SHORT CIRCUIT FAULT CALCULATIONS

Short circuit fault calculations as required to be performed on all electrical service entrances by National Electrical Code 110-9, 110-10. These calculations are made to assure that the service equipment will clear a fault in case of short circuit.

To perform the fault calculations the following information must be obtained:

1. Available Power Company Short circuit KVA at transformer primary : Contact Power Company, may also be given in terms of R + jX.

2. Length of service drop from transformer to building, Type and size of conductor, ie., 250 MCM, aluminum.

3. Impedance of transformer, KVA size.

   A. %R = Percent Resistance
   B. %X = Percent Reactance
   C. %Z = Percent Impedance
   D. KVA = Kilovoltamp size of transformer. (Obtain for each transformer if in Bank of 2 or 3)

4. If service entrance consists of several different sizes of conductors, each must be adjusted by $\frac{\text{(Ohms for 1 conductor)}}{\text{(Number of conductors)}}$

This must be done for R and X

Three Phase Systems

Wye Systems: 120/208V 3∅, 4 wire
277/480V 3∅ 4 wire

Delta Systems: 120/240V 3∅, 4 wire
240V 3∅, 3 wire
480 V 3∅, 3 wire

Single Phase Systems:

Voltage 120/240V 1∅, 3 wire. Separate line to line and line to neutral calculations must be done for single phase systems. Voltage in equations (KV) is the secondary transformer voltage, line to line.

Base KVA is 10,000 in all examples.

Only those components actually in the system have to be included, each component must have an X and an R value. Neutral size is assumed to be the same size as the phase conductors.

See page 14 & 27 for example in Buss Book.

Short Circuit Calculations

Only one calculation needs to be done for most 3 phase systems. This is for the per unit method.

3 Phase

$$I\ SCA = \frac{KVA\ Base}{\sqrt{3}\ KVLL\ total\ PUZ}$$

KVA Base = 10,000

Single Phase

Two separate calculations must be done for single phase systems.

$$I\ SCA = \frac{KVA\ Base}{(KV\ line\ to\ line)\ (total\ PUZ)}$$

$$I\ SCA = \frac{KVA\ Base}{(KV\ line\ to\ neutral)\ (total\ PUZ)}$$

KVA Base = 10,000

KVLL .230KV

KVLL .115KV

See page 12 Buss Book for transformer and wire equations.

Table 1- Transformer Impedance Data

Percent R, X and Z based on Transformer KVA

Transformer Rating KVA	X/R	R %	X %	Z %
150	3.24	1.23	4.0	4.19
225	3.35	1.19	4.0	4.17
300	3.50	1.14	4.0	4.16
500	3.85	1.04	4.0	4.12
750	5.45	0.94	5.1	5.19
1000	5.70	0.89	5.1	5.19
1500	6.15	0.83	5.1	5.18
2000	6.63	0.77	5.1	5.17
150	1.5	1.111	1.665	2.0
225	1.5	1.111	1.665	2.0
300	1.5	1.111	1.665	2.0
500	1.5	1.111	1.665	2.0

Note 1: These values are for three phase, liquid filled, self-cooled transformers.

Note 2: Due to the trend toward lower impedance transformers for better voltage regulation, the actual transformer impedances may deviate from the NEMA Standard given at left. Therefore, for actual values, obtain nameplate impedance from owner or manufacturer. The percent X and percent R values are desirable for calculation.

Table 12—Distribution Transformers—Three-phase Padmount—Single-voltage Primary Maximum Line-to-Line Primary Voltage—25 kV WYE—18 kV Delta

kVA	LOW VOLTAGE 208Y/120			LOW VOLTAGE 480Y/277		
	% IZ*	% IR	% IX	%IZ*	% IR	% IX
75	1.55	1.27	0.89	1.60	1.29	0.94
75▲	2.68	1.34	2.32	2.87	1.37	2.52
112.5	1.60	1.10	1.16	1.60	1.11	1.16
112.5▲	3.54	1.10	3.36	3.56	1.11	3.38
150	1.95	1.08	1.63	1.90	1.11	1.55
150▲	4.63	1.08	4.50	4.62	1.11	4.48
225	2.00	1.05	1.70	2.00	1.01	1.73
225▲	4.66	1.09	4.53	4.74	1.06	4.62
300	2.05	0.95	1.82	2.15	0.88	1.96
300▲	5.23	0.95	5.14	4.93	0.88	4.85
500	2.00	0.88	1.80	2.10	0.85	1.92
500▲	5.56	0.89	5.49	5.33	0.85	5.26
750	5.75	0.93	5.68	5.75	0.88	5.68
1000	5.75	0.92	5.68	5.75	0.85	5.69
1500	......	......	......	5.75	0.72	5.70
2000	......	......	......	5.75	0.68	5.71
2500	......	......	......	5.75	0.61	5.72

*% IZ typical only through 500 kVA.

▲Optional impedance values—not standard.

3-phase pads COMPAD III maximum coil voltage of 18,000 volts.

TYPICAL PERFORMANCE DATA - GENERAL PURPOSE-1966 DESIGNS,
1.2 KV CLASS, 60 HZ, 40°C AMBIENT

KVA & Phase	Core Loss (Watts)	Coil Loss (Watts) @ 25°C	Coil Loss (Watts) @ STD Base Temp.	Full Load Losses (Watts)	Impedance % R	Impedance % X	Impedance % Z	Percent Efficiency Full Load	Percent Efficiency 3/4 Load	Percent Efficiency 1/2 Load	Percent Efficiency 1/4 Load	% Voltage Regulation .8 P.F.	% Voltage Regulation Unity P.F.	Avg Wind. Temp Rise ° C	Max Case Surface Temp ° C	Max KVA in 50°C Amb.
PL-21B (All values given are at 135°C except coil loss which is also given at 25°C)																
5-1Ø	44	103	147	191	2.94	1.68	3.4	96.3	96.75	96.8	95.9	3.4	2.95	102	52.9	
7-1/2-1Ø	56	127	181	237	2.42	1.84	3.04	96.95	97.25	97.35	96.5	3.1	2.45	100	55.2	
10-1Ø	68	142	204	272	2.04	1.92	2.75	97.35	97.6	97.65	96.8	2.8	2.05	112	62.5	
15-1Ø	95	167	239	334	1.60	2.02	2.58	97.8	98.0	98.0	97.2	2.5	1.65	104	58.3	
25-1Ø	160	246	352	512	1.41	2.29	2.7	98.0	98.1	98.0	97.1	2.5	1.48	109	63.7	
PL-23A (All values given are at 170°C except coil loss which is also given at 25°C)																
37-1/2-1Ø	160	900	1405	1565	3.75	2.88	4.7	95.9	96.7	97.3	97.4	4.7	3.8		45	36
50-1Ø	208	1040	1625	1833	3.25	3.0	4.4	96.4	97.0	97.6	97.5	4.4	3.3		48	50
75-1Ø	218	1170	1825	2043	2.44	3.65	4.4	97.3	97.8	98.2	98.2	4.2	2.5			75
100-1Ø	320	1425	2230	2550	2.24	3.44	4.1	97.5	97.9	98.2	98.1	3.9	2.3		41	100
167-1Ø	520	1660	2590	3110	1.55	3.33	3.7	98.1	98.4	98.6	98.3	3.3	1.6		34	167
PL-21A (All values given are at 135°C except coil loss which is also given at 25°C)																
3-3Ø	45	79	113	158	3.76	1.0	3.9	95.0	95.1	95.3	93.5	3.6	3.75	114	62	
6-3Ø	83	114	163	246	2.72	1.72	3.2	96.1	96.3	96.0	94.2	3.2	2.74	112	62	
9-3Ø	120	120	172	292	2.31	1.16	2.6	96.9	96.9	96.5	94.6	2.6	2.32	112	64	
15-3Ø	140	220	315	455	2.10	1.82	2.8	97.1	97.3	97.2	96.0	2.7	2.14	110	65	
PL-23A (All values given are at 170°C except coil loss which is also given at 25°C)																
30-3Ø	268	720	1125	1393	3.75	2.04	4.3	95.5	96.1	96.4	95.6	4.2	3.8		35	30
45-3Ø	360	785	1225	1585	2.73	1.97	3.4	96.5	96.9	97.1	96.2	3.4	2.8		35.2	45
75-3Ø	510	1160	1815	2325	2.42	2.1	3.2	97.0	97.3	97.4	96.7	3.2	2.5		41.5	75
112.5-3Ø	415	1850	2890	3305	2.56	3.69	4.5	97.1	97.6	98.0	97.9	4.3	2.7		46	109
150-3Ø	580	1860	2910	3490	1.94	4.07	4.5	97.7	98.0	98.2	98.0	4.0	2.1		38	150
225-3Ø	770	2800	4370	5140	1.95	4.8	5.2	97.7	98.1	98.3	98.1	4.5	2.1		54.5	217
300-3Ø	1200	3260	5090	6290	1.7	4.96	5.3	97.9	98.2	98.3	98.0	4.4	1.8		55	295
500-3Ø	1900	4500	7030	8930	1.4	5.11	5.3	98.2	98.4	98.5	98.1	4.3	1.6		52	483

Table 5—Estimated Secondary Short-circuit Currents For Single-phase, Three-wire Secondary Distribution Transformers

(7200/12,470Y—120/240-VOLT TRANSFORMER)

MAXIMUM SYMMETRICAL SHORT-CIRCUIT CURRENT FOR STANDARD 120/240-VOLT, 3 WIRE, SINGLE-PHASE DISTRIBUTION TRANSFORMER (LINE-TO-NEUTRAL FAULT AT TRANSFORMER TERMINALS)

Available Primary 3-phase Short-circuit MVA	Transformer kVA Rating, Single Phase					
	25	37.5	50	75	100	167
	Normal-load Continuous Current—Amperes at 240 Volts					
	104	156	208	313	417	696
	Short-circuit Symmetrical Current at 120 Volts					
25	7,600	13,300	16,500	22,100	29,800	42,400
50	7,800	14,000	17,600	24,300	34,000	51,900
100	7,950	14,400	18,200	25,600	36,500	58,100
150	8,000	14,500	18,400	26,100	37,400	60,500
250	8,000	14,600	18,600	26,400	38,200	62,500
500	8,100	14,700	18,700	26,700	38,700	64,000
750	8,100	14,700	18,800	26,800	38,900	64,500
Unlimited	8,100	14,800	18,850	27,000	39,300	65,600

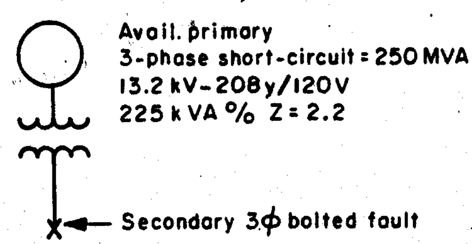
TRANSFORMER FULL-WINDING IMPEDANCE ON RATED kVA, (7200/12,470Y—120/240-VOLT TRANSFORMER)

% IR	1.2	1.0	1.0	0.9	0.9	0.9
% IX	1.6	1.3	1.4	1.6	1.4	1.4

Table 6—Estimated Secondary Short-circuit Currents for GE Three-phase Padmount Distribution Transformers Single-voltage Primary.

LINE-TO-LINE PRIMARY VOLTAGE 25 kV WYE—18 kV DELTA

Available Primary 3-phase Short-circuit MVA	Secondary Voltage Rating		Transformer kVA Rating					
			75	112.5	150	225	300	500
			Transformer Impedance—%					
	(1) 480Y/277V	%IR	1.29	1.11	1.11	1.01	0.89	0.85
		%IX	0.94	1.16	1.55	1.73	1.96	1.92
	(2) 208Y/120V	%IR	1.27	1.10	1.08	1.05	1.05	0.89
		%IX	0.90	1.16	1.63	1.70	1.82	1.80
			Maximum Short-circuit Symmetrical rms Amperes					
100	(1)		5,500	8,050	8,900	12,300	14,900	23,500
	(2)		13,000	18,575	20,000	28,500	35,200	56,300
250	(1)		5,600	8,300	9,250	13,000	16,000	26,400
	(2)		13,225	19,150	20,800	30,100	37,800	63,400
500	(1)		5,625	8,400	9,375	13,300	16,400	27,500
	(2)		13,300	19,350	21,000	30,700	38,700	66,200



Solve for the Secondary Fault using the per-unit method.

Select 225 kVA as the study base

$$\text{X Utility Source} = \frac{225\text{ kVA}}{250{,}000\text{ kVA}} = 0.0009\text{ pu}$$

$$\text{X Trans} = \left(.017\right)\left(\frac{225\text{ kVA}}{225\text{ kVA}}\right) = 0.017\text{ pu}$$

$$\text{X} = \text{X trans} + \text{X utility} = 0.0179$$

$$\text{R trans} = \left(0.0105\right)\left(\frac{225\text{ kVA}}{225\text{ kVA}}\right) = 0.0105\text{ pu}$$

$$Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{(0.0105)^2 + (0.0179)^2}$$

$$= 0.0208$$

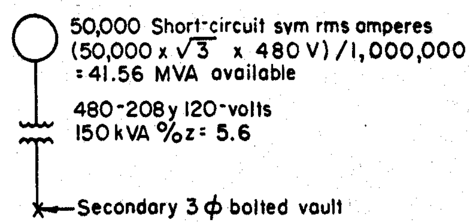
$$I_{sc} = \frac{kVA_h}{\sqrt{3}\ (KV)\ (Z\text{ pu})} = \frac{225}{\sqrt{3}\ (.208)\ (.0208)}$$

= 30,095 3φ Short-circuit Symmetrical rms Amperes at Transformer Terminals

Table 7—Estimated Secondary Short-circuit Currents For GE Type "QHT" Dry-type 3-phase Transformers

PRIMARY RATING 600 VOLTS AND BELOW, SECONDARY RATING 480Y/277V and 208/120V

Available Short-circuit Symmetrical rms Amperes	Transformer kVA Rating	6	9	15	30	45	75	112.5	150	225	300	500
	Transformer Impedance											
	% IR	2.72	2.31	2.1	3.8	2.52	2.27	2.43	2.35	1.15	1.8	1.6
	% IX	1.72	1.16	1.80	1.37	1.73	1.91	-3.87	5.0	5.5	4.5	5.9
	Short-circuit Symmetrical rms Amperes											
	Secondary Voltage											
25,000	480	225	415	640	885	1,700	2,810	2,690	2,925	4,050	5,800	7,100
	208	515	960	1,475	2,035	3,925	6,500	6,200	6,750	9,350	13,400	16,400
50,000	480	225	420	645	890	1,740	2,925	2,820	3,085	4,400	6,550	8,260
	208	520	965	1,485	2,050	4,005	6,750	6,500	7,125	10,151	15,100	19,160
200,000	480	226	420	650	845	1,760	3,010	2,925	....	4,700	7,200	9,400
	208	520	970	1,495	2,060	4,065	7,010	6,750	7,450	10,860	16,600	21,700



Solve for the Secondary Fault using the per-unit method.

Select 150 kVA as the study base.

$$X\ \text{available} = \frac{150\ \text{kVA}}{41{,}570\ \text{kVA}} = 0.0036\ \text{pu}$$

$$X\ \text{trans} = (.050)\frac{150\ \text{kVA}}{150\ \text{kVA}} = 0.050\ \text{pu}$$

$$X = X\ \text{avail.} + \text{trans} = 0.0036 + .050 = .0536\ \text{pu}$$

$$R\ \text{trans} = (.0235)\left(\frac{150\ \text{kVA}}{150\ \text{kVA}}\right) = 0.0235\ \text{pu}$$

$$Z = \sqrt{R^2 + X^2}$$

$$= \sqrt{(0.0235)^2 + (0.0536)^2}$$

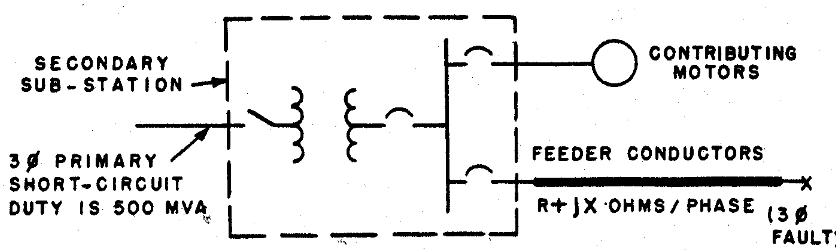
$$= 0.0585$$

$$I_{sc} = \frac{\text{kVA}_b}{\sqrt{3}\ (\text{kV})\ (Z)} = \frac{150}{\sqrt{3}\ (.208)\ (.0585)}$$

$I_{sc} = 7{,}117$ 3ϕ Short-circuit Sym. rms Amperes at transformer terminals

Estimated Short-circuit Current at the End of Low-voltage Feeder (See Figs. 25-1—25-30)

Power - system maximum estimated short - circuit currents, as functions of distance along feeder conductors fed from standard three-phase radial secondary unit substations, can be read directly in rms symmetrical amperes from a series of curves, Fig. 25-1 through 25-30. The one-line diagram shows the typical radial circuit investigated.



Typical circuit investigated to show effect on short-circuit duty as point of fault is moved away from the low-voltage bus along the feeder conductors

The conditions on which the curves are based were as follows:

1. The fault was a bolted three-phase short circuit.
2. The primary three-phase short-circuit duty was 500 MVA (60 cycles) for all curves. A typical supply-system X/R at the low-voltage bus was used in calculating the curves for each case.
3. Motor contributions through the bus to the point of short circuit were included in the calculations on the basis of 100 percent contribution for the 240-, 480-, and 600-volt systems and 50 percent contribution for the 208-volt systems.
4. The feeder-conductor impedance values used in the calculations are indicated for various conductor sizes.

These curves can also be used to select feeder conductor sizes and lengths needed to reduce short-circuit duties to desired smaller values. Note that conductors thus selected must be further checked to assure adequate load and short-circuit capabilities and acceptable voltage drop.

Appendix

Table 11—Distribution Transformers—Single-phase

kVA	Low Voltage	%IR	%IX	%IZ
HIGH VOLTAGE 2400/4160Y				
5	120/240	2.0	1.5	2.5
10	120/240	1.2	0.7	1.4
15	120/240	1.2	1.1	1.6
25	120/240	1.1	1.4	1.8
37½	120/240	0.9	1.2	1.5
50	120/240	0.9	1.3	1.6
75	120/240	0.9	1.3	1.6
100	120/240	0.9	1.6	1.8
167	120/240	0.9	1.6	1.8
10	240/480	1.1	1.0	1.5
15	240/480	1.1	1.0	1.5
25	240/480	1.1	1.5	1.9
37½	240/480	0.9	1.3	1.6
50	240/480	0.9	1.3	1.6
75	240/480	0.9	1.4	1.7
100	240/480	0.9	1.4	1.7
167	240/480	0.9	1.3	1.6
HIGH VOLTAGE 4160/7200Y				
5	120/240	2.1	1.5	2.6
10	120/240	1.2	0.7	1.4
15	120/240	1.2	1.1	1.6
25	120/240	1.1	1.4	1.8
37½	120/240	0.9	1.2	1.5
50	120/240	0.9	1.3	1.6
75	120/240	0.9	1.3	1.6
100	120/240	0.9	1.7	1.9
10	240/480	1.2	0.9	1.5
15	240/480	1.2	1.1	1.6
25	240/480	1.1	1.4	1.8
37½	240/480	1.0	1.1	1.5
50	240/480	1.0	1.3	1.6
75	240/480	0.9	1.3	1.6
100	240/480	0.9	1.3	1.6
HIGH VOLTAGE 4800/8320Y				
5	120/240	2.1	1.5	2.6
10	120/240	1.2	0.9	1.5
15	120/240	1.2	0.9	1.5
25	120/240	1.1	1.4	1.8
37½	120/240	0.9	1.2	1.5
50	120/240	0.9	1.3	1.6
75	120/240	0.9	1.3	1.6
100	120/240	0.9	1.4	1.7
167	120/240	0.9	1.6	1.8
10	240/480	1.2	0.7	1.4
15	240/480	1.2	0.9	1.5
25	240/480	1.1	1.5	1.9
37½	240/480	1.0	1.1	1.5
50	240/480	1.0	1.1	1.5
75	240/480	0.9	1.4	1.7
100	240/480	0.9	1.3	1.6
167	240/480	0.9	1.4	1.7

kVA	Low Voltage	%IR	%IX	%IZ
HIGH VOLTAGE 7200/12470Y OR 12470GRDY/7200				
5	120/240	2.2	2.2	3.1
10	120/240	1.4	0.8	1.6
15	120/240	1.3	1.2	1.8
25	120/240	1.2	1.6	2.0
37½	120/240	1.0	1.3	1.6
50	120/240	1.0	1.4	1.7
75	120/240	0.9	1.6	1.8
100	120/240	0.9	1.4	1.7
167	120/240	0.9	1.4	1.7
10	240/480	1.4	0.8	1.6
15	240/480	1.3	0.9	1.6
25	240/480	1.2	1.6	2.0
37½	240/480	1.1	1.3	1.7
50	240/480	1.1	1.2	1.6
75	240/480	0.9	1.6	1.8
100	240/480	0.9	1.4	1.7
167	240/480	0.9	1.3	1.6
50	2400 or 4800	1.0	1.1	1.5
100	2400 or 4800	0.9	1.1	1.4
167	2400 or 4800	0.8	1.4	1.6
HIGH VOLTAGE 7620/13200Y OR 13200GRDY/7620				
5	120/240	2.2	2.2	3.1
10	120/240	1.4	0.8	1.6
15	120/240	1.3	1.2	1.8
25	120/240	1.2	1.6	2.0
37½	120/240	1.0	1.3	1.6
50	120/240	1.0	1.5	1.8
75	120/240	0.9	1.6	1.8
100	120/240	0.9	1.6	1.8
167	120/240	0.9	1.7	1.9
10	240/480	1.4	0.9	1.6
15	240/480	1.3	1.0	1.6
25	240/480	1.2	1.4	1.9
37½	240/480	1.1	1.5	1.9
50	240/480	1.1	1.7	2.0
75	240/480	0.9	1.5	1.8
100	240/480	0.9	1.5	1.7
167	240/480	0.9	1.5	1.8
HIGH VOLTAGE 14400/24940GRDY OR 24940GRDY/14400				
5	120/240	2.2	2.5	3.3
10	120/240	1.6	1.0	1.9
15	120/240	1.4	1.1	1.8
25	120/240	1.3	1.8	2.2
37½	120/240	1.1	1.8	2.1
50	120/240	1.1	1.8	2.1
75	120/240	1.0	2.0	2.2
100	120/240	1.0	2.0	2.2
10	240/480	1.6	1.0	1.9
15	240/480	1.4	1.3	1.9
25	240/480	1.3	1.9	2.3
37½	240/480	1.1	1.8	2.1
50	240/480	1.1	1.8	2.1
75	240/480	1.0	2.0	2.2
100	240/480	1.0	1.8	2.1
50	2400 or 4800	1.1	1.2	1.4
100	2400 or 4800	1.0	1.8	2.1

Table 12—Distribution Transformers—Three-phase Padmount—Single-voltage Primary Maximum Line-to-Line Primary Voltage—25 kV WYE—18 kV Delta

kVA	Low Voltage					
	208Y/120			480Y/277		
	%IZ	%IR	%IX	%IZ	%IR	%IX
75	1.55	1.27	0.90	1.60	1.29	0.94
75*	2.70	1.34	1.29	2.90	1.37	1.35
112	1.60	1.10	1.16	1.60	1.11	1.16
112*	3.55	1.10	2.76	3.60	1.11	2.77
150	1.95	1.08	1.63	1.90	1.11	1.55
150*	4.65	1.08	3.88	4.65	1.11	3.66
225	2.00	1.05	1.70	2.00	1.01	1.73
225*	4.65	1.09	3.85	4.75	1.06	4.13
300	2.05	1.05	1.82	2.15	0.88	1.96

kVA	Low Voltage					
	208Y/120			480Y/277		
	%IZ	%IR	%IX	%IZ	%IR	%IX
300*	5.25	0.95	5.70	4.95	0.88	6.29
500	2.00	0.89	1.80	2.10	0.85	1.92
500*	5.50	0.89	6.96	5.35	0.85	7.21
750	5.75	0.93	6.56	5.75	0.88	7.32
1000	5.75	0.93	6.53	5.75	0.86	7.71
1500	.....	.....	.....	5.75	0.74	10.32
2000	.....	.....	.....	5.75	0.70	11.82
2500	.....	.....	.....	5.75	0.63	14.40

*Optional—Non-Standard

Table 13—Transformers for Integral Distribution Centers and Secondary Unit Substations

kVA	Dry-type 480V %Z	Dry-type 480V X/R *	Dry-type 2400–4800V %Z	Dry-type 2400–4800V X/R *	Dry-type 6.9kV–15kV %Z	Dry-type 6.9kV–15kV X/R *	Liquid-filled 2400–15,000V Percent Impedance %Z	Liquid-filled 2400–15,000V X/R *
75	3.0	0.83	6.2	2.15				
112.5	4.6	1.63	4.5	1.77	6.1	1.93		
150	5.5	2.08	4.2	1.95	5.3	2.33		
225	5.9	4.58	4.6	1.75	6.1	2.48	2.0†	2.5
300	4.9	2.50	5.2	3.57	6.0	3.22	4.5†	3.0
500	6.1	3.69	5.3	4.33	6.4	4.43	4.5†	3.5
			Dry-type 2400–15,000V %Z		Dry-type 2400–15,000V X/R			
750	5.2	2.88	5.75		5.0		5.75	4.0
1000	4.7	3.46	5.75		5.7		5.75	4.75
1500			5.75		6.5		5.75	5.5
2000			5.75		7.2		5.75	5.9
2500			5.75		7.5		5.79	6.0

* Typical ratios based on serveral manufacturers' data.
† Minimum impedance.

Table 14—Dry-type transformers—Type QHT, % Impedance, Reactance and Resistance (Temp. Base 170°C)‡

kVA	Single-phase %IX	Single-phase %IR	Single-phase %IZ	Three-phase kVA	Three-phase %IX	Three-phase %IR	Three-phase %IZ
5	1.68	2.94	3.4	6	1.72	2.72	3.2
7.5	1.84	2.42	3.0	9	1.16	2.31	2.6
10	1.92	2.04	2.75	15	1.82	2.1	2.8
15	2.02	1.60	2.6	30	1.37	3.8	4.0
25	2.3	1.4	2.7	45	1.73	2.52	3.1
37.5	2.7	3.6	4.5	75	1.91	2.27	3.0
50	2.8	3.1	4.2	112½	3.87	2.43	4.6
75	3.7	2.48	4.45	150	5.0	2.35	5.5
100	3.55	2.12	4.14	225	5.5	1.15	5.9
167	3.25	1.60	3.63	300	4.5	1.8	4.9
				500	5.9	1.6	6.1

‡ Typical values based on data from several manufacturers.

Table 15—Standard Current Limiting Reactors

600 Volt Insulation Class — Indoor Service 3φ

Amperes	Fault △ Current 1 second Duration	OHMS per Phase
1000	23,000	0.015
1000	34,000	.010
800	12,000	.0285
800	34,000	.010
600	15,000	.0285
600	15,000	.0230
600	20,000	.0170
600	25,000	.0130
600	25,000	.010
600	25,000	.0046
400	8,000	.0485
400	15,000	.0285
400	15,000	.0230
400	20,000	.0170
400	25,000	.0130
400	25,000	.010
400	25,000	.0046
225	12,500	.0285

5 kV Insulation Class — Single-phase and Three-phase

Continuous Current Amperes	OHMS per Phase
200	0.25
	.40
300	.10
	.16
	.25
400	.10
	.16
	.25
600	.063
	.10
	.16
	.25
1200	.04
	.063
	.10
	.16
2000	.04
	.063
	.10

15 kV Insulation Class — Single-phase and Three-phase

Continuous Current Amperes	OHMS per Phase
30	0.50
	.63
	.80
	1.0
	1.6
	2.5
400	.40
	.50
	.63
	.80
	1.0
	1.6
600	.25
	.40
	.50
	.63
	.80
	1.0
1200	.16
	.25
	.40
	.50
	.63
2000	.10
	.16
	.25
	.40

△ Maximum allowable sustained symmetrical rms amperes

Table 16—Approximate Machine Reactances

LARGE INDUCTION MOTORS

The short-circuit reactance of an induction motor (or induction generator) in percent on its own kVA base may be taken as percent X″ d =

$$\frac{100}{\text{*times normal stalled rotor current}}$$

*with rated voltage and frequency applied.

The reactance of such a machine will generally be approximately (in percent on own kVA base).

X″d Range	X″d Most Common
15–25	25

Table 17—Grouped Small Motors

In many short-circuit studies, the number and size of motors, either induction or synchronous, is not known precisely. However, the short-circuit contribution from these motors must be estimated. In such cases the following table of reactances is used to account for a large number of small induction and synchronous motors.

Item	Motor Ratings and Corrections	Subtransient Reactance X″d (Percent)	Transient Reactance X′d (Percent)
1	600 volts or less—induction	25	—
2	600 volts or less—synchronous (items 1 and 2 include motor leads)	25	33
3	600 volts or less—induction	31	—
4	600 volts or less—synchronous (items 3 and 4 include motor leads and step-down transformers)	31	39
5	Motors above 600 volts—induction	20	—
6	Motors above 600 volts—synchronous	15	25
7	Motors above 600 volts—induction	26	—
8	Motors above 600 volts—synchronous (items 7 8 include step-down transformers)	21	31

Table 18—Synchronous Machines

Percent Values on Machine kVA Rating

	X″d Range	X″d Mean	X′d Range	X′d Mean
(A) Generators (1) Turbo Generators (distributed pole)				
2 pole, 625–9375 kVA	6–13	9	Not used in normal short-circuit calculations.	
2 pole, 12,500 kVA–up	8–12	10		
4 pole, 12,500 kVA–up	10–17	14		
(2) Salient-pole Generators (without amortisseur)				
12 poles or less	15–35	25		
14 poles or more	25–45	35		
(3) Salient-pole Generators* (with amortisseur)				
12 poles or less	10–25	18		
14 poles or more	18–40	24		
(B) Synchronous Condensers	9–38	24		
(C) Synchronous Converters				
600 V dc	17–22	20		
250 V dc	28–38	33		
(D) Synchronous Motors**				
6 pole	7–16	10	10–22	15
8–14 pole (incl.)	11–22	15	17–36	24

* Nearly all salient-pole generators built by GE since 1935 have amortisseur windings.
**These data are useful for estimating reactances of individual large motors of several hunared or several thousand horsepower.

Appendix

Feeder Impedance Values Used in Investigation

Feeder Conductor Size/Phase	Resistance (R) Ohms/Phase/1000 Ft	60-cycle Inductive Reactance (X) Ohms/Phase/1000 Ft
#4	.321	.0483
#1/0	.128	.0414
250 MCM	.055	.0379
2–500 MCM	.0147	.0174
4–750 MCM	.0054	.0081

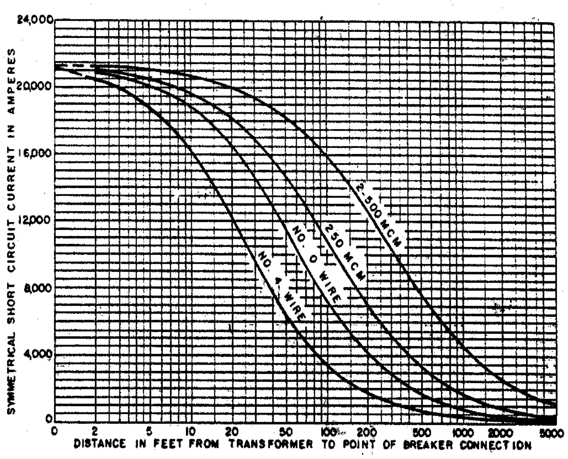


Fig. 25-1. Transf: 150 kVA, 208 V, 2.0% Z

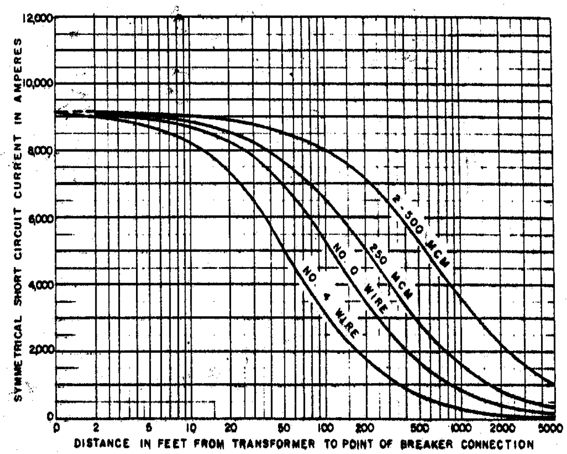


Fig. 25-2. Transf: 150 kVA, 208 V, 4.5% Z

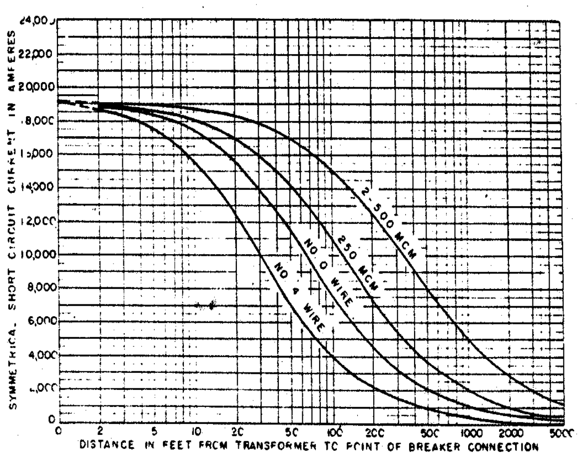


Fig. 25-3. Transf: 150 kVA, 240 V, 2.0% Z

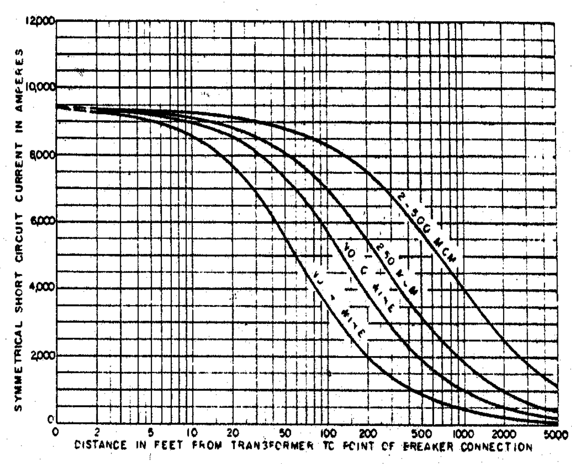


Fig. 25-4. Transf: 150 kVA, 240 V, 4.5% Z

Circuit Breaker Data

Catalog Number Prefix	No. Poles	Ampere Rating	UL Listed Interrupting Rating—RMS Symmetrical Amperes: AC Voltage 120	AC 120/240	AC 240	AC 277	AC 277/480	AC 480	AC 600	DC Voltage 250	*Federal Specs. W-C-375B/GEN	DP Catalog Class	Digest 162 Page No.
QO-GFI, QOB-GFI	1	15-30	10000	.....	.....	.....	.....	.....	.....	.....	11a	910	3, 78, 80
	2	15-30	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a		
QO-VHGFI, QOB-VHGFI	1	15-30	22000	.....	.....	.....	.....	.....	.....	.....	11a	910	3, 78, 80
QO-QOB	1	10-70	.....	10000	.....	.....	.....	.....	.....	.....	10a, 11a, 12a	730	2, 58, 78, 80
	2	●10-100	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a		
	3	10-60	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
QO-H, QOB-H	2	15-30	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b	730	2, 78, 80
QOT	1	15-30	.....	▲10000	.....	.....	.....	.....	.....	.....	10a, 11a, 12a	731	2
	2	15-30	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a		
QO-VH, QOB-VH	1	10-30	.....	22000	.....	.....	.....	.....	.....	.....	14a	730	2, 78, 80
	2	15-30	.....	22000	.....	.....	.....	.....	.....	.....	14a		
	3	15-30	.....	.....	22000	.....	.....	.....	.....	.....	...		
QOU	1	10-70	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a	720	59
	2	10-70	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a		
	3	10-50	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
QH-QHB	1	10-30	.....	65000	.....	.....	.....	.....	.....	.....	15a	730	2, 78, 80
	2	15-30	.....	65000	.....	.....	.....	.....	.....	.....	15a		
	3	15-30	.....	.....	65000	.....	.....	.....	.....	.....	15b		
Q1	2	80-150	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a	733	2, 58, 78
	3	70-100	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
Q1B	2	80-100	.....	10000	.....	.....	.....	.....	.....	.....	10a, 12a	733	58, 80
	3	70-100	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
Q1-H, Q1B-H	2	35-100	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b	733	2, 78, 80
Q1-VH	2	35-125	.....	22000	.....	.....	.....	.....	.....	.....	14a	733	2, 78
	3	35-100	.....	.....	22000	.....	.....	.....	.....	.....	14b		
Q1B-VH	2	35-100	.....	22000	.....	.....	.....	.....	.....	.....	14a	733	80
	3	35-100	.....	.....	22000	.....	.....	.....	.....	.....	14b		
Q1H	2	35-125	.....	42000	.....	.....	.....	.....	.....	.....	14a	733	2, 78
Q1BH	2	35-100	.....	42000	.....	.....	.....	.....	.....	.....	14a	733	80
Q1L	1	15-100	10000	.....	5000	.....	.....	.....	.....	.....	10a, 12a	733	59
	2	15-125	.....	10000	5000	.....	.....	.....	.....	.....	10a, 10b, 12a		
	3	15-100	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
Q1U	2	15-125	.....	10000	5000	.....	.....	.....	.....	.....	10a, 10b, 12a	733	59
	3	15-100	.....	.....	10000	.....	.....	.....	.....	.....	10b, 11b, 12b		
Q2	2	100-225	.....	10000	.....	.....	.....	.....	.....	.....	...	734	95
Q2L	2	100-225	.....	10000	.....	.....	.....	.....	.....	.....	...	734	59
Q2, Q2L	3	100-225	.....	.....	10000	.....	.....	.....	.....	.....	12b	734	59, 95
Q2-H, Q2L-H†	2	100-225	.....	.....	22000	.....	.....	.....	.....	.....	12b, 14b	734	59, 95
	3	100-225	.....	.....	22000	.....	.....	.....	.....	.....	12b, 14b		
Q2H, Q2LH	2	100-225	.....	.....	42000	.....	.....	.....	.....	.....	12b, 14b	734	59, 95
Q4, Q4L	2	250-400	.....	.....	22000	.....	.....	.....	.....	.....	14b	735	59, 95
	3	250-400	.....	.....	22000	.....	.....	.....	.....	.....	14b		
EH, EHB	1	15-30	65000	.....	.....	14000	.....	.....	.....	.....	11a, 13a	652	58, 89
	2	15-60	.....	65000	.....	.....	14000	.....	.....	.....	13b, 15a		
	3	15-60	.....	.....	65000	.....	14000	.....	.....	.....	13b, 15b		
FY	1	15-30	18000	.....	.....	14000	.....	.....	.....	.....	11a, 13a	651	95
FA-FAL 240V.	1	15-100	10000	.....	.....	.....	.....	.....	.....	5000■	11a	650	60, 95
	2	15-100	.....	.....	10000	.....	.....	.....	.....	5000	11b, 12b		
	3	15-100	.....	.....	10000	.....	.....	.....	.....	.....	11b, 12b		
FA-FAL 480V.	1	15-100	18000	.....	.....	14000	.....	.....	.....	10000■	11a, 12c, 13a	650	60, 95
	2	15-100	.....	.....	18000	.....	.....	14000	.....	10000	13b		
	3	15-100	.....	.....	18000	.....	.....	14000	.....	.....	13b		
FA-FAL 600V.	2	15-100	.....	.....	18000	.....	.....	14000	14000	10000	18a	650	60, 95
	3	15-100	.....	.....	18000	.....	.....	14000	14000	.....	18a		
FH-FHL	1	15-30	.....	.....	.....	65000	.....	.....	.....	10000■	13a	650	62, 96
	1	35-100	65000	.....	.....	25000	.....	.....	.....	10000■	13a		
	2	15-100	.....	.....	65000	.....	.....	25000	18000	10000	22a		
	3	15-100	.....	.....	65000	.....	.....	25000	18000	.....	22a		
IF-IFL	2	20-100	.....	.....	100000	.....	.....	100000	.....	.....	16a	820	63, 96
	3	20-100	.....	.....	100000	.....	.....	100000	.....	.....	16a		
KA-KAL	2	70-225	.....	.....	25000	.....	.....	22000	22000	10000	20a	655	60, 95
	3	70-225	.....	.....	25000	.....	.....	22000	22000	.....	20a		
KH-KHL	2	70-225	.....	.....	65000	.....	.....	35000	25000	10000	23a	655	62, 96
	3	70-225	.....	.....	65000	.....	.....	35000	25000	.....	23a		
IK-IKL	2	110-225	.....	.....	100000	.....	.....	100000	.....	.....	16a	825	63, 96
	3	110-225	.....	.....	100000	.....	.....	100000	.....	.....	16a		
LA-LAL	2	125-400	.....	.....	42000	.....	.....	30000	22000	10000	21a	660	61, 95
	3	125-400	.....	.....	42000	.....	.....	30000	22000	.....	21a		
LH-LHL	2	125-400	.....	.....	65000	.....	.....	35000	25000	10000	23a	660	62, 96
	3	125-400	.....	.....	65000	.....	.....	35000	25000	.....	23a		
IL-ILL	3	250-400	.....	.....	100000	.....	.....	100000	.....	.....	...	830	63, 96
MA-MAL	2	125-1000	.....	.....	42000	.....	.....	30000	22000	14000	21a	665	61, 95
	3	125-1000	.....	.....	42000	.....	.....	30000	22000	.....	21a		
MH-MHL	2	125-1000	.....	.....	65000	.....	.....	50000	25000	14000	23a	665	62, 96
	3	125-1000	.....	.....	65000	.....	.....	50000	25000	.....	23a		
ME-MEL	2	125-800	.....	.....	65000	.....	.....	50000	25000	.....	23a	666	64, 97
	3	125-800	.....	.....	65000	.....	.....	50000	25000	.....	23a		
NHL	2	600-1200	.....	.....	65000	.....	.....	50000	.....	.....	23a	670	61
	3	600-1200	.....	.....	65000	.....	.....	50000	.....	.....	23a		
PAF	2	600-2000	.....	.....	65000	.....	.....	50000	42000	.....	24a	675	61
	3	600-2000	.....	.....	65000	.....	.....	50000	42000	.....	24a		
PHF	2	600-2000	.....	.....	125000	.....	.....	100000	65000	.....	25a	675	62
	3	600-2000	.....	.....	125000	.....	.....	100000	65000	.....	25a		
PEF, PEC	2	1000-2000	.....	.....	125000	.....	.....	100000	65000	.....	25a	677	65
	3	1000-2000	.....	.....	125000	.....	.....	100000	65000	.....	25a		
PCF	2	1600-2500	.....	.....	125000	.....	.....	100000	65000	.....	25a	676	61
	3	1600-2500	.....	.....	125000	.....	.....	100000	65000	.....	25a		

*Federal Specs. do not require dc ratings.
■125V. dc.
▲QOT 1515, QOT 1520 and QOT 2020 rated 120V. ac.
†2 Pole rated 10,000 AIC, 240V., 3Ø, Grd. BØ.
●QO only. QOB maximum rating 70 amperes.