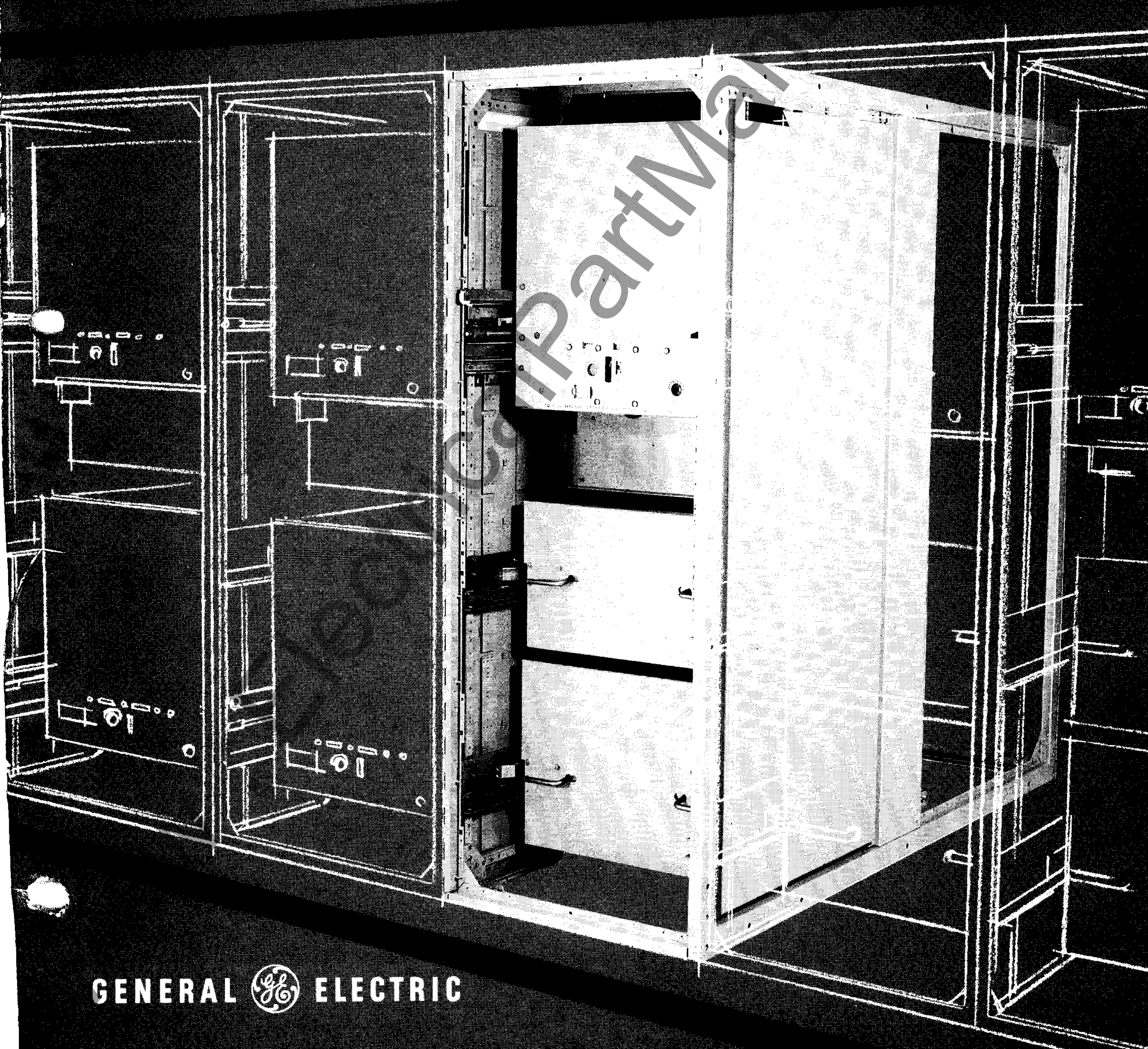
OEM

GENERAL ELECTRIC OEM METALCLAD SWITCHGEAR COMPONENTS

with the POWER/VAC® Breaker

Application Guide



GENERAL ELECTRIC

Information contained in this Application Guide is based on established industry standards and practices. It is published in the interest of assisting in the preparation of plans and specifications for medium-voltage metalclad switchgear. Neither the General Electric Company nor any person acting on its behalf assumes any liability with respect to the use of, or for damages or injury resulting from the use of any information contained in this Application Guide. This information in this guide does not supplement or replace performance data contained in other product publications of the Company.

Sections

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Section 1

Foreword

Foreword

USE OF APPLICATION GUIDE

This *Application Guide* provides information necessary to help plan and specify medium-voltage power system switchgear, using General Electric's POWER/VAC® breaker. This guide is organized to present the information in an orderly, step-by-step manner. Since it is intended to be a workbook, only the data necessary to choose applicable switchgear is included.

Complete specifications can be written for most switchgear applications using this publication, a system one-line diagram, and reference to appropriate literature for guidance in calculating short-circuit currents or for other extensive technical information beyond the usual scope of an application guide.

The topics discussed in the sections of this guide are of a general nature, applicable to any type of medium-voltage metalclad switchgear. Information is provided relating to one-line diagrams, circuit breaker ratings and selection, and control power requirements.

POWER/VAC BREAKER AND SWITCHGEAR COMPONENTS

POWER/VAC breaker and switchgear components are designed for application on 5-kV, 7.2-kV, and 15-kV power systems with available short-circuit capacities from 250 through 1000 MVA nominal.

POWER/VAC circuit breakers are rated per ANSI C37.06-1971, Table 2. Available ratings are shown on page 3-3 of this application guide.

Switchgear components are designed, built, and tested to the applicable industry standards shown in Table 1-1.

Table 1-1. Applicable Industry Standards

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) 70 East 45th Street New York, New York 10017		**NATIONAL ELECTRICAL MANUFACTURERS ASS'N (NEMA) 2101 L St. NW, Suite 300 Washington, D.C. 20037**	
Standard No.	Description	Standard No.	Description
C37.04	AC Power Circuit Breaker Rating Structure	SG-2	High-voltage Fuses
C37.06	Preferred Ratings of Power Circuit Breakers		
C37.07	Interrupting Factors — Reclosing Service	SG-4	Power Circuit Breakers
C37.09	Test Procedure for Power Circuit Breakers		
C37.010	Application Guide for Power Circuit Breakers	SG-5	Power Switchgear Assemblies
C37.11	Power Circuit Breaker Control Requirements		
C37.20	Switchgear Assemblies and Metal-Enclosed Bus		
C37.100	Definitions for Power Switchgear		

Specifically, OEM switchgear components incorporate the following new basic design elements, compared to air-magnetic and early designs of vacuum metalclad switchgear.

- The steel skeleton frame offers two-tier POWER/VAC® breaker stacking for application flexibility and floorspace savings.
- The steel skeleton frame utilizes modular construction resulting in one basic vertical section size, thus simplifying equipment planning and providing installation savings.

These fundamental design improvements affect certain elements in the switchgear, principally the one-line diagram and the arrangement of switchgear units in a lineup. Since these application considerations are a result of the equipment design, a brief illustration of the switchgear component design concepts is provided.

TWO-TIER BREAKER STACKING

Mixing and matching of a variety of unit types and breaker ratings is possible using two-tier unit stacking. The nine standard combinations of upper and lower units are shown in Figure 1-2.

MODULAR CONSTRUCTION

Breakers and auxiliary devices can be accommodated in the upper and lower breaker compartments as shown in Figure 1-3.

AVAILABLE UNIT COMBINATIONS

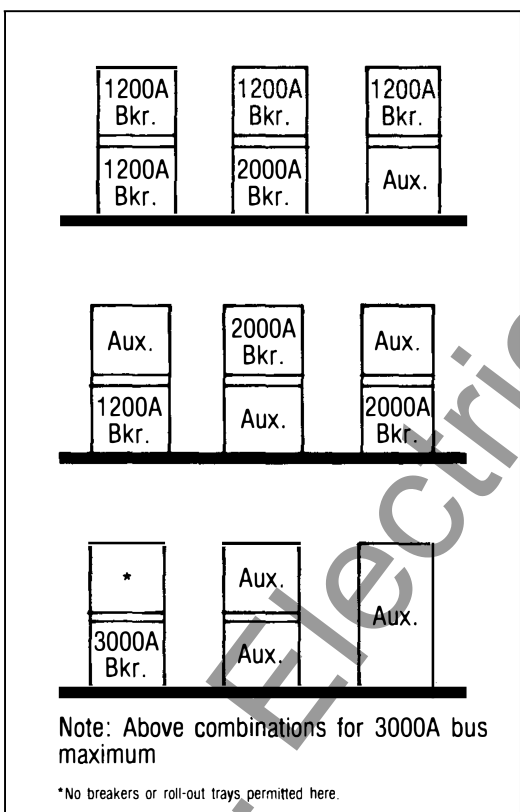

Figure 1-2. Nine standard combinations of upper and lower units.

TYPICAL UPPER AND LOWER UNIT CONFIGURATIONS

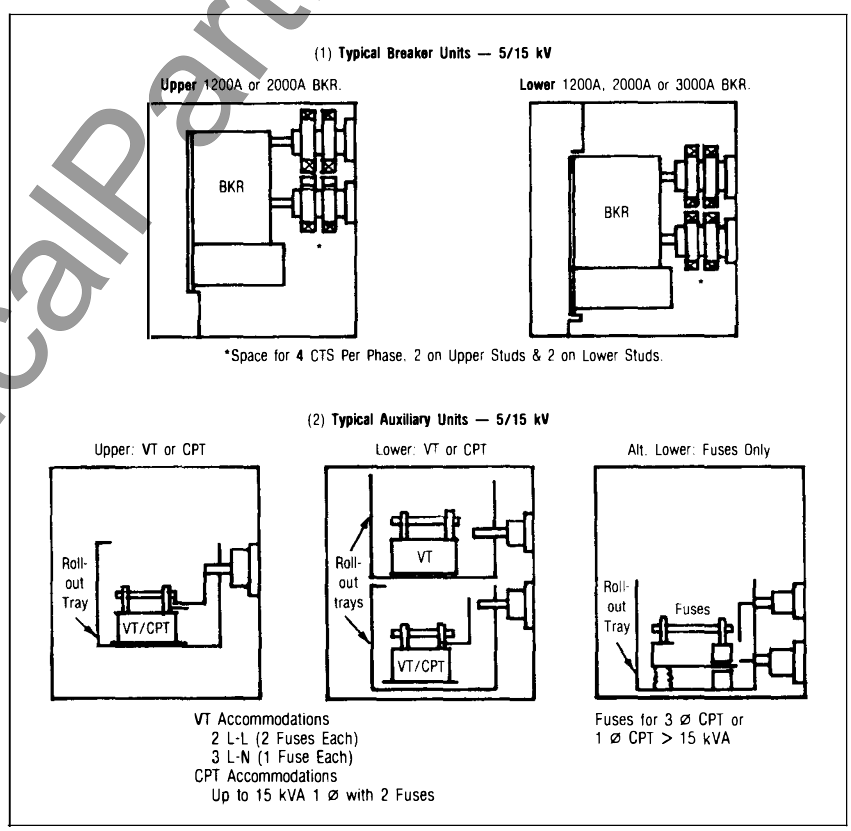

Figure 1-3. Typical upper and lower unit configurations.

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Section 2

System One-Line Diagram

System One-Line Diagram

INTRODUCTION

The first step in preparing a specification for metalclad switchgear is to develop a one-line diagram. A one-line diagram (single-line) is "a diagram that shows, by means of single line and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used therein". (See Ref. 1 of this section.)

When preparing switchgear one-line diagrams, use graphic symbols in accordance with IEEE and ANSI standards in References 2 and 3.

One-line diagrams employ device function numbers which, with appropriate suffix letters, are used to identify the function of each device in all types of partially automatic, fully automatic, and in many types of manual switchgear. A complete list of such device function numbers is published in Reference 4 and shown in Table 2-2.

DEVELOPING A ONE-LINE DIAGRAM

To illustrate the development of a one-line diagram, a typical resistance grounded system has been chosen. The same general procedures would apply to solidly grounded distribution systems.

Three steps are used in producing a one-line diagram: the preliminary diagram, followed by the partially developed diagram, and finishing with the developed diagram.

The abbreviations used for the principal meters, instruments, and other devices (not including relaying, which is listed in Table 2-2), as found in the application guide, are listed in Table 2-1.

Each device in an automatic switching equipment has a device function number which is placed adjacent to or within the device symbol on all wiring diagrams and arrangement drawings so that its function and operation may be readily identified.

These numbers are based on a system which was adopted as standard for Automatic Switchgear by the American National Standards Institute and appear in ANSI C37.2-1970. (See Ref. 4 of this section.)

Table 2-2 is a list of device numbers and functions as taken from this standard.

Table 2-1. Abbreviations

Abbr.	Description	Abbr.	Description
AM	Ammeter	S	Synchronous motor
AS	Ammeter switch	S/A	Surge arrester
Aux	Auxiliary	SS	Synchronizing switch
Bkr	Breaker	SYN	Synchroscope
CO	Cut off switch	SYN BR	Synchronizing bracket
CPT	Control power transformer	TD	Test device
CS	Control switch	VAR	Varmeter (one-line)
CT	Current transformer	VARM	Varmeter (device list)
FA	Field ammeter	VM	Voltmeter
FM	Frequency meter	VR	Voltage regulator
G	Generator	VS	Voltmeter switch
GS	Governor Switch	WHM	Watthour meter
I	Induction motor	WHDM	Watthour demand meter
PT	Potential transformer	WM	Wattmeter

Section 2

Table 2-2. ANSI Standard Device Function Numbers

Dev. No.	Function
1	Master Element
2	Time-Delay Starting or Closing Relay
3	Checking or Interlocking Relay
4	Master Contactor
5	Stopping Device
6	Starting Circuit Breaker
7	Anode Circuit Breaker
8	Control Power Disconnecting Device
9	Reversing Device
10	Unit Sequence Switch
11	Reserved for future application
12	Over-Speed Device
13	Synchronous-Speed Device
14	Under-Speed Device
15	Speed or Frequency Matching Device
16	Reserved for future application
17	Shunting or Discharge Switch
18	Accelerating or Decelerating Device
19	Starting-to-Running Transition Contactor
20	Electrically Operated Valve
21	Distance Relay
22	Equalizer Circuit Breaker
23	Temperature Control Device
24	Reserved for future application
25	Synchronizing or Synchronism-Check Device
26	Apparatus Thermal Device
27	Undervoltage Relay
28	Flame Detector
29	Isolating Contactor
30	Annunciator Relay
31	Separate Excitation Device
32	Directional Power Relay
33	Position Switch
34	Master Sequence Device
35	Brush-Operating or Slip-Ring Short-Circuiting Device
36	Polarity or Polarizing Voltage Device
37	Undercurrent or Underpower Relay
38	Bearing Protective Device
39	Mechanical Condition Monitor
40	Field Relay
41	Field Circuit Breaker
42	Running Circuit Breaker
43	Manual Transfer or Selector Device
44	Unit Sequence Starting Relay
45	Atmospheric Condition Monitor
46	Reverse-Phase or Phase-Balance Current Relay
47	Phase-Sequence Voltage Relay
48	Incomplete Sequence Relay
49	Machine or Transformer Thermal Relay
50	Instantaneous Overcurrent or Rate-of-Rise Relay
51	AC Time Overcurrent Relay
52	AC Circuit Breaker
53	Exciter or DC Generator Relay
54	Reserved for future application
55	Power Factor Relay
56	Field Application Relay
57	Short-Circuiting or Grounding Device
58	Rectification Failure Relay
59	Overvoltage Relay
60	Voltage or Current Balance Relay
61	Reserved for future application
62	Time-Delay Stopping or Opening Relay
63	Pressure Switch
64	Ground Protective Relay
65	Governor
66	Notching or Jogging Device
67	AC Directional Overcurrent Relay
68	Blocking Relay
69	Permissive Control Device
70	Rheostat
71	Level Switch
72	DC Circuit Breaker
73	Load-Resistor Contactor
74	Alarm Relay
75	Position Changing Mechanism
76	DC Overcurrent Relay
77	Pulse Transmitter
78	Phase-Angle Measuring or Out-of-Step Protective Relay
79	AC Reclosing Relay
80	Flow Switch
81	Frequency Relay
82	DC Reclosing Relay
83	Automatic Selective Control or Transfer Relay
84	Operating Mechanism
85	Carrier or Pilot-Wire Receiver Relay
86	Locking-Out Relay
87	Differential Protective Relay
88	Auxiliary Motor or Motor Generator
89	Line Switch
90	Regulating Device
91	Voltage Directional Relay
92	Voltage and Power Directional Relay
93	Field-Changing Contactor
94	Tripping or Trip-Free Relay
95	Used only for specific appli-
96	cations in individual installa-
97	tions where none of the
98	assigned numbered functions
99	from 1 to 94 are suitable.

System One-Line Diagram

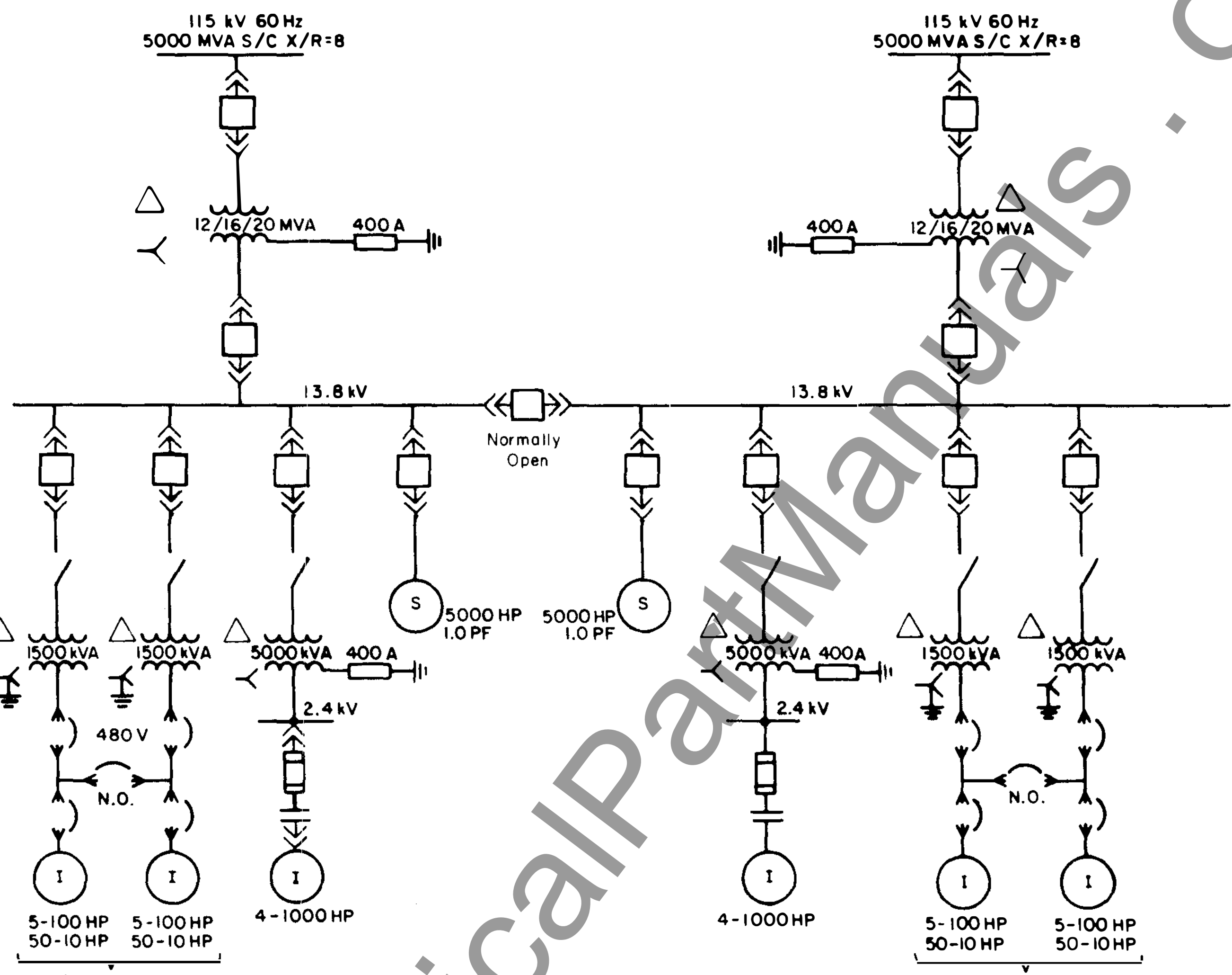


Figure 2-1. Preliminary one-line diagram.

PRELIMINARY ONE-LINE DIAGRAM

On this diagram (Figure 2-1) show:

- System voltage and major component ratings.
- Major medium-voltage cable lengths, sizes, and construction. (Not shown in example.)
- Approximate number and ratings of all motors.
- Supply system available short-circuit capability in symmetrical MVA (plus X/R ratio) or per unit R + jX (on a given base).

Using data on the one-line diagram, perform short-circuit calculations. (See Ref. 5 of this section.) From these calculations:

- Compare the calculated "first cycle" (momentary) asymmetrical current duty with the close and latch circuit breaker capability.
- Compare the calculated "1-1/2 to 4-cycle" (interrupting) current duty with the circuit breaker symmetrical interrupting capability. (See Ref. 3 of Section 3.)
- Determine the applicable circuit breaker ratings.
- Compare the feeder cable short-circuit heating limit with the maximum available short-circuit current times K_t times K_o. (See Ref. 10 and 12 of this section.)

Note that the calculations performed in accordance with Reference 5 determine only medium- and high-voltage circuit breaker ratings. Perform short-circuit studies to determine relay operating currents in accordance with procedures outlined in Reference 6. For other than power circuit breakers, refer to the appropriate ANSI standard for short-circuit calculation procedure.

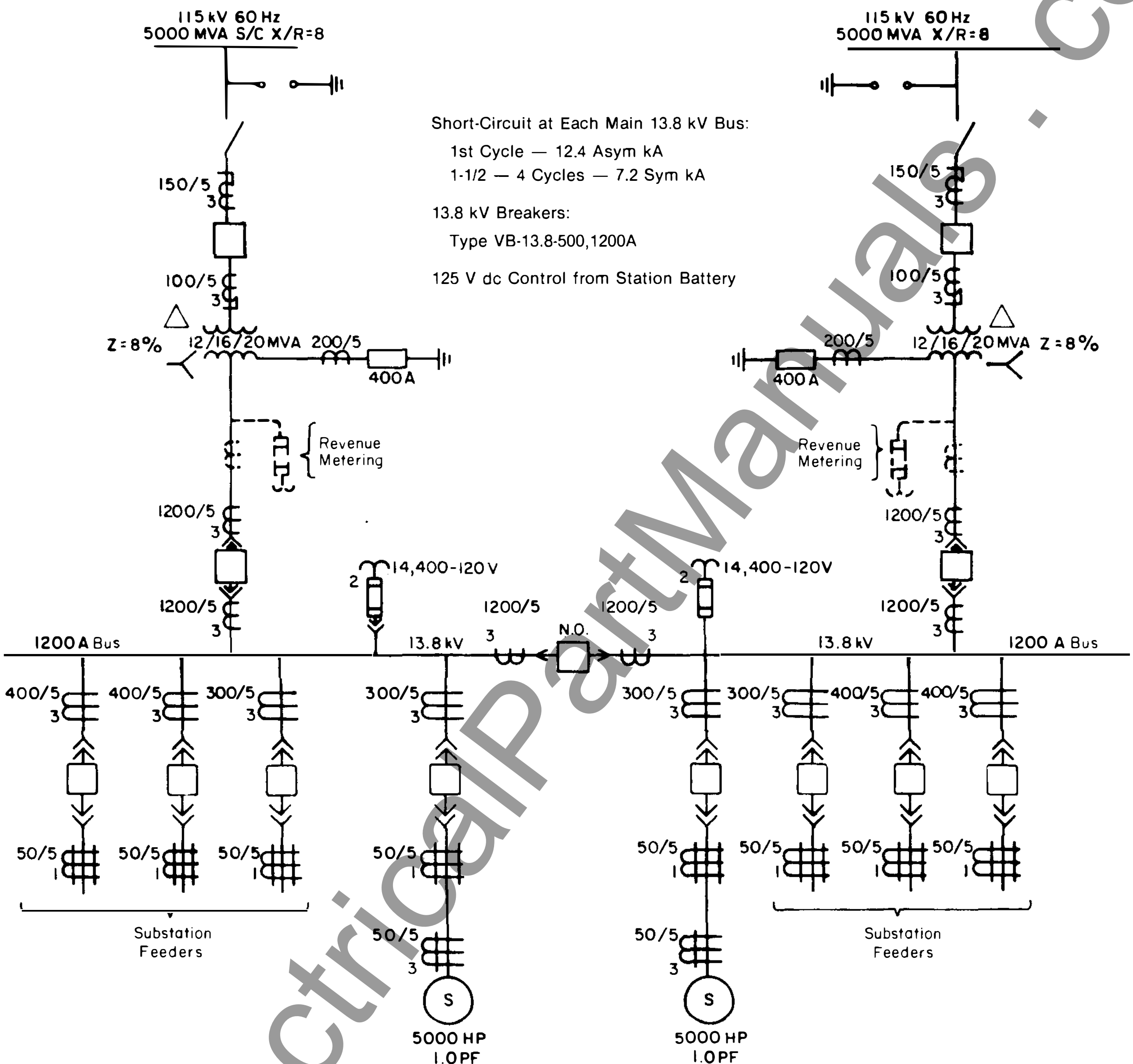


Figure 2-2. Partially developed one-line diagram.

PARTIALLY DEVELOPED ONE-LINE DIAGRAM

Using the sample system, a partially developed one-line diagram is shown in Figure 2-2. On this diagram, the specifier should:

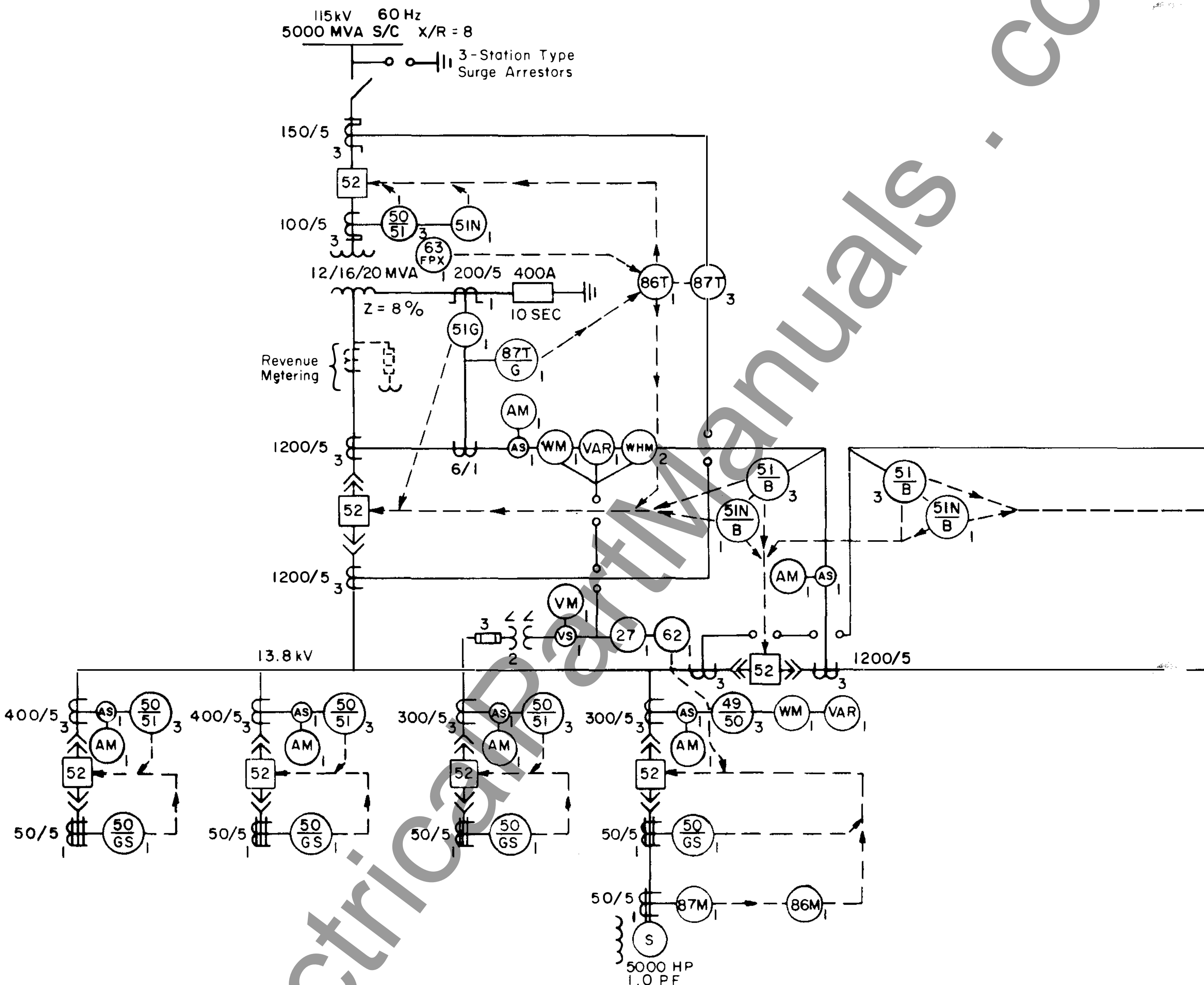
— Show the results of the short-circuit calculations performed, using the preliminary one-line diagram and selected circuit breaker ratings.

— Show ratings selected for external devices, such as grounding resistors, control power transformers, and batteries.

— Select tentative current transformer (CT) ratios in considering the maximum transformer ratings, motor ratings, and ampacity of the circuits involved. (See Section 5.)

— Locate current transformers and potential transformers, considering the type of protective relaying instrumentation and metering required.

System One-Line Diagram



DEVELOPED ONE-LINE DIAGRAM

A developed one-line diagram for the system is shown in Figure 2-3. In addition to the information shown on the partially developed one-line diagram, the specifier should:

— Show all relaying, instrumentation, and metering.

— Select relaying, instrumentation, and metering.

— Confirm the selection of relay ratings and characteristics by performing a complete system short-circuit and coordination study. (See Ref. 7 through 10 of this section.)

— Include in the study an examination of all circuits for compliance with applicable local and national codes. (See Ref. 11 of this section.)

— Verify that all circuit conductors are applied within the conductor short-circuit heating limit. (See Ref. 10 and 12 of this section.)

(General Electric, under special contract agreements, will perform power system studies, including the necessary calculations and comparisons.)

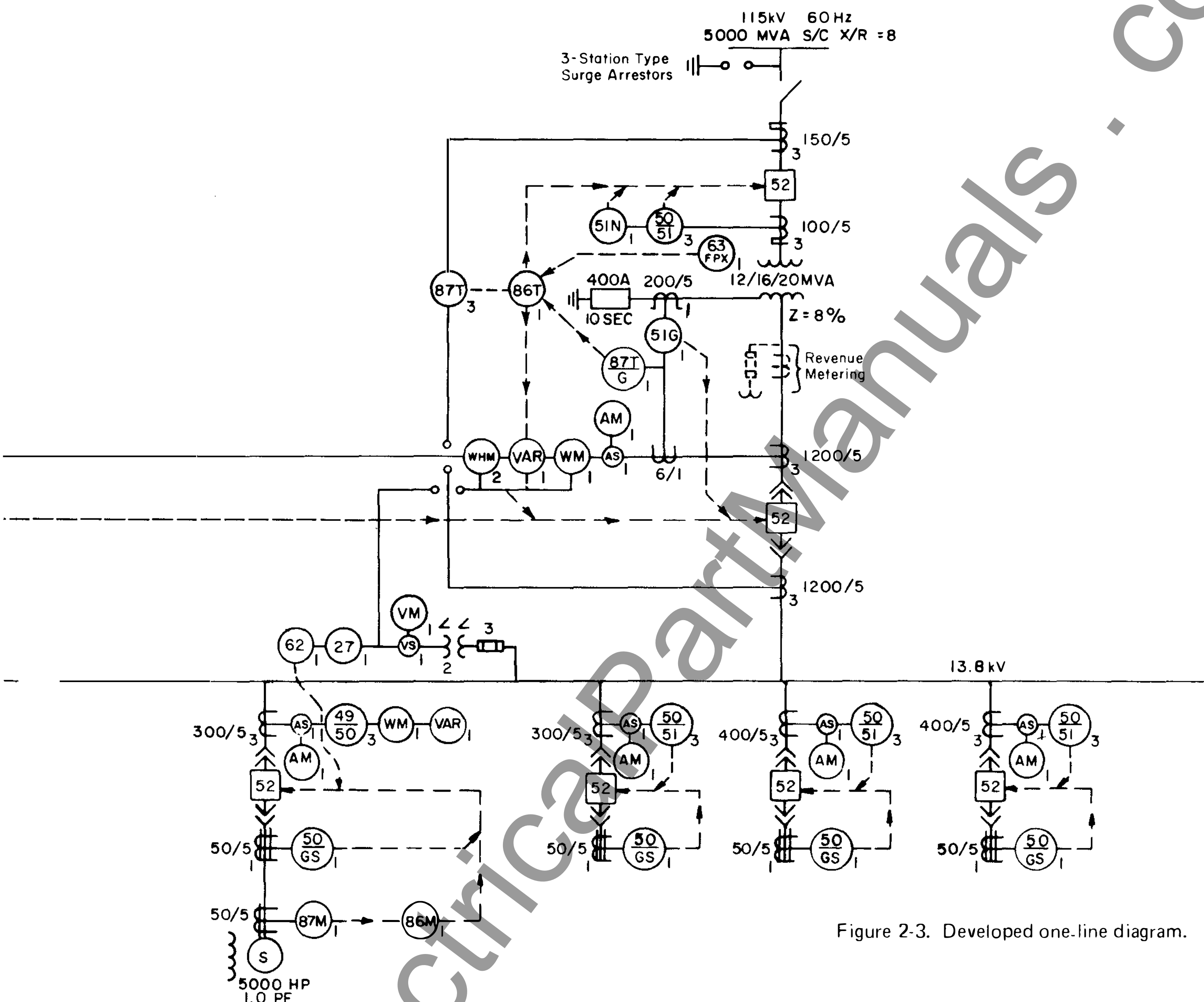


Figure 2-3. Developed one-line diagram.

PROTECTIVE RELAYS

50/51	Phase Time & Instantaneous Overcurrent Relay	87T/G	Transformer Ground Differential Relay
51N	Residually Connected Time Overcurrent Relay	86T	Transformer Lockout Relay
51G	Ground Time Overcurrent Relay	87M	Motor Differential Relay
50/GS	Ground Sensor Instantaneous Overcurrent Relay	86M	Motor Lockout Relay
51/B	Phase Time Overcurrent Relay	49/50	Motor Thermal & Instantaneous Relay
51N/B	Residually Connected Time Overcurrent Relay	27	Undervoltage Relay
87T	High Speed Transformer Differential Relay	62	Timer 0.5 to 5 seconds

ADAPTING ONE-LINE DIAGRAM TO EQUIPMENT

Figure 2-4 shows two possible arrangements of two-high metalclad switchgear as developed from the one-line diagram in Figure 2-3. Both save space when compared to air-magnetic metalclad switchgear, and both permit the addition of future units on either end.

The arrangements shown are not the only ones which can be developed to satisfy the conditions of the one-line diagram.

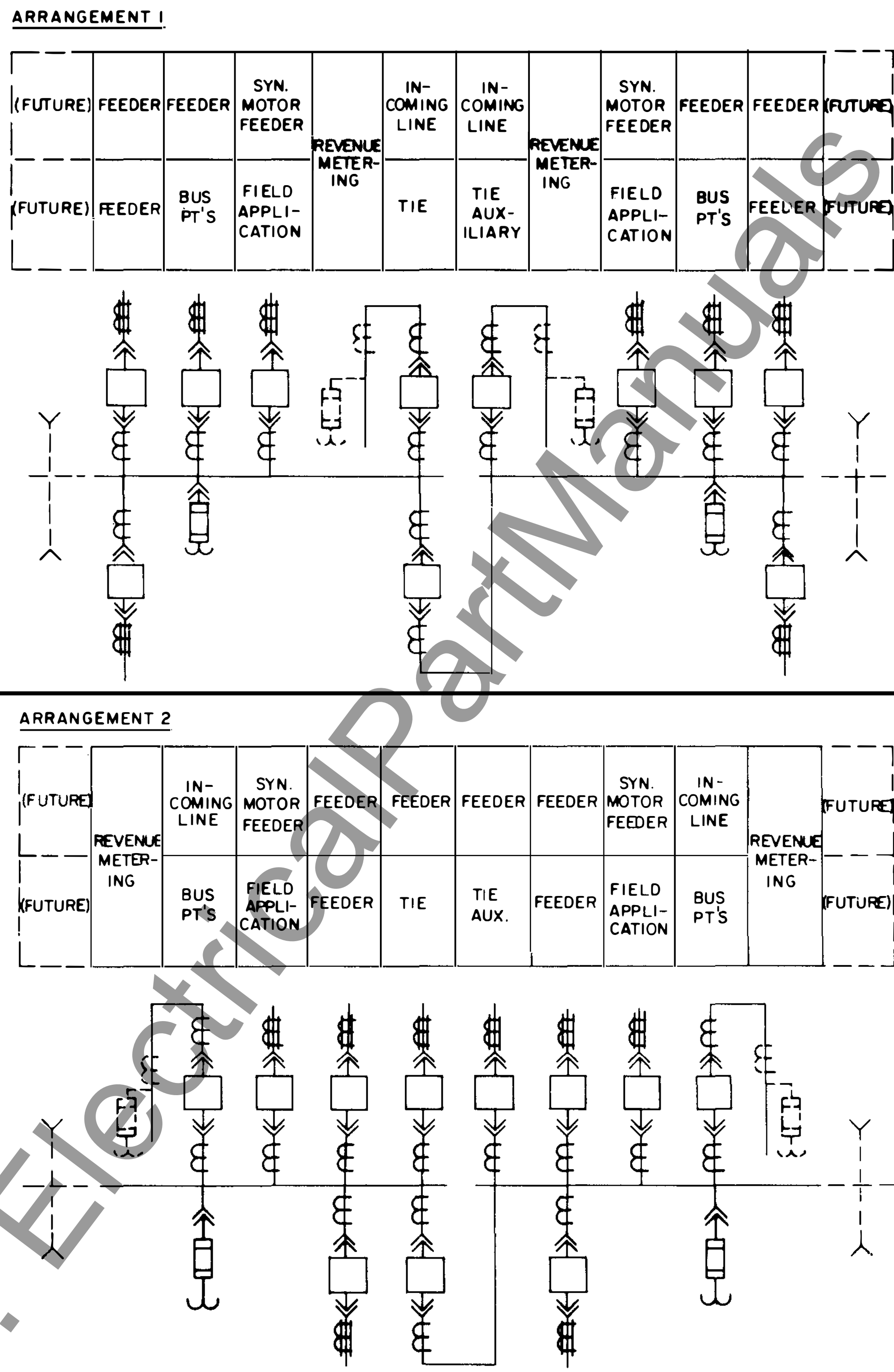


Figure 2-4. Two possible arrangements of metalclad switchgear, using OEM switchgear components and POWER/VAC® breakers.

System One-Line Diagram

REFERENCES

	Standards ANSI Standard	IEEE Standard	Title
1.	C42.100-1977	100-1977	IEEE Standard Dictionary of Electrical and Electronic Terms.
2.	Y32.2-1975	315-1975	Graphic Symbols for Electrical and Electronic Diagrams.
3.	Y14.15-1966 (R1973)	—	Electrical and Electronics Diagrams.
4.	C37.2-1979	—	Electrical Power System Device Function.
5.	C37.010-1979	—	Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
6.	C37.95-1974	357-1973	IEEE Guide for Protective Relaying of Utility-Consumer Interconnections.
7.	—	141-1969	Electric Power Distribution for Industrial Plants.
8.	—	142-1972	IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.
9.	—	241-1974	IEEE Recommended Practice for Electric Power Systems in Commercial Buildings.
10.	—	242-1975	IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.

Codes

11. 1981 National Electrical Code — NFPA Publication 70-1981.

Books

12. Industrial Power Systems Handbook — D.L. Beeman, Editor McGraw-Hill Book Co., 1955.

Publications

13. GEA-11345 — General Electric OEM Metalclad Switchgear Components.

Standards may be purchased from:

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018

Institute of Electrical and Electronics Engineers, Inc.
Service Center
445 Hoes Lane
Piscataway, NJ 08854

National Electrical Manufacturers Association
Publication Department
2101 L St. N.W.
Washington, D.C. 20037

National Fire Protection Association
470 Atlantic Avenue
Boston, MA 02210

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Section 3

Circuit Breaker Selection

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Circuit Breaker Selection

INTRODUCTION

A circuit breaker's function and intended use are established in ANSI-C-37.100-1972, Definitions for Power Switchgear, which defines a circuit breaker as:

"A mechanical switching device, capable of making, carrying, and breaking currents under normal circuit conditions and also, making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short-circuit."

In addition, it is noted that a circuit breaker is intended usually to operate infrequently, although some types are suitable for frequent operation.

A circuit breaker is applied generally to carry and switch load current and to interrupt short-circuit current when required. The application process is simple: each of the duty requirements is specified or calculated and is then compared to the corresponding capability of the circuit breaker. The fundamental rule for selection of the proper circuit breaker is that the ratings or related capabilities of the circuit breaker must equal or exceed each of the calculated or specified duty requirements of the circuit in which it is applied.

Circuit characteristics which must be defined and compared to the circuit breakers' capabilities (given in Table 3-1) are:

- Circuit voltage
- System frequency
- Continuous current
- Short-circuit current
- Closing and latching current

In addition, certain special application conditions can influence circuit breaker selection. Special applications include the following:

- Repetitive switching duty (except arc furnace)
- Automatic reclosing
- Arc furnace switching
- Reactor switching
- Capacitor switching
- Fast bus transfer
- Unusual service conditions

This section of the *Application Guide* provides specific parameters and guidelines for circuit breaker selection and application. Specifically, those circuit parameters and special applications noted in the preceding paragraph are addressed.

CIRCUIT BREAKER RATINGS

POWER/VAC circuit breaker ratings are shown in Table 3-1. Interrupting ratings are for 60-Hz applications. For more complete information concerning service conditions, definitions, and interpretation of ratings, tests, and qualifying terms, refer to the applicable ANSI and NEMA standards listed in Table 1-1.

SELECTION CONSIDERATIONS

Application of the proper circuit breaker requires a definition of its duty requirements, which can then be compared with the choice of a circuit breaker using the ratings and capabilities shown in Table 3-1. It is recommended that ANSI Standard C37.010 (see Ref. 2 of this section) be consulted for guidance in proper determination of duty requirements.

Circuit characteristics which must be considered are discussed in the following paragraphs.

CIRCUIT VOLTAGE

The nominal voltage classes of medium-voltage metalclad switchgear are 4.16 kV, 7.2 kV and 13.8 kV. Switchgear may be applied at operating voltages from 2400 volts through 13,800 volts, provided the maximum circuit operating voltage does not exceed the POWER/VAC circuit breaker rated maximum voltage.

POWER/VAC® power circuit breaker characteristics

SYMMETRICAL RATING BASIS ANSI C37.06

Identification (6&7)*		Rated Values								Related Required Capabilities			
		Voltage		Insulation Level		Current					Current Values		
				Rated Withstand Test Voltage							Maximum Symmetrical Interrupting Capability (5)	3 Sec Short-time Current Carring Capability	
Nominal rms Voltage Class (kV)	Nominal 3-phase Class (MVA)	Rated Maximum rms Voltage (kV) (1)	Rated Voltage Range Factor, K (2)	Low Frequency rms Voltage (kV)	Crest Impulse Voltage (kV)	Continuous rms Current Rating at 60 Hz (amperes)	Short-circuit rms Current Rating (at Rated Max kV) (kA) (3) (4)	Rated Interrupting Time (Cycles)	Rated Permissable Tripping Delay, Y (Seconds)	Rated Maximum rms Voltage Divided by K (kV)	K Times Rated Short-circuit rms Current		Closing and Latching Capability rms Current (kA)
											(kA)	(kA)	
† 4.16	250	4.76	1.24	19	60	1200	29	5	2	3.85	36	36	58
† 4.16	250	4.76	1.24	19	60	2000	29	5	2	3.85	36	36	58
4.16	250	4.75	1.24	19	60	3000	29	5	2	3.85	36	36	58
4.16	350	4.76	1.19	19	60	1200	41	5	2	4.0	49	49	78
4.16	350	4.76	1.19	19	60	2000	41	5	2	4.0	49	49	78
4.16	350	4.76	1.19	19	60	3000	41	5	2	4.0	49	49	78
7.2	500	8.25	1.25	36	95	1200	33	5	2	6.6	41	41	66
7.2	500	8.25	1.25	36	95	2000	33	5	2	6.6	41	41	66
7.2	500	8.25	1.25	36	95	3000	33	5	2	6.6	41	41	66
†13.8	500	15	1.30	36	95	1200	18	5	2	11.5	23	23	37
†13.8	500	15	1.30	36	95	2000	18	5	2	11.5	23	23	37
13.8	500	15	1.30	36	95	3000	18	5	2	11.5	23	23	37
13.8	750	15	1.30	36	95	1200	28	5	2	11.5	36	36	58
13.8	750	15	1.30	36	95	2000	28	5	2	11.5	36	36	58
13.8	750	15	1.30	36	95	3000	28	5	2	11.5	36	36	58
13.8	1000	15	1.30	36	95	1200	37	5	2	11.5	48	48	77
13.8	1000	15	1.30	36	95	2000	37	5	2	11.5	48	48	77
13.8	1000	15	1.30	36	95	3000	37	5	2	11.5	48	48	77

† Breaker is type VB1

*Numbers in parenthesis refer to the notes, below.

1. Maximum voltage for which the breaker is designed and the upper limit for operation.

2. K is the ratio of rated maximum voltage to the lower limit of the range of operating voltage in which the required symmetrical and asymmetrical interrupting capabilities vary in inverse proportion to the operating voltage.

3. To obtain the required symmetrical interrupting capability of a circuit breaker at an operating voltage between 1/K times rated maximum voltage and rated maximum voltage, the following formula shall be used:

Required Symmetrical Interrupting Capability =

$$\text{Rated short-circuit Current} \times \frac{\text{(Rated Max. Voltage)}}{\text{(Operating Voltage)}}$$

For operating voltages below 1/K times rated maximum voltage, the required symmetrical interrupting capability of the circuit breaker shall be equal to K times rated short-circuit current.

4. With the limitation stated in 5.10 of ANSI-C37.04 1979, all values apply for polyphase and line-to-line faults. For single phase-to-ground faults, the specific conditions stated in 5.10.2.3 of ANSI-C37.04-1979 apply.

5. Current values in this column are not to be exceeded even for operating voltages below 1/K times rated maximum voltage. For voltages between rated maximum voltage and 1/K times rated maximum voltage, follow (3) above.

In accordance with ANSI-C37.06, users should confer with the manufacturer on the status of various circuit breaker ratings.

6. General Electric POWER/VAC circuit breakers are designated as type VB–"KV"–"MVA" or type VB1—"KV"—"MVA".

7. NOTE: General Electric reserves the right to improve the design and/or modify the specifications in this publication without notice.

Circuit Breaker Selection

SYSTEM FREQUENCY

The frequency rating of metalclad switchgear should coincide with the nominal frequency of the power system and is available in 60-Hz and 50-Hz ratings.

SHORT-CIRCUIT CURRENT

Quick interruption of short-circuit current is usually considered the primary function of a circuit breaker. The fault-current interrupting capability of POWER/VAC® circuit breakers is stated in three-phase, symmetrical, rms ac amperes. Accordingly, calculation of the maximum available fault duty of a circuit breaker assumes a three-phase bolted fault.

After calculation of short-circuit current duty, choose a POWER/VAC breaker which has a short-circuit current capability that equals or exceeds the expected duty, and, remember to consider the circuit operating voltage when evaluating the circuit breaker's interrupting capability. For example: at 4160 volts, a 4.16 kV — 350 MVA-class circuit breaker with a rated short-circuit current of 41 kA at a maximum rated voltage of 4.76 kV has an interrupting capability of $41 \text{ kA} \times \frac{4.76 \text{ kV}}{4.16 \text{ kV}} = 47 \text{ kA}$ symmetrical rms current. But at 2.4 kV, the interrupting capability is 49 kA, the maximum symmetrical interrupting capability listed in the rating tables, because 2.4 kV is less than 4.76 kV/"k" = 4.76/1.19 = 4.0 kV. (See footnote No. 5, Table 3-1).

CLOSING AND LATCHING CURRENT

Circuit breakers are designed to stay latched, or to close and latch, against a first-cycle maximum asymmetrical rms current of 1.6 times the maximum symmetrical rms interrupting capability of the circuit breaker. Ordinarily this close and latch capability is satisfactory for most applications. There are some applications, however, in which the calculated[2] rms value of first-cycle asymmetrical short-circuit current exceeds the closing and latching capability of the circuit breaker. Applications which include a large motor load are a typical example. In these cases, breaker selection may depend on closing and latching capability rather than symmetrical short-circuit capability. The breaker selected might have the next-higher short-circuit current capability or it might have a higher-than-standard closing and latching capability.

CONTINUOUS CURRENT

Feeder and main breaker loading determine required continuous current duty. For continuous loads, select a POWER/VAC breaker with rated continuous current (defined at 60-Hz) equal to or greater than load current.

Note that circuit breakers have no continuous overload rating. When considering circuit breaker application with a generator, a motor, a transformer, or other apparatus having a long-time overload rating, the circuit breaker (and switchgear equipment) must have a continuous-current rating at least equal to the overload rating of the served apparatus. When applied with a forced-cooled transformer, the switchgear continuous-current rating must equal or exceed the transformer forced-cooled current rating.

Circuit breakers may be operated, for short periods, in excess of rated continuous current. This covers such operations as starting motors or energizing cold loads.

SPECIAL SWITCHING APPLICATIONS

Application of power circuit breakers for switching duty may require derating of the circuit breaker. Particular attention should be given to breakers intended for use in any of the following switching applications:

- Repetitive switching (except arc furnace)
- Automatic reclosing
- Arc furnace switching
- Reactor switching
- Capacitor switching
- Fast bus transfer

For these applications, the usual practice is to first select a circuit breaker based on the criteria provided under "SELECTION CONSIDERATIONS" of this section. Then, consider the switching duty and, if necessary, redetermine the circuit breaker capabilities (continuous-current rating, interrupting rating, etc.), and factor in any modified operating or maintenance requirements. Recheck the circuit breakers' evaluated capabilities against all the basic duty requirements under "SELECTION CONSIDERATIONS".

If the circuit breaker selected initially, and as derated (or otherwise modified), no longer meets the duty requirements of the application, choose the next-higher rated breaker. Repeat the derating or rating adjustment process to confirm that the new breaker has adequate capability.

REPETITIVE SWITCHING (EXCEPT ARC FURNACE)

POWER/VAC® circuit breakers can be applied on most power circuits without attention to frequency of operation, since highly repetitive switching duty is uncommon. Typical switching duties include motor starting, switching of distribution circuits, transformer magnetizing current, and other miscellaneous load-current switching. While magnitude of current switched in these applications can vary from very light load to the maximum permissible for a particular circuit breaker, switching is generally infrequent; thus, no derating is required.

Standard POWER/VAC circuit breakers may be operated as often as 20 times in 10 minutes or 30 times in one hour without derating for switching duty. Further frequency of operation capabilities are given in Table 3-2. When operated under usual service conditions and for other than arc furnace switching, standard POWER/VAC circuit breakers are capable of operating the number of times shown in the table. Operating conditions, servicing requirements and permissible effects on the breakers are specified in the notes under the table.

AUTOMATIC RECLOSING

When POWER/VAC circuit breakers are used for automatic reclosing duty to maintain service continuity, they must be derated in accordance with standard capability factors[1]. These apply to all high-voltage circuit breakers rated up to 72.5 kV.

All POWER/VAC circuit breakers may be used for reclosing duty. Certain system conditions such as large motors connected to the bus or electrically close generators may prohibit reclosing.

Capability factors for POWER/VAC circuit breakers used in automatic reclosing duty applications are shown in Figures 3-1 and 3-2. To ensure proper determination of POWER/VAC circuit breaker capabilities in reclosing applications, use this step-by-step calculating procedure.

Calculation of Reclosing Capabilities

- A duty cycle shall not contain more than five opening operations.
- All operations within a 15-minute period are considered part of the same duty cycle.
- The circuit breaker may be applied, at the determined operating voltage and duty cycle, to a circuit for which the calculated short-circuit current does not exceed the symmetrical interrupting capability, as determined by the following procedure.
- If the X/R ratio for the circuit exceeds 15, refer to ANSI-C37.010 for guidance.

Procedure

Step 1 — Determine the breaker symmetrical interrupting capability at the operating voltage from Table 3-1 (Note 3).

Table 3-2. Repetitive Duty and Normal Maintenance for POWER/VAC® Breakers Used in Mild Environments for Other than Arc Furnace Switching

Breaker Type	Breaker Continuous Rating — Amps	Maximum No. of Operations Before Servicing	Number of Operations (Each = 1 Close Plus 1 Open Operation): No-Load Mechanical	Continuous Current Switching	Inrush-Current Switching
Column 1		Column 2	Column 3	Column 4	Column 5
		A. Servicing consists of adjusting, cleaning, lubricating, changing parts, as recommended by the Company. The operations listed are on the basis of service in a mild environment.	B. Close and trip, no-load.	C. Close and trip within rated current, rated maximum voltage and 80% PF or greater.	D. Closing 600% of rated current or less at no less than 30% PF. Otherwise, same as C.
			E. Rated control voltage.	E. Applies.	E. Applies.
			F. Frequency of operation not more than 20 in 10 minutes or not more than 30 in 1 hour.	F. Applies	F. Applies.
			G. Servicing at intervals given in Column 2.	G. Applies.	G. Applies.
			H. No parts replacement.	H. Applies.	H. Applies.
			I. Breaker meets all current, voltage, interrupting current ratings.	I. Applies.	I. Applies.
				J. At the first servicing interval, the amount of vacuum interrupter contact erosion should be used to estimate the additional life at that continued duty.	J. Applies.
				K. After 15 full short circuit faults check the contact erosion.	K. Applies.
All	All	10,000 or 10 years	10,000 minimum	10,000	10,000

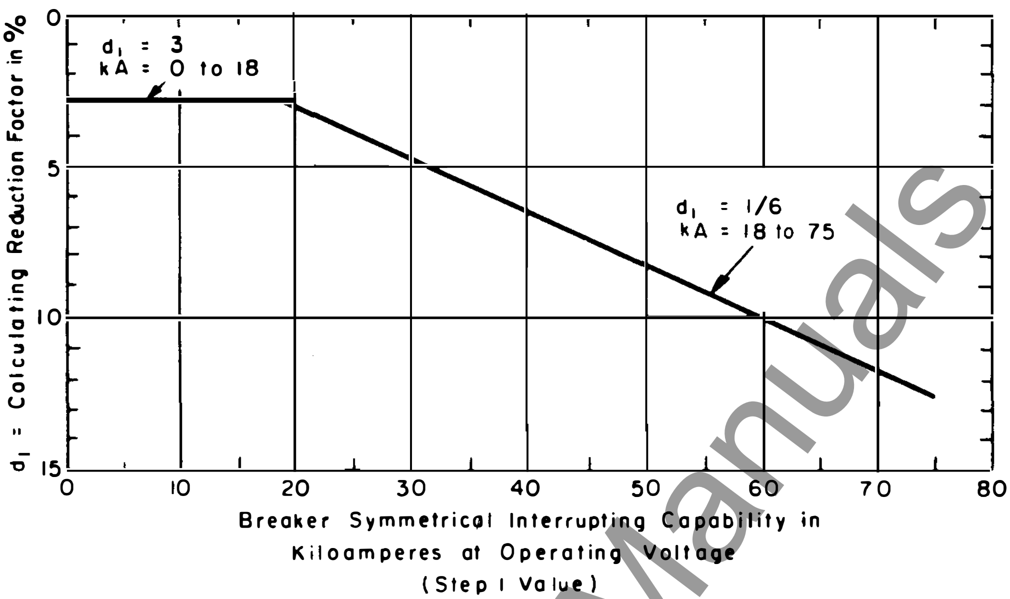

Figure 3-1. Reclosing capability curve for determining d_1.

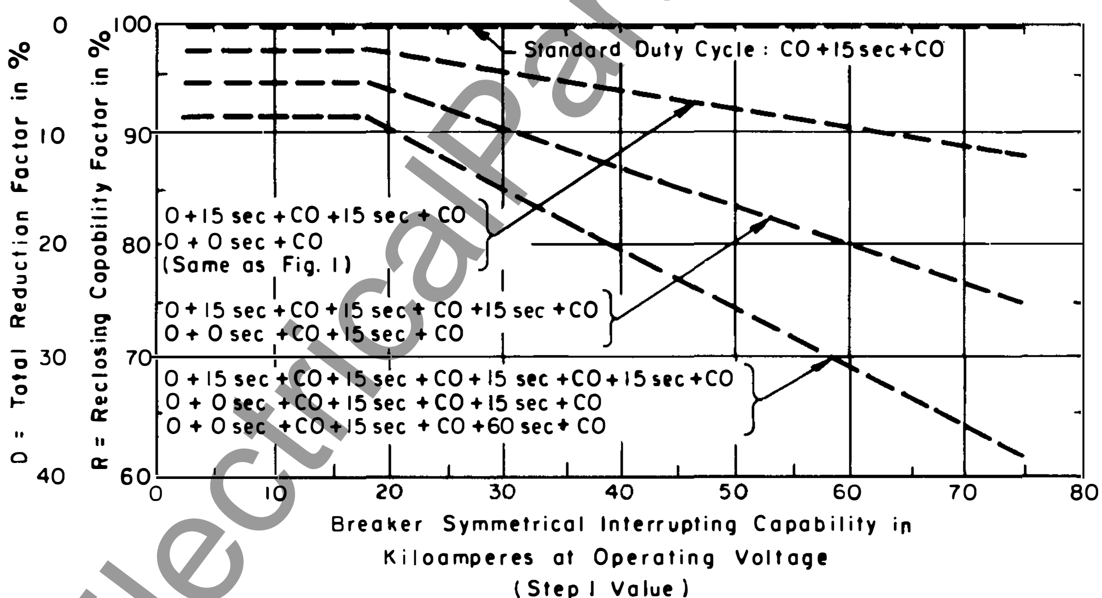

Figure 3-2. Reclosing capability factor curves for typical duty cycles.

Step 2 — Determine the factor d_1 from the reclosing capability curve in Figure 3-1 for the current value determined in Step 1.

Step 3 — Determine the factor D from the following equation:

$$D = d_1 (n-2) + d_1 \frac{(15-t_1)}{15} + d_1 \frac{(15-t_2)}{15} + \ldots + d_1 \frac{(15-t_n)}{15}$$

where:

D = total reduction factor (in percent).

d_1 = calculating factor for D in percent of breaker symmetrical interrupting capability at operating voltage.

n = total number of openings in duty cycle.

t_1 = duration (in seconds) of first time interval between operations that is less than 15 seconds.

t_2 = duration (in seconds) of second time interval between operations that is less than 15 seconds.

t_n = duration in n^{th} time interval . . .

Step 4 — Calculate the reclosing capability factor (R) in percent where:

R = 100 minus D

For some typical duty cycles, R can be determined directly from the appropriate curves in Figure 3-2.

Step 5 — The revised symmetrical interrupting capability of the circuit breaker for the operating voltage and duty cycle desired is now determined by multiplying the Step 1 symmetrical interrupting capability by R, as determined in Step 4.

ARC FURNACE SWITCHING

Arc furnace switching duty is more repetitive than normal switching duty. The circuit breaker is applied on the primary side of a relatively high-impedance transformer and the usual duty is frequent switching (50 to 100 times per day) of the transformer magnetizing current. Switching is required when the transformer is de-energized for tap changing, when taking melt samples, or when adding alloys. In addition to this switching duty, transformer through-faults must occasionally be interrupted.

REACTOR SWITCHING

Consult the factory or nearest sales office for information on reactor switching.

CAPACITOR SWITCHING

Capacitor banks are generally applied on both utility and industrial power systems to improve voltage regulation and system stability. POWER/VAC® circuit breakers are applicable to shunt-capacitor-bank switching in accordance with the capabilities listed in Table 3-3.

Shunt-bank capacitor switching means one breaker feeding one 3-phase capacitor bank. If this circuit is closely paralleled by another switched capacitor bank, see the notes of Table 3-3.

Table 3-3. POWER/VAC Circuit Breaker Capacitor Switching Capability

Breaker VB-1	Capacitor Voltage	Capability for 1200A, 2000A, and 3000A continuous current rated POWER/VAC circuit breakers General Purpose circuit breaker	
		Capacitor Switching Capability (Amperes)	Equivalent Capacitor Bank Rating (kvar*)
4.16-250	2400 4160	400 400	1200 2100
1.38-500	12470 13800	250 250	4000 4400

*Maximum three-phase, single capacitor bank, nameplate kvar, including required multiplying factor of 1.35.

Footnotes: The capacitor-bank rating is subject to the following conditions:

1. The transient voltage from line to ground shall not exceed 3 times maximum design line-to-ground crest voltage measured at the breaker terminals.
2. The number of restrikes or reignitions shall not be limited as long as the transient voltage to ground does not exceed the value given in Footnote 1.
3. The capacitor bank rating applies only to single bank switching as noted herein.
4. Interrupting time is in accordance with the rated interrupting time of the circuit breaker.
5. For capacitor switching capability of breakers having Definite-Purpose Capacitor Switching capability (higher than General Purpose rating and or Back-to-Back Switching) please contact the factory.

FAST BUS TRANSFER

Fast bus transfer is normally used for transferring a generating station auxiliary bus to an emergency power source upon failure of the normal source of power. During this transfer it is essential that bus "dead time" be as short as possible to prevent loss of critical auxiliary functions. "Fast" transfer means there is no intentional time delay in the transfer of a bus or load from one source of power to another. POWER/VAC® circuit breakers with stored-energy closing meet the critical requirements for fast transfer.

The preferred circuit breaker operation sequence used to achieve fast transfer consists of giving a trip signal to the opening breaker. Then a "b" contact (open when the breaker contacts are closed) on the opening breaker initiates closing of the second breaker. The amount of dead time depends upon whether the POWER/VAC breaker is standard or is provided with a special early "b" (faster) contact and special closing coil.

Typical dead times for fast transfer, using standard and special POWER/VAC breakers, are shown in Table 3-4.

Table 3-4. Typical Dead-Times Using POWER/VAC Circuit Breakers

Power/Vac Breakers	Control Voltage	Dead Bus Times (milliseconds) Trip then close using standard "b" contact	
		No Arching (1)	With Arching (2)
VBI Ratings	All — See 4-2	100	88

Footnotes:
(1) Main contact parting to main contact making.
(2) End of arcing to main contact making.
NOTE: For "fast transfer" breakers refer to factory.

SERVICE CONDITIONS

POWER/VAC breaker and OEM component ratings and capabilities are based on operation under certain defined service conditions, defined as "usual". Conditions other than usual are called "unusual". Factors used to classify service conditions are altitude, ambient temperature, and a variety of others, such as the presence of atmospheric contaminants, unusual storage conditions, and requirements for tamper-resistance. These factors are specified for circuit breakers in ANSI-C37.04-1979 (Circuit Breaker Rating Structure) and for equipment in ANSI-C37.20.2-1983 (Switchgear Assemblies), and are summarized here for application guidance.

Application of POWER/VAC circuit breakers under conditions other than "usual" may require derating, special construction or use of special protective features.

USUAL SERVICE CONDITIONS

POWER/VAC circuit breakers (and switchgear components) are suitable for operation at their standard nameplate ratings:

- Where ambient temperature is not above 40 C or below −30 C (104 F and −22 F)
- Where the altitude is not above 3300 feet (1000 meters).

  NOTE: For switchgear assemblies (breakers and housings combined) there is one additional stipulation:
- Where the effect of solar radiation is not significant. (See Ref. 5 of this section.)

UNUSUAL SERVICE CONDITIONS

Abnormal Temperature

The planned use of POWER/VAC circuit breakers or switchgear components at other than normal ambient temperatures (+40 C to −30 C) shall be considered as special. Such applications should be referred to the nearest General Electric Sales Office for evaluation.

High Altitude

POWER/VAC circuit breakers and switchgear components utilize air for an insulating and cooling medium. Operation at altitudes above 1000 meters will result in a higher temperature rise and lower dielectric strength because the air is thinner. Thus, certain circuit breaker and switchgear capabilities must be corrected to adjust for high-altitude operation.

For operation of POWER/VAC® circuit breakers and switchgear components at altitudes above 1000 meters, the basic impulse insulation level (BIL) and the rated continuous current shall each be multiplied by the appropriate correction factors shown in Table 3-5.

Table 3-5. Altitude Correction Factors for POWER/VAC Circuit Breakers and Switchgear Components

Altitude (feet)	Rating Correction Factor*	
	Rated Continuous Current	Insulation Level
3,300 (and below)	1.00	1.00
5,000	0 99	0.95
10,000	0.96	0.80

Footnote:
*Values for intermediate altitudes may be determined by linear interpolation.

For proper application, the derated values should equal or exceed the duty requirements of the application. Short circuit current ratings and rated operating voltage are not affected.

Other Unusual Conditions

Besides abnormal temperature and high altitude there are other unusual service conditions which may require special protecting features or affect construction. Some of these are:

- Exposure to corrosive vapors, explosive fumes, excessive dust or dirt, salt spray, steam, dripping water, and other similar conditions.
- Exposure to abnormal vibration, shock, unusual transportation, or special storage conditions.
- Installations accessible to the general public.

BREAKER MOUNTED ACCESSORIES

Each breaker and its equipment skeleton will be equipped with Rating Interference blocks so that only the proper rated breaker can be inserted into the equipment breaker cubicle.

A four-stage auxiliary switch is furnished on every POWER/VAC circuit breaker. Three contacts are used for the close-and-trip circuits, leaving two "a" and three "b" contacts for Purchaser use. Additional switch stages are not available on the breaker. They must be provided using an auxiliary switch stationary-mounted on the equipment.

REFERENCES

1. ANSI Standard C37.06-1979, Schedules of Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
2. ANSI Standard C37.010-1979, Application Guide for AC High Voltage Circuit Breakers.
3. ANSI Standard C37.04-1979, Circuit Breaker Rating Structure.
4. ANSI Standard C37.20.2-1983, Switchgear Assemblies.
5. ANSI Standard C37.24-1971, Guide for Evaluating the Effect of Solar Radiation on Outdoor Metalclad Switchgear.
6. ANSI Standard C37.07-1969 (R-1976), Interrupting Capacity Factors for Reclosing Service for AC High Voltage Circuit Breakers.

Contents

Section 4

Control Power Equipment

Control Power Equipment

INTRODUCTION

This section of the Application Guide addresses specific control power requirements and provides guidance in selecting the proper type of control power equipment.

CONTROL POWER REQUIREMENTS

Equipment necessary to provide control power for metalclad switchgear must have sufficient capacity to deliver the maximum power required, at the proper voltage, under any operating condition.

The most important consideration in selecting a control power source is that it must provide tripping power for the circuit breakers during protective relay operation. Also, it should be capable of closing the breakers without direct manual operation. Other requirements can include:

DC	AC
Indicating lamps	Indicating lamps
Emergency lights	Equipment heaters
Emergency motors	Equipment lights and convenience outlets
Excitation power (brushless motors, etc.)	Excitation power (brushless motors, etc.)
	Equipment ventilating fans
	Remote lights (on structures, etc.)

All of these requirements must be considered in determining the type and rating of the control power source.

Sources of control power for metalclad switchgear are storage batteries (with charger) for dc control, and transformers for ac control. When ac is used for closing, the tripping power must be obtained from capacitors fed from rectified ac, or from a "tripping only" battery. The choice between these alternatives depends on factors such as the size of the switchgear installation, the need to operate breakers simultaneously, the degree of reliability required, expansion plans, the expected environmental conditions, maintenance support availability, and the economics related to these considerations.

CLOSING AND TRIPPING

Successful operation of metalclad switchgear depends on a reliable source of control power which will, at all times, maintain a voltage at the terminals of electrically operated devices within the rated operating voltage range. In general, the operating voltage range of a switchgear equipment is determined by the rated operating voltage range of the circuit breaker. These ranges, as established by NEMA standards, are given in Table 4-1.

Operating currents for POWER/VAC® circuit breakers are given in Table 4-2.

Table 4-1. Standard Control Voltage and Operating Ranges for POWER/VAC Circuit Breakers

Nominal Control Voltage	Operating Range (Volts)	
	Stored-energy Mechanism	
Volts	Spring Motor and Closing Spring Release Coil	Tripping Coil
DC 48	38-56	28-56
DC 125	100-140	70-140
DC 250	200-280	140-280
AC (60 Hz) 120	104-127	not available in POWER/VAC
AC (60 Hz) 240	208-254	

Table 4-2.
Operating Currents of POWER/VAC® Circuit Breakers

Type of Breaker	Closing Curent (Amperes)										Tripping Current* (Amperes)		
	At 48 Volts DC		At 125 Volts DC		At 250 Volts DC		At 120 Volts AC		At 210 Volts AC		At 48 Volts DC	At 125 Volts DC	At 250 Volts DC
	Closing Spring Release Coil	Spring Motor	Closing Spring Release Coil	Spring Motor	Closing Spring Release Coil	Spring Motor	Closing Spring Release Coil	Spring Motor	Closing Spring Release Coil	Spring Motor			
VB-4.16-250 VB-4.16-350 VB-7.2-500 VB-13.8-500 VB-13.8-750 VB-13.8-1000	8.0	12.3	6	3.7	2.2	2.3	8	8	4	5	19.0	10.0	4.5
VB1-4.16-250 VB1-13.8-500	6.9	12.0	3.4	4.5	1.6	2.5	12.0	4.5	10.0	2.5	17.0	7.3	4.7

*Fuses for the tripping circuit should have an ampere rating of at least 2 times the tripping current and not less than 35 amperes.

Breaker Tripping

POWER/VAC circuit breakers are provided with means for manual tripping (push button) and for electrically actuated tripping (trip coil). Electrically actuated tripping devices are used for two functions:

- As a means of opening the breaker in the process of normal switching operations initiated by an operator, or
- As a means of automatically opening the breaker for circuit protective purposes, under abnormal conditions.

Electrical tripping is accomplished when external power, from a battery or from a rectified ac source (with capacitor), is directed into the breaker trip coil. Normal switching tripping uses an operator control switch. Automatic tripping occurs when a contact on a protective relay closes, actuated by power circuit instrument transformers.

When deciding between dc battery trip and ac capacitor trip, the following points must be considered:

- For a single breaker, or a few breakers, the capacitor trip device has lower cost than a battery, but a trip device is required for each breaker.
- A battery source is more reliable, but requires more maintenance than a capacitor trip device.
- If a battery is used for tripping, dc closing power can also be obtained for little additional cost.

DC BATTERY TRIP — When properly maintained, a battery offers the most reliable tripping source. It requires no auxiliary tripping devices, and uses single-contact relays which directly energize a single trip coil in the breaker. Power circuit voltage and current conditions during time of faults do not affect a battery-trip supply; therefore, it is considered the best source for circuit breaker tripping. Additional advantages are that, usually, only one battery is required for each location, and it may be used to operate other equipment such as high-voltage circuit breakers or protective grounding switches.

Once a battery has been selected for tripping purposes, it can, after proper evaluation of additional loads, also be used for breaker closing power. For indoor applications, if the battery can be located close to the switchgear, a 48-volt battery operating level is usually suitable. For more general use, a 125-volt battery is recommended, but 250-volt batteries can be used if other conditions require that voltage. In outdoor locations, space considerations in the switchgear usually restrict the battery to a 48-volt rating.

Long service can be obtained from batteries when they receive proper maintenance, are kept fully charged, and when the electrolyte is maintained at the proper level. For equipment in outlying locations where periodic battery maintenance would be difficult, the capacitor trip device may offer overall advantages.

Control Power Equipment

CAPACITOR TRIP

An "auto-charge" capacitor trip device is available, and consists of the "simple" device, plus a voltage amplifier, a battery, and a battery charger. Under normal conditions, with 230-volt ac power used for breaker closing, the single-cell, sealed, rechargeable, nickel-cadmium battery is maintained at full charge by the small charger connected to the 230-volt ac source. Upon loss of ac power, the voltage amplifier steps up the low battery voltage to the higher voltage needed to maintain charge on the capacitor for several days.

The "auto-charge" capacitor trip device (ST-230-3) is available whenever ac trip or capacitor trip is specified.

Breaker Closing

Closing power availability should be independent of voltage conditions on the power system associated with the switchgear. Accordingly, a 125-volt or 250-volt dc battery is normally considered to be the most reliable auxiliary power source. Nevertheless, in many instances, the storage battery or other independent power source necessary to achieve this goal may require an investment which is considered too high for the advantages gained. This is particularly true for small lineups, consisting of only a few circuit breaker units.

Generally, the choice between dc closing power derived from a battery and ac closing power derived from a control power transformer is an economic one, dictated by desired system reliability. There are other factors, however, which also influence this choice. These are:

- Need to close breakers with the power system de-energized.
- Availability of housing space for a battery and its associated charging equipment.
- Estimated lowest ambient temperature and its effect on battery capability.
- Maintenance requirements for a battery and battery charger.
- Expected future equipment additions which may affect the present choice of closing-power source.

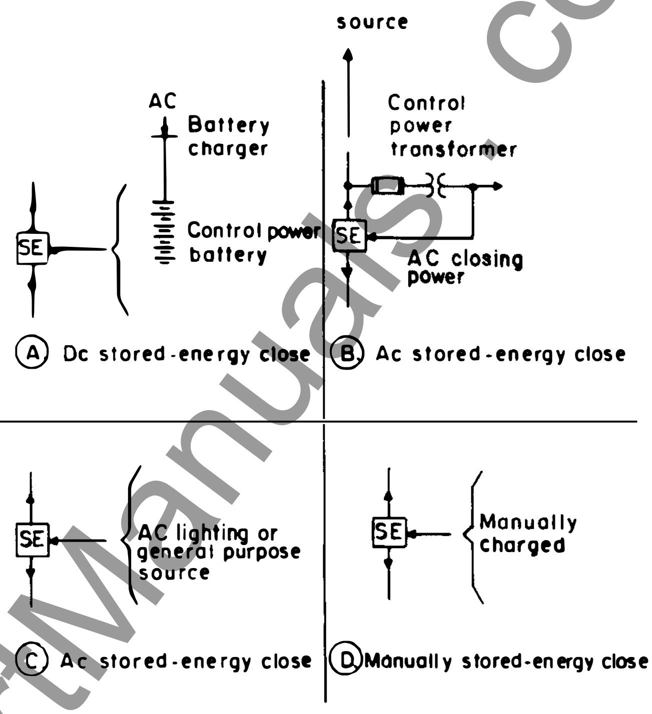

Figure 4-1. Closing mechanism arrangements.

The POWER/VAC® stored-energy operating mechanism can use the closing arrangements shown in Figures 4-1A through 4-1D.

When the mechanism is operated from alternating current, the current required is such that it can be taken from a control power transformer or a general-purpose or lighting source, as shown by Figures 4-1B and 4-1C. The energy for the next operation is stored in the springs as soon as the breaker is closed. To permit control switch or automatic initiation of closing, the ac source must also be present at the time of breaker closing to energize the spring-release solenoid. The POWER/VAC breaker mechanism is also suitable for manual operation (Figure 4-1D), both for charging the springs and for releasing them to close the breaker, in an emergency situation.

BREAKER REMOTE RACKING

When the usual manual racking means is supplemented by a motor, the load on the control power source is the same as for the breaker spring-charging motor; see Table 4-2.

Contents

Section 5

System and Equipment Protection

System and Equipment Protection

SURGE PROTECTION

Every medium voltage ac power system is subject to transient voltages in excess of the normal operating voltages. There are many sources of transient voltages.

The most prominent ones are:

- Lightning.
- Physical contact with a higher voltage system.
- Resonant effects in series inductive-capacitive circuits.
- Repetitive restrike (intermittent grounds).
- Switching surges.

To mitigate the effects of these transient voltages, both surge arresters and, where appropriate, surge capacitors should be used. Surge arresters limit the crest voltage of a voltage surge; surge capacitors reduce the steepness of the voltage wave which reaches the protected equipment.

Surge capacitors, to be most effective, should be located as close to the protected equipment (usually motors) as possible with minimum inductance connections.

For ac rotating-machine protection refer to General Electric Handbook Section 591D.

Surge suppressors in lieu of surge arresters may be ordered from the MVSBS. The 200A IR DISCHARGE PROTECTIVE LEVEL is:

4.16 kV = 9.25 – 10.9 kV
7.2 kV = 17.2 – 23.0 kV
13.8 kV = 32.1 – 38.0 kV

These devices are rated to operate continuously at rated line-to-line voltage for up to 1000 hours.

For other low BIL equipment (i.e., ventilated dry-type transformers) consult the manufacturer for recommendation for surge protection.

VACUUM BREAKER HEAT LOSS

Heat loss data is estimated to be as follows for vacuum breakers:

1 — 1200A Breaker = 550 Watts
1 — 2000A Breaker = 1200 Watts
1 — 3000A Breaker = 2000 Watts

Adequate ventilation must be provided to maintain ANSI temperature rise values within the metalclad equipment.

MEDIUM VOLTAGE SWITCHGEAR BUSINESS SECTION
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GENERAL ELECTRIC

GET-6801 5M (10/83)