect the outcomes. The variables are utility source short circuit capabilities, motor contribution, transformer percent impedance tolerance, and voltage variance.

In most situations, the utility source(s) or on-site energy sources, such as on-site generation, are the major short-circuit current contributors. In the Point-to-Point method presented in the next few pages, the steps and example assume an infinite available short-circuit current from the utility source. Generally this is a good assumption for highest worst case conditions and since the property owner has no control over the utility system and future utility changes. And in many cases a large increase in the utility available does not increase the short-circuit currents a great deal for a building system on the secondary of the service transformer. However, there are cases where the actual utility medium voltage available provides a more accurate short circuit assessment (minimum bolted short-circuit current conditions) that may be desired to assess the arc-flash hazard.

When there are motors in the system, motor short circuit contribution is also a very important factor that must be included in any short-circuit current analysis. When a short circuit occurs, motor contribution adds to the magnitude of the short-circuit current; running motors contribute 4 to 6 times their normal full load current. In addition, series rated combinations can not be used in specific situations due to motor short circuit contributions (see the section on Series Ratings in this book).

For capacitor discharge currents, which are of short time duration, certain IEEE (Institute of Electrical and Electronic Engineers) publications detail how to calculate these currents if they are substantial.

Procedures and Methods

To determine the fault current at any point in the system, first draw a one-line diagram showing all of the sources of short-circuit current feeding into the fault, as well as the impedances of the circuit components.

To begin the study, the system components, including those of the utility system, are represented as impedances in the diagram.

The impedance tables include three-phase and single-phase transformers, cable, and busway. These tables can be used if information from the manufacturers is not readily available.

It must be understood that short circuit calculations are performed without current-limiting devices in the system. Calculations are done as though these devices are replaced with copper bars, to determine the maximum "available" short-circuit current. This is necessary to project how the system and the current-limiting devices will perform.

Also, multiple current-limiting devices do not operate in series to produce a "compounding" current-limiting effect. The downstream, or load side, fuse will operate alone under a short circuit condition if properly coordinated.

The application of the point-to-point method permits the determination of available short-circuit currents with a reasonable degree of accuracy at various points for either 3Ø or 1Ø electrical distribution systems. This method can assume unlimited primary short-circuit current (infinite bus) or it can be used with limited primary available current.

Three-Phase Short Circuits

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amps (F.L.A.) from either the nameplate, the following formulas or Table 1:

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

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

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

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

*** 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 (Std. 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.

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

1Ø Line-to-Line (L-L) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-L}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Neutral (L-N) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-N}^{\dagger}}{C \times n \times E_{L-N}}$$

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, $I_{L-N} = 1.5 \times I_{L-L}$ 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.

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

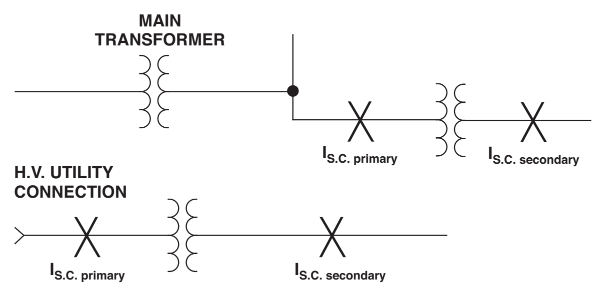
Step 6. Calculate the available short circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

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

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 at Second Transformer in System

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.



Procedure for Second Transformer in System

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)

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

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

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

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

System A

Available Utility
Infinite Assumption

1500 KVA Transformer, 480V, 3Ø, 3.5%Z, 3.45%X, .56%R

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

25' - 500kcmil
6 Per Phase
Service Entrance
Conductors in Steel Conduit

2000A Switch

KRP-C-2000SP Fuse

Fault X_1

400A Switch

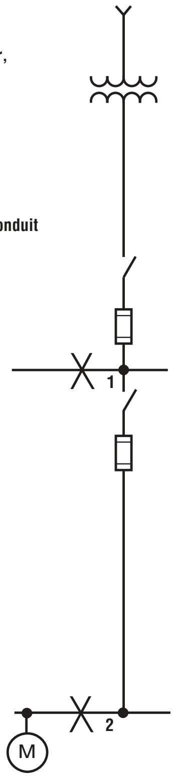
LPS-RK-400SP Fuse

50' - 500 kcmil
Feeder Cable
in Steel Conduit

Fault X_2

Motor Contribution

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \dfrac{1500 \times 1000}{480 \times 1.732} = 1804A$

Step 2. Multiplier $= \dfrac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804 \times 28.57 = 51{,}540A$

$I_{S.C.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS} = 51{,}504 + 7{,}216 = 58{,}720A$

Step 4. $f = \dfrac{1.732 \times 25 \times 51{,}540}{22{,}185 \times 6 \times 480} = 0.0349$

Step 5. $M = \dfrac{1}{1 + .0349} = .9663$

Step 6. $I_{S.C.sym\ RMS} = 51{,}540 \times .9663 = 49{,}803A$

$I_{S.C.motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{totalS.C.\ sym\ RMS\ (fault\ X_1)} = 49{,}803 + 7{,}216 = 57{,}019A$

Fault X_2

Step 4. Use $I_{S.C.sym\ RMS}$ @ Fault X_1 to calculate "f"

$f = \dfrac{1.732 \times 50 \times 49{,}803}{22{,}185 \times 480} = .4050$

Step 5. $M = \dfrac{1}{1 + .4050} = .7117$

Step 6. $I_{S.C.sym\ RMS} = 49{,}803 \times .7117 = 35{,}445A$

$I_{sym\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS\ (fault\ X_2)} = 35{,}445 + 7{,}216 = 42{,}661A$

*Assumes 100% motor load. If 50% of this load was from motors, $I_{S.C.}$ motor contrib. = 4 x 1,804 x .5 = 3608A

System B

System B

Available Utility
Infinite Assumption

1000 KVA Transformer, 480V, 3Ø, 3.5%Z

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

30' - 500 kcmil
4 Per Phase
Copper in PVC Conduit

1600A Switch

KRP-C-1500SP Fuse

Fault X_1

400A Switch

LPS-RK-350SP Fuse

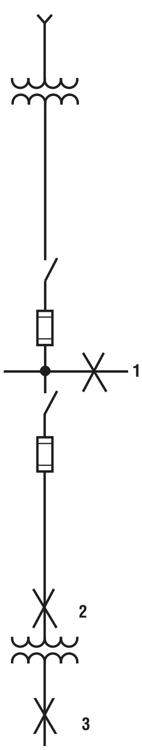
20' - 2/0
2 Per Phase
Copper in PVC Conduit

Fault X_2

225 KVA transformer, 208V, 3Ø
1.2%Z

Fault X_3

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \dfrac{1000 \times 1000}{480 \times 1.732} = 1203A$

Step 2. Multiplier $= \dfrac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1203 \times 28.57 = 34{,}370A$

Step 4. $f = \dfrac{1.732 \times 30 \times 34{,}370}{26{,}706 \times 4 \times 480} = .0348$

Step 5. $M = \dfrac{1}{1 + .0348} = .9664$

Step 6. $I_{S.C.sym\ RMS} = 34{,}370 \times .9664 = 33{,}215A$

Fault X_2

Step 4. $f = \dfrac{1.732 \times 20 \times 33{,}215}{2 \times 11{,}424 \times 480} = .1049$

Step 5. $M = \dfrac{1}{1 + .1049} = .905$

Step 6. $I_{S.C.sym\ RMS} = 33{,}215 \times .905 = 30{,}059A$

Fault X_3

Step A. $f = \dfrac{30{,}059 \times 480 \times 1.732 \times 1.2}{100{,}000 \times 225} = 1.333$

Step B. $M = \dfrac{1}{1 + 1.333} = .4286$

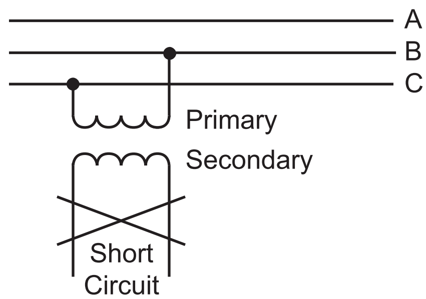
Step C. $I_{S.C.\ sym\ RMS} = \dfrac{480 \times .4286 \times 30{,}059}{208} = 29{,}731A$

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 only considered 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.

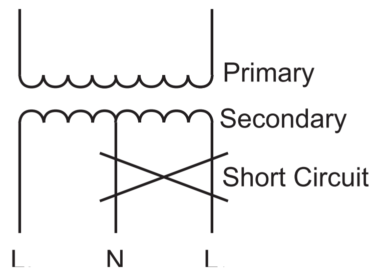
   However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.



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:

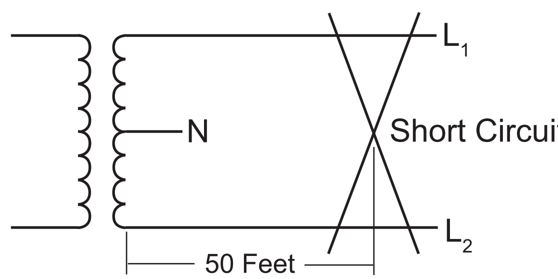
   - 1.5 times full winding %R on full winding basis.
   - 1.2 times full winding %X on full winding basis.



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

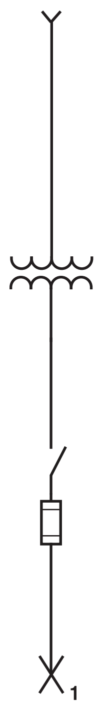
c. The kVA and voltage bases used in the per-unit calculations.

Single-Phase Short Circuits

Line-to-Line Fault @ 240V — Fault X_1

One-Line Diagram

Available Utility
Infinite Assumption



75KVA, 1Ø Transformer,
1.22%X, .68%R
1.40%Z
120/240V

Negligible Distance

400A Switch

LPN-RK-400SP Fuse

25' - 500kcmil

Magnetic Conduit

Fault X_1

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

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.} = 312.5 \times 71.43 = 22{,}322A$

Step 4. $f = \frac{2 \times 25 \times 22{,}322}{22{,}185 \times 240} = .2096$

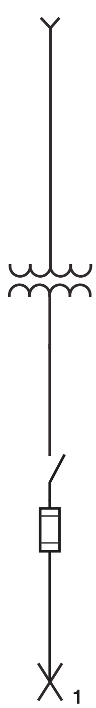
Step 5. $M = \frac{1}{1 + .2096} = .8267$

Step 6. $I_{S.C.\ L\text{-}L\ (X_1)} = 22{,}322 \times .8267 = 18{,}453A$

Line-to-Neutral Fault @ 120V — Fault X_1

One-Line Diagram

Available Utility
Infinite Assumption



75KVA, 1Ø Transformer,
1.22% X, .68%R,
1.40%Z
120/240V

Negligible Distance

400A Switch

LPN-RK-400SP Fuse

25' - 500kcmil

Magnetic Conduit

Fault X_1

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

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.\ (L\text{-}L)} = 312.5 \times 71.43 = 22{,}322A$

$I_{S.C.\ (L\text{-}N)} = 22{,}322 \times 1.5 = 33{,}483A$

Step 4. $f = \frac{2^{*} \times 25 \times 22{,}322 \times 1.5}{22{,}185 \times 120} = .6288$

Step 5. $M = \frac{1}{1 + .6288} = .6139$

Step 6. $I_{S.C.\ L\text{-}N\ (X_1)} = 33{,}483 \times .6139 = 20{,}555A$

*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.

COOPER Bussmann

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.

Simple Methods for Calculating Short Circuit Current Without a Computer

By Dennis McKeown, PE
GE Senior System Application Engineer

A Short Circuit analysis is used to determine the magnitude of short circuit current the system is capable of producing and compares that magnitude with the interrupting rating of the overcurrent protective devices (OCPD). Since the interrupting ratings are based by the standards, the methods used in conducting a short circuit analysis must conform to the procedures which the standard making organizations specify for this purpose. In the United States, the America National Standards Institute (ANSI) publishes both the standards for equipment and the application guides, which describes the calculation methods.

Short circuit currents impose the most serious general hazard to power distribution system components and are the prime concerns in developing and applying protection systems. Fortunately, short circuit currents are relatively easy to calculate. The application of three or four fundamental concepts of circuit analysis will derive the basic nature of short circuit currents. These concepts will be stated and utilized in a step-by-step development.

The three phase bolted short circuit currents are the basic reference quantities in a system study. In all cases, knowledge of the three phase bolted fault value is wanted and needs to be singled out for independent treatment. This will set the pattern to be used in other cases.

A device that interrupts short circuit current, is a device connected into an electric circuit to provide protection against excessive damage when a short circuit occurs. It provides this protection by automatically interrupting the large value of current flow, so the device should be rated to interrupt and stop the flow of fault current without damage to the overcurrent protection device. The OCPD will also provide automatic interruption of overload currents.

Listed here are reference values that will be needed in the calculation of fault current.

<u>Impedance Values for Three phase transformers</u>

HV Rating 2.4KV – 13.8KV	300 – 500KVA	Not less than 4.5%
HV Rating 2.4KV – 13.8KV	750 – 2500KVA	5.75%
General Purpose less then 600V	15 – 1000KVA	3% to 5.75%

Reactance Values for Induction and Synchronous Machine

		X" Subtransient
Salient pole Gen	12 pole	0.16
	14 pole	0.21
Synchronous motor	6 pole	0.15
	8-14 pole	0.20
Induction motor above 600V		0.17
Induction motor below 600V		0.25

TRANSFORMER FAULT CURRENT

Calculating the Short Circuit Current when there is a Transformer in the circuit. Every transformer has " %" impedance value stamped on the nameplate. Why is it stamped? It is stamped because it is a tested value after the transformer has been manufactured. The test is as follows: A voltmeter is connected to the primary of the transformer and the secondary 3-Phase windings are bolted together with an ampere meter to read the value of current flowing in the 3-Phase bolted fault on the secondary. The voltage is brought up in steps until the secondary full load current is reached on the ampere meter connected on the transformer secondary.

So what does this mean for a 1000KVA 13.8KV – 480Y/277V.

First you will need to know the transformer Full Load Amps

Full Load Ampere = KVA / 1.73 x L-L KV

FLA = 1000 / 1.732 x 0.48

FLA = 1,202.85

The 1000KVA 480V secondary full load ampere is 1,202A.

When the secondary ampere meter reads 1,202A and the primary Voltage Meter reads 793.5V. The percent of impedance value is 793.5 / 13800 = 0.0575. Therefore;
% Z = 0.0575 x 100 = 5.75%

This shows that if there was a 3-Phase Bolted fault on the secondary of the transformer then the maximum fault current that could flow through the transformer would be the ratio of 100 / 5.75 times the FLA of the transformer, or 17.39 x the FLA = 20,903A

Based on the infinite source method at the primary of the transformer. A quick calculation for the Maximum Fault Current at the transformer secondary terminals is FC = FLA / %PU Z   FC = 1202 / 0.0575 = 20,904A

This quick calculation can help you determine the fault current on the secondary of a transformer for the purpose of selecting the correct overcurrent protective devices that can interrupt the available fault current. The main breaker that is to be installed in the circuit on the secondary of the transformer has to have a KA Interrupting Rating greater then 21,000A. Be aware that feeder breakers should include the estimated motor contribution too. If the actual connected motors are not known, then assume the contribution to be 4 x FLA of the transformer. Therefore, in this case the feeders would be sized at 20.904 + (4 x 1202 = 25,712 Amps

GENERATOR FAULT CURRENT

Generator fault current differs from a Transformer. Below, we will walk through a 1000KVA example.

800KW 0.8% PF 1000KVA 480V 1,202FLA

KVA = KW / PF

KVA = 800 / .8
KVA = 1000

FLA = KVA / 1.732 x L-L Volts

FLA = 1000 / 1.732 x 0.48

FLA = 1,202

(As listed in the table for generator subtransient X" values is 0.16)

FC = FLA / X"

FC = 1202 / 0.16

FC = 7,513A

So, the fault current of a 1000KVA Generator is a lot less then a 1000KVA transformer. The reason is the impedance value at the transformer and Generator reactance values are very different. Transformer 5.75% vs. a Generator 16%

SYSTEM FAULT CURRENT

Below is a quick way to get a MVA calculated value. The MVA method is fast and simple as compared to the per unit or ohmic methods. There is no need to convert to an MVA base or worry about voltage levels. This is a useful method to obtain an estimated value of fault current. The elements have to be converted to an MVA value and then the circuit is converted to admittance values.

Utility MVA at the Primary of the Transformer

MVAsc = 500MVA

Transformer Data

13.8KV - 480Y/277V

1000KVA Transformer Z = 5.75%

MVA Value

1000KVA / 1000 = 1 MVA

MVA Value = 1MVA / Z_{pu} = 1MVA / .0575 = 17.39 MVA

Use the admittance method to calculate Fault Current

1 / Utility MVA + 1 / Trans MVA = 1 / MVAsc

1 / 500 + 1 / 17.39 = 1 / MVAsc

0.002 + 0.06 = 1/ MVAsc

MVAsc = 1 / (0.002 + 0.06)

MVAsc = 16.129

FC at 480V = MVAsc / (1.73 x 0.48)

FC = 16.129 / 0.8304

FC = 19.423KA

FC = 19, 423 A

The 480V Fault Current Value at the secondary of the 1000KVA transformer based on an Infinite Utility Source at the Primary of the transformer as calculated in the Transformer Fault Current section in this article is 20,904A

The 480V Fault Current Value at the secondary of the 1000KVA transformer based on a 500MVA Utility Source at the Primary of the transformer as calculated in the System Fault Current section in this article is 19,432A

The 480V Fault Current Value at the secondary of the 1000KVA transformer based on a 250MVA Utility Source at the Primary of the transformer the calculated value is 18,790A

When the cable and its length is added to the circuit the fault current in a 480V system will decrease to a smaller value. To add cable into your calculation use the formula. Cable MVA Value $MVAsc = KV^2 / Z$ cable. Use the cable X & R values to calculate the Z value then add to the Admittance calculation as shown in this article.

The conclusion is that you need to know the fault current value in a system to select and install the correct Overcurrent Protective Devices (OCPD). The available FC will be reduced as shown in the calculations when the fault current value at the primary of the transformer is reduced. If the infinite method is applied when calculating fault current and 4 x FLA is added for motor contributions, then the fault current value that is obtained will be very conservative. This means the calculated value in reality will never be reached, so you reduce any potential overcurrent protection device failures due to fault current.