AN - 804

DETERMINATION OF AVAILABLE FAULT CURRENT FOR SEMICONDUCTOR FUSING

One of the problems facing the design engineer is selecting adequate circuit interrupting devices for his equipment. With the increased emphasis on safety today, it is mandatory that short circuit faults be cleared quickly and without danger to personnel and equipment. Of prime consideration is the determination of the available fault current at the location of the protective device.

The commonly used circuit interrupting devices are circuit breakers and fuses. Circuit breakers are rated for specific maximum current interrupting capacities, and it is common practice to employ various sizes and interrupting capacities in plant distribution systems according to location and service. Some industrial fuses are rated up to a certain stated current interrupting rating, such as 10,000 amperes. Other fuses are tested and certified to be capable of interrupting very large currents. The proper selection of semiconductor protective fuses is dependent upon the available fault current. The sizing of semiconductor devices subject to multiple cycle short circuit currents, such as encountered with a slow-blow fuse or a slow circuit breaker, is also dependent upon the available fault current.

In applying semiconductors and their protective fuses, there are two different sets of conditions to consider. In the first case there is no transformer associated with the semiconductors. One example is a thyristor AC controller working directly off the plant AC supply. Another example is a three-phase bridge also working directly off the plant AC supply.

The second case is where a rectifier transformer is used to supply the power to the semiconductors. An example would be an electroplating rectifier power supply. In this case, the impedance of the associated transformer is high compared to the supply circuit impedance.

The impedance of a transformer is defined as the percentage of rated applied voltage required to cause full rated current to flow through a short circuited secondary winding. Another way of expressing transformer impedance is to say that the impedance of the transformer will limit the short circuit current in the secondary with full rated voltage applied to the primary to a value according to the following relationship:

$$I_{sc} = \frac{I_s}{Z_t}$$

Where:

I_{sc} = Steady state short circuit current

I_s = Rated secondary current

Z_t = Transformer impedance (percent)

Therefore, a transformer with a 5 percent impedance will limit the short circuit current to 20 times the rated current. A transformer with a 4 percent impedance will limit the short circuit current to 25 times the rated current. Transformer impedance values can be obtained from the nameplate or from the manufacturer.

Under the first set of conditions, where the semiconductors are connected directly to the AC supply, the current limitation during short circuit conditions comes from transformer impedances, cable drops, and accumulated impedances reaching back to the source. Normally, the semiconductors are not connected on a primary input supply system with very low impedance and corresponding extremely high available fault current. They are usually installed in an industrial plant where the AC supply has a number of distribution transformers in the line, along with circuit breakers, various sized feeder conductors and cables. Of major interest is the distribution transformer feeding the applicable power line.

The common situation involves a low voltage three-phase system of 60 Hz supplied through transformers. As shown in Fig. 1, the available fault current depends on the following items: available fault current in the primary, transformer size and impedance, secondary voltage, sizes and

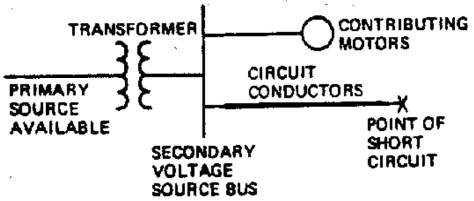


Figure 1 — Circuit Investigated and Results Obtained

effective impedances of motors contributing to the short-circuit current, and the size, length, and cross-section geometry of the feeder conductors connecting the secondary voltage source bus to the point at which the short-circuit duty is being investigated. Electrical motors can contribute substantial amounts of current, when the voltage source is interrupted by acting as generators and converting the kinetic energy into electrical energy.

In Figures 2 through 9, the results of calculations are presented for various transformer sizes. The short circuit current and power factor for each transformer size is defined in terms of distance from the transformer to the point of fault and for various cable sizes. Each figure shows curves for 208, 240, 480 and 600 volt systems.

The magnitude of the AC RMS symmetrical component of the short-circuit current and the power factor of the short-circuit current can be determined from these curves.

Approximate short-circuit current and power factor values for other feeder conductor sizes and arrangements can be obtained by interpolating between the lines on any curve sheet, using impedance values as a rough basis for the interpolation.

The total asymmetrical short-circuit current may be determined from the plotted symmetrical short-circuit current by using a multiplier that is a function of short-circuit power factor, as shown in Fig. 10.

System Conditions Used for Calculations

The equivalent circuit investigated consists of impedances that are considered minimum values. It is assumed that a 500 Megavolt-ampere (MVA) short-circuit capacity is available at the primary of the transformer, and that the source circuit reactance-resistance (X/R) ratio is 25. This ratio corresponds roughly to the standard multiplier of 1.6 used to obtain maximum phase RMS total currents in primary circuits from calculated symmetrical current values. The probability of any set of conditions being more stringent than those selected is very low.

To determine the transformer characteristics, nominal standard transformer impedances of 4-1/2 percent for transformers having ratings up to and including 500 kVA and 5-1/2 percent for transformers having ratings above 500 kVA are assumed. Data supplied by numerous manufacturers were used to determine characteristics.

The impedance of the cables as computed is almost the minimum possible impedance for the conductor sizes considered and is, therefore, conservative. The motors connected to the transformer secondary bus have the characteristics of individual 30-horsepower induction motors and are assumed to have a total kVA equal to that of the transformer.

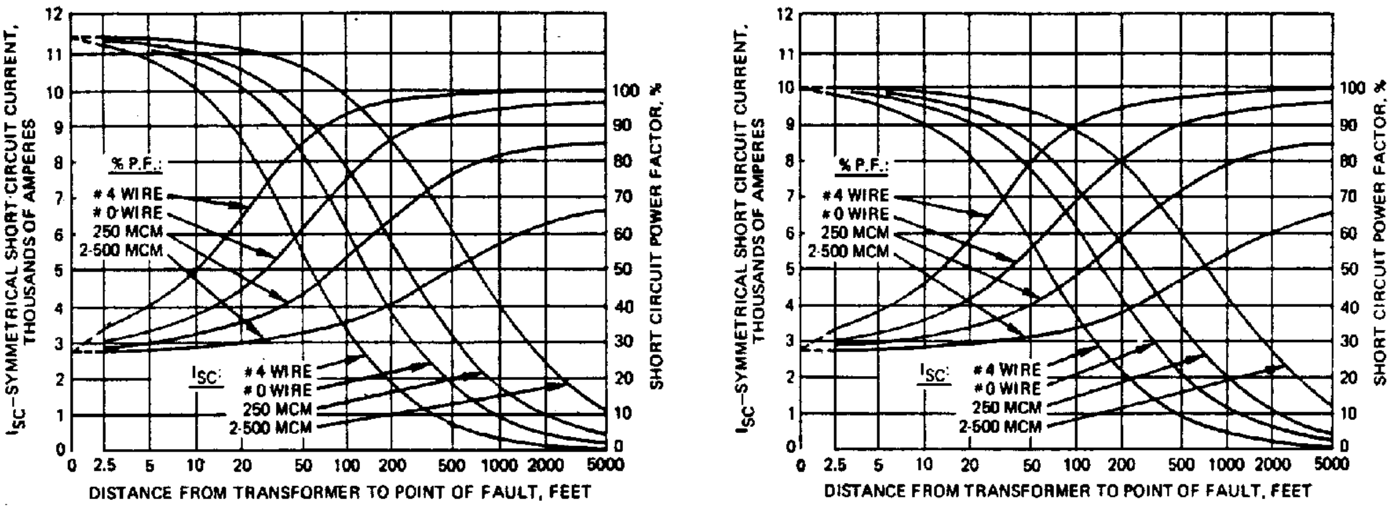
Using the Curves to Find Short-Circuit Duties

The curves in Figures 2 through 9 are used directly to find the short-circuit current duties and power factor. To find a short-circuit current at the end of the given length of a given size feeder originating at the low voltage bus of a given kVA substation, find a point corresponding to the length of the feeder as read on the horizontal scale of the appropriate graph on the short-circuit current curve marked with the feeder size; then find the short-circuit current corresponding to that point on the vertical current scale. Power factors are found in a similar manner.

Asymmetrical Current Values

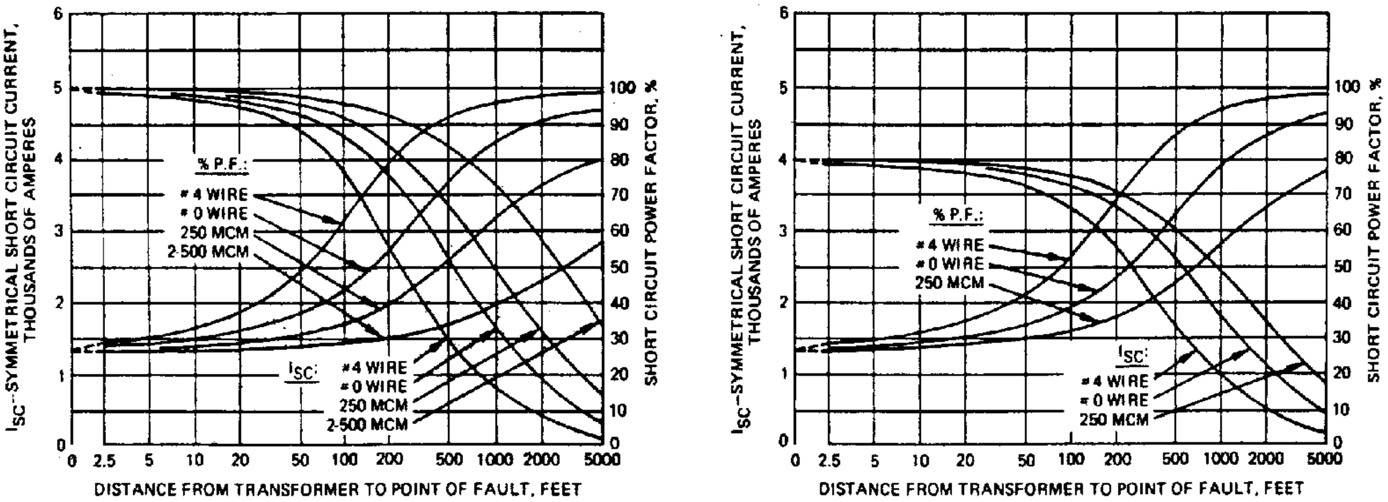
To find the asymmetrical current values corresponding to the symmetrical current values determined from the curves, refer to Fig. 10. The average short-circuit asymmetrical current can be found by multiplying the symmetrical current by the multiplier M_A shown in Fig. 10, corresponding to the short-circuit power factor. To find the maximum possible RMS asymmetrical current among the three that are averaged for the value found previously, then use the multiplier M_M found in Fig. 10 corresponding to the power factor.

BIBLIOGRAPHY: AIEE Paper 55-442



(A) 150 KVA Transformer, 208 Volts

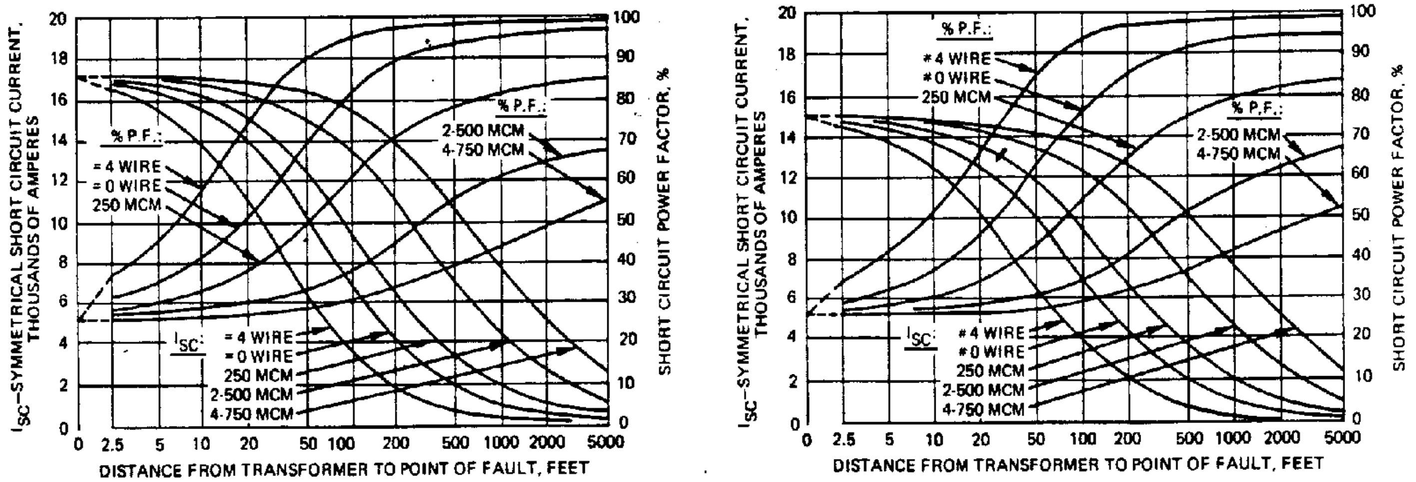
(B) 150 KVA Transformer, 240 Volts



(C) 150 KVA Transformer, 480 Volts

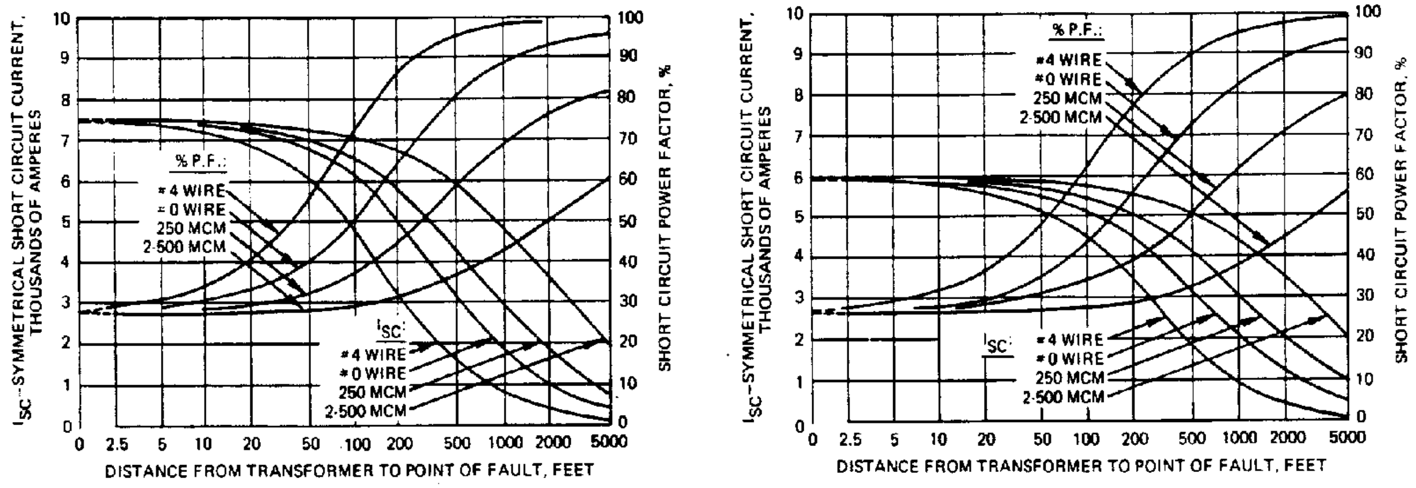
(D) 150 KVA Transformer, 600 Volts

Figure 2 — Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 150-kva Liquid-Filled Power Transformer: X/R = 3.24; R = 1.23 Per Cent; X = 4.0 Per Cent; and Z = 4.19 Per Cent



(A) 225 KVA Transformer, 208 Volts

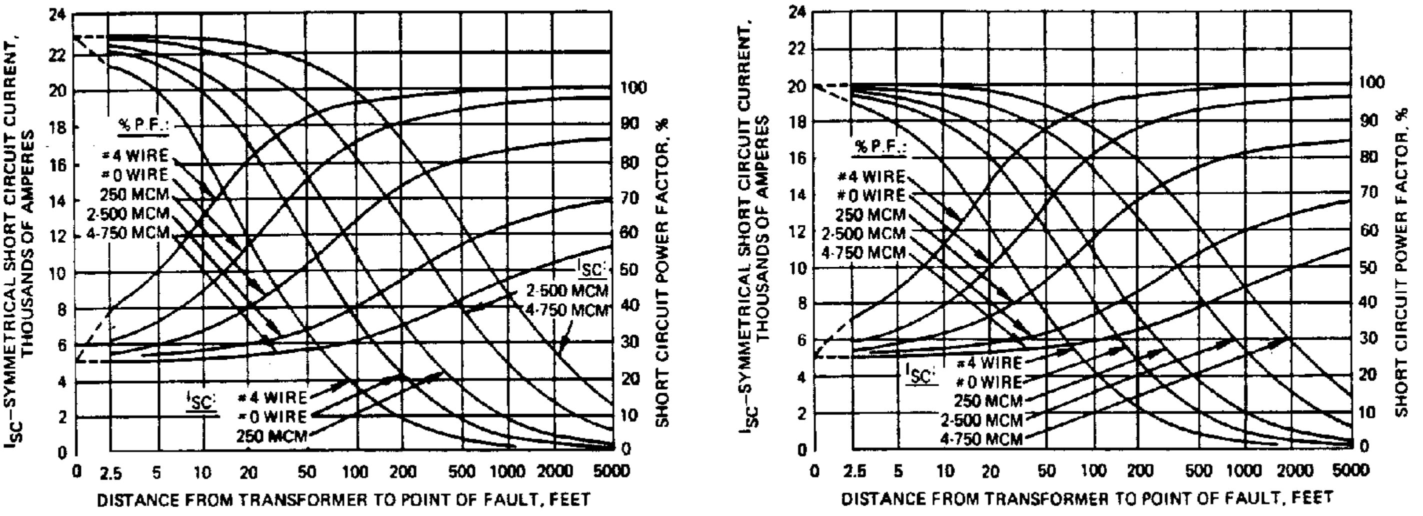
(B) 225 KVA Transformer, 240 Volts



(C) 225 KVA Transformer, 480 Volts

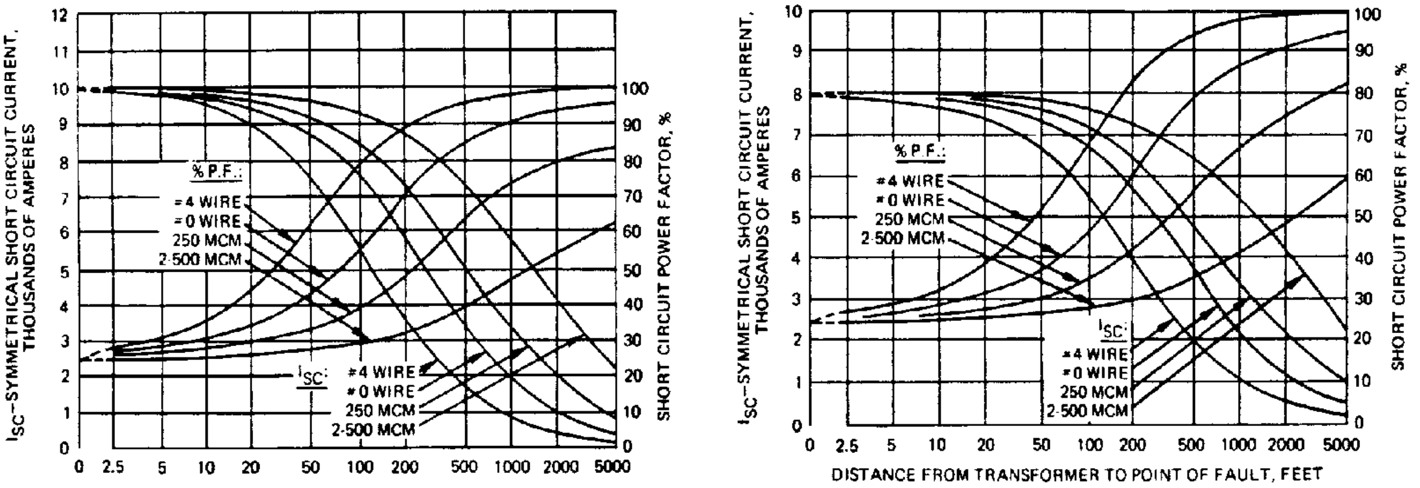
(D) 225 KVA Transformer, 600 Volts

Figure 3 — Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 225-kva Liquid-Filled Power Transformer: X/R = 3.35; R = 1.19 Per Cent; X = 4.0 Per Cent; and Z = 4.17 Per Cent



(A) 300 KVA Transformer, 208 Volts

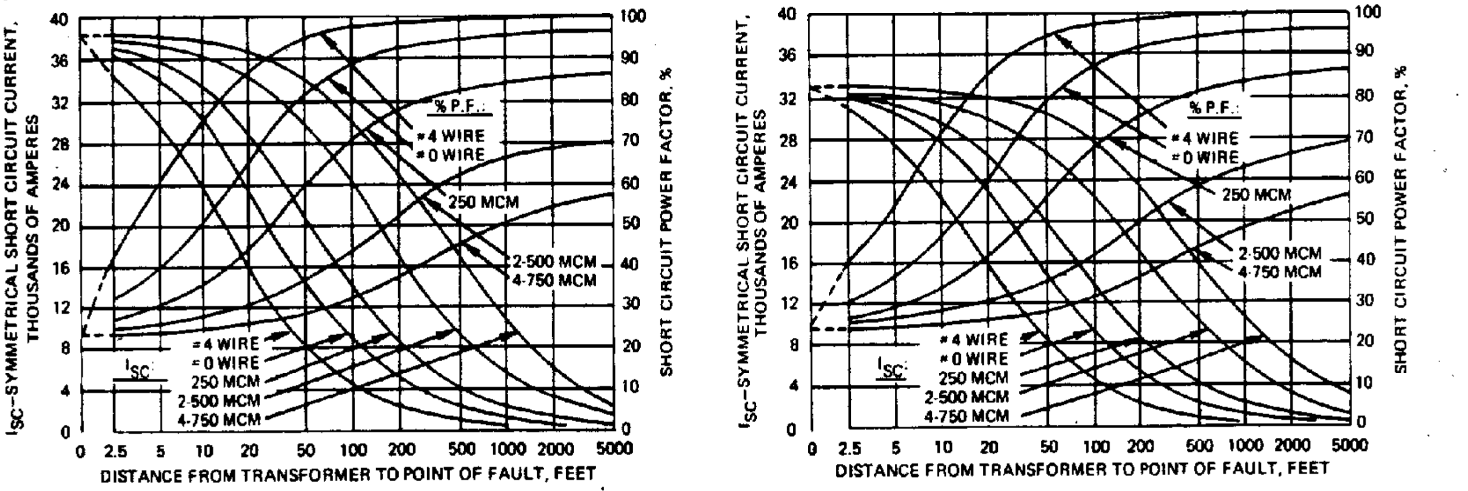
(B) 300 KVA Transformer, 240 Volts



(C) 300 KVA Transformer, 480 Volts

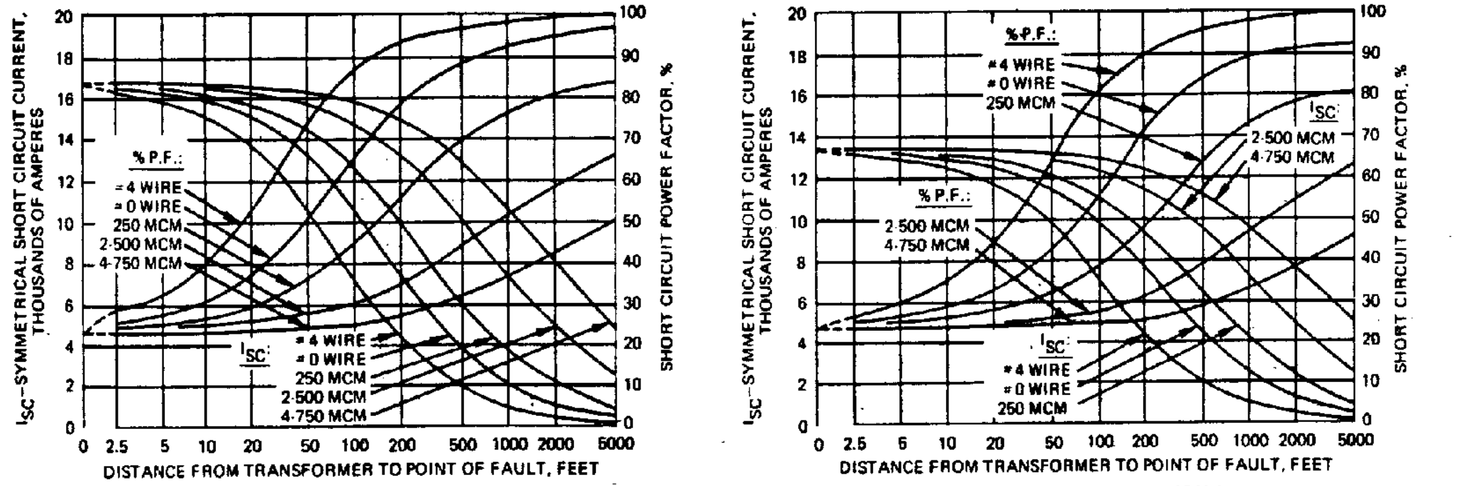
(D) 300 KVA Transformer, 600 Volts

Figure 4 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 300-kva Liquid-Filled Power Transformer: X/R = 3.50; R = 1.14 Per Cent; X = 4.0 Per Cent; and Z = 4.16 Per Cent



(A) 500 KVA Transformer, 208 Volts

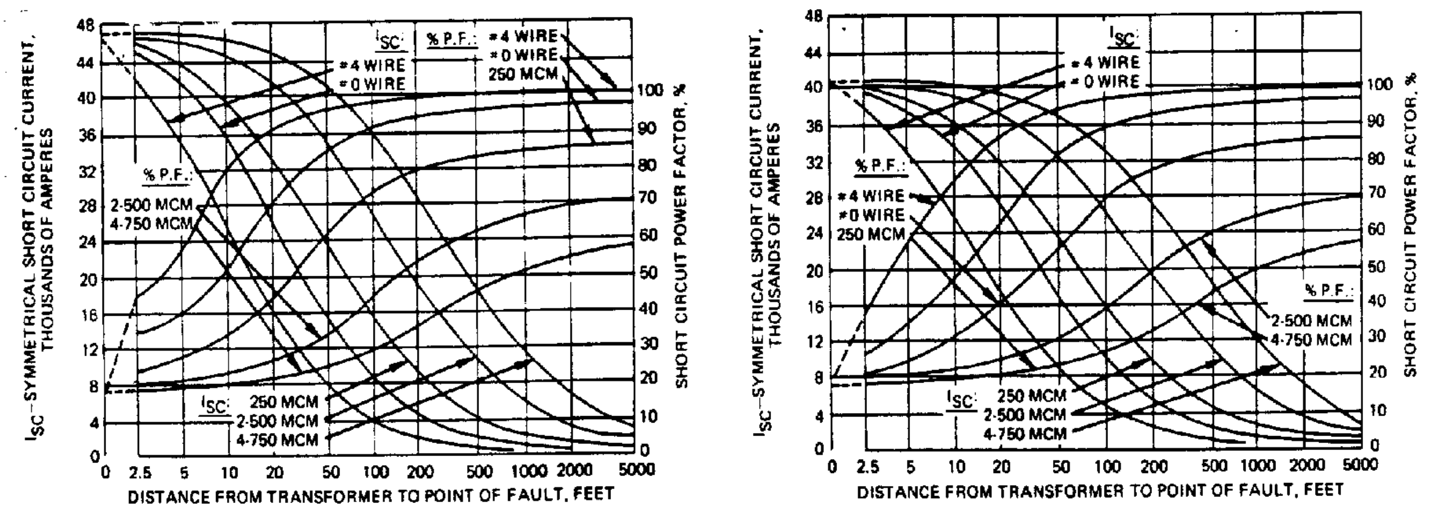
(B) 500 KVA Transformer, 240 Volts



(C) 500 KVA Transformer, 480 Volts

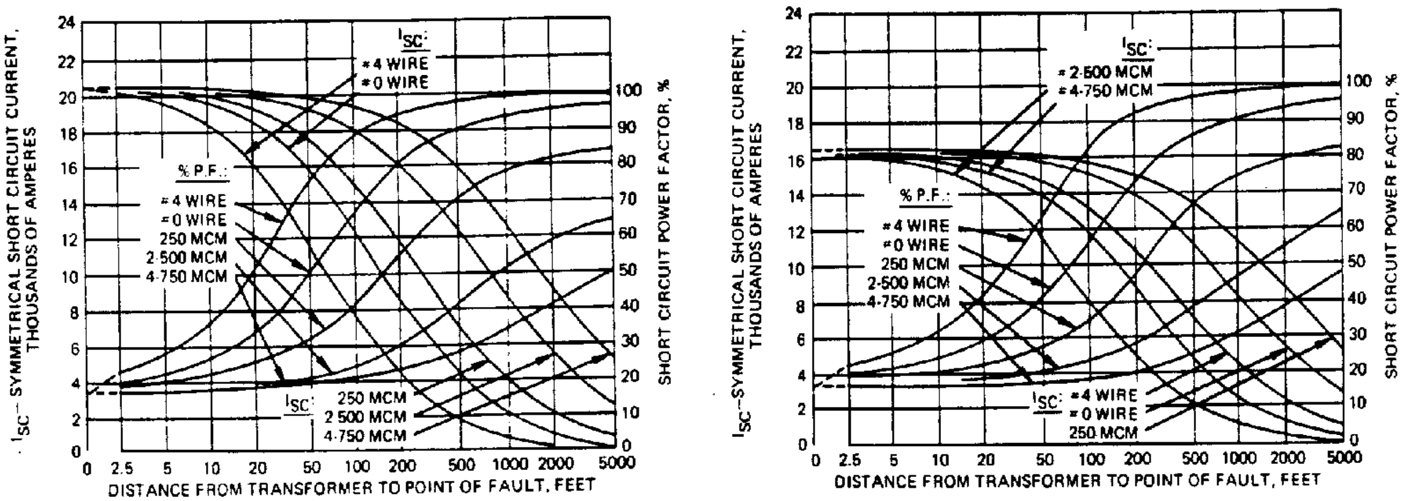
(D) 500 KVA Transformer, 600 Volts

Figure 5 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 500-kva Liquid-Filled Power Transformer: X/R = 3.84; R = 1.04 Per Cent; X = 4.0 Per Cent; and Z = 4.12 Per Cent



(A) 750 KVA Transformer, 208 Volts

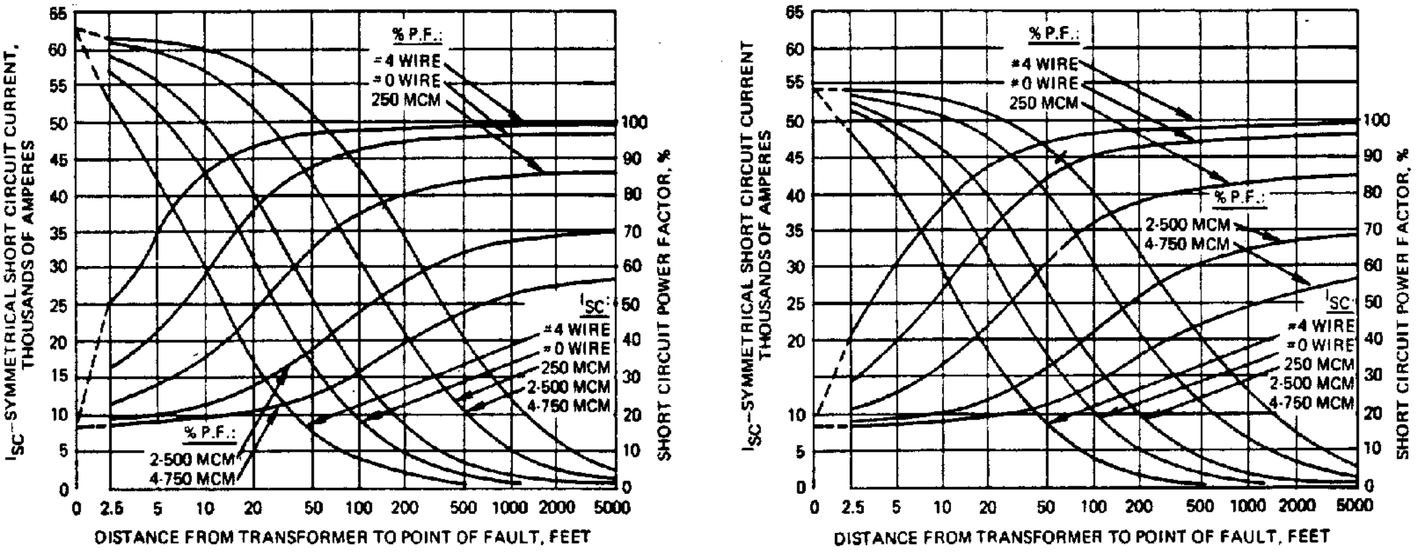
(B) 750 KVA Transformer, 240 Volts



(C) 750 KVA Transformer, 480 Volts

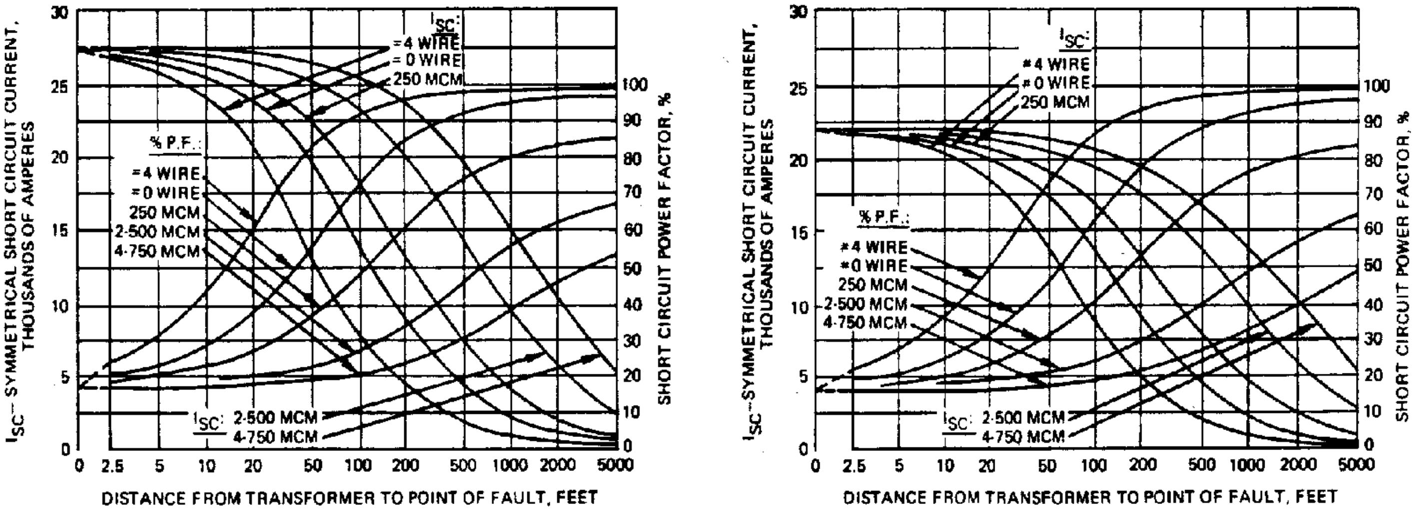
(D) 750 KVA Transformer, 600 Volts

Figure 6 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 750-kva Liquid-Filled Power Transformer: X/R = 5.45; R = 0.94 Per Cent; X = 5.1 Per Cent; and Z = 5.19 Per Cent



(A) 1000 KVA Transformer, 208 Volts

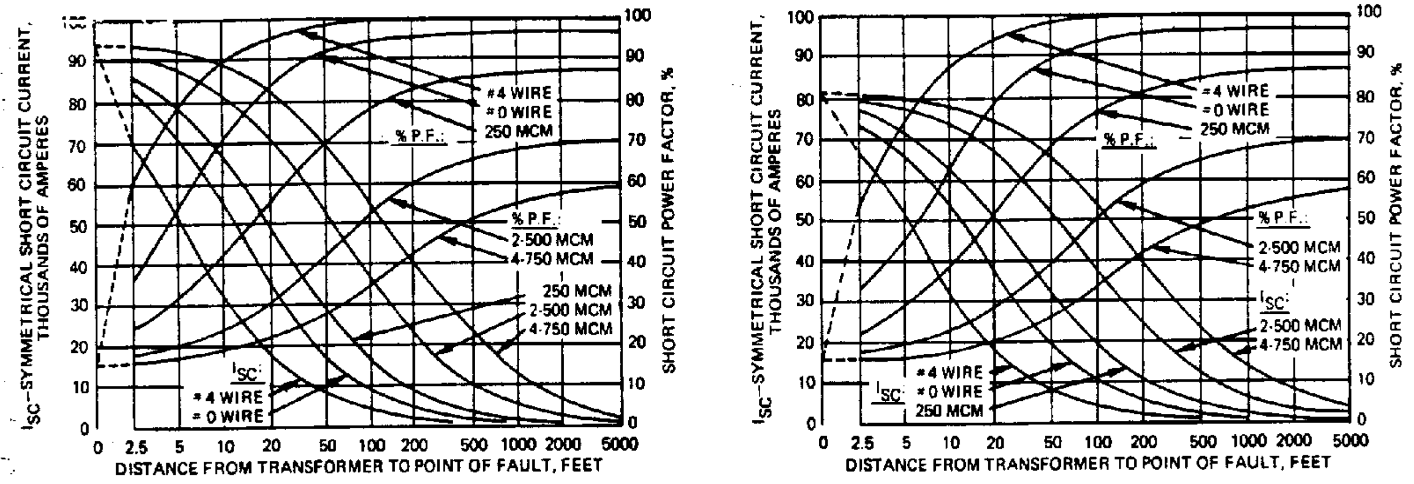
(B) 1000 KVA Transformer, 240 Volts



(C) 1000 KVA Transformer, 480 Volts

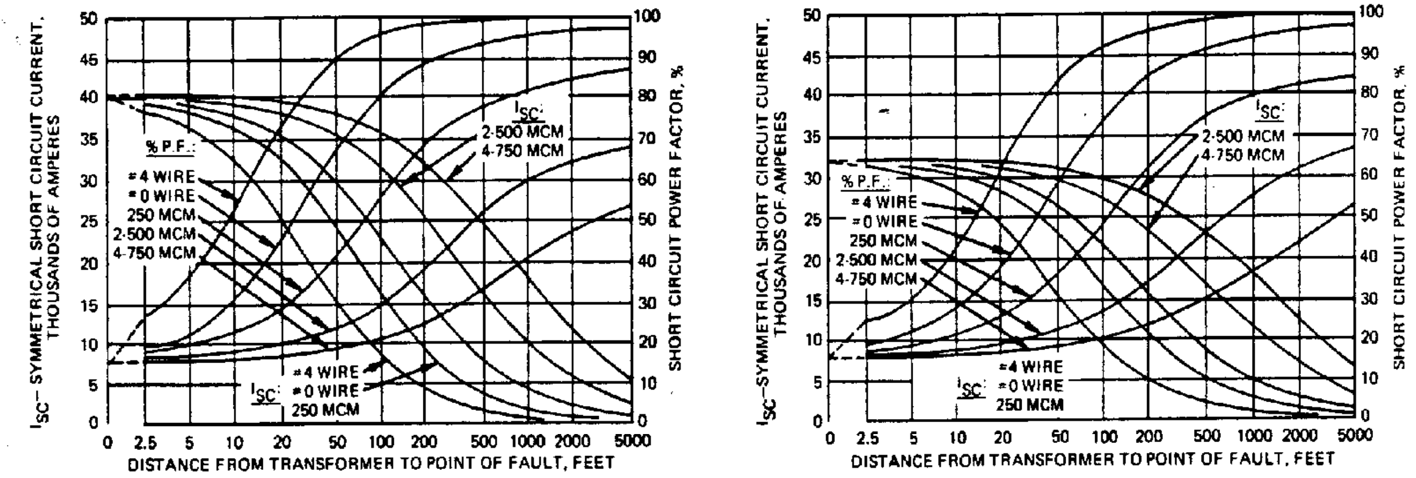
(D) 1000 KVA Transformer, 600 Volts

Figure 7 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 1,000-kva Liquid-Filled Power Transformer: X/R = 5.70; R = 0.89 Per Cent; X = 5.1 Per Cent; and Z = 5.19 Per Cent



(A) 1500 KVA Transformer, 208 Volts

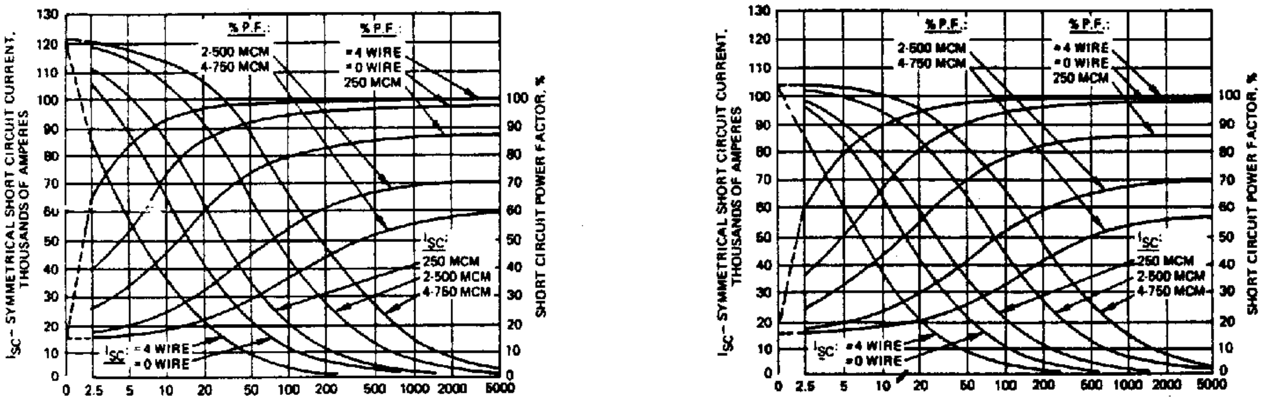
(B) 1500 KVA Transformer, 240 Volts



(C) 1500 KVA Transformer, 480 Volts

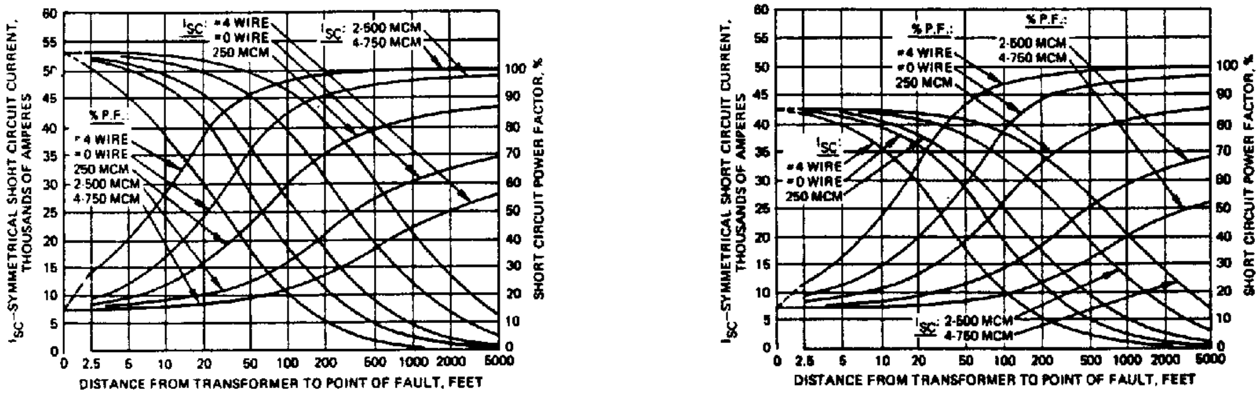
(D) 1500 KVA Transformer, 600 Volts

Figure 8 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 1,500-kva Liquid-Filled Power Transformer: X/R = 6.15; R = 0.83 Per Cent, X = 5.1 Per Cent; and Z = 5.18 Per Cent



(A) 2000 KVA Transformer, 208 Volts

(B) 2000 KVA Transformer, 240 Volts



(C) 2000 KVA Transformer, 480 Volts

(D) 2000 KVA Transformer, 600 Volts

Figure 9 – Symmetrical Short-Circuit Current and Power Factor Versus Distance From a 2,000-kva Liquid-Filled Power Transformer: X/R = 6.63; R = 0.77 Per Cent; X = 5.1 Per Cent; and Z = 5.17 Per Cent

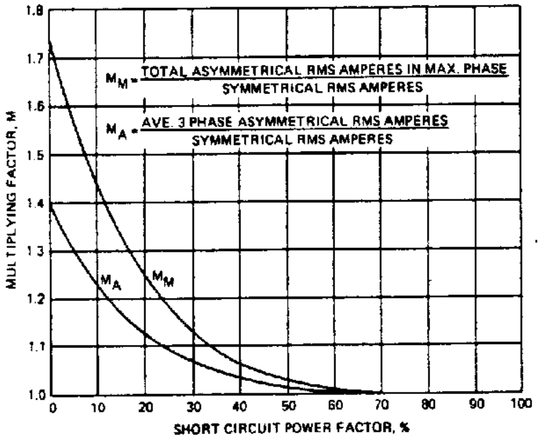


Figure 10 – Multiplying Factors to Obtain Short-Circuit Asymmetrical Current From Symmetrical Values, at a Point in Time 1/2 Cycle (60-Cycle Basis) after Initiation of a Fault

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