Power/Vac® Product Family

Application Guide

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Application Guide
Power/Vac®

Metalclad Switchgear
And Related Products

Sections

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Section 1

Power/Vac® Switchgear Concepts And Basic Configurations

USE OF APPLICATION GUIDE

This *Application Guide* provides information necessary to help plan and specify medium-voltage power system switchgear, using Power/Vac® vacuum metalclad switchgear application procedure 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. Guidance is given in developing a system one-line diagram, calculating short circuit currents, and references to appropriate literature is presented. This technical information goes beyond the usual scope of an application guide. Powell Electrical, under special contract agreements, will perform power system studies, including the necessary calculations and comparisons.

The topics discussed in the first five 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, control power requirements, basic circuit protections considerations, and specific recommendations for protection, instrumentation, and control for basic switchgear circuits.

The remainder of the application guide explains the application and specification of Power/Vac metalclad switchgear. The concepts of modular construction and device package structuring are basic to Power/Vac switchgear and are introduced and illustrated through application details covering the use of Power/Vac switchgear and breakers in basic circuit applications. Auxiliary unit and power conductor compartment structuring are also included. Following the selection of individual units, an optimum lineup configuration can be developed using the guidelines given. Finally, a specification procedure, complete with Guide Form Specifications, is suggested to facilitate the documentation of Power/Vac metalclad switchgear requirements. This approach to metalclad switchgear application is typical and its use is recommended. Where practical, begin with Section 2 and work through the guide in a step-by-step fashion. The guide's structure is based on extensive engineering experience and will serve as a check list which will aid in preparing complete specifications.

Since the application of Power/Vac metalclad switchgear is the underlying purpose of this guide, a brief introduction of Power/Vac will serve as useful starting point to begin the application procedure.

Power/Vac® METALCLAD SWITCHGEAR

Power/Vac metalclad switchgear is designed for applications on 4.76kV, 8.25V, and 15-kV power systems with available short-circuit capacities from 20kA through 63kA symmetrical. A typical four section, six curcuit breaker lineup of indoor Power/Vac switchgear is shown in Figure 1-1.

Figure 1-1. Typical lineup of indoor Power/Vac switchgear.

Power/Vac circuit breakers are rated per ANSI C37.06-2009, Table 1. Breakers tested to earlier ANSI C37.06-2009 ratings with K>1.0 are also available. Available ratings are shown on page 3-1.1 and 3.1.2 of this application guide.

Power/Vac switchgear is designed, built, and tested to the applicable industry standards shown in Table 1-1.

Power/Vac equipment is furnished in four basic types; indoor, outdoor weather proof (no aisle), protected-aisle outdoor, and common-aisle outdoor (aisle shared by two facing lineups). Typical section outlines for each of the basic equipment types, along with dimensions and weights are shown in Section 7.

Table 1-1. Applicable Industry Standards

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)		NATIONAL ELECTRICALMANUFACTURERS ASS'N(NEMA)	
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		
C37.09	Test Procedure for Power Circuit Breakers	SG-4	Power Circuit Breakers
C37.010	Application Guide for Power Circuit Breakers		
C37.11	Power Circuit Breaker Control Requirements	SG-5	Power Switchgear Assemblies
C37.20.2	Metal-Clad Switchgear Assemblies		
C37.100	Definitions for Power Switchgear		

Compliance with other National Standards Must be reviewed with Powell Electrical.

Underwriters Laboratories, Inc. (UL)

Power/Vac vacuum metalclad switchgear and associated circuit breakers are optionally available with UL labeling.

The requirement for UL labeling must be made known as a requirement in the bidding stage.

CAUTION: Not all medium voltage switchgear assemblies qualify for UL listing.

Canadian Standards Association (CSA)

Power/Vac metalclad switchgear and associated circuit breakers are optionally available with CSA markings and are in compliance with CSA C22.2 NO. 31.

Requirements for CSA marking must be made known as a requirement in the bidding stage.

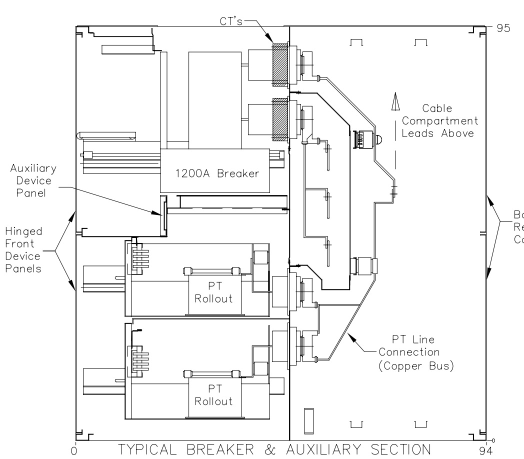


Figure 1-2A. Typical 1-High Side View

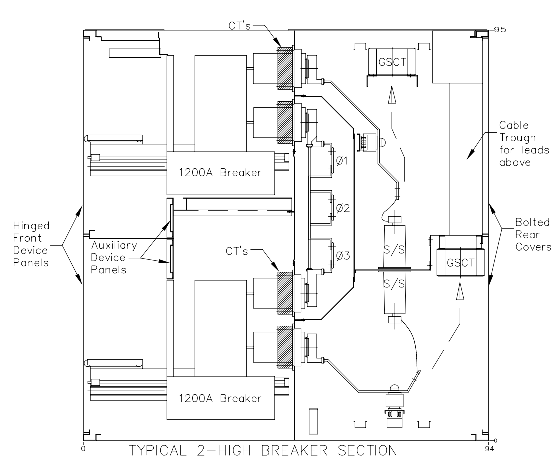


Figure 1-2B. Typical 2-High Side View

Power/Vac® Switchgear Concepts

Power/Vac metalclad switchgear combines the advantage of metalclad construction- safety and flexibility-with the benefits of vacuum interrupters-reliability, low maintenance, and reduced breaker size and weight.

Specifically, Power/Vac switchgear incorporates the following basic design elements, compared to SF6 and other designs of vacuum metalclad switchgear.

- Power/Vac offers two-high breaker stacking for application flexibility and floor space savings.
- Power/Vac utilizes modular construction resulting in one basic vertical section size, thus simplifying system planning and providing installation savings.
- Power/Vac features four-high auxiliary arrangements, providing additional flexibility and use of floor space.

These fundamental design features affect certain elements in the switchgear application procedure, 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 Power/Vac switchgear design concepts is provided.

TWO-HIGH BREAKER STACKING

Mixing and matching of a variety of 94" deep unit types and breaker ratings is possible using two-high unit stacking. The twelve basic combinations of upper and lower units are shown in Figure 1-4. Indoor 82" deep structure as well as 106" deep optional stacks are available. If 2-high switchgear is required in 82" depth, cables for the A compartment breaker must exit the top of the stack and the cables for the B compartment breaker must exit out the bottom of the stack. In addition, several other restrictions apply and contact your Powell representative for more information.

MODULAR CONSTRUCTION

Breakers and auxiliary devices can be accommodated in the upper and lower compartments as shown in Figure 1-3. Typical equipment section views in Figures 1-6 thru 1-15 illustrate how upper and lower units can be combined.

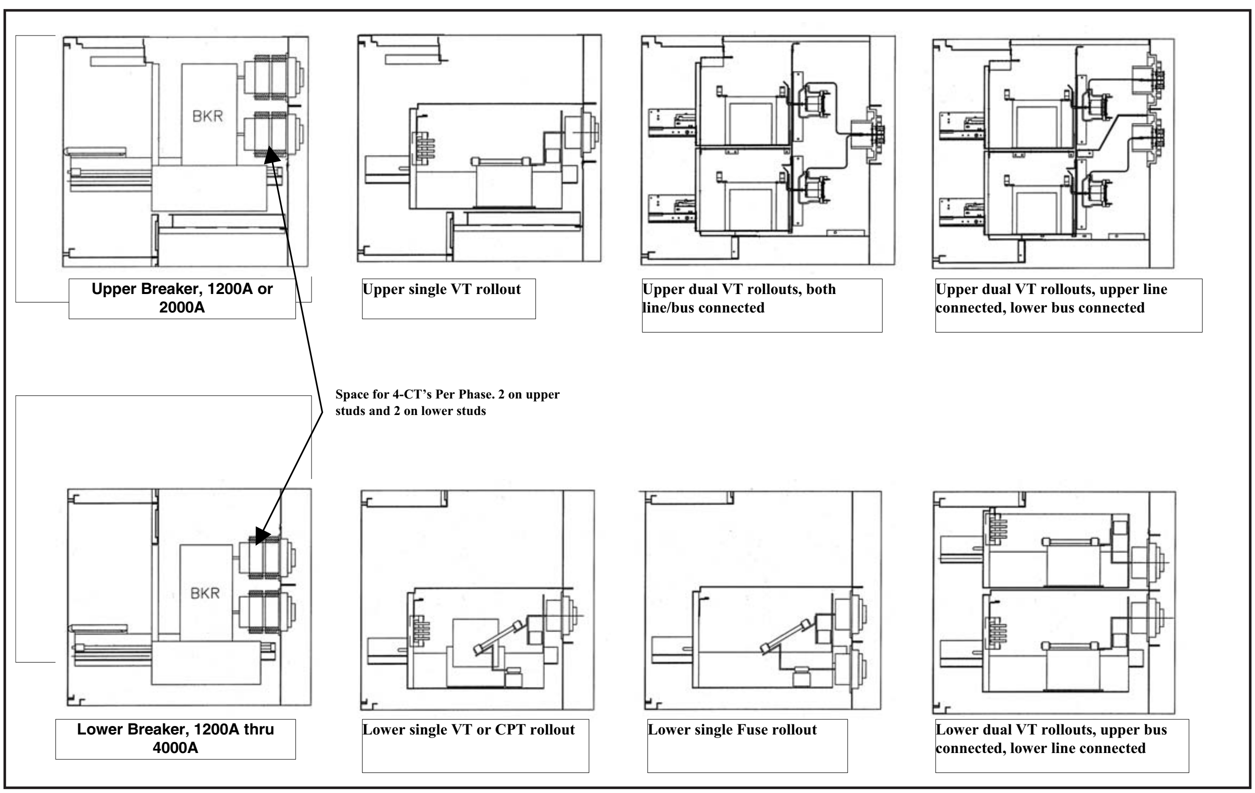
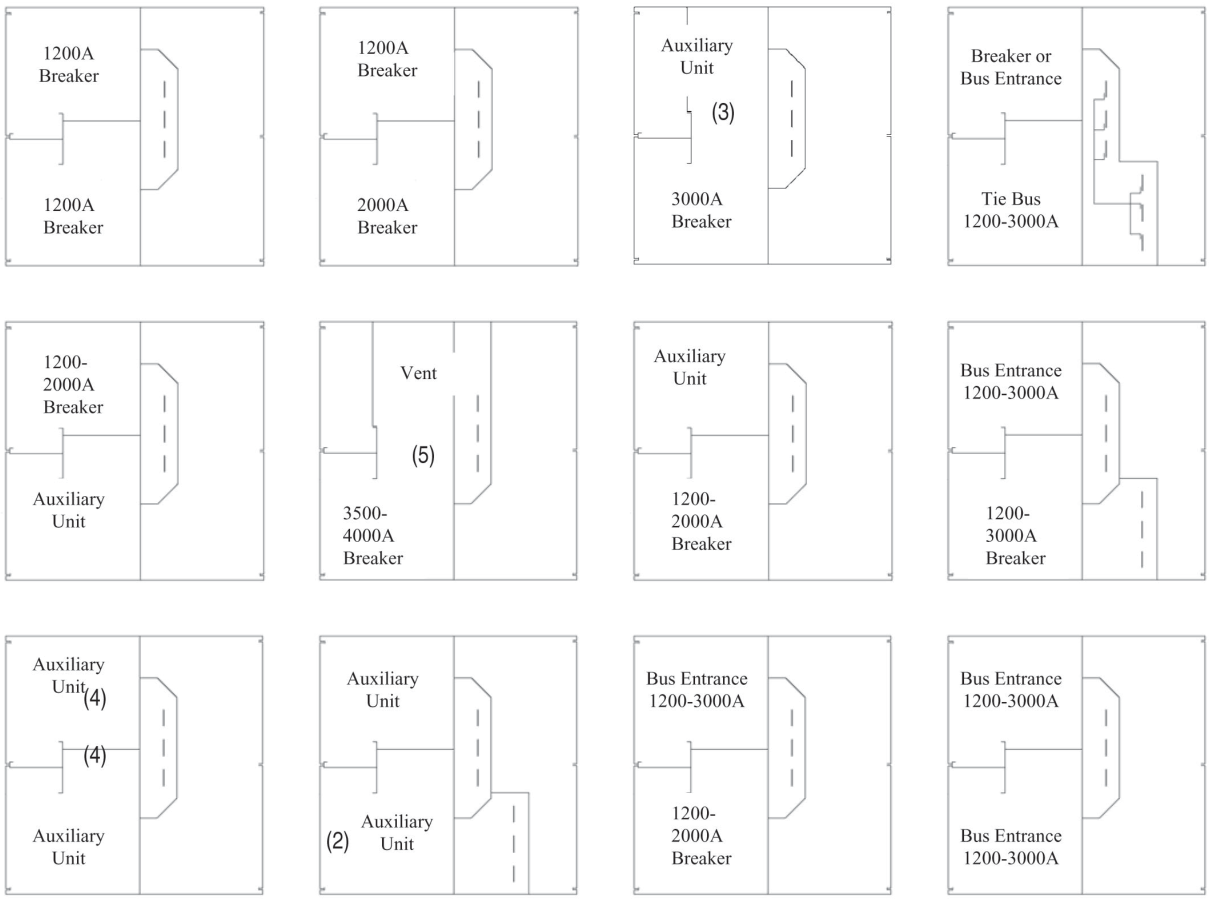


Figure 1-3. Typical upper and lower unit configurations.

Figure 1-4 Available Unit Combinations



Note:

(1) Blank Unit (above 3000A outdoor, 3500A & 4000A breakers)—device mounting space in door. Unit provides venting for breaker and bus compartment.

(2) Auxiliary Unit: adjacent to tie bus auxiliary can house 1 bus connected rollout tray.

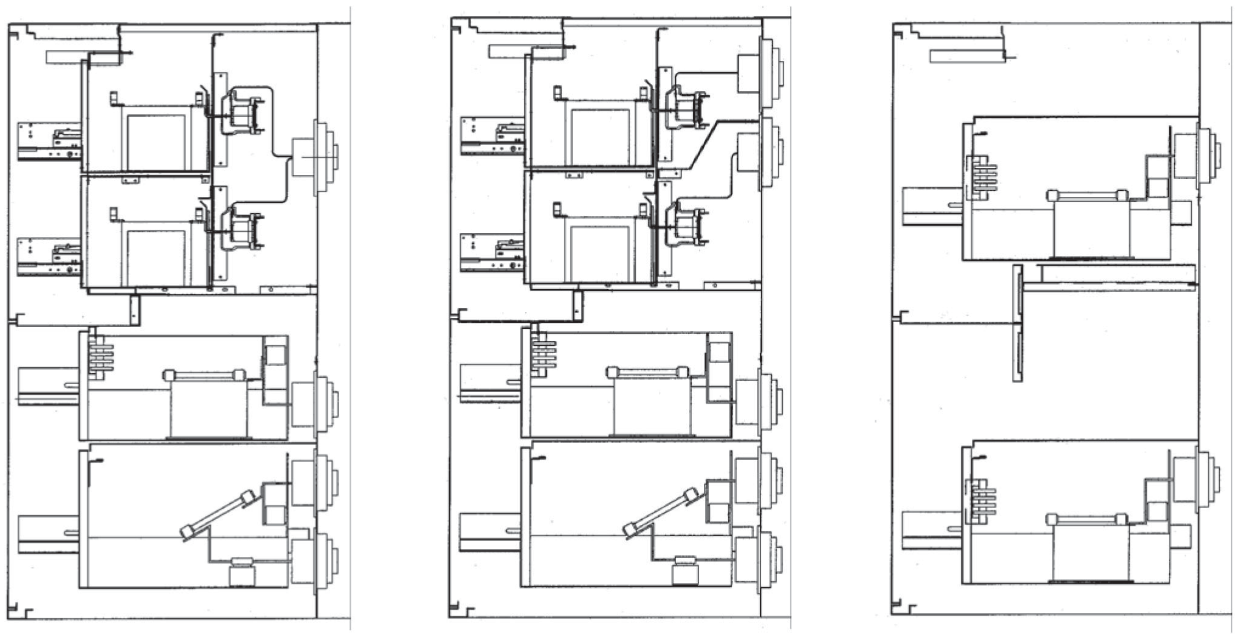
(3) Auxiliary Unit: Used for line or bus connected roll-out trays when located above or below a circuit breaker.
Can house 1 or 2 rollouts in A and/or B compartment. See figure 1-5

(4) Can house 2 rollouts in A and/or B compartment. See figure 1-5

(5) 1200A through 3500A are convection air cooled breakers. 4000A breakers are fan cooled.

Figure 1-5 Auxiliary Rollouts

Rollouts



Upper dual rollouts-both line or bus connected
Lower dual rollouts

Upper dual rollouts-top line connected, bottom bus connected
Lower dual rollouts

Upper single rollout
Lower single rollout

Devices	Ratings	"A" compartment with single rollout	"A" compartment with dual rollouts (note 4)		"B" compartment with single rollout	"B" compartment with dual rollouts (note 5)	
			Upper rollout	Lower rollout		Upper rollout	Lower rollout
VT rollout	5KV-15KV	Yes	Yes	Yes	Yes	Yes	Yes
CPT rollout	5/10/15KVA	Yes	Yes	No	Yes	No	Yes
Fuse rollout	(note 1)	Yes (note 3)	No	No	Yes	No	Yes

Note 1 All fuse rollouts are equipped with fuse clips for size C EJ1/EJO1 fuses. Clips can be adjusted for 9" or 12" centers. Fuse rollouts require the installation of a keylock to prevent pulling the drawer out under load.

Note 2 A single rollout in “A” or “B” compartment will be located as shown in the third view.

Note 3 A fused rollout in “A” compartment is available as bus connected only.

Note 4 The upper rollout in “A” compartment can be bus connected as long as the lower rollout n “A” compartment is bus connected. The lower rollout in “A” compartment can be bus connected no matter what the connection to the upper rollout in “A” compartment. The lower rollout in “A” compartment can only be line connected if the upper rollout in “A” compartment is also line connected.

Note 5 The lower rollout in “B” compartment can be bus connected as long as the upper rollout in “B” compartment is bus connected. The lower rollout in “B” compartment can be line connected no matter what the connection to the upper rollout in “B” compartment. The upper rollout in “B” compartment can only be line connected if the lower rollout in “B” compartment is also line connected.

Figure 1-6 through 1-11. Typical Section Views

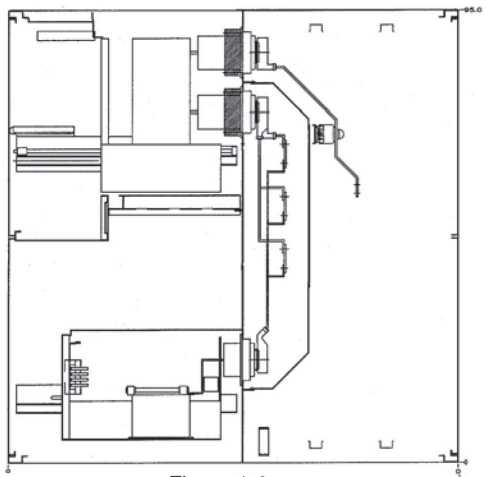


Figure 1-6
"A" Compartment Breaker with "B" Compartment
Single PT Rollout Bus Connected

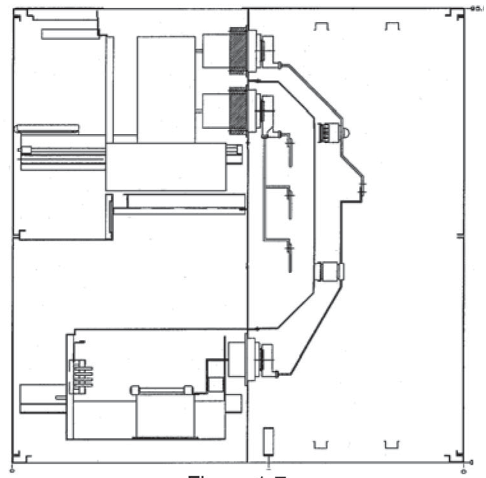


Figure 1-7
"A" Compartment Breaker with "B" Compartment
Single PT Line Connected

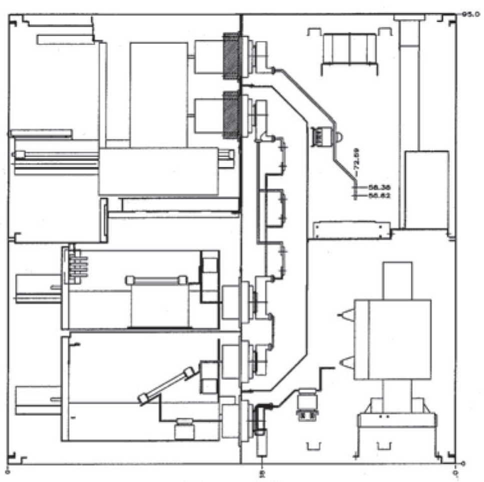


Figure 1-8
"A" Compartment Breaker with 2 Rollouts in "B", Upper
PT Bus Connected, Lower Fuse Bus Connected

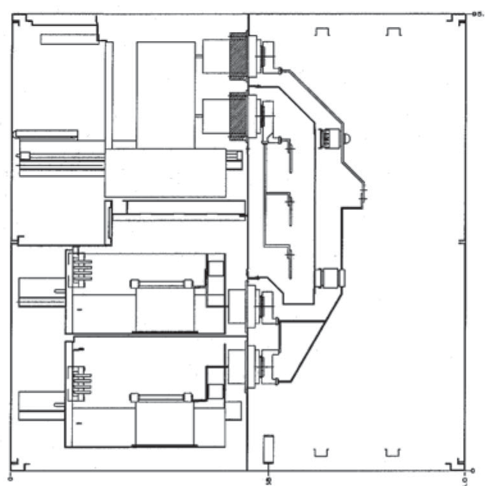


Figure 1-9
"A" Compartment Breaker with 2 Rollouts in "B", Upper
PT Line Connected, Lower PT Line Connected

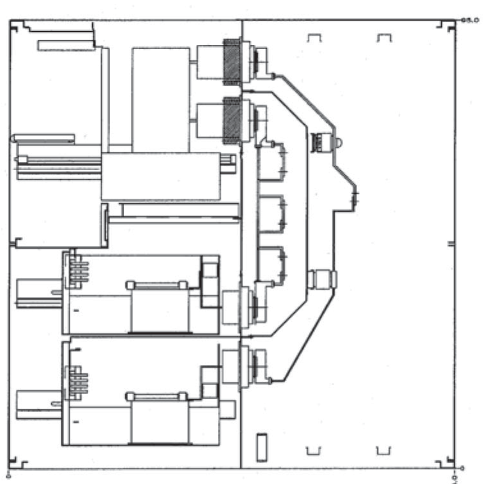


Figure 1-10
"A" Compartment Breaker with 2 Rollouts in "B",
Upper PT Bus Connected, Lower PT Line Connected

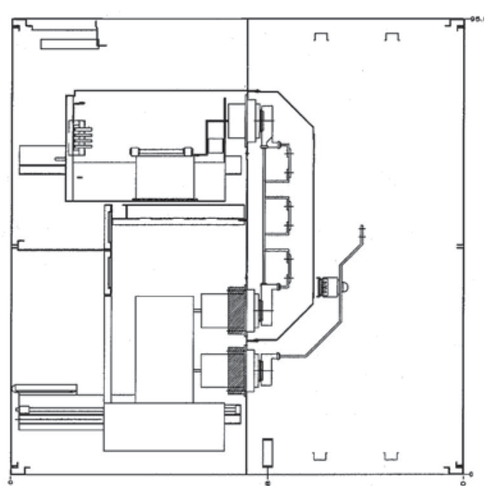


Figure 1-11
A"" Compartment Single PT Rollout Bus Connected, "B"
Breaker

Figure 1-12 through 1-15. Typical Section Views

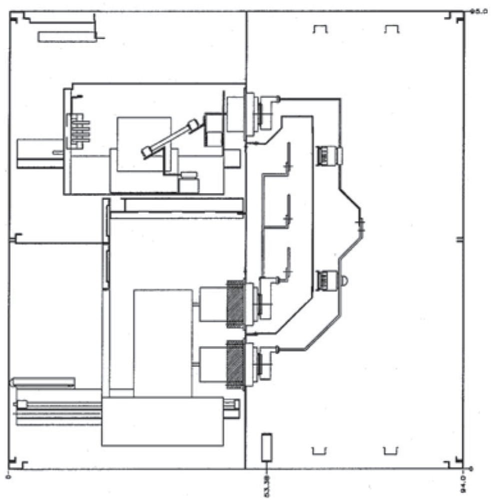


Figure 1-12
"A" Compartment Single CPT Rollout Line Connected, "B" Compartment Breaker

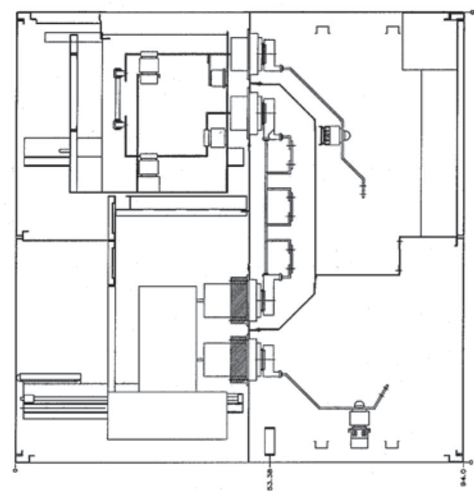


Figure 1-13
"A" Compartment Single Fuse Rollout Bus Connected, "B" Compartment Breaker

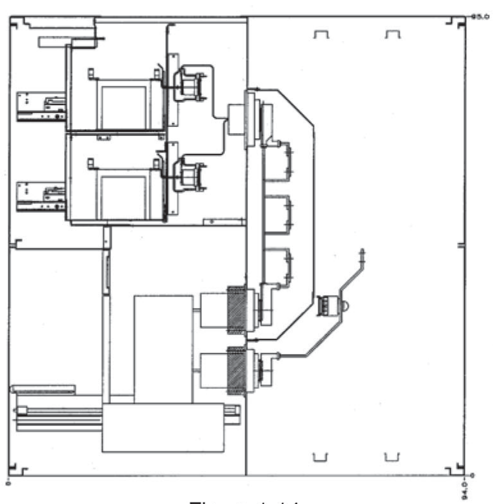


Figure 1-14
"A" Compartment 2-Rollouts Bus Connected, "B" Compartment Breaker

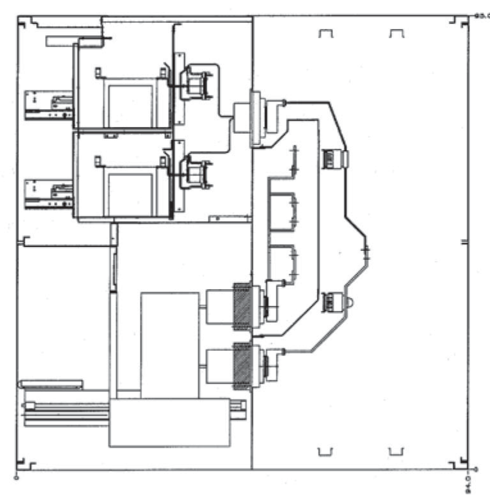


Figure 1-15
"A" Compartment 2-Rollouts Line Connected, "B" Compartment Breaker

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 on Page 2-10.)

When preparing switchgear one-line diagrams, use graphic symbols in accordance with IEEE and ANSI standards listed in References 2 and 3 on page 2-10.

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 C37.2.1996 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 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 C37.2-1996. (See Ref. 4 on page 2-10.)

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

Table 2-1. Abbreviations

Abbr.	Description		Abbr.
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 center
VT	Voltage transformer	WM	Wattmeter

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	Multifunction Relay
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/Cell 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 applications
96	in individual installations
97	where none of the
98	assigned numbered functions
99	from 1-94 are suitable.

System One-Line Diagram

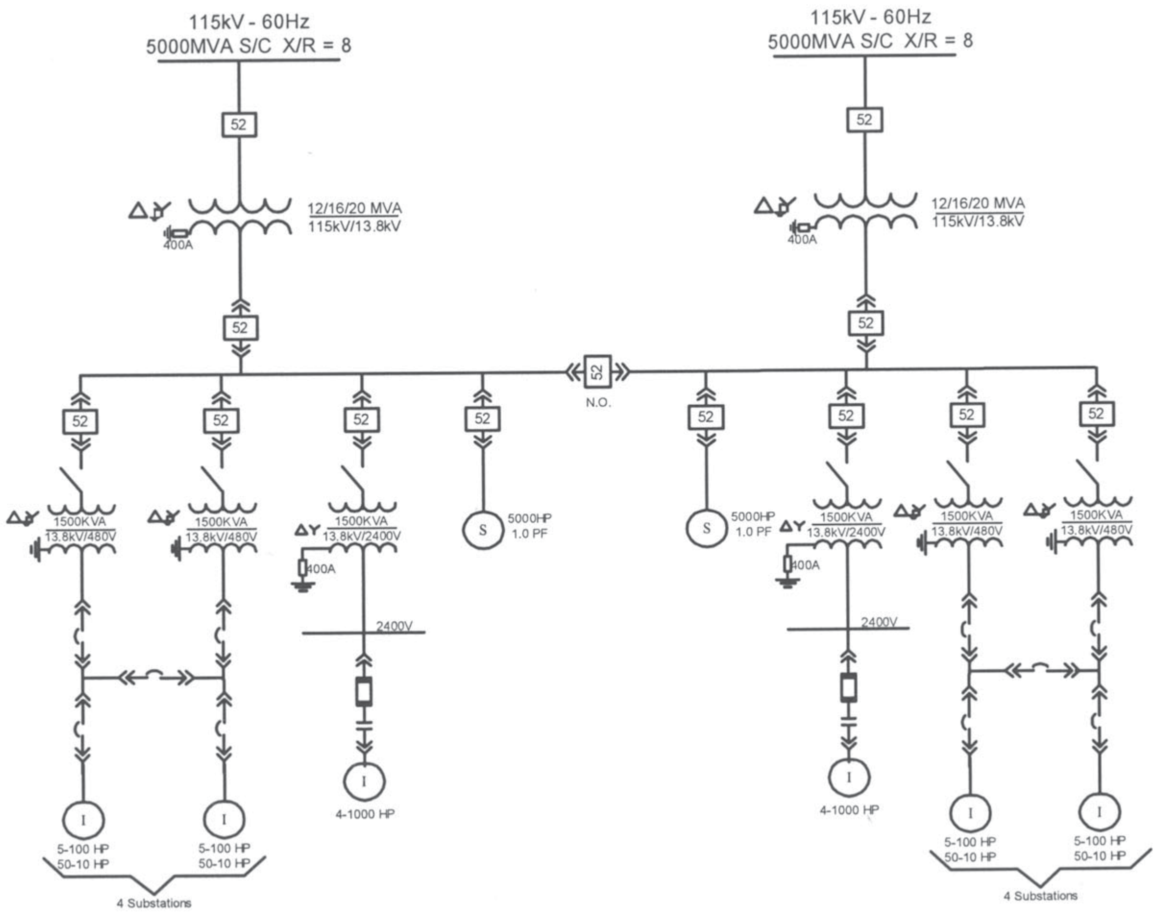


Figure 2-1. Preliminary one-line diagram

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 capabilityin symmetrical MVA (plus X/R ratio) or per unit R+jX (on a given basis).

Using data on the one-line diagram, perform short circuit 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. 5 on page 2-10.)
- Determine the applicable circuit breaker ratings.
- Compare the feeder cable short-circuit heating limit with the maximum available short-circuit current time K_t times K_o. (See Ref. 10 and 11 on page 2-10.)

Note that the calculations performed in accordance with Reference 5 (on page 2-10) 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 (on page 2-10). For other than power circuit breakers, refer to the appropriate ANSI standard for short-circuit calculation procedure.

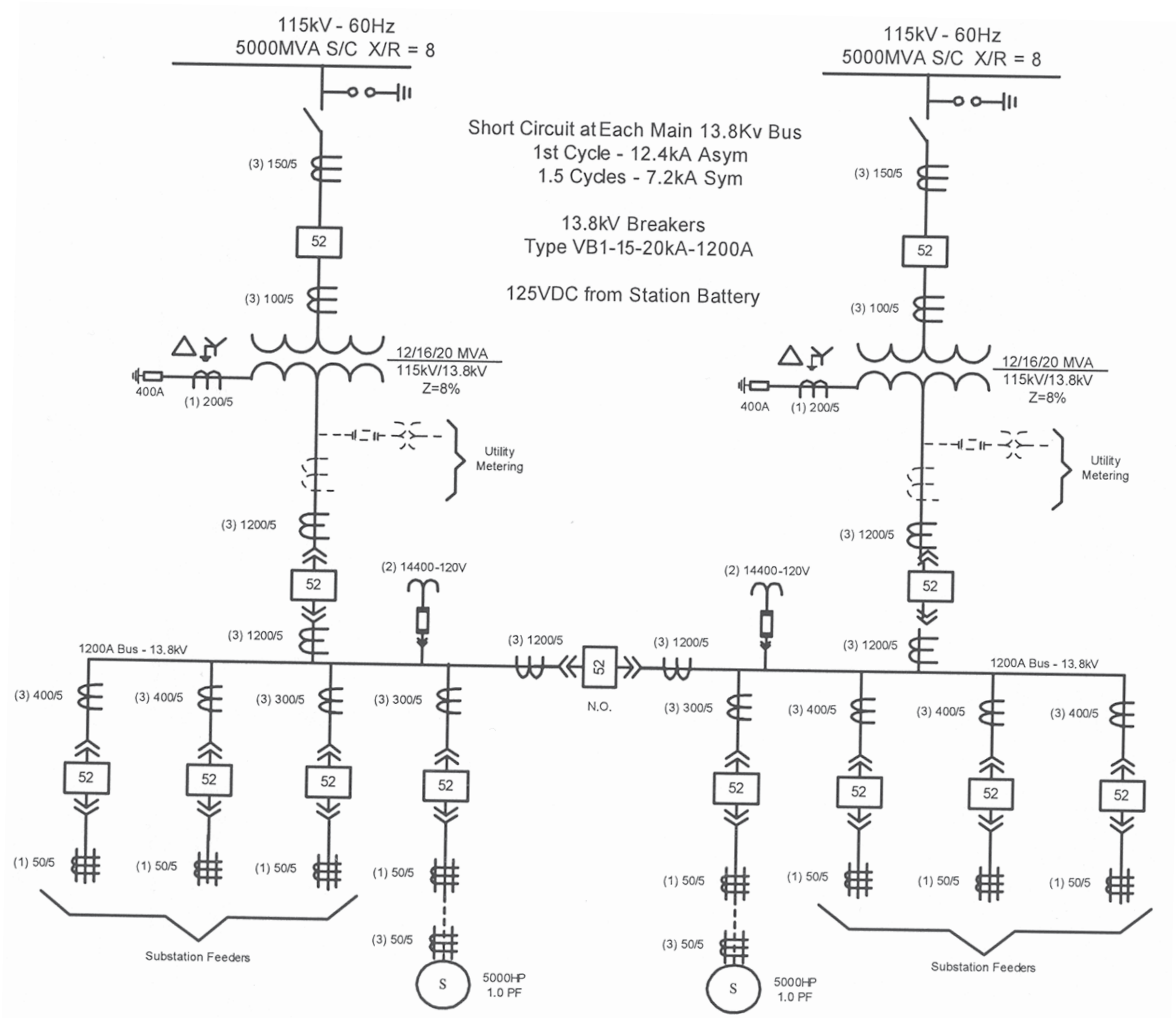


Figure 2-2. Partially developed one-line diagram

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, considering the type of protective relaying instrumentation and metering required.
- Select tentative current transformer (CT) ratios inconsidering the maximum transformer rating, motor ratings, and ampacity of the circuits involved. (See Section 5.)
- Locate current transformers and voltage transformers, considering the type of protective relaying instrumentation and metering required.

50/51	Phase Time & Instantaneous Relay	87T/G	Transformer Ground Differential Relay
51N	Residually Connected Time Overcurrent Relay	86T	Transformer Differential 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	87/B	Bus Differential Relay
51N/B	Residually Connected Time Overcurrent Relay	86/B	Bus Differential Lockout Relay
87T	High Speed Transformer Differential Relay	62	Time (Typical) 0.5 to 5 seconds

Figure 2-4. Typical Protective Relay Symbols

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 using the information given in Sections 5 and 6 of this Application Guide.
- Confirm the selection of relay ratings and characteristics by performing a complete system short-circuit and coordination study. (See Ref. 7 through 10 on page 2-10.)
- Include in the study an examination of all circuits for compliance with applicable local and national codes.
(See Ref. 11 on page 2-10.)
- Verify that all circuit conductors are applied within the conductor short-circuit heating limit.
(See Ref.10 on page 2-10.)

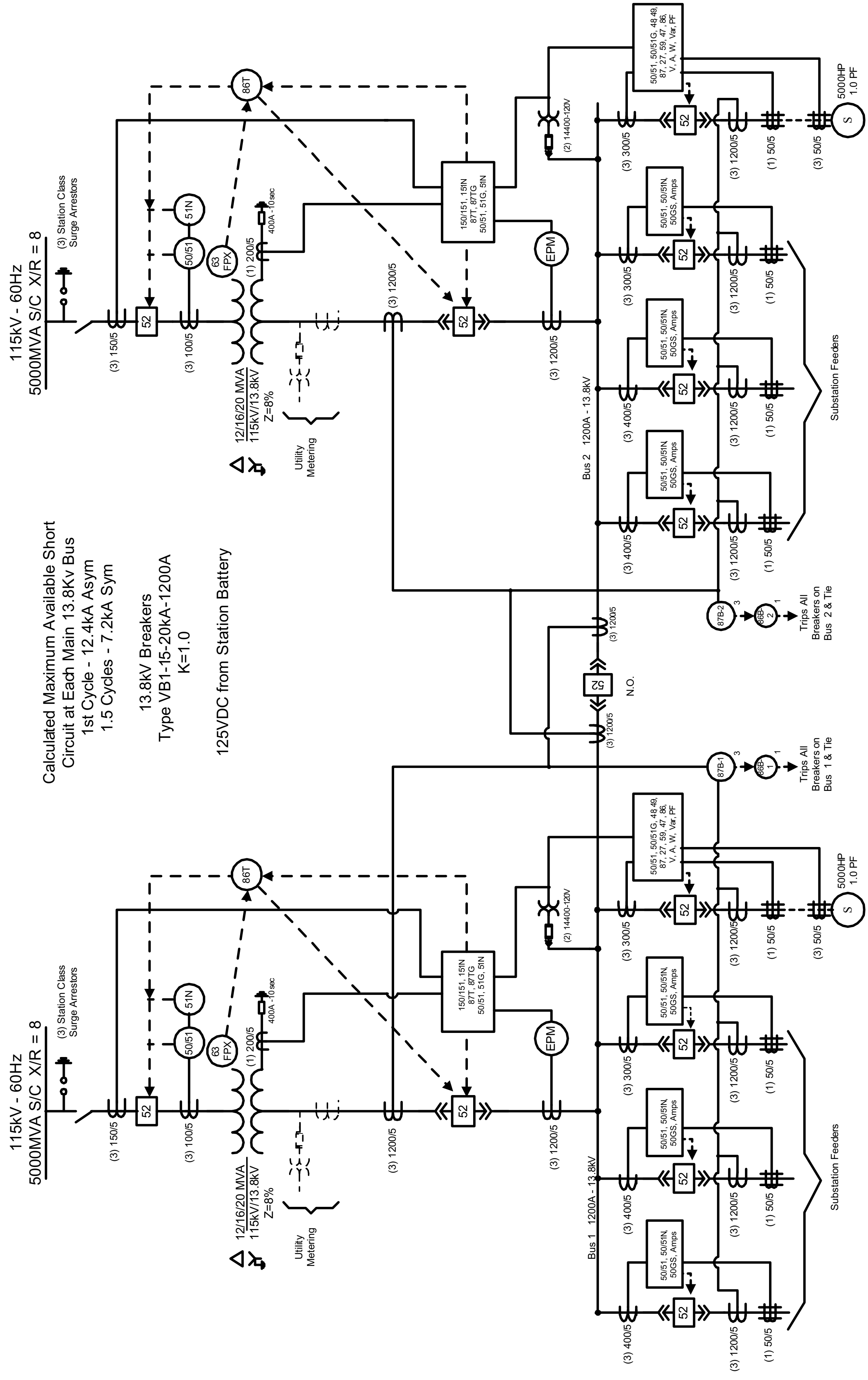
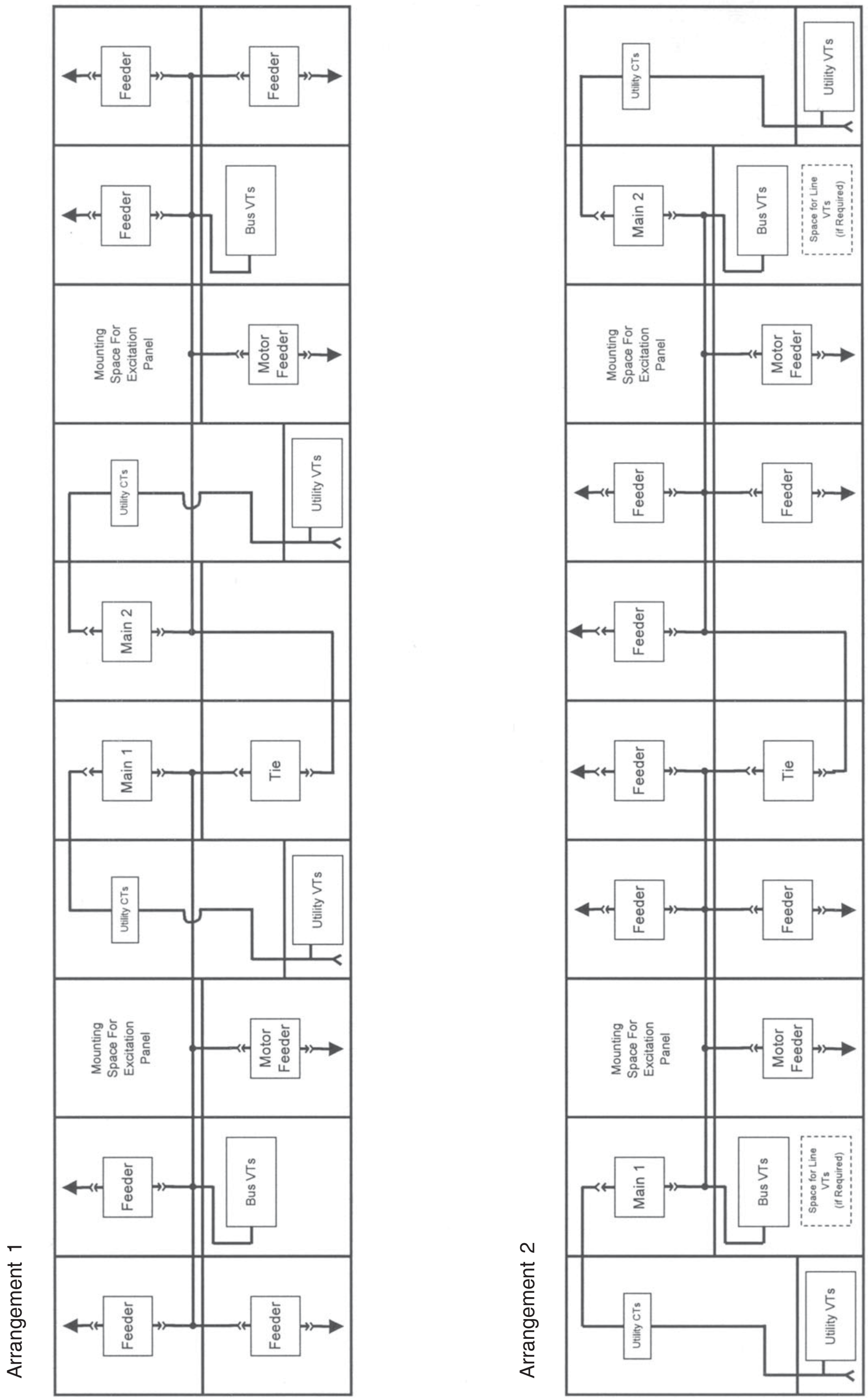


Figure 2-3. Developed one-line diagram.

System One-Line Diagram

Figure 2-5. Two possible arrangements of Power/Vac® Metalclad switchgear.



ADAPTING ONE-LINE DIAGRAM TO EQUIPMENT

Figure 2-5 shows two possible arrangements of Power/Vac metalclad switchgear as developed from the one-line diagram in Figure 2-3. Both save space when compared to one-high 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. Use the information in Sections 6 and 7 to adapt the one-line diagram to the equipment and develop a suitable arrangement for the particular installation.

REFERENCES

Standards

	ANSI Standard	IEEE Standard	Title
1.	C42.100-1992	100-1977	IEEE Standard Dictionary of Electrical and Electrical Terms.
2.	Y32.2-1975	315-1975	Graphic Symbols for Electrical and Electronic Diagrams.
3.	Y14.15-1966 (R1973)	—	Electrical and Electronics Diagram.
4.	C37.2-1996	—	Electrical Power System Device Function.
5.	C37.010-1999	—	Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
6.	C37.95-1989 (R1994)	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 Electrical Power Systems in Commercial Buildings.
10.	—	242-1975	IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.

Books

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

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. Suite 300
Washington, D.C. 20037

National Fire Protection Association
470 Atlantic Avenue
Boston, MA 02210

Section 3

Circuit Breaker Selection

Circuit Breaker Selection

INTRODUCTION

A circuit breaker's function and intended use are established in ANSI-C37.100-1992, 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 BREAKER RATINGS

Power/Vac circuit breaker ratings with K=1 are shown in Table 3-1.1. Table 3-1.2 lists Power/Vac circuit breakers with ratings based on the previous revision of ANSI C37.06 (1987), with K factors greater than 1.0. Interrupting ratings are for 60-HZ and 50-HZ applications. For more complete information concerning service conditions, definitions, interpretation of ratings, tests, and qualifying terms, refer to the applicable ANSI and NEMA standards listed in Table 1-1, Page 1-3.

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 Power/Vac circuit breaker with ratings and capabilities shown in Table 3-1.1 or 3-1.2. 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 that must be considered are discussed in the following paragraphs. Circuit characteristics which must be defined and compared to the circuit breaker's capabilities (given in the various Tables in this Section) 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 furnaces)
- Arc furnace switching
- Reactor switching
- Capacitor switching
- Fast bus transfer
- Unusual service conditions

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

CIRCUIT VOLTAGE

The nominal voltage classes of medium-voltage metalclad switchgear based on ANSI standards are 4.16 kV, 7.2 kV and 13.8 kV. Power/Vac switchgear may be applied at operating voltages from 2400 volts through 15,000 volts, provided the maximum circuit operating voltage does not exceed the Power/Vac rated maximum voltage, see Table 3-1.1 or Table 3-1.2 .

Table 3-1.1 Power/Vac® Circuit Breaker Characteristics, K = 1.0

Power/Vac Circuit Breaker Characteristics
Symmetrical Ratings Basis per ANSI C37.06 - 2009

AVAILABLE RATINGS											
Rated Maximum rms Voltage (kV) (1)	Nominal ANSI Voltage Class (kV)	Typical System Operating Voltages (kV)	Rated Voltage Range Factor, K	Rated Withstand Test Voltage: Low Frequency rms Voltage (kV)	Rated Withstand Test Voltage: Crest Impulse Voltage (kV)	Continuous rms Current Rating at 60Hz (amperes) (2)	Rated Short Circuit Current (Maximum Interrupting Capability) (kA) (3)	Rated Interrupting Time (Cycles)	Rated Permissible Tripping Delay, Y (Seconds)	2 Sec Short time Current Carrying Capability (kA)	Peak Close and Latch (2.6K x short circuit current rating) (kA)
4.76	4.16	2400	1.0	19	60	1200-4000	31.5	5 or 3	2	31.5	82
		4160				1200-4000	40	5 or 3		40	104
		4200				1200-4000	50	5 or 3		50	130
						1200-4000	63 *	5		63	164
8.25	7.2	6600	1.0	36	95	1200-4000	40	5 or 3	2	40	104
		6900				1200-4000	50 *	5 or 3		50	130
		7200				1200-4000	63 *	5		63	164
15	13.8	12000	1.0	36	95	1200-4000	20	5 or 3	2	20	52
		12470				1200-4000	25	5 or 3		25	65
		13200				1200-4000	31.5	5 or 3		31.5	82
		13800				1200-4000	40	5 or 3		40	104
		14400				1200-4000	50	5 or 3		50	130
						1200-4000	63	5		63	164

Notes:

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

2 Available current ratings are 1200A, 2000A, 3000A, 3500A and 4000A. 4000A rating is forced-air cooled, indoor construction only. 3500A is available in outdoor construction, but must be derated to 3250A.

3 At system operating voltages equal to or less than rated maximum voltage.

* Ratings offered in addition to the ANSI preferred values

Table 3-1.2 Power/Vac® Circuit Breaker Characteristics, K>1.0

Power/Vac® Circuit Breaker Characteristics
Symmetrical Ratings Basis ANSI C37.06 (1987)

Identification		Rated Values								Related Required Capabilities				
		Voltage		Insulation Level		Current								
				Rated Withstand Test Voltage							Maximum Symmetrical Interrupting Capability (5)	3 Sec Short time Current Carrying Capability (5)		
Nominal rms Voltage Class (kV)	Nominal MVA Class (6)	Rated Maximum Voltage rms (kV) (1)	Rated Voltage Range Factor, K (2)	Low Frequency rms Voltage (kV)	Crest Impulse Voltage (kV)	Continuous rms Current Rating at 60Hz (amperes) (7) & (8)	Short Circuit rms Current Rating (at Rated Max. kV) (kA) (3) (4)	Rated Interrupting Time (Cycles) (9)	Rated Permissible Tripping Delay, Y (Seconds)	Rated Maximum rms Voltage Divided by K (kV)	K times Related Short circuit rms Current		Closing and Latching Capability rms Current (kA) (10)	Peak Close and Latch (2.7K x max S/C rating) (kA) (6)
											(kA)	(kA)		
4.16	250	4.76	1.24	19	60	1200-4000	29	5	2	3.85	36	36	58	97
	350		1.19			1200-4000	41			4.0	49	49	78	132
	450 (6)		1.00			1200-4000	63			4.76	63	63	101	164
7.2	500	8.25	1.25	36	95	1200-4000	33			6.6	41	41	66	111
	785 (6)		1.00			1200-4000	63			8.25	63	63	101	164
13.8	500	15	1.30	36	95	1200-4000	18			11.5	23	23	37	62
	750		1.30			1200-4000	28			11.5	36	36	58	98
	1000		1.30			1200-4000	37			11.5	48	48	77	130
	1500 (6)		1.00			1200-4000	63			15	63	63	101	164

Notes:

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

(2) K is the ratio of the maximum voltage to the lower limit of the range of operating voltage in which the required symmetrical and asymmetrical interruptingcapabilities 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 = Rated Short-Circuit Current X (Rated Maximum Voltage) / (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 the rated short-circuit current.

(4) With the limitation stated in 5.10 of ANSI-C37.04-1991, all values apply for polyphase and line-to-line faults. For single phase-to-phase faults, thespecific conditions stated in 5.10.2.3 of ANSI-C37.04-1991 apply.

(5) Current values in this column are not to be exceeded even for operating voltages below 1/K times maximum voltage.

(6) MVA Class listed for reference only. Note 4160V-450MVA, 7.2KV-785MVA and 13.8KV-1500MVA are not listed as preferred ratings according to table 2.1 of ANSI-C37.06-1987. For these ratings the Short Time current is on a 2 sec basis, and the peak C&L is 2.6 X S/C rating.

(7) Available current ratings are 1200A, 2000A, 3000A, 3500A and 4000A. 3500A and 4000A are indoor construction only.

(8) 4000A breaker is forced-air cooled, and indoor construction only.

(9) 3 cycle interruping ratings may be available, consult Factory.

(10) Non-standard, high Close & Latch ratings may be available, consult Factory.

SYSTEM FREQUENCY

The frequency rating of Power/Vac metalclad switchgear should coincide with the nominal frequency of the power system. Standard Power/Vac is rated at 60-Hz (Tables 3-1.1 and 3-1.2) per ANSI standards, however can typically be applied at 50-Hz as well.

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 of the proper voltage class and which has a short-circuit current capability that equals or exceeds the expected duty. If applying breakers with K factors > 1.0, remember to consider the circuit operating voltage when evaluating the circuit breaker's interrupting capability. For example: a 4.16 kV- 350 MVA-class circuit breaker has a rated short-circuit current of 41 kA at a maximum rated voltage of 4.76 kV, but has a short-circuit capability of 47 kA symmetrical rms current at 4.16 kV. However when applied on a 2.4 kV system, the interrupting capability increases to 49 kA, which is the maximum symmetrical interrupting capability listed in the rating tables, because 2.4 kV is less than 4.76 kV divided by "k", or 4.76/1.19 = 4.0 kV. (See footnote No. 5, Table 3-1.2).

CLOSING AND LATCHING CURRENT

Circuit breakers are designed to stay latched, or to close and latch, against a first-cycle maximum asymmetrical rms current which is approximately 1 1/2 times the maximum symmetrical rms interrupting capability of the circuit breaker. This close and latch capability is satisfactory for most applications (Table 3-1.1 and 3-1.2). However there are some applications in which the calculated rms value of first-cycle asymmetrical short-circuit current, exceeds the closing and latching capability of the otherwise suitable circuit breaker. Applications which include large motor loads may generate these higher first-cycle currents. In these cases, breaker selection may depend on closing and latching capability rather than symmetrical short-circuit capability. The breaker selected may have the next higher short-circuit current capability.

For circuit breakers with K factor =1.0, the closing and latching capability (kA, rms) of the circuit breaker is equal to 1.55 K times rated short-circuit current. If close & latch is expressed in peak amperes, the value is equal to 2.6 K times rated short-circuit current.

For circuit breakers with K > 1.0, closing and latching capability (kA, rms) of the circuit breaker is equal to 1.6 K times rated short-circuit current and if expressed in peak amperes, the value is equal to 2.7 K times rated short-circuit current (see ANSI C37.06-2009 for details)

CONTINUOUS CURRENT

Feeder and main breaker loading determines the 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 Power/Vac circuit breakers are 100% rated, and have no continuous overload rating. When considering circuit breaker applications 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-air cooled transformer, the switchgear continuous-current rating must equal or exceed the transformer forced-air cooled current rating.

Circuit breakers may be operated for short periods, in excess of their rated continuous current. This covers such operations as starting motors or energizing cold loads. Consult ANSI C37.20.2 for overload current capability guidelines.

RATED INTERRUPTING TIME

Power/Vac circuit breakers are available with interrupting ratings of 5-cycles or 3-cycles, as stated in Tables 3-1.1 and 3-1.2.

DUTY CYCLE

Power/Vac circuit breakers have a rated duty cycle of: O – 0 sec – CO – 15 sec – CO. Power/Vac vacuum breakers do not require derating for reclosing duties.

SPECIAL SWITCHING APPLICATIONS

Application of power circuit breakers for switching duty may require derating of the circuit breaker, or increased maintenance. Power/Vac circuit breakers do not require derating when applied in automatic reclosing duty.

Particular attention should be given to breakers intended for use in any of the following switching applications:

- Repetitive switching (except arc furnace)
- 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 breaker's evaluation 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 concern 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 the 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 (open-close) as often as 20 times in 10 minutes, or 30 times in one hour without adverse effect. 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 Table 3-2.

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 application requires 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

This heavy-duty application requires circuit breaker capabilities and maintenance schedules different from those required for other switching duty.

Power/Vac circuit breakers designed for arc furnace switching are capable of operating the number of times given in Table 3-3, providing they are operated under usual service conditions. Operating conditions, servicing requirements, and permissible effects on the breakers are given in the table.

REACTOR SWITCHING

Standard Power/Vac circuit breakers are capable of switching reactive load current up the full continuous current rating of the breaker.

Table 3-2 Repetitive Duty and Normal Maintenance for Power/Vac® Breakers used in Mild Environments other than for Arc Furnace Switching

BREAKER		MAXIMUM NO. OF OPERATIONS BEFORE SERVICING	NUMBER OF OPERATIONS (EACH = 1 CLOSE PLUS 1 OPEN OPERATION)		
KA Rating	CONTINUOUS RATING - AMPS		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, lubrication, 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. E. Rated control voltage. F. Frequency of operation not more than 20 in 10 minutes or not more than 30 in 1 hour. G. Servicing at intervals given in Column 2. H. No parts replacement. I. Breaker meets all current, voltage, interrupting current ratings.	C. Close and trip within rated current, rated maximum voltage and 80% PF or greater. E. Applies F. Applies G. Applies H. 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. K. After 15 full short circuit faults check the contact erosion.	D. Closing 600% of rated current or less at no less than 30% PF. Otherwise, same as C. E. Applies F. Applies G. Applies H. Applies I. Applies J. Applies K. Applies
20-40kA	All	10,000 or 10 years	10,000 minimum	10,000	10,000
50 & 63kA	All	5,000 or 10 years	5,000 minimum	5,000	5,000

Table 3-3—Repetitive Duty and Maintenance Requirements for Power/Vac® Circuit Breakers Applied to Arc Furnace Switching

BREAKER		ARE FURNACE FULL-LOAD RATING (AMPERES)	MAXIMUM NUMBER OF OPERATIONS BETWEEN SERVICING	NUMBER OF OPERATIONS	
TYPE	CONTINUOUS RATING (AMPERES)			NO-LOAD MECHANICAL	SWITCHING AND INTERRUPTING
COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4	COLUMN 5	COLUMN 6
			A. Servicing consists of adjusting, cleaning, lubrication, tightening, changing parts, as recommended by the Company. The operations listed are on the basis of service in a mild environment. H. If the weighted average of the currents interrupted during load and secondary furnace cave-ins is equal to the breaker continuous current, this column applies. I. After 15 full short circuit faults check the contact erosion.	B. When closing and opening no-load. C. Within 90 to 100% of rated control voltage. D. Frequency of operation not more than 20 in 10 minutes or not more than 30 in 1 hour. E. Servicing at no greater interval than shown in Column 4. F. No parts replacement. G. Breaker meets all current, voltage, interrupting current ratings.	C. Applies D. Applies E. Applies F. Applies G. 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.
18-40kA	All	All	10,000 or 10 years	10,000 minimum	
50 & 63kA	All	All	5,000 or 10 years	5,000 minimum	

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 properly equipped are applicable as General Purpose circuit breakers for shunt-capacitor-bank switching, or as Definite Purpose Circuit Breakers with back-to-back capacitor switching capabilities as listed in Table 3-4.

Shunt-bank capacitor switching means one breaker feeding one 3-phase capacitor bank. If this circuit is closely paralleled by another switched capacitor bank, the duty is considered back-to-back. These situations require evaluation of such factors as local high-frequency equalizing currents flowing between the separated, switched capacitor banks.

Table 3-4 Power/Vac® Breaker Capacitor Switching Capabilities

Breaker Rated Maximum Voltage (kV RMS)	Breaker Rated Short Circuit Current (kA RMS)	Breaker Continuous Current Rating (Amps)	
		1200	2000 - 4000
		Isolated-Capacitor Bank or Back-to-Back Switching Amps	
4.76	29 - 50	1200	1200
4.76	63	1200	1600
8.25	33 - 40	1200	1200
8.25	50 - 63	1200	1600
15	18 & 20	1200	1200
15	25 - 40	1200	1200
15	50 - 63	1200	1600

Footnote — The capacitor bank rating is subject to the following conditions:

1. The transient voltage from line-to-ground, shall not exceed 3 times the maximum design line-to-ground crest voltage measured at the breaker terminals.
2. The number of re-strikes or re-ignitions shall not be limited as long as the transient voltage to ground does not exceed the value given in footnote 1.
3. Interrupting time shall be in accordance with the rated interrupting time of the circuit breaker.
4. Maximum Capacitor Bank KVAR rating is calculated as follows:

$$\frac{\text{System Voltage (kV)} \times \text{Cap. Switching Current (A)} \times \sqrt{3}}{1.25 \text{ (for ungrounded banks) or } 1.35 \text{ (for grounded banks)}}$$

5. For Back-to-Back switching, the bank inrush currents are limited to 15KA at 2000hz.
6. For capacitor switching requirements other than shown above, consult Powell Electrical.

FAST BUS TRANSFER

Fast bus transfer (FBT) is an option used when there is a need for transferring from a normal power source bus to an emergency or alternate power source upon failure of the normal source of power or vice-versa, as quickly as possible without paralleling, typically within a maximum of 3 cycles (50 milliseconds). It is utilized when serving essential loads such as motors and pump applications.

During this transfer, it is essential that bus “dead time” be as short as possible to prevent loss of downstream critical auxiliary functions, such as contactors and relays. It is important that the main and alternate breakers are not closed at the same time since the sources may not be synchronous or even if they are, some short circuit conditions may result in the loss of both sources, if they are both closed at the same time. Also, when both are closed at the same time, system short circuit currents can exceed the feeder breaker rating.

Circuit Breaker Selection

In order to provide the utmost assurance that one breaker will be open before the other is closed, accepted practice requires that the first breaker's primary contacts have started to open before the second breaker is given a closing signal. "Fast" transfer means there is no intentional time delay in the transfer of a bus or load from one source of power to another.

Representative timing sequences using ML-18/18H breaker mechanisms for both standard and fast bus transfer equipped breakers are shown in Figures 3-1 and 3-2.

The amount of dead bus time depends upon whether the Power/Vac breaker is standard, or is equipped for FBT capability (provided with an early "b" (faster) contact and/or special closing coil). A breaker "b" contact is open when the breaker primary contacts are closed.

Fast bus transfer using Power/Vac circuit breakers with the ML-18 or 18H mechanisms do not utilize an early "b" contact. The standard "b" contact is already sufficiently fast - approximately 10 milliseconds from main contact part to "b" contact close. They are equipped with a special close coil, which reduces closing time to as little as 40 milliseconds.

Power/Vac circuit breakers with an ML-17 or 17H mechanism, a special early "b" contact is provided. This "b" contact closes 3 milliseconds after the vacuum interrupter main contacts open on the opening breaker, which initiates a closing of the second breaker. The other breaker (tie or incoming breaker) must have a special close coil that closes the main interrupter contact in approximately 50 milliseconds.

Typical dead times for fast bus transfer, using standard and special Power/Vac breakers for the ML-18 mechanism are shown in Table 3-5. **Fast bus transfer is only offered for 1200, 2000 and 3000 ampere breakers having 125 VDC or 250 VDC control voltages.**

Fast bus transfer breakers must be specified when placing an order. **Fast Bus Transfer does not require the use of circuit breakers rated for 3-cycle interrupting, as interruption speed does not impact the amount of dead bus time.**

Table 3-5—Typical Dead-Times for Fast Transfer Using Power/Vac Circuit Breakers

Power/Vac Breakers	Mechanism	Control Voltage (volts) (1)	Nominal Dead Bus Times (Milliseconds) Trip then close using:					
			Early "b" contact & Special closing coil		Standard "b" contact Special closing coil		Standard "b" contact Standard closing coil	
			No Arcing (2)	With Arcing (3)	No Arcing (2)	With Arcing (3)	No Arcing (2)	With Arcing (3)
All Rating	ML-17	125/250 DC	62	50	N/A	N/A	90	78

Footnotes:
(1) Control voltage at rated value.
(2) Main contact parting to main contact making.
(3) End of arcing to main contact making.
Dead bus times noted include allowable + operational tolerances.

SERVICE CONDITIONS

Power/Vac metalclad switchgear ratings and capabilities are based on operation under certain specific service conditions, defined by ANSI as "usual." Conditions other than usual are considered "unusual" or "harsh". 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-C37.04-1999 (Circuit Breaker Rating Structure) and for equipment in ANSI-C37.20.2 -1999 (Metalclad Switchgear), and are summarized here for application guidance.

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

USUAL SERVICE CONDITIONS

Power/Vac circuit breakers (and switchgear assemblies) 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 1000 meters (3300 feet).

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 on page 3-14.) Where radiation is significant the user is responsible for specifying the cooling/ ventilation required to limit the temperature rise.

UNUSUAL SERVICE CONDITIONS

Abnormal Temperature

The planned use of Power/Vac circuit breakers and switchgear outside the normal ambient temperature range (-30°C to +40°C) shall be considered special. Reference should be made to ANSI C37-20.2, Table 10. Example: if installed in a 50°C ambient temperature, the switchgear continuous current ratings must be derated by 8%, per ANSI Table 10. Such applications of increased temperature should be referred to Powell Electrical for evaluation.

Temperature Rise

Per the ANSIC37.20.2 standard, the temperature rise of buses and bolted connections under rated full load current in an enclosed switchgear assembly, above the ambient air temperature outside the enclosure, must not exceed 65°C, and the total hot spot temperature must not exceed 105°C. Connections to insulated cables must not exceed a 45°C temperature rise, and a 85°C hot spot temperature when operated at rated continuous current in rms amperes at rated frequency.

The maximum rated ambient temperature is 40°C. The temperature of the air surrounding all devices in an enclosed switchgear assembly, considered in conjunction with their standard rating and loading as used, will not cause these devices to exceed their maximum allowable temperature when the switchgear assembly is surrounded by air at the maximum average ambient temperature of 40°C.

The average temperature of the air surrounding primary insulated cables in any compartment of an enclosed switchgear assembly will not exceed 65°C when the assembly is equipped with the maximum rated current devices for which it is designed.

High Altitude

Medium voltage metal-clad switchgear is designed and tested in conformance to ANSI Standards. Inherent is these standards is the use of air as a heat transfer and dielectric medium. In the application of metalclad switchgear at high altitudes, there are two characteristics which degrade above 1000 meters (3300ft). They are the continuous current rating and the dielectric withstand capability, which may result in excessive corona at operating voltages and an inability to operate due to the dielectric breakdown of the air insulation due to the reduced air density.

Power/Vac circuit breakers and switchgear assemblies utilize air for an insulating and cooling medium. Operation at altitudes above 1000 meters (3300 ft) will result in a higher temperature rise and lower dielectric withstand capability because the air is thinner at the higher altitudes. For applications at higher altitudes, the rated 1 minute power-frequency withstand voltage, the impulse withstand voltage, and continuous current rating of the switchgear should be multiplied by the correction factors listed in Table 3-6 to obtain the modified or derated ratings.

When the **Voltage Correction Factor** is applied to the maximum designed voltage rating of 15 kV, 8.25kV or 4.76 kV for metal-clad switchgear, the derating may not permit the equipment to be installed at altitudes above 1000 meters, at their respective typical nominal system voltages.

Since it is more realistic to apply these correction factors to the BIL rating (impulse withstand voltage) of the switchgear, an industry accepted option is to apply the equipment at their rated nominal voltages, with no change in clearances, by the addition of lighting arresters to protect the equipment.

The recommended practice is to apply the Voltage Correction Factor to the rated BIL level of the equipment, and provide surge protection on the load side of the switchgear using station type lightning arresters (Tranquell® arresters), selected such that the maximum discharge voltage of the arrester is about 20% less than the modified impulse voltage rating of the switchgear. (See ANSI C37.010-1999, 4.2.2)

The **Current Correction Factor** is applied to the continuous current rating of the equipment only. It is necessary to derate the continuous current rating, because switchgear assemblies depend on the air for cooling and will have a higher temperature rise when operated at altitudes above 1000 meters. The short-time and interrupting current ratings on vacuum breakers are not affected by altitude. Since the Current Correction Factor is small and the actual continuous current duty is usually less than the equipment rating, current correction is typically not as serious a consideration as the voltage correction. An additional consideration is that often at higher altitude, the ambient is reduced, which can offset the higher altitude continuous current derating effect.

NOTE: The recommendations are subject to modification depending on the actual system conditions.

Table 3-6
Altitude Correction Factors for Power/Vac Circuit Breakers and Switchgear

Altitude (feet / meters)	Rating Correction Factors*		
	Rated Continuous Current	Rated Voltage	
3300ft - 1000m	1.00	1.00	
4000ft - 1200m	0.995	0.98	
5000ft - 1500m	0.991	0.95	
6000ft - 1500m	0.987	0.92	
7000ft - 2100m	0.985	0.89	
8000ft - 1500m	0.970	0.86	
9000ft - 1500m	0.965	0.83	
10000ft - 3000m	0.960	0.80	
12000ft - 3600m	0.950	0.75	
13000ft - 4000m	0.940	0.72	
14000ft - 4300m	0.935	0.70	

* From ANSI C37.20.2 - 1999, Table 8.

Application of metal-clad switchgear above 1000 meters (3300 ft) should be referred to Powell Electrical. It should be cautioned that the correction factors of power transformers are different than those for switchgear.

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 atmosphere, explosive fumes, excessive dust (e.g., coal dust, paper fibers) or particulate contamination, 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.
- Special duty/operating requirements of equipment.

BREAKER MOUNTED ACCESSORIES

Each Power/Vac breaker has two "a" and three "b" breaker auxiliary contacts wired from the breaker-mounted auxiliary switch for the Purchaser's use. Additional breaker contacts from optional compartment mounted switches are available, see Section 7.

A redundant tripping circuit on Power/Vac circuit breakers can also be furnished via an optional second or "dual" trip coil. This option was designed specifically for use on utility breakers and on breakers applied in power-station switchgear applications. This feature is seldom used in industrial or commercial applications since the standard Power/Vac trip circuit is extremely reliable.

Power/Vac circuit breakers can be provided with an optional direct-acting undervoltage trip device. The undervoltage trip device is a factory installed unit, which is an integral part of the breaker mechanism. Its function is to monitor the trip circuit control voltage and to mechanically trip the breaker if that control power drops below a preset value. (See page 4-5.)

Note that the options for a dual trip coil and the undervoltage trip device are mutually exclusive. Both cannot be utilized on the same breaker.

Standard Power/Vac design uses a lift truck, for lifting and inserting/removing the circuit breakers from the breaker cells. For designs using only 1-high breaker arrangements, with the breakers located in the bottom compartments, Powell Electrical offers an option for roll-in breakers. Roll-in breakers have a wheeled undercarriage bolted to the bottom of the breaker frame, which raises the breaker to the proper height to interface with the breaker cell connections. The breaker cell floor frame is modified to allow the breaker to roll directly from the finished floor into the cell, without the need for the lift truck described in the following section. Note roll-in breakers cannot be inserted into a "standard" breaker cell without removing the bolt-on undercarriage, and using the lift truck.

BREAKER LIFT TRUCKS

Powell Electrical offers two basic styles of lift trucks for handling Power/Vac circuit breakers, ground and test devices, roll-out transformer trays and fuse roll-outs. The first is a double masted truck that is available with two swivel casters in the rear and two straight wheels in the front. This truck is compatible with indoor switchgear and provided as a standard with every order. However, to reach the top rollout drawer in an upper compartment, a different single masted truck is required. The dimensions of the double masted truck carriage are width of 47 inches and a total width of 50 inches with the winch handle installed. The depth with arms extended is 46 inches, and the standing height is 86 inches. This style of truck cannot be used with outdoor aisle-less switchgear. See Figure 3-3.

The second style is a single-masted truck that is available with all swivel casters. As shown in Figure 3-4. This truck is compatible with outdoor switchgear and is required to reach the upper compartment rollout on indoor equipment. The maximum handle load is 15 lb. with a 850 lb. load. The typical dimensions of the single masted truck are width 36.5 inches, depth is 47 inches (with arms extended 55.5 inches), and the standing height is 79.5 inches extendible to 137.5 inches. The legs at the base of the lift truck are adjustable in width from 31.5 inches to 58 inches. This allows the legs to be narrowed to the width of the breaker for moving through doorways. **Caution; while lowering the breaker from the cubicle to the floor the width of the legs must maintain a minimum width of 44 inches.**

The single-mast lift truck can be collapsed for storage. The width is 39 inches with arms and legs collapsed, the depth is 29 inches and the height is 77 inches.

Figure 3-3

Circuit Breaker Selection

Both style of lift trucks are provided with interlocks to retain the device being handled and to lock the lift truck to the switchgear while a device is being inserted or removed. The carriage, which lifts a device, is raised or lowered by means of a winch and cable. When the winch handle is released the carriage is held in that position by means of a clutch-brake internal to the winch. Two arms are attached to the carriage for engaging the track rollers on the sides of each device.

The lift trucks are functional for both the upper and lower compartments of Power/Vac provided the equipment is mounted on no more than a 4 inch housekeeping pad. Pad cannot extend beyond the front frame of the equipment more than 3 inches.

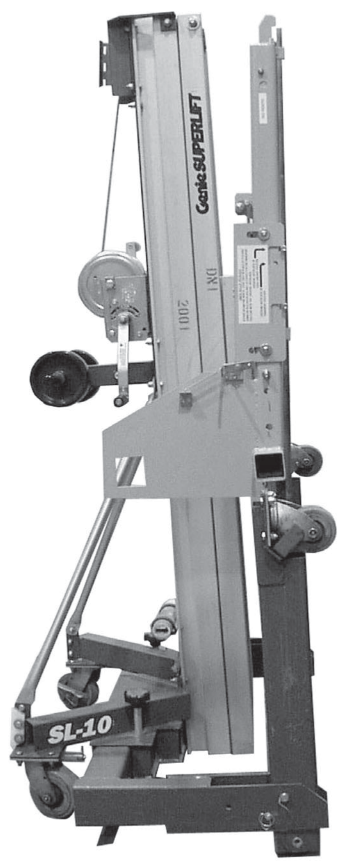


Figure 3-4

Recommended minimum working access requirements for the lift trucks of indoor switchgear is a 78 inch front aisle space with an 18 inch right side and a 12 inch left side clearance. Outdoor switchgear requires a 66 inch front aisle space with a 36 inch left side and a 18 inch right side clearance required as standard minimum space. Smaller front aisles may be used if the required right side space is available but the factory must be consulted for an engineering evaluation.

REFERENCES

1. ANSI Standard C37.06-2009, Schedules of Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical CurrentBasis.
2. ANSI Standard C37.010-1999, Application Guide for AC High Voltage Circuit Breakers.
3. ANSI Standard C37.04-1999, Circuit Breaker Rating Structure.
4. ANSI Standard C37.20.2-1999, Metalclad Switchgear Assemblies.
5. ANSI Standard C37.24-1986, Guide for Evaluating the Effect of Solar Radiation on Outdoor Metalclad Switchgear.
6. ANSI Standard C37.100-1992 Definitions for Power Switchgear.

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 Power/Vac 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
- Indicating lamps
- Relay power supplies
- Emergency lights
- Emergency motors
- Excitation power (brushless motors, etc.)

AC
- Indicating lamps
- Relay power supplies
- Equipment Heaters
- Equipment Lights and Convenience Outlets
- 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 Power/Vac metalclad switchgear are storage batteries (with charger) for DC control, and transformers for AC control. When AC is used for control, the tripping power is obtained from capacitors contained within trip devices, which are fed from rectified AC. 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 Power/Vac 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 required operating range of the control power voltage in the switchgear equipment is determined by the rated operating voltage range of the circuit breaker. These ranges are established by ANSI C37.06 standards. Control voltage and operating currents for Power/Vac circuit breakers are given in Table 4-1 and 4-2.

Table 4-1 Control Voltage and Operating Currents for
Power/Vac ML-17 & 17H Breaker Mechanisms (Type VB)

Breaker Control Source Voltage	Closing Voltage Range	Tripping Voltage Range	Closing Coil Current		Tripping Coil Current		Charge Motor Inrush Current	Charge Motor Run Current (3)
			Standard	W/FBT	5 Cycle	3 Cycle		
48VDC	38-56VDC	28-56VDC	9.6	N/A	26.0	26.0	29.0	12.3
125VDC	100-140VDC	70-140VDC	6.0	32.0	10.2	6.0	18.3	3.7
250VDC	200-280VDC	140-280VDC	3.0	12.0	5.2	5.2	9.9	2.3
120VAC	104-127VAC	108-132VAC (1)	8.0	N/A	10.2	6.0	13.6	4.9
240VAC	208-254VAC	216-264VAC (2)	10.3	N/A	2.3	2.3	7.2	3.0

1. 120VAC control voltage for tripping requires the use of a 120VAC capacitor trip device. Cap trip device delivers 170VDC (peak) into a 125VDC trip coil.
2. 240VAC control voltage for tripping requires the use of a 240VAC capacitor trip device. Cap trip device delivers340VDC (peak) into a 340VDC trip coil.
3. Approximate spring charging time for ML-17 & ML-17H mechanisms is 7 seconds.
4. FBT = Fast Bus Transfer, requires special closing coil.

Breaker Tripping

Tripping power availability should be independent of the voltage conditions present on the power system associated with the switchgear.

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 circuit switching operations use an operator control switch to energize the trip coil. Automatic tripping occurs when a protective relay senses an abnormal system condition through the power circuit instrument transformers, and closes output contacts in the trip circuit.

When deciding between DC battery trip and AC capacitor trip, the following points must be considered:

- For a single breaker or a few breakers, AC control with capacitor trip devices may have lower cost than a battery system, but a separate trip device is required for each breaker and lockout relay.

- A battery source is more reliable, but requires more maintenance than a capacitor trip device. However capacitor trip devices also contain small rechargeable NiCad batteries, which must be checked and replaced periodically.

- If a battery is used for tripping, DC closing power can also be obtained for little additional cost.

- If non-self powered microprocessor relays are utilized for protection with AC control power, a small UPS should be included to ensure the relay power supplies remain powered-up during system disturbances or during transfers of the AC control power from normal to emergency source.

DC BATTERY TRIP—When properly maintained, a battery bank 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 bank 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 bank 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 bank 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.

General space requirements when the batteries are to be mounted in the outdoor (NEMA 3R) switchgear, are one 36 inch wide Power/Vac stack for a 48VDC battery bank and two 36 inch wide Power/Vac stacks for a 125VDC bank. In aisle type outdoor construction, 36 inch wide empty “work-spaces” are added to house the battery system. Note on indoor (NEMA 1) applications, batteries are typically not located within the switchgear structure.

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.

Power/Vac AUTO-CHARGE CAPACITOR TRIP DEVICE— The Automatic Charging Capacitor Trip Device is used to trip circuit breakers and lockout relays when AC control power source is utilized. The Applicator Trip Device converts AC control bus voltage to DC voltage and stores enough energy to operate a lockout relay or trip a circuit breaker, often more than once. The Applicator Trip Device, with batteries fully charged, will maintain a charge for a minimum of 3 days after the AC power has been interrupted. In normal operation, the batteries are trickle charged from the AC voltage source.

DC voltage is available from the unit for tripping immediately upon AC voltage power up. Capacitors do not need to be charged to have tripping voltage available on the output of the device. This is because the output is automatically fed from the full wave bridge rectified AC signal, or the charged capacitors, whichever is greater. Capacitor charge current is limited to protect the control power system from a large current in-rush. This feature allows the use of many Applicator Trip Device units from the same control power voltage source without coordination problems. Additionally, the Applicator Trip Device is self-protected from short circuit damage on the output. The Automatic Charging Capacitor Trip Device is provided on PowerVAC circuit breakers whenever AC control voltage is specified. 120VAC and 240VAC control power sources are available.

DIRECT ACTING UNDERVOLTAGE TRIP DEVICE—Most Power/Vac circuit breakers can be provided with a direct acting undervoltage trip device. The undervoltage trip device is a factory-installed unit, which is an integral part of the breaker mechanism. Its function is to monitor the DC trip control voltage and to mechanically trip the breaker if that control voltage is lost. The UV device will also block closing of the breaker if the control voltage is not 80% or more of the nominal value.

NEMA Standard Publication No. SG4-1990 paragraph 3.9 requires the dropout range of undervoltage trip devices to be 30 to 60 percent of the rated voltage. The Power/Vac undervoltage device trips the breaker in the range of 15 to 60 percent of the nominal tripping control voltage.

Control Voltage	Tripping Range
48 VDC	7-29 VDC
125 VDC	19-75 VDC
250 VDC	38-150 VDC

Specifications, which require tripping to occur at some voltage higher than 15 percent of normal, should be provided with a voltage sensing relay to remove trip control voltage from the undervoltage trip device to assure breaker tripping at the desired voltage.

Breaker Closing

Closing power availability should also be independent of voltage conditions on the power system associated with the switchgear as with tripping. Accordingly, a DC battery bank is normally considered to be the most reliable auxiliary power source. Nevertheless, in many instances, the battery bank 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 switchgear installations, consisting of only a few circuit breaker units.

NOTE: When equipment is initially installed and control power is first energized, all Power/Vac breakers that are in the connected position will immediately begin to charge their closing springs, which may overload an otherwise properly sized AC or DC source. It is recommended to either rack breakers in to the connected position one at a time after control power is established, or pull all the individual breaker close circuit fuse blocks/ disconnects prior to energizing the control power circuit.

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 ambient temperature extremes and the 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.

When the closing mechanism is operated from AC, the current required is such that it can be taken from a control power transformer or a general-purpose or lighting source, internal or external to the switchgear. 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 (close coil). The Power/Vac breaker mechanism is also capable of manual operation, if necessary, both for charging the springs and for releasing them to close the breaker.

For any control power source used for breaker closing, the maximum closing load should be calculated using Table 4-1 and 4-2 values. Usually, only one breaker will be closed at a time, but the possibility of simultaneous closing of two or more breakers must be examined. This possibility will depend on the type of application and any special control requirements, such as load restoration. Simultaneous closing of two breakers could occur with multiple-breaker, motor starting equipment, or with automatic reclosing breakers. Also, on large installations, with several different control points, different operators could cause simultaneous manual operations.

INDICATING LAMPS

Position indicating lamps for each circuit breaker are operated from the trip fuses with DC closing power, or the closing fuses on either AC control or a "tripping only" battery. These lamps represent a small, but steady load, which is of concern particularly in DC applications. The total load is the sum of:

- One indicating lamp per breaker.
- Lamps used to supervise fuses of lockout relays, etc.
- Additional lamps, if any, used for remote indication in parallel with switchgear lamps.

Burden is usually 0.035 amperes per lamp, regardless of voltage, and is assumed to be carried (by the battery) for not more than eight hours.

EQUIPMENT HEATERS

On outdoor designs, moisture condensation is minimized through the use of strip heating elements. Heater elements are located in each breaker or auxiliary compartment and each cable compartment with a total of 300 watts per vertical section. Heaters are rated 300W at 240VAC, but are applied at half-voltage, which reduces heat output to 75 watts each for extended life and are protected by perforated metal guards to prevent inadvertent contact with the heater element. Heaters are supplied on indoor designs only if specified by the purchaser.

Heaters should be energized at all times to guard against condensation caused by wide ambient temperature excursions. Accordingly, heater switches or thermostats are provided in the heater circuit only upon customer request.

COMFORT HEATING

Portable Comfort heaters for use in outdoor aisle-type Power/Vac installations, must be supplied by the Purchaser. A grounding-type receptacle, rated 250 volt AC, 20 amperes, is provided at each end of the aisle for portable comfort heater connection.

When sizing the AC control power source, allow 5000VA load at 240VAC for each heater receptacle intended for use.

RELAYING

With DC control power, allowance must be made for simultaneous tripping of two or more breakers. Requirements for simultaneous tripping depend first, on the number of breakers on the DC source, and second, on the kind of relaying. Based on probability considerations, a guide to the possible number of simultaneous tripping is given in Table 4-3.

Table 4-3
Simultaneous Breaker Tripping

Number of Breakers in lineup	1	2	3-5	6-10	Above 10
Breakers Tripped By:	**Probable Maximum Number of Breakers Tripping Simultaneously**				
Time delay fault protection	1	1	2	3	(a)
Instantaneous fault protection	1	1	3	4	(a)
Undervoltage or bus differential (b)	1	1	All	All	All

(a) Depends upon operating conditions.
(b) Use of single undervoltage or bus differential relay for tripping all breakers.

Lockout relays, when present, as in differential relay circuits, require special treatment:

- With AC operation, a capacitor trip device must be included for operation of each lockout relay.
- With DC operation, the lockout (86) relay coil current must be added to the simultaneous breaker demand, since the relay does not cut itself off until after the breaker coils have been energized.

In addition, all solid-state relays unless "self-powered", have internal AC or DC power supplies which must be included in the total steady-state load. VA burden for typical solid-state protective relays fall between 10VA and 35VA, depending on manufacturer and model. Consult the specific device manufacturer's catalog.

FANS

On outdoor aisle-type Power/Vac switchgear, roof fans for aisle ventilation are available as an option. The standard fan uses a 1/3 hp single-phase motor, for operation from 120VAC only; allow 333 VA per fan.

Substation transformers associated with switchgear sometimes include fans. When energized from the switchgear control power source, the fan load must be included in the total burden on the source. Usually this is a 240-volt, single-phase load; from one to several kVA per transformer.

On indoor 4000A Power/Vac switchgear, 4000A rated breakers require forced-air cooling. Each 4000A breaker utilizes two fans, each drawing 6A at 120VAC or 3A at 240VAC.

LIGHTS

Outdoor Power/Vac switchgear, both aisle and non-aisle types, is provided with receptacles for 120-volt incandescent lamps. The control power allowance for these should be 100 Watts per vertical section.

Other lighting loads, such as outside floodlights, must be factored into the AC control power load based on actual requirements.

CONVENIENCE OUTLETS

In outdoor Power/Vac switchgear, 115-volt duplex grounding convenience outlets are provided.

With aisle-less design, one outlet is provided per vertical section. With aisle-type construction, one outlet is located at each end of the aisle.

Control power allowance should be a nominal 500 Watts for each duplex outlet.

EXCITATION POWER

When synchronous motors with brushless field excitation are controlled directly from the switchgear, power for the exciter field source is sometimes required from the switchgear control power source.

This excitation demand varies with the machine, from 1 to perhaps 8 amperes DC, usually at approximately 100 volts. With rectified AC supply to the field, the AC equivalent of the DC field current must be included the total CPT loading. (As a first approximation, multiply the DC amperes by 1.15 and convert to VA by multiplying this product by 125 volts.) When the exciter field is fed directly from the battery, the field demand, as a nominal 8-hour load, must be included in the DC steady load total.

Generators with static regulators usually require a separate transformer on the incoming leads of the generator breaker. This transformer is of the same epoxy-cast coil, dry type, as the switchgear CPT, but is located in its own rollout tray. Such dedicated transformers are not part of the regular control power loading.

BREAKER REMOTE RACKING

When the optional motor driven remote racking device is utilized, the load on the control power source is 4.5A for the120VAC model and 2.5A for the 240VAC.

OTHER LOADS

With DC control, when the charger is supplied from the switchgear AC control power transformer, the charger load must be included in the total AC demand. Using charger DC ampere rating as a base, some ratios of equivalent AC load at different supply and battery voltages are tabulated in Table 4-4.

Table 4-4

AC Supply Voltage	AC Load Factor for Charger Battery Voltage 48V	AC Load Factor for Charger Battery Voltage 125V
115 V	75%	230%
230 V	38%	115%

For example, a 6-ampere charger, fed 115VAC, and supplying a 125VDC battery bank, has an AC load of approximately 13.8 amperes (6 A x 230%) at full output, or 1590 VA (13.8 A x 115 V). While this would be an intermittent condition, with the normal load being about 0.5 to 1.0 amperes DC, the AC control source must be sized to handle the 13.8 ampere load.

With automatic control schemes, some relays will be energized continuously after the first breaker is closed. The amperes drawn by these relays must be totaled and included with the indicating lamp load, etc., to arrive at the total steady load.

Emergency loads on switchgear batteries, such as room lights or DC pump motors, usually result in a much larger battery bank than required for the switchgear alone. Lights are usually assumed to be used for three hours, and then extinguished. Motor load duration must be specified by the user.

CONTROL POWER SOURCE SELECTION

For a particular station, selection of a control power source may require sizing of a battery, a control power transformer, or sometimes both. The first step is to establish the size of each load of the various types discussed. Second, for batteries, the short-time loads, such as breaker tripping, and the steady load, such as lamps, must be converted to a common rate base.

With the relatively small demands placed on the control power source by individual breakers, as detailed in Table 4-1 and 4-2, other loads must be evaluated carefully, since they may represent the major demand. Particularly with batteries, long-time loads must have a time period stated, since a battery bank, with the charger “off”, is not a “continuous” source.

DC CONTROL POWER EQUIPMENT

Powell Electrical does not design, manufacture or test storage batteries. Powell, when required, will select and furnish batteries and their charger as specified by the customer and in accordance with the requirements of the switching devices and the over-all station operation.

A DC control power source consists of a storage battery bank, rack and an associated charger. The battery bank is connected to the DC control power bus and the charger at all times. Large momentary loads are supplied from the battery bank, but it otherwise does very little work in normal operating situations.

The basic requirements of a storage battery are it must be capable of being trickle charged so that under normal conditions the battery is always fully charged and its terminal voltage held substantially constant. The trickle charge voltage must be less than the upper voltage limits of lamps and continuously energized coils and should not fall below a specified minimum voltage during maximum normal momentary discharge. This is to insure adequate closing voltage at the breaker mechanism terminals after making allowances for voltage drop in connections between the battery bank and the breaker mechanism.

Two types of batteries are used with switchgear that have the characteristics which meet the requirements for closing and tripping functions: lead-acid or nickel-cadmium. Several classes of each type are produced, each with different costs and with different ratios between short-time and long-time capacities. The exact type and class must be established before performing the conversion of loads to a common rate base.

Lead-acid Batteries

Common lead-acid battery types:

- Pasted plate, with lead-antimony grids.
- Lead-calcium; a pasted-plate construction with calcium replacing antimony as the additive for grid strength.

Pasted plate, lead antimony, is the basic lead-acid battery, familiar in another form as the automobile battery. For control work (compared to auto batteries), thicker plates and lower gravity of acid provide longer life and allow long-time trickle or “float” charging. With different plate thicknesses, expected life is from 6 to 14 years.

Lead-calcium construction has longer expected life (up to 25 years) than lead-antimony at a rather small increase in cost. The “pure lead” electrochemical characteristics, compared to the other classes, require slightly different (higher) charging voltages.

Nickel-cadmium Batteries

Nickel-cadmium batteries are more expensive than lead-acid, in general, but have advantages. Maintenance is less, life is longer, low-temperature discharge currents are higher for a given size, and they can be charged more rapidly.

Pocket-plate cells are the normal construction used with switchgear; they are made in three different plate thicknesses. The thickest plates are not suitable for short-time applications. Medium or thin-plate cells are used with switchgear; the choice depending upon the relative amounts, respectively, or long- or short-time load.

Sintered-plate construction, which is relatively new, is used mostly in “cordless” appliances, seldom in switchgear.

	Lead-Acid	NiCad
Initial Cost	Lower	Higher
Maintenance	Higher	Lower
Life Expectancy	Lower	Higher

Battery Capacity and Sizing

The capacity of a storage battery is usually expressed in ampere-hours (one amp for one hour, or the product of amperes output multiplied by hours of discharge, with the basic rate being eight hours). Battery capacity, however, may be expressed at many time-rates other than the eight-hour rate.

For switchgear short-time loads, such as breaker tripping, the one minute rate per cell (discharging to 1.75 volts for lead, or 1.14 volts for nickel-cadmium) is used. The one-minute rate does not exhaust the battery completely; rather, it is the rate which causes the terminal voltage to drop to the stated value early in the discharge period.

Further, the actual value of discharge capacity of a storage battery may vary over a wide range with battery temperature. Published data is for cells at 25° C (77° F), and battery rating factors must be reduced when the battery is at a lower temperature. For capacity rating factors refer to IEEE worksheets.

Generally the effect of high temperatures for every 15° F above 77° F the lead acid battery loses 50% of its useful life and for the same temperature decrease, the nickel-cadmium loses 20% of its useful life. The one-minute rating at -10° C (15° F), for instance is half the 25° C rating.

In calculating the battery loads you must consider three types of loads: Continuous loads are those that are energized for the duration of the duty cycle. These have a major effect of battery capacity. Non-continuous loads are energized for only a portion of the duty cycle. If the inception of the load is known, but the end is not or reverse, then you must consider it as the known portion of the duty cycle. Last are momentary loads which are very short in duration, they can be a fraction of a second, but you must treat it as lasting one full minute.

- Direct use of specification sheets, or software programs, etc. from battery makers.
- Referral of data to battery manufacturers.
- Referral of calculated data to switchgear manufacturers.

For direct calculation, the battery is assumed to have carried its steady loads for eight hours, and then as the worst case subject to the maximum load involving the one-minute rate.

Indoor locations assume that the battery is at 25° C (77° F); outdoor locations at -10° C (15° F). A minimum size limit of cell is suggested to allow for unknowns: 20 ampere-hours for lead-acid, or 15 ampere hours for nickel-cadmium.

A small station, for example, with the battery located indoors, might have three breakers, with closing and tripping duty, and no steady load except the switchgear indicating lamps. Two of the breakers have instantaneous settings on their overcurrent relays, so that per Table 4-3 simultaneous tripping of these two breakers might occur. Steady lamp load, thus, is 0.035 A x 3 = 0.105 amperes. Maximum short-time loads, given for both 48-volt and 125-volt DC to illustrate procedure, are shown in Table 4-5.

Table 4-5 Battery Sizing Information

Control Voltage	48 VDC	125 VDC
Battery System Voltage Range	42-56 VDC	105-140 VDC
Breaker Mechanism Type	ML-17	ML-17
Breaker Quantity	9.6 Amps	6.0 Amps
Breaker Close Current	5 Cycles	5 Cycles
Breaker Close Time	26 Amps	10.2 Amps
Breaker Trip Current	5 Cycles	5 Cycles
Breaker Trip Time	29 Amps	18.3 Amps
Spring Charge Inrush Current	12.3 Amps	3.7 Amps
Spring Charge Windup Current	8 Seconds	8 Seconds
Breaker Spring Charge Time		

Example:

Control voltage, DC	48 V	125 V
ML-17 Trip coil current	26 A	10.2 A
ML-17 Spring motor current	12.3 A	3.7 A

Since two breakers can trip at once in this example, maximum current from this load is either 17A x 2, or 10.2A x 2, respectively, 34 or 20.4 amperes total at 48 or 125 volts. Comparing this with charging motor current, we see that the trip current is larger, so trip current will be used in the next step as illustrated in Table 4-6.

Table 4-6 Battery Sizing Example

Battery Type:	Lead-acid		Nickel-cadmium	
Control voltage (volts)	45	125	48	
Maximum 1-minute demand (amperes)	34	20.4	34	30.4
8-hr. equiv. of 1-min. demand (Max. demand divided by conversion factor*) (amp-hrs)	22.7	13.6	11.7	7.03
Lamp load (0.105A x 8 hrs.) (amp-hrs)	0.84	0.84	0.84	0.84
Total amp-hrs (8 hr. rate)	23.54	14.44	12.54	7.87

* Conversion factors to convert to “common rate base” (i.e., from one-minute rate to eight-hour rate) are: 1.5 for the lead-acid batteries (pasted plate); 2.9 for the nickel-cadmium batteries (thin plate or high rate). Please note that conversion factors vary by cell size; therefore, the factors used in this example are not applicable for batteries of other sizes.

Analyzing these totals, the lead-acid battery at 48 volts with a nominal ampere-hour rating of 30AH will be required. As an alternate at 125 volts, the minimum 20AH lead-acid battery will be sufficient. The minimum nickel-cadmium battery of 15AH will be sufficient at 48 volts and at 125 volts.

In addition, since the total ampere-hours required in each case is less than the ampere-hour capacity of the selected cell, reserve capacity is available. The matter of reserve capacity is largely related to how long the charger may be off. This no-charge condition has been known to last for several days. Thus, a “DC low-voltage alarm” option in the charger may be desirable to warn of such conditions.

For the same station, with the battery at outdoor temperatures, the one-minute demand must be doubled before converting to ampere-hours. The eight-hour rate needs a smaller increase of about 30 percent. Note that these conversion ratios generally decrease as cell size increases; hence, the approximate size of cell being considered must be determined before the conversion factors can be determined.

In arriving at the actual size of the battery bank, care must be taken to review the calculated amp-hours or cell requirement and then take into account the recommended design factor of 10% times the calculated values and then an aging factor of 25% times the calculated values. The combined sum of these calculations will provide the actual size of the battery bank.

Control Power Equipment

Battery Chargers

Battery chargers have been built both as unregulated or "trickle" chargers, and as voltage-regulated chargers. The latter type provides longer life for the battery, particularly if it is a lead-acid battery. Voltage-regulated chargers are considered standard for switchgear applications.

The charger must be selected with an ampere rating sufficient to satisfy the simultaneous demand of the following three functions:

- Self-discharge losses of the battery.
- Steady load of the station: indicating lamps, relays, etc.
- Equalizing charges, or other high-rate output requirements.

The self-discharge or "trickle" current of a lead-acid battery starts at about 0.25 percent of the eight-hour rate, and increases with age to about 1.0 percent of that rate. Nickel-cadmium cells can be assigned a similar trickle current.

Steady load is made up of the long-time loads mentioned earlier in this section.

Equalizing charge is a monthly requirement for lead-acid batteries except for the lead-cadmium class. When the charger is first switched to the higher equalizing voltage, the battery demands current equal to about 20% of its eight-hour rate. Nickel-cadmium batteries do not require equalizing, but it is convenient to use the same numbers as for lead-acid in establishing the charger capacity to be used for occasional "boosting" of the nickel-cadmium battery.

In sizing the charger, the first number considered should be the steady load from the preceding battery calculations. Add to this load, the equalizing charge current. A quick way to find equalizing amperes is to divide the battery ampere-hour capacity (at the eight-hour rate) by 40. The sum of steady load and equalizing amperes is then compared with a list of battery charger ratings; select a charger with a rating that equals or exceeds this sum. The trickle current, unless known to be quite large, is usually covered by the margin between the standard charge rating and the sum of steady and equalizing loads.

Occasionally a battery is shipped "dry," with electrolyte added at its destination. Such batteries require a "conditioning" charge after filling; the amperes needed for this are 25% of the eight-hour rate, but with no other load connected.

AC CONTROL EQUIPMENT

Application

To minimize the possibility of inadvertent interruption of control power for AC-operated Power/Vac switchgear, it is recommended that control power be derived from a separate transformer used only for control and other power requirements, which are directly associated with the performance of the switchgear. The transformer should be energized from that part of the main power system least likely to be de-energized.

Where the switchgear is energized from multiple sources of power, a control-power transformer is usually provided for each source, for operation of breakers associated with that source. Breakers such as feeder and bus-tie breakers not associated exclusively with any one source are supplied either from a transformer connected to the switchgear bus, or by control power transfer panel located in the switchgear, which automatically connects the AC control bus to an energized transformer.

Selection

With AC control, if breaker tripping power is being obtained from capacitor-trip devices, its demand need not be included in the control power transformer section. Similarly, closing demand is relatively small, except for the breaker spring-charging motors. The principal caution regarding closing demand is to review for conditions where two or more spring-charging motors may be energized at the same time.

NOTE: When equipment is initially installed and control power is first energized, all connected Power/Vac breakers will immediately begin to charge their closing springs, which may overload the otherwise properly sized AC source. It is recommended to either rack breakers in one at a time after control power is established, or pull the close circuit fuse blocks or close circuit disconnects prior to energizing the control power circuit.

Other loads, such as those listed on page 4-6, must be totaled and evaluated to determine their demand on the control power transformer. The total load is then compared to the available sizes of control power transformers, and the next larger size selected.

As an example, consider an outdoor, protected-aisle station having five breakers and one auxiliary compartment (in four vertical sections). Control of breakers is from local control switches. No ventilating fan is used, but 400 Watts are needed for remote lights. As shown in Table 4-7, the load is approximately 8 kVA, so the next larger available transformer (10 or 15 kVA) is selected.

Table 4-7 AC Load Estimating Example

Type of Load	Load (VA)
Indicating lamps (0.035A x 230V x 5 Breakers)	40
Equipment heaters (300 W x 4)	1200
Comfort heater (plug in)	5000
Equipment lights (100 W x 4)	400
Convenience outlets (500 W x 2)	1000
Remote lights	400
TOTAL	8040

GUIDE FOR ESTIMATING THE HEAT LOSS IN Power/Vac® SWITCHGEAR

When operating at nameplate rating, Power/Vac metalclad switchgear heat losses per vertical section may be estimated by adding the individual components of heat loss as indicated below.

Table 4-8

Breaker and Bus Work Per Vertical Section	Heat Loss In Watts
1-1200 AMP BKR	675
1-2000 AMP BKR	1335
1-3000 AMP BKR	2030
3500/4000 AMP BKR	2765
2-1200 AMP BKRS. STACKED	1220
1-1200 AMP & 1-2000 AMP BKR	1880

To the above figures add the following as they apply to the line-up.

Table 4-9

Each vertical section with simple (typical) relaying and control	150 watts
Each vertical section with complex relaying and control (Differential relaying, backup protective relays, etc)	330 watts
Each VT rollout	50 watts
Each CPT rollout up to 15KVA	600 watts
Equipment heaters if supplied (per section)	300 watts

To convert Watts to BTU'S:

Watts x 0.05688 = BTU'S per minute

Watts x 3.4128 = BTU'S per hour

Section 5

System and Equipment Protection

INTRODUCTION

This selection Guide covers some of the basic considerations used when selecting relays for the protection of Medium Voltage Power Systems. It is organized by protection packages according to the types of equipment generally encountered in medium voltage systems. Feeders, Incoming Lines, Bus, Transformers, Motors, Generators and Metering will be addressed.

Protection considerations can be provided by either single phase and multi-function three phase relays that can include phase and ground directional, non-directional relays, overcurrent, differential, directional power, under-frequency and under-over voltage relaying.

Newer multifunctional digital relays offer several benefits; expanded relay functions, digital metering, diagnostics, reduction in relay costs per function, reduction in wiring and increased panel space with the reduction in the quantity of relays.

Instrumentation, metering, current and voltage detection considerations include selection of instrument transformer ratios, as well as scales of analog meters if used.

Control considerations include a discussion of permissive control operation as well as supervision of trip coils by indicating lamps.

Since all AC power systems are subject to transient voltages, a discussion of surge protection is also included.

PROTECTION CONSIDERATIONS

BASIC SYSTEM PROTECTION

Phase-overcurrent Protection

Recommended phase over-current protection consists of one time and instantaneous phase-overcurrent element (50/51) in each phase operated from a current transformer in each phase. This arrangement provides complete phase-overcurrent protection for the circuit, even when one phase element is removed from the circuit for testing; it also provides local backup if one of the three phase elements is inoperative.

Overcurrent relays today are available with the standard ANSI inverse, very inverse, or extremely inverse and definite time characteristics. Many microprocessor-based relays also offer the IEC time characteristics. In the absence of additional system information, for a single characteristic device the very inverse characteristic is most likely to provide optimum circuit protection and selectivity with other system protective devices. This characteristic is intended for application where the magnitude of fault current is determined primarily by the distance from the source to the fault. If selectivity with fuses or reclosers is a requirement, the extremely inverse characteristic is well suited for applications. The inverse characteristic is useful in those rare applications in which selectivity with other inverse or definite time relays is a concern. It is also useful on systems that have a multiplicity of local generators at the distribution voltage and where the magnitude of fault current is determined primarily by how many generators are in service at the same time. Most microprocessor-based relays have all the above characteristics field-selectable which would allow the specifier to select a relay with minimal information and select a characteristic when more complete information is available.

INCOMING LINES—Incoming line phase-over-current protection is typically time delay only (51), furnished without instantaneous attachments (50), or on digital multi-function relays, the instantaneous is disabled but the functions stays available. This allows the relay to be selective with feeder relays having instantaneous attachments (50/51).

FEEDERS — Instantaneous phase-overcurrent relay (50) settings for radial *utility distribution feeders* are set usually as low as possible considering, among other things, “cold-load” pickup and other circuit requirements. Instantaneous phase-overcurrent relays for *industrial or commercial building radial circuits* are usually set high enough (but well below the available short-circuit current) to prevent false tripping for faults at the lower-voltage terminals of large transformer banks and to provide selectivity with groups of large motor starters. Instantaneous settings should be low enough so that the combination of time and instantaneous settings provides protection below the conductor short-circuit heating limit.

FEEDER TIES — For feeder-tie (cable connected) circuits to *downstream* distribution circuit-breaker lineups, selectivity is enhanced by disconnecting, disabling, or delaying the instantaneous element (50) of the phase-overcurrent relays and setting the time-overcurrent (51) element to trip at less than the short-circuit heating limit of the conductors.

BUS TIES—Bus-tie circuits, within the same lineup of switchgear including two incoming lines, are frequently specified without overcurrent-protection. When overcurrent protection is provided for this type of circuit, relays are connected in what is termed a “current summation” connection. The use of this connection provides the opportunity for selectivity between main or tie breakers and feeder breakers minimizing relay operating time delay. (See the one-line diagram on page 2-7 for an example of this connection.)

TRANSFORMERS—Transformer-overcurrent protection criteria are specified in Section 450 of the 2005 National Electrical Code. Permissible short-circuit capabilities for transformers are specified in ANSI Standard C57.12. Selection of transformer-overcurrent protection is governed by these criteria.

The NEC requirements determine the pickup of the time-overcurrent phase protective relays. The ANSI requirements and the connection of the transformer determine the time dial setting. The inrush and short-circuit current magnitudes determine the instantaneous setting of the phase-overcurrent protective relays.

GENERATORS —Overcurrent relays, applied on generator circuits, are used for feeder backup rather than overload protection. These overcurrent relays are typically voltage-restrained overcurrent relays (51V). They operate faster and are more sensitive for faults close to the generator than for faults remote from the generator.

Ground-overcurrent Protection

Ground-overcurrent protection is provided by either time-overcurrent or instantaneous overcurrent relays. Sensitive ground-fault protection is desirable to minimize damage to circuit equipment and circuit conductors.

The three most commonly used connections for ground-overcurrent relays are the residual connection (51N), the ground-sensor (balanced-flux or zero-sequence) connection (50GS or 51GS), and the neutral current transformer connection (51G).

Residually connected ground-overcurrent relays (51N) are wired in the ground (neutral)-return current transformer lead of three current transformers connected in wye. The relay detects the current of a ground fault by measuring the current remaining in the secondary of the three phases of the circuit as transformed by the current transformers. The minimum pickup of the relay is determined by the current transformer ratio. On systems with line-to-neutral connected loads, the ground-overcurrent relay (51N) pickup must be set above any expected maximum single-phase unbalanced load. If an instantaneous ground-overcurrent element (50N) is used, it must be set above any expected unbalance due to unequal current transformer saturation on phase faults or transformer inrush currents. Residually connected ground-overcurrent relays are usually applied on solidly grounded systems.

Ground-sensor (GSCT) relaying schemes use an instantaneous (50GS) or time-delay (51GS) overcurrent relay or relay element connected to the secondary of a window-type current transformer through which all load current-carrying conductors pass. The relay detects the ground current directly from this current transformer, provided the equipment ground conductor and cable shielding bypass the current transformer. Ground faults 15 amperes (or less) in the primary circuit can be detected with this scheme. Ground-sensor relaying schemes are usually applied on low resistance or solidly grounded systems.

Neutral ground relaying typically uses a time-delay overcurrent relay (51G) connected in the secondary of the current transformer, located in the neutral of a wye-connected transformer, wye-connected generator, or the neutral of a neutral-deriving transformer bank.

Some systems are designed with no intentional grounds. To detect the first ground on this type of system, a sensitive directional ground overcurrent device may be employed. Optionally, a set of potential transformers wired wye-wye or wye-broken delta with indicating lights or voltmeters can be used to indicate the presence of a ground fault on an otherwise ungrounded system.

INCOMING LINES —Incoming line ground-over-current relay protection consists of either a residually connected relay (51N) or a relay (51G) connected to a current transformer in the transformer neutral ground connection. Ground-sensor relaying (51GS) on incoming lines is not recommended because of the size, number, and construction of the incoming line conductors.

For solidly grounded systems with source transformers located remote from the switchgear, residually connected ground-overcurrent relays (without instantaneous) are most often applied. Some utility users omit all incoming line ground relays on solidly grounded systems and rely on three phase-overcurrent relays to provide complete phase- and ground-fault protection.

For impedance or resistance grounded systems with local source transformers, a ground relay (51G) connected to a current transformer in the transformer neutral connection is most applicable. A typical current transformer ratio for the neutral current transformer is one-half to one-quarter the maximum ground-fault current, e.g., a 200:5 CT ratio is appropriate for the neutral CT in series with a 400A, 10-second neutral grounding resistor. This ratio permits sensitive settings of the ground relay and selective operation with downstream ground-sensor relays. The ground relay is the system backup relay for the medium-voltage system. It also provides ground-fault protection for the transformer and its secondary conductors. If a transformer primary circuit breaker is used, the secondary ground-overcurrent relay (51G) in the transformer neutral connection should trip both the transformer primary and secondary circuit breaker.

FEEDERS —Ground-sensor (zero-sequence) relay arrangements use instantaneous-overcurrent relays (50GS) or time-overcurrent relays (51GS) and are appropriate for both resistance grounded and solidly grounded systems. These arrangements provide sensitive ground-fault protection for both branch circuits and feeder-distribution circuits. Good selectivity can be obtained for a distribution system incorporating this type of relaying on all branch and feeder distribution circuits; however, a feeder breaker with ground-sensor relaying usually cannot be made selective with downstream feeders using residual ground relaying. In addition, ground-sensor relaying is not applicable to circuits with metal-enclosed conductors (non-seg Bus Duct) because of the impracticability of passing the phase conductors through a single current transformer. Ground-sensor relaying is rarely applied to circuits terminated with potheads because of the special installation procedures required for mounting the potheads.

Residual-ground relaying (51N or 50/51N) is suitable for feeders on solidly grounded systems or resistance grounded systems with available ground-fault currents greater than about twice the maximum current transformer rating. It is also required for feeders, which must be selective with other downstream feeders having residual-ground overcurrent relaying.

TRANSFORMERS AND GENERATORS—Ground-overcurrent relaying for wye-connected transformers, wye-connected generators and neutral-deriving transformers usually employs neutral-ground relaying, as discussed previously under “Incoming Lines.” This provides system backup ground relaying. Settings, however, are normally too high to provide good ground-fault protection for the apparatus. Ground-fault protection is better obtained by using a scheme of differential relaying, which is described later in this section.

Directional Phase-overcurrent Protection

Directional phase-overcurrent relays (67) operate for current flow in only one pre-determined direction. Incoming lines, operating in parallel from separate sources, require directional phase-overcurrent relay protection to provide sensitive operation and to assure selectivity between incoming-line breakers for phase faults on the source side of one of the breakers. This directional phase-overcurrent protection is furnished by using relays, polarized to operate on current flowing toward the source. The directional- overcurrent relay without instantaneous function is appropriate for most applications. The pickup of this relay should be set at a value slightly below full-load current. The time delay function can be set to permit selectivity with upstream feeder breaker or line instantaneous relays.

Occasionally a directional-overcurrent relay (67) with directional instantaneous function is applied to incoming lines fed by long “dedicated” service lines, the instantaneous directional unit is set to operate for faults located approximately 80 to 90 percent of the distance from the incoming line to the source. For large local transformers, the instantaneous unit on a high side directional overcurrent relay is set slightly above the low-voltage symmetrical rms amperes contributed through the transformer to a fault on the higher voltage side of the transformer.

Directional phase-overcurrent relays can be voltage polarized from bus VT's connected in open-delta, delta-delta or wye-wye. Polarization is necessary to establish the current phase relationships between voltage and current to determine the direction of current flow.

While earlier electromechanical directional-overcurrent relays usually had only one time-current characteristic, digital multi-function versions are available in three-phase (and ground, if desired) packages with inverse, very inverse, and extremely inverse (and other) characteristics that are field-selectable.

Directional Ground-overcurrent Protection

Incoming lines operated in parallel from separate grounded sources require directional-ground-overcurrent relays (67N) to assure selectivity between incoming-line breakers for ground faults on the source side of each of the incoming-line breakers. For solidly grounded systems and many impedance-grounded systems, a multi-functional digital relay usually is appropriate. This relay is set at a low pickup to permit selectivity with the other incoming-line non-directional ground-overcurrent relaying.

All directional-ground relays must be polarized. For systems with local, grounded supply transformers, the current transformer located in the transformer neutral-ground connection may be used for polarizing. For systems with remote-supply transformers, a set of local wye-broken delta connected voltage transformers (or wye-wye VTs with wye-broken delta auxiliary transformers) may be used for polarization. On occasion, dual polarization may be desirable.

As mentioned in the phase units above, digital versions are available in packages with inverse, very inverse, and extremely inverse (and possibly other) characteristics field-selectable. This function (67N) may also be packaged in with all three phases of directional phase overcurrent.

High Impedance Ground Fault Detection

Many distribution system ground faults do not generate enough current to be detected by traditional overcurrent protection. These faults frequently result from a broken conductor falling in contact with a poor conducting surface or an object having relatively high impedance (tree branches, dry ground). A high percentage of arcing downed conductors may be detected by new digital relays with “High Z” capabilities, specifically designed for this purpose.

Differential Protection

Differential Protection is a method of equipment protection in which an internal fault is identified by comparing electrical conditions at all incoming and outgoing terminals of the equipment. By virtue of the connection and settings, this protection only operates for faults in the apparatus being protected, or “in the zone of protection”. Hence differential protection does not need to coordinate with devices protecting other downstream conductors and equipment. Differential protection considerations for specific equipment will be discussed in the later sections.

BUS PROTECTION—Bus-differential relays should be applied to generator buses, buses with high available short-circuit current, and buses which, if faulted, create system disturbances which could lead to system instability in other portions of the system if the fault is not rapidly isolated. High-speed bus differential can also reduce the level of incident energy released during an internal arcing fault, increasing operator safety and reducing equipment damage. This type of relaying uses equally rated phase-current transformers of like characteristics in each circuit connected to or from the bus to be protected. Bus-differential relays (87B) are available in both single phase, or three phase designs.

TRANSFORMER PROTECTION — Transformer-differential relays (87T) are high-speed relays with harmonic restraint. These relays use current transformers of different ratios and connections and compensating relay taps. Liquid-filled transformers, larger than approximately 5000 kVA, are protected usually with both differential and fault-pressure relays (63FP) and occasionally with gas-detector relays.

Differential relays protect the internal transformer circuit, including conductors, bushings and windings. Fault-pressure relays provide excellent internal tank-fault protection for liquid-filled transformers, but do not include the entire circuit in the protected zone.

Transformers connected delta-wye, with the secondary neutral grounded through resistance, frequently require ground-fault as well as phase-fault differential protection because the pickup of phase-differential relays may not be low enough to detect secondary ground faults. This results from the large CT's necessary to carry transformer load currents at forced air ratings.

MOTORS —Motor differential relays are usually applied to motors 1500 hp and larger. Three-phase motor-differential relays (87M) used for this application employ the balanced-current principle. This type of protection provides for detecting motor-fault currents as small as 15 amperes. An example for a typical application is shown in the one-line diagram in Section 2. In some applications, differential relay schemes are used to protect both the motor and its feeder cable. These schemes use three CT's on each side of the motor.

LINES — Line-differential protection (87L) for short lines and important tie lines between medium-voltage switchgear lineups is obtained by using pilot-wire relays. These relays compare the currents at each end of a two-terminal line. These high-speed relays are sensitive to both phase and ground faults. Pilot wire supervision and transfer tripping relays are used in conjunction with the pilot-wire relays.

GENERATORS —All generators should be protected with differential relaying. Generator-differential relays (87G) are high-speed relays sensitive to phase faults and many ground faults. These relays compare the currents in and out of generators using three CT's on each side of the generator. For small generators, balanced-current-differential relaying may be used. This type of relaying is described under "Differential Protection Motors".

Open-phase Protection (Negative-sequence Voltage)

Incoming line open-phase operation occurs when one conductor is opened due to either a single upstream fuse melting or a single-line conductor or circuit breaker pole opening. System protection for either of these events for systems without local generation consists of a negative-sequence voltage unbalanced relay (60). To avoid tripping on system transient disturbances, this relay should operate through a time delay usually set from 2 to 4 seconds. For systems subject to harmonics, a harmonic filter applied to the input to this relay may be required. The negative-sequence voltage function (60) may also be incorporated in a multi-function motor protection relay.

Automatic Reclosing

Radial feeders supplying overhead lines, with or without line sectionalizing, sometimes employ automatic reclosing for better service continuity. Relaying for this type of application is used for open-wire overhead circuits, which are prone to develop non-persistent faults. A series of three or four attempts to close a breaker at variable times may either be programmed with an immediate initial reclosure or an initial time-delay reclosure. A multi-shot automatic reclosure option is utilized for this function. The use of the immediate initial reclosure option is not recommended on feeders serving large motors or on feeders originating on a generator bus. Frequently, the automatic reclosing relay is programmed to block an instantaneous overcurrent relay (50 or 50N) after the initial trip, for part of or all of the reclosing schedule. This function may also be incorporated as part of a multi-function microprocessor-based protection relay, which is directional or non-directional.

Directional Power, Underfrequency, and Undervoltage Protection

Systems with local generation or large motors require relaying to detect fault conditions on the utility tie circuit or to detect loss of the utility source. Relays used to detect these circumstances should be high-speed to trip the utility tie prior to any automatic reclosing operations and to promptly initiate any programmed load shedding. Complete protection for these circumstances is provided by a combination of functions including under frequency (81); a sensitive directional-power (32); and undervoltage (27). For some applications where the (32) and (27) functions are only instantaneous, a timer is used which is set at about 0.2 second. The directional-power element may be connected to current transformers either in the incoming line circuit or in a large motor circuit depending on the application. A study of the specific system is required to select the appropriate relays and connections for this type of protection.

BASIC EQUIPMENT PROTECTION

Circuit Breaker Control and Control Power Protection

Basic circuit breaker control consists of a control switch, located at the breaker to close and trip the breaker. Associated with the control switch are two indicating lamps, one red and one green. The red lamp indicates a closed breaker and supervises the trip coil integrity. The green lamp indicates an open breaker. This lamp is connected through a breaker "b" contact.

For switchgear applications requiring remote control, a permissive control (69CS) function is available. This function provides local or remote control of a circuit breaker under certain defined conditions, and is available in three schemes as shown in Table 5-1. Scheme C is recommended for remote control, since it provides maximum operating flexibility. When a local "trip" operation is initiated, the breaker cannot be closed remotely until the local switch handle is returned to the "NORMAL AFTER CLOSE" position. When the breaker is in the "TEST" position, closing and tripping can only be done locally.

Table 5-1 Remote Control Schemes

Control Location		**Local**				**Remote**				**Devices Required (in addition to remote control switch)**
Breaker Operation		**Close**		**Trip**		**Close**		**Trip**		
Breaker Position		**Conn**	**Test**	**Conn**	**Test**	**Conn**	**Test**	**Conn**	**Test**	
Remote Control Scheme	A			X	X	X	X	X	X	Local permissive switch (69CS), plus breaker position sw (52POS)
	B		X		X	X		X		Local control switch (52CS), plus breaker position sw (52POS)
	C*		X	X	X	X		X		Local control switch (52CS), plus breaker position sw (52POS)
Basic Control		X	X	X	X					Control Switch, (52CS)

X = This manually initated operation is possible

* = This scheme uses same devices as scheme B, but different wiring

An optional white "breaker disagreement" lamp is also available. This lamp is by-passed by a slip contact of the control switch and connected to a "b" contact of the breaker and provides indication of a breaker opening not initiated by the control switch. An alternate option for this white lamp is to provide indication of the circuit breaker spring-charged condition.

Each breaker trip and close circuit is individually protected by a two-pole fuse-block with properly selected fuses, or molded case breaker.

Instrumentation, Current, and Voltage Transformers.

INSTRUMENTS —Basic current or voltage indication in Power/Vac switchgear can be via a switchboard type analog meter and transfer switch, a digital meter or can be a feature of a multifunction protective relay.

Most all solid-state multi-function relays today offer metering capabilities too, including voltage, current, watts, vars, frequency and the demand functions.

SCALES, CURRENT TRANSFORMER, AND VOLTAGE TRANSFORMER RATIOS — Ammeter scales are determined by the CT ratio. Current transformer ratings are normally selected based on approximately 125% of the ampacity of the feeder circuit conductors. Current transformer ratios selected in this manner permit settings of circuit overcurrent-protective relays to provide good selectivity and protection. For a properly designed circuit, operating at full load, this means a maximum scale reading of between half and three-quarter scale. For a circuit which provides for substantial future expansion, lower scale readings will indicate initial-load conditions.

The voltmeter scale, determined by the voltage transformer ratio, is 125 percent of the nominal line-to-line VT rating. Optional wattmeters and varmeters, switchboard type, are available for most equipment. Wattmeter and varmeter scales are determined by the CT and VT ratios.

CURRENT TRANSFORMERS AND VOLTAGE TRANSFORMERS—Standard window-type current transformers are available in ratios ranging from 50:5 to 4000:5 amperes. The basic ground-sensor window-type CT (GSCT) ratio is 50:5 amperes, with a 7.25" window, and an optional GSCT with a 12" window is available for circuits with a large number of conductors. Relay accuracy class is per IEEE C37.20.2-1999, Table 4. Higher accuracy classes may be available, however space for mounting is limited.

Table 5-2 SINGLE RATIO CTS

CT Ratio	Standard Accuracy Class	High Accuracy Class (1)
50:5A	C10	C10
100:5A	C10	C20
150:5A	C20	C50
200:5A	C20	C50
250:5A	C20	C50
300:5A	C50	C100
400:5A	C50	C100
500:5A	C100	C100
600:5A	C100	C200
800:5A	C100	C200
1000:5A	C200	C400
1200:5A	C200	C400
1500:5A	C200	C400
1600:5A	C200	C400
2000:5A	C200	C400
2500:5A	C200	C400
3000:5A	C200	C400
4000:5A	C200	C400
5000:5A	C200	C400

1 - High accuracy requires twice the mounting space of a standard accuracy CT.

Table 5-3 MULTI RATIO CTS

MULTI RATIO CTS

CT Ratio	Standard Accuracy Class	High Accuracy Class (1)
600:5A 50/100/150/200 250/300/400 450/500/600	C100	C200
1200:5A 100/200/300/400 500/600/800/900 1000/1200	C200	C400
2000:5A 300/400/500/800 1100/1200/1500 1600/2000	C200	C400
3000:5A 300/500/800/1000 1100/1500/2000 2200/2500/3000	C200	C400
4000:5A 500/1000/1500 2000/2500/3000 3500/4000	C200	C400

1 - High accuracy requires twice the mounting space of a standard accuracy CT.

Current transformer relaying accuracy's and excitation characteristics are particularly important when considering lower-rated current transformers on systems with high available short-circuit currents and for all differential relay applications. Excitation characteristics and accuracy classes are available upon request.

Standard voltage transformers are mounted in draw-out trays, with primary and secondary fusing. Models are available rated for line-to-line, or line-to-neutral applications with system voltages from 2400V to 14400V.

Metering and Test Blocks

Test blocks and plugs can be furnished to facilitate circuit testing, using portable instruments and meters. The current test block is arranged so that the current circuit is maintained when the plug is removed from the block.

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 restrikes (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.

Surge arresters and capacitors should be applied per the recommendations found in standards such as IEEE 141, IEEE 242, ANSI C62 and IEEE C37.20.2.

Section 6

Power/Vac® Switchgear Equipment

INTRODUCTION

This section contains information covering typical circuit application packages for Power/Vac® metalclad switchgear equipment.

The first part of this section contains basic equipment description for the protection, instrumentation, and control portions of the equipment. Eleven standard applications are shown, complete with the type of the basic equipment and devices for these commonly used configurations. Charts showing the allowable Power/Vac breaker and auxiliary compartment stacking combinations follow this data. The last part of this section shows a sample lineup developed from the preceding information.

Devices illustrated in Section 6 are assumed to utilize 125V dc control voltage.

To use Section 6, proceed in the following manner:

- Determine the type of each circuit in the one-line diagram (developed in accordance with procedures outlined in Section 2).
- Select from the 11 basic circuit descriptions, the circuits which meet the requirements of the installation.
- Select from the option tables those options desired for the protection, instrumentation, and control portion of each circuit.
- Determine the requirements for auxiliary compartments to house voltage transformers or control power transformers.
- Determine the incoming and outgoing circuit conductor configurations required for each circuit.
- Select the equipment configurations necessary for each circuit and auxiliary compartment from the part of this section covering Breaker and Auxiliary Compartments (pages 6-27 to 6-28).

The basic equipment and options in this section constitute a structured lineup of metalclad equipment. Some lineups, however, may require devices and circuit arrangements other than those included in this section.

BASIC EQUIPMENT APPLICATIONS

DEFINITION

A brief definition of each of the 11 basic equipment circuits is given in the following paragraphs.

GENERAL PURPOSE FEEDERS

General purpose feeder (GPF) equipment is a metalclad circuit breaker and compartment controlling and protecting a set of conductors supplying one or more secondary distribution centers, one or more branch-circuit distribution centers, or any combination of these two types of equipment. A general purpose feeder includes circuit overcurrent protection, circuit current indication, and circuit control.

BREAKER BYPASS FEEDERS

Breaker bypass feeder (BBF) is metalclad equipment similar to a general purpose feeder, except two breaker units are connected in parallel to feed a common load. Phase current transformers for both circuit breakers are connected in parallel to a common set of phase relays and instruments. This arrangement is used when a means to remove a feeder circuit breaker for maintenance is desired, yet still maintain service to the connected load. Every breaker bypass vertical section has positions for two circuit breaker removable elements. It is not necessary to include a circuit breaker removable element in each breaker bypass position. One spare circuit breaker removable element per lineup or bus section is usually considered sufficient for each equipment lineup.

TRANSFORMER PRIMARY FEEDERS

Transformer primary feeder (TPF) is similar to a general purpose feeder except, the entire load is one transformer and often includes differential protection for the entire circuit. Liquid filled transformers of a MVA rating to justify differential protection for the circuit are usually equipped with fault-pressure relays for additional internal protection. Both the differential and fault-pressure relays trip a hand reset lockout relay, which trips the primary and secondary transformer circuit breakers.

SINGLE-SOURCE INCOMING LINES

Single source incoming line (SSIL) equipment is metalclad equipment for a circuit to a main power distribution bus from the only source of power supplying the bus. A system with this type of incoming line is called a radial system. A system with two or more incoming lines supplying distribution buses sectionalized by normally open bus-tie circuit breakers requires the same type of protection, instrumentation, and control as single source incoming lines, with the possible exception of the connection of the overcurrent relays.

DUAL SOURCE INCOMING LINES

Dual source incoming line (DSIL) equipment is metalclad equipment for a circuit to a main power distribution bus from one or two sources of power supplying the main bus. The other source of power may be either another incoming line or a local generator. Both sources supply a common distribution bus with or without a normally closed bus-tie circuit breaker.

BUS TIES

Bus-tie (BT) is metalclad equipment connecting two power distribution buses through a tie breaker. Such equipments often are not equipped with overcurrent relays because of the difficulty of obtaining selective system operation with bus-tie overcurrent relays. A bus tie requires two compartments of adjacent sections; see available arrangements later in this section. (Figure 6-15)

BUS ENTRANCES

A bus entrance (BE) is a metalclad vertical section in which one of the compartments contains incoming conductors (cable or bus duct) which are connected directly to the main bus (also referred to as a cable tap). No incoming breaker is used. This arrangement applies to lineups of switchgear, without main circuit breakers, which connect the incoming line directly to the main bus. It also applies to sub feeds, from a lineup of switchgear, without circuit breakers, connecting the outgoing conductors to the main bus.

INDUCTION MOTOR FEEDERS, FULL-VOLTAGE-START

Induction motor feeder (IMF) is similar to a general purpose feeder except it is used for controlling and protecting full-voltage-start motors and is designated as motor “branch circuit” protective equipment. For motors greater than 1500 hp, motor differential protection is typically required.

Reduced-voltage-start applications, utilizing reactors or autotransformers, are available.

SYNCHRONOUS MOTOR FEEDERS, FULL-VOLTAGE-START

Synchronous motor feeder (SMF) is similar to an induction motor feeder, except it is used for controlling and protecting full-voltage-start synchronous motors and is designated as motor “branch circuit” protective equipment. For motors greater than 1500 hp, motor differential protection is typically required.

GENERATORS

These metalclad equipments (GEN) connect, control and protect synchronous generators driven by gas turbines or diesel engines.

FUTURE UNIT

These metalclad future unit (FU) compartments are a basic mechanically prepared circuit breaker unit, except the breaker is to be provided at a future date. Provisions are made to receive a breaker of specified rating.
It is recommended to equip these base units with the breaker stationary auxiliary switch and breaker position switch if the active feeders are so equipped, and install current transformers (possibly multiratio). This minimizes field installation, down time and adjustment procedures when the application of this base unit is determined.

The selected relays may be added to the door when the circuit application is determined, or a new door may be purchased with relays and devices completely wired.

GENERAL PURPOSE FEEDERS

DEFINITION

A general purpose feeder equipment (GPF) is a metalclad equipment controlling and protecting a set of conductors supplying one or more branch-circuit distribution centers, one or more branch-circuit distribution centers, or any combination of these centers.

PROTECTIVE SCHEME SELECTION

GPF-1

Use this type of feeder for systems which are impedance or solidly grounded and for which selectivity is not required with downstream residually connected ground relays.
This type of feeder equipment includes three phase-overcurrent protection (50/51) and one instantaneous overcurrent element (50GS) connected to a ground-sensor CT (GSCT).

GPF-2

Use this type of feeder for systems which are impedance or solidly grounded and for which selectivity is required with downstream residually connected ground relays. This type of feeder equipment includes three phase-overcurrent protection (50/51) and residually connected time-overcurrent ground element (51N).

GPF-3

Use this type of feeder for ungrounded or solidly grounded systems for which no ground relays are desired. This type of feeder equipment includes three phase-overcurrent protection (50/51) and no ground fault element.

OPTIONAL EQUIPMENT SELECTION

Protection

AUTOMATIC RECLOSING— For open-wire overhead distribution circuits on which this feature is desired, use and relay which includes automatic-reclosing (79) and cut-off switch (79CO) functionality.

Current Transformers for Differential Circuits

For a feeder included in a bus-differential-protected zone, add a separate set of three current transformers located on the outgoing side of the feeder. For a transformer-differential-protected zone, add a separate set of three current transformers located so that the feeder circuit breaker is included in the zone.

Indication

INSTRUMENTATION AND METERING—— Most solid-state protective relays today offer basic load current indication. Some relays include extensive metering func-tions such as Amps, Volts, Watts, Vars, PF and demand functions.

TEST BLOCKS— On circuits that require the provisions for insertion of portable recording meters or other similar devices, add current and voltage test blocks. The basic current test block is wired to maintain the circuit when the test plug is removed.

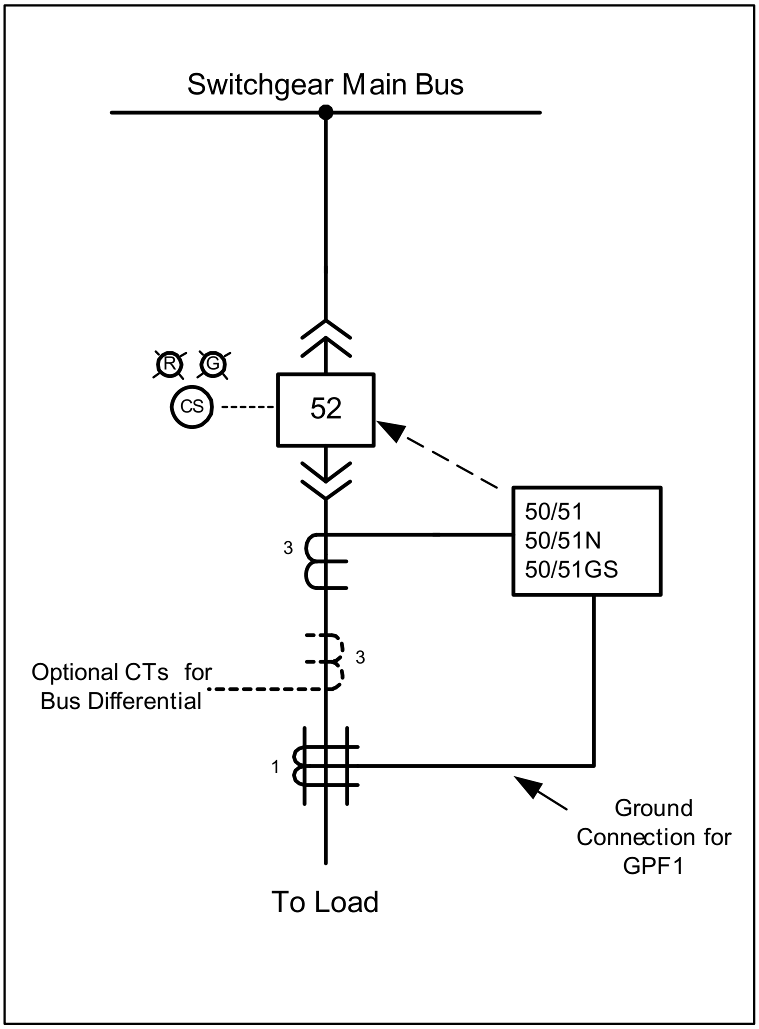
INDICATING LAMP— Additional indicating lamps can be provided, such as for circuits requiring a circuit breaker disagreement or spring-charged indication function.

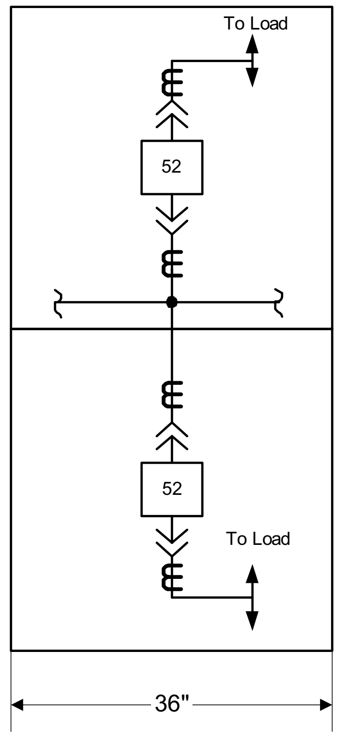
Control

CONTROL VOLTAGE— Available control voltages are 48VDC, 125VDC, 250VDC, 120VAC and 240VAC. For AC control, if a reliable 120/240VAC source is not available at the site, then include a control power transformer connected to each incoming line in each lineup, plus an auto-charged, capacitor-trip device for each circuit breaker in the lineup.

REMOTE CONTROL— For circuit breakers controlled from a remote location, choose the remote control scheme from those listed in Table 5-1 (page 5-7 of this guide). From this table, Scheme C is recommended, since it provides maximum operating flexibility. It requires the use of a breaker position switch in conjunction with the breaker control switch to provide the permissive function. With Scheme C, remote close and trip is possible only with the breaker in the “test” position; and local trip with the breaker in the “connected” or “test” position.

Figure 6-1 General Purpose Feeder





BREAKER BYPASS FEEDERS

DEFINITION

A breaker bypass feeder (BBF) is metalclad equipment similar to a general purpose feeder, except two breaker units are connected in parallel to feed a common load. A complete vertical section (Unit A and Unit B) is required for each breaker bypass feeder circuit. The purpose of this arrangement is to allow removal of the normal service breaker for maintenance without interrupting service on the feeder. Previously, this type of service required either a main and transfer bus arrangement or feeder tie switches.

A lineup utilizing this arrangement of feeders is often specified with only one bypass position breaker element for the lineup, since typically only one feeder circuit breaker is bypassed at a time.

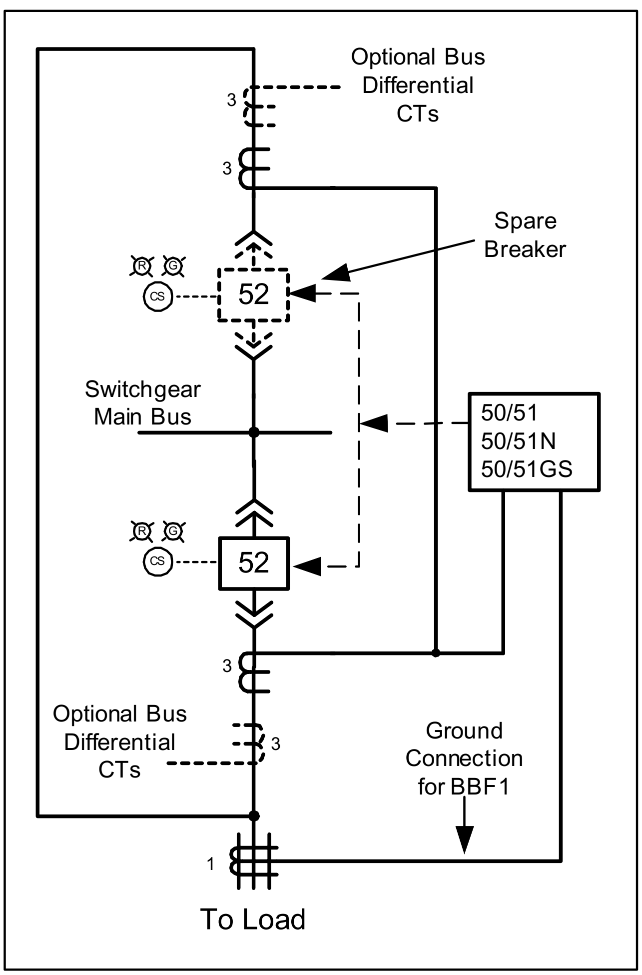
PROTECTIVE SCHEME SELECTION

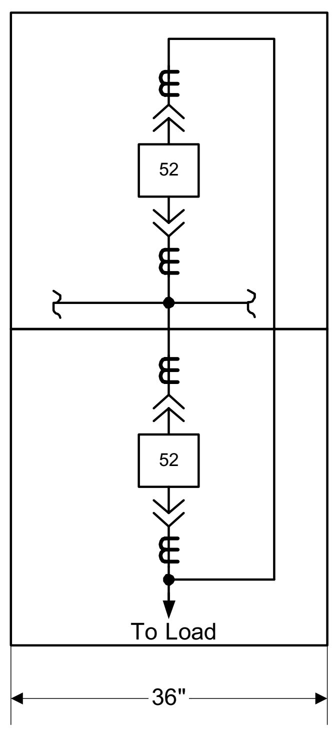
Basic devices included in a breaker bypass feeder are the same as those included in a general purpose feeder. Select BBF-1, BBF-2, or BBF-3 on the same basis as GPF-1, GPF-2, or GPF-3.

OPTIONAL EQUIPMENT SELECTION

Options for a breaker bypass feeder are the same as for a general purpose feeder. Select options for BBF-1, BBF-2, or BBF-3 on the same basis as for GPF-1, GPF-2, and GPF-3.

Figure 6-2 Breaker Bypass Feeder





TRANSFORMER PRIMARY FEEDERS

DEFINITIONS

A transformer primary feeder (TPF) equipment, is similar to a general purpose feeder except the entire load is one transformer, and the circuit is typically protected with transformer differential relays. If transformer differential protection is not required, use a General Purpose Feeder.

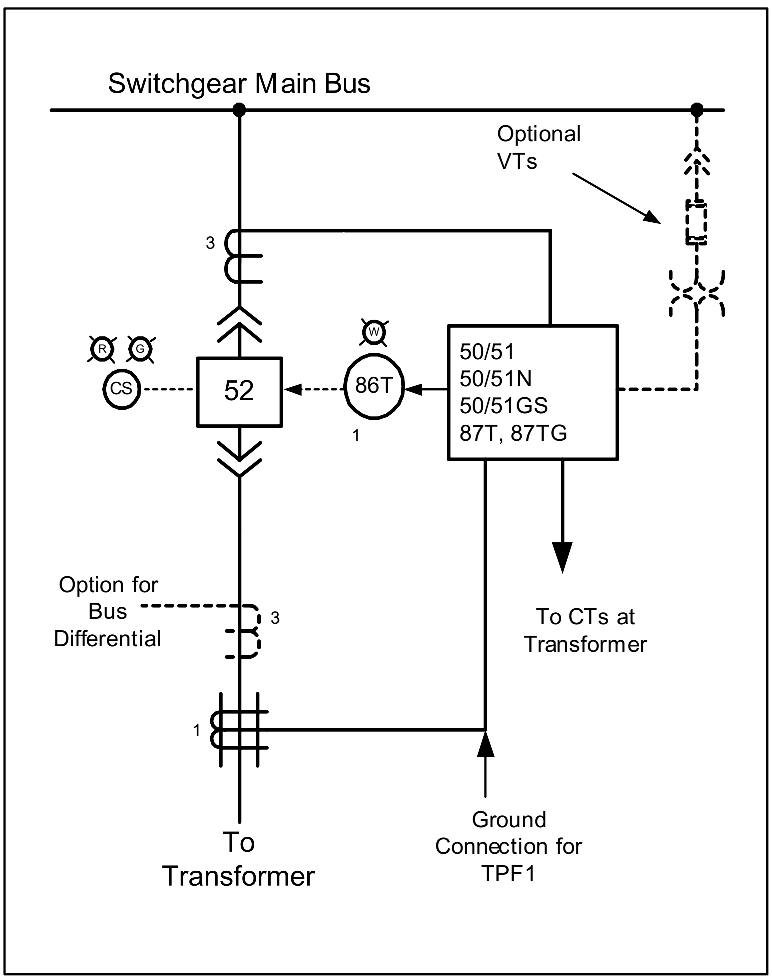
PROTECTIVE SCHEME SELECTION

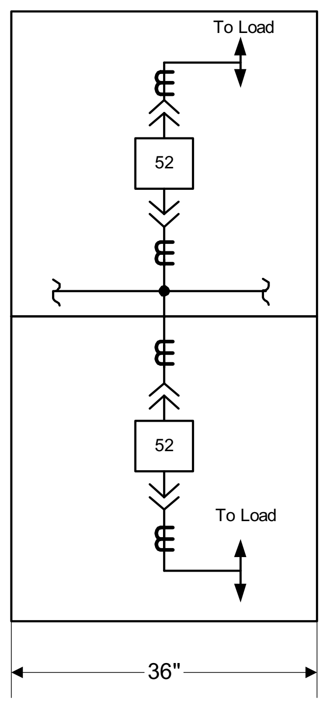
Basic devices included in a transformer primary feeder are the same as those included in a general purpose feeder plus three additional current transformers for the differential protection, a transformer fault-pressure auxiliary relay (63PX) and a lockout relay (86T). Differential protection can be in the form of separate relays, such as single-phase transformer differ-ential relays (87T), or as part of a complete multi-function transformer protection package.

OPTIONAL EQUIPMENT SELECTION

Options for a transformer primary feeder are the same as for a general purpose feeder except that automatic reclosing is not used. Select options for TPF-1, TPF-2, or TPF-3 on the same basis as for GPF-1, GPF-2, or GPF-3.

Figure 6-3 Transformer Primary Feeder





SINGLE SOURCE INCOMING LINES (or dual source with normally open tie breakers)

DEFINITION

A single source incoming line (SSIL) is a metalclad section containing a power circuit breaker, acting as is the main disconnect between a main power distribution bus and the only source of power supplying the bus.

A system with two or more incoming lines, which supply distribution buses sectionalized by normally open bus-tie breakers, requires essentially the same type of protection, instrumentation, and control for each incoming line as a single source incoming line.

PROTECTIVE SCHEME SELECTION

SSIL-1 Use this type of incoming line for an impedance or solidly grounded system fed from a local wye-connected transformer with a current transformer in the transformer neutral connection. This type of incoming line would include three-phase time-overcurrent protection (51), and a ground-over-current element (51G) to be connected to the neutral current transformer of a local power transformer feeding the incoming line.

SSIL-2 Use this type of incoming line for and impedance or solidly grounded system fed from a remote wye-connected transformer, or a local wye-connected transformer with no current transformer in the transformer neutral connection.
This type of incoming line would include three-phase time-overcurrent protection (51), and residually connected ground-overcurrent relay (51N).

SSIL-3 Use this type of incoming line for ungrounded or solidly grounded systems for which no ground relays are desired.
This type of incoming line would include three-phase time-overcurrent protection (51), and no ground relays.

OPTIONAL EQUIPMENT SELECTION

Protection

OVERCURRENT RELAY CHARACTERISTICS — Time current characteristics for overcurrent relays are determined by system studies. After the time current characteristic has been established, make sure the relays selected offer the required time current characteristics that satisfy the application.

CURRENT SUMMATION CONNECTION — For line-ups containing bus-tie breakers, specify the incoming line overcurrent relays to be wired for current summation (also known as partial differential). Add a lockout relay (86) and a set of three CT's mounted on the tie breaker, for each set of relays to be wired this way.

OPEN-PHASE PROTECTION — For incoming lines fed from transformers with fused primaries or sources subject to single-phase operation, add negative-sequence voltage protection (60/47) and time delay (62). The function is available in multi-function relay protection packages.

TRANSFORMER DIFFERENTIAL PROTECTION — Add differential protection for incoming lines fed from transformers with a means to trip a primary breaker. Differential protection can be in the form of separate relays or as part of a complete multi-function transformer pro-tection package. In addition, add one lockout relay (86T), one fault pressure auxiliary tar-get relay (63FPX), and a set of three current trans-formers. For impedance grounded systems with larger transformers and for which three-phase trans-former differential relaying is not sensitive enough to detect secondary ground faults, include ground differential relay protection (87TG) with a single function relay, or as part of a com-plete multi-function transformer protection pack-age.

BUS DIFFERENTIAL PROTECTION — For systems requiring bus differential protection, add a three-phase solid state differential protection relay (87B) and one hand reset lockout relay (86B). Bus differential requires a dedicated set of three CTs on the incoming line.

CURRENT TRANSFORMERS FOR REMOTELY LOCATED DIFFERENTIAL RELAYS — For incoming lines included in bus or transformer differential zones for which relays are not mounted on the incoming line equipment, add a separate set of three current transformers for each differential function.

DIRECTIONAL POWER, UNDERFREQUENCY, AND UNDERVOLTAGE PROTECTION — To detect utility tie circuit fault conditions prior to automatic reclosing and to initiate programmed load shedding, add, either singly or in combination, a power directional relay (32), underfrequency relay (81), undervoltge relay (27) and timer (62). This applies for systems with local generation or large motors.
A study of each system is required to assure proper selection and circuit location of these relays.

AUTOMATIC THROWOVER — For lineups with a normally open tie breaker or a normally open alternate incoming line breaker, add automatic primary throwover equipment if desired. This consists of two undervoltage relays (27), two multi-contact auxiliary relays (27X), two timers (2 and 62), two auxiliary relays (2X and 62X), and one manual-automatic selector switch (43). Automatic throwover equipment requires an empty auxiliary compartment for mounting, custom designed for each application.

Indication

INSTRUMENTATION AND METERING — For incoming lines for which voltage indication and a relay voltage source are not required, omit the voltmeter, voltmeter switch, and two voltage transformers. For circuits requiring the indication or metering of additional electrical quantities, add indicating analog meters as appropriate, or a multifunction meter. Some relays include extensive metering functions such as Amps, Volts, Watts, Vars, PF and demand functions.

TEST BLOCKS — For circuits that require the provisions for insertion of portable recording meters or other similar devices, add current and voltage test block. Basic test block is wired to maintain the circuit when the test plug is removed.

INDICATING LAMP —Additional indicating lamps can be provided, such as for circuits requiring a circuit breaker disagreement or spring-charged indication function.

Control

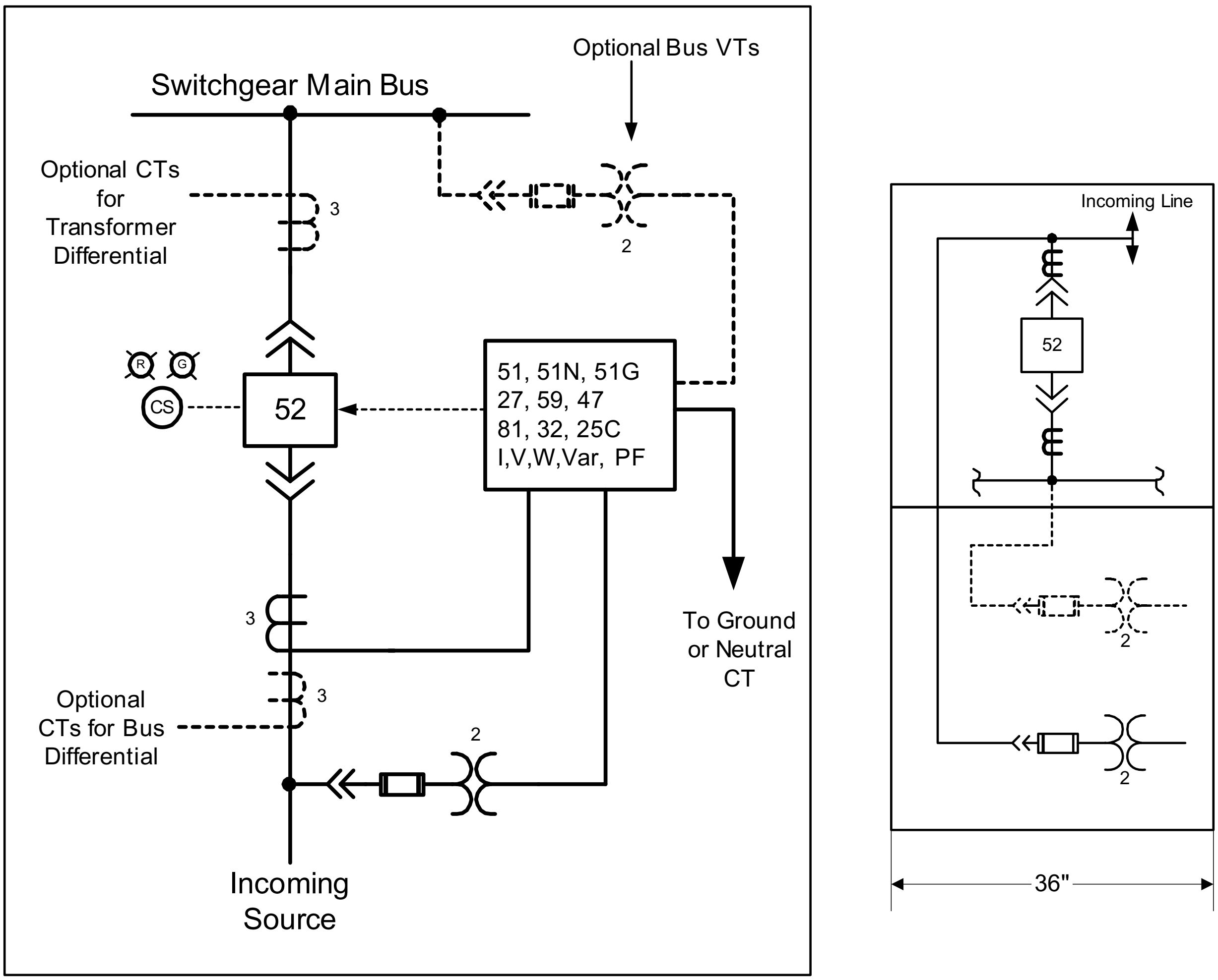
CONTROL VOLTAGE —Available control voltages are 48VDC, 125VDC, 250VDC, 120VAC and 240VAC. For AC control, if a reliable 120/240VAC source is not available at the site, then include a control power transformer connected to each incoming line in each lineup, plus an auto-charged, capacitor-trip device for each circuit breaker and each lockout relay (86) in the lineup. For dual sources with normally open-tie circuit breaker and ac control, add CPT throwover contactor.

REMOTE CONTROL — For circuit breakers controlled from a remote location, choose the remote control scheme for those listed in Table 5-1 (page 5-7 of this guide). From this table, Scheme C is recommended, since it provides maximum operating flexibility. It requires the use of a breaker position switch in conjunction with the breaker control switch to provide the permissive function. With Scheme C, remote close and trip is possible only with the breaker in the “connected” position; local close with the breaker in the “test” position; and local trip with the breaker in the “connected” or “test” position.

Location of Optional Devices

If several optional devices are added to an incoming line section, there may not be sufficient space to mount them all. In this case, specify excess relays to be mounted on the tie-breaker vertical section or on an adjacent auxiliary compartment.

Figure 6-4 Single Source Incoming Line



DUAL SOURCE INCOMING LINES

DEFINITION

Dual source incoming line equipment (DSIL) is a metalclad section containing a power circuit breaker acting as is a main disconnect between a main power distribution bus, and one of two sources of power supplying the main bus. The other source of power may be either another incoming line or a local generator. Both sources supply a common distribution bus, with or without a normally closed bus-tie breaker.

BASIC EQUIPMENT SELECTION

DSIL-1 Use this type of incoming line for an impedance or solidly grounded system fed from a local wye-connected power transformer, with a current transformer in the transformer neutral connection.

This type of incoming line equipment includes three phase-overcurrent relays (51) and three directional phase-overcurrent relays (67). It includes one ground-overcurrent relay, (51G) connected to the neutral CT of a local power transformer feeding the incoming line and one residually connected directional ground-overcurrent relay (67N), polarized from the power transformer neutral CT. These protective functions are available in a single relay package.

DSIL-2 Use this type of incoming line for an impedance or solidly grounded system fed from a remote wye-connected power transformer.

This type of incoming line equipment includes three phase-overcurrent (51) and directional phase-overcurrent (67). It also includes residual connected ground-overcurrent (51G) and residually connected directional ground-overcurrent (67N) polarized from a wye-broken delta auxiliary VT connected to a set of wye-wye VT's. These protective functions are available in a single relay package.

DSIL-3 Use this type of incoming line for ungrounded systems only.

This type of incoming line equipment includes three phase-overcurrent (51) and directional phase-overcurrent relays (67), no ground fault detection. These protective functions are available in a single relay package. There are additional functions available as required.

OPTIONAL EQUIPMENT SELECTION

Protection

OVERCURRENT RELAY CHARACTERISTICS — Time current characteristics for overcurrent relays are determined by system studies. After the time current characteristic has been established, make sure the relays selected offer the required time current characteristics that satisfy the application.

OPEN-PHASE PROTECTION — For incoming lines fed from transformers with fused primaries or sources subject to single-phase operation, add negative-sequence voltage protection (60) and timer (62), as well as current-balance detection (60C), to distinguish which incoming line has single-phase operation.

TRANSFORMER AND BUS DIFFERENTIAL PROTECTION — Add relays and current transformers to obtain this protection, using the same considerations as for single source incoming lines.

DIRECTIONAL POWER, UNDERFREQUENCY, AND UNDERVOLTAGE PROTECTION — Add separate relays or enable these functions in multifunction relays to obtain this protection using the same considerations as for single source incoming lines.

Indication

INSTRUMENTATION AND METERING — For circuits requiring the indication or metering of additional electrical quantities, add indicating analog meters as appropriate, or a multifunction meter. Some relays also include extensive metering functions such as Amps, Volts, Watts, Vars, PF and demand functions.

TEST BLOCKS — For circuits that require the provisions for insertion of portable recording meters or other similar devices, add current and voltage test block. Basic test block is wired to maintain the circuit when the test plug is removed.

INDICATING LAMP— Additional indicating lamps can be provided, such as for circuits requiring a circuit breaker disagreement or spring-charged indication function.

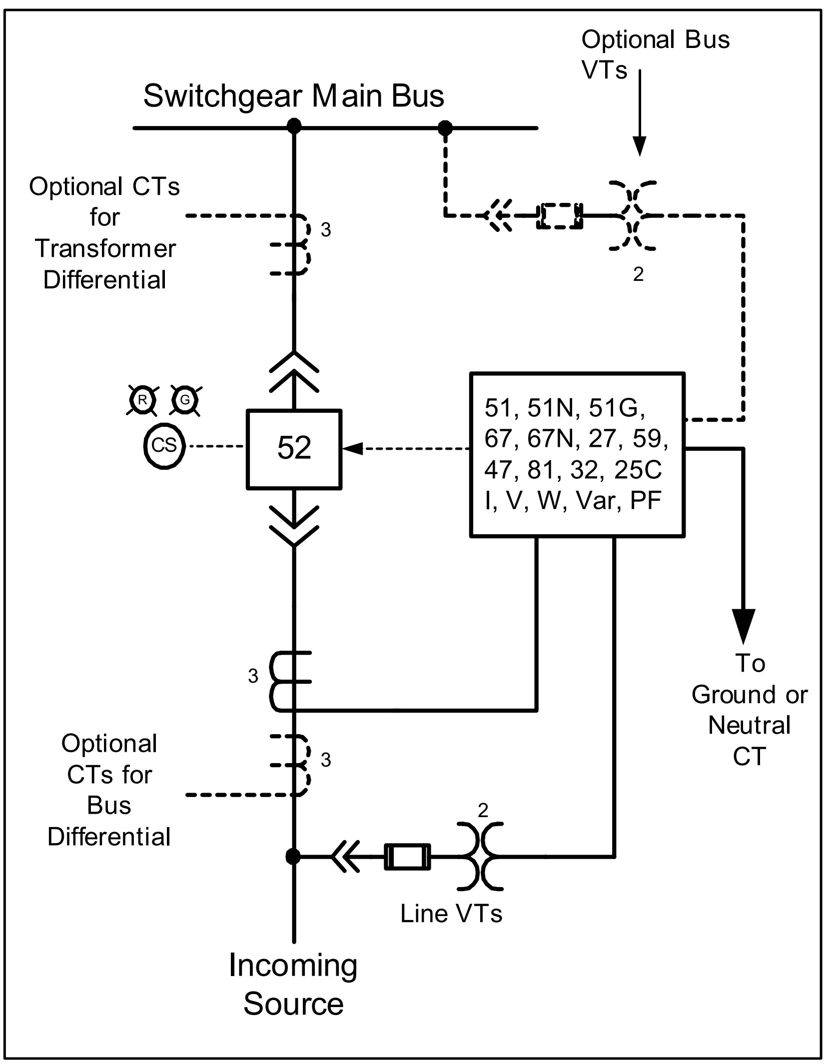
Control

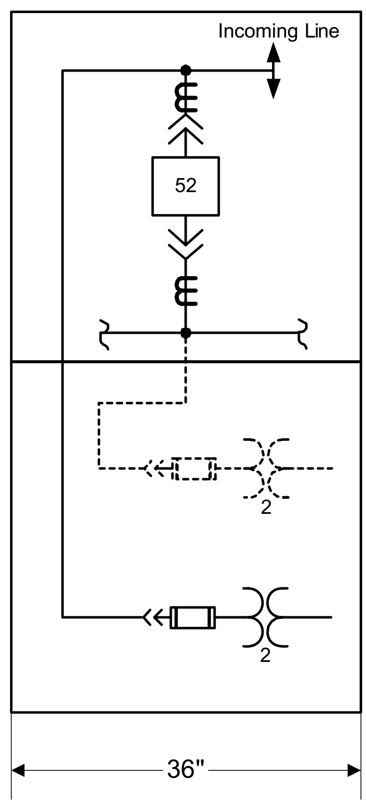
Optional feature involving control voltage and permissive control switch are the same as for single-source incoming line equipments.

Location of Optional Devices

If several optional devices are added to an incoming line equipment, there may not be sufficient space to mount them all. In this case, specify excess relays to be mounted on the tie-breaker vertical section, or on an adjacent auxiliary compartment.

Figure 6-5 Dual Source Incoming Line





BUS TIES

DEFINITION

A bus-tie is metalclad equipment connecting two power distributions buses through a tie breaker. Such equipment is sometimes specified without overcurrent relays because of the difficulty of obtaining selective system operation when using bus-tie over-current relays.

BASIC EQUIPMENT SELECTION

Basic bus-tie circuit breaker and auxiliary bus is located in the bottom compartment of each of two vertical sections. The top compartment of either or both vertical sections can be used as either an auxiliary compartment or a feeder compartment. See Figure 6-15 for arrangement restrictions when selecting Bus Tie equipment.

The basic equipment included in a bus-tie is a circuit breaker control switch and indicating lights.

OPTIONAL EQUIPMENT SELECTION

Protection

OVERCURRENT PROTECTION — For systems requiring overcurrent protection relays for bus-tie equipment, specify incoming line overcurrent relay(s) (50/51) to be wired for a summation current connection. If residually connected ground-overcurrent relays (51N) are required with an incoming line, the equipment may be wired also for a summation current connection. Include a second set of three current transformers if your system has a second incoming line.

BUS-DIFFERENTIAL PROTECTION — For systems requiring bus-differential protection, relays can be mounted in bus-tie vertical sections. Each set of bus-differential protection includes three phase high-speed bus-differential relays (87B), one hand-reset lock-out relay (86B), and three current transformers. If the bus-differential relays have been included in the incoming line (SSIL or DSIL) package, then additional relays are not required.

AUTOMATIC THROWOVER — For systems with a normally open bus tie circuit breaker that require automatic throwover, add equipment listed under “Single Source Incoming Line Options” in a auxiliary compartment above one of the bus-tie compartments. The control panel for automatic throwover of CPTs can be placed on a swinging auxiliary panel, above a bus-tie, behind the front door of an auxiliary compartment.

Indication

INSTRUMENTATION —For indication of current, add three current transformers (if no CTs are present for overcurrent relaying), an ammeter, and an ammeter switch, or a digital three phase ammeter.

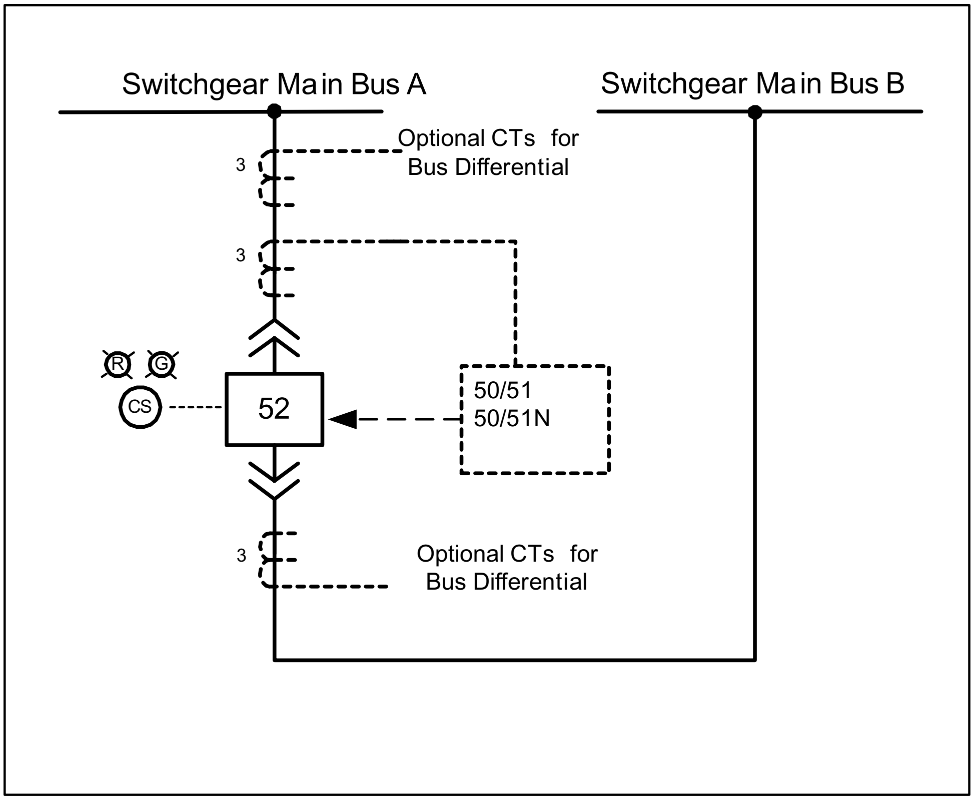
TEST BLOCKS — For circuits that require the provisions for insertion of portable recording meters or other similar devices, add current and voltage test blocks. Basic current test block is wired to maintain the circuit when the test plug is removed.

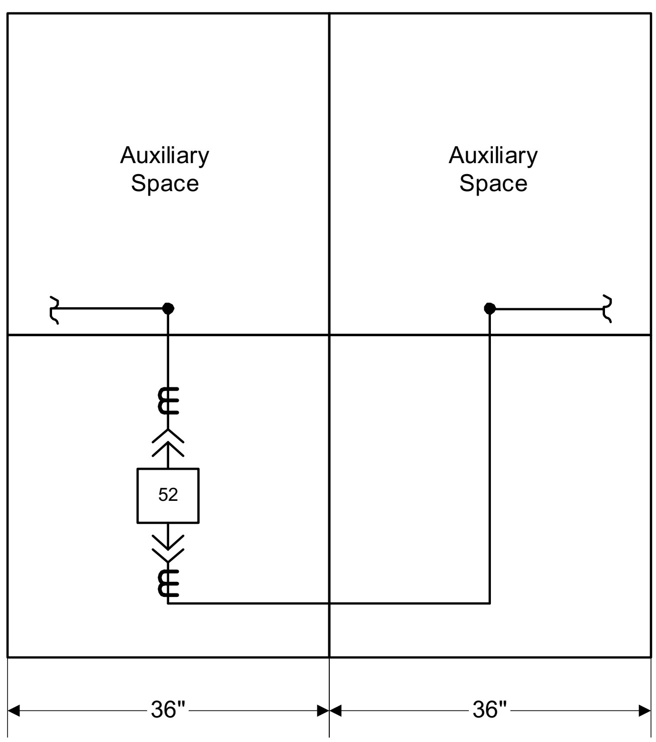
INDICATING LAMP —Additional indicating lamps can be provided, such as for circuits requiring a circuit breaker disagreement or spring-charged indication function.

Control

Optional features involving control voltage and a permissive control switch are the same as for single source incoming line equipment. For circuit breakers where ac control is specified, include a secondary automatic-throwover contactor for control power.

Figure 6-6 Bus Tie





BUS ENTRANCES

DEFINITION

Bus-entrance equipment, also referred to as a cable tap, is a metalclad vertical section in which one of the compartments contains incoming or outgoing conductors which connect directly to the main bus without the use of a circuit breaker. Conductors can be either cables or non-seg bus duct.

BASIC EQUIPMENT SELECTION

Select this type of equipment as a means to connect either incoming or outgoing conductors directly to the bus for circuits that require no circuit breakers. See Section 1 and Figure 6-15 for configuration restrictions when selecting Bus Entrances.

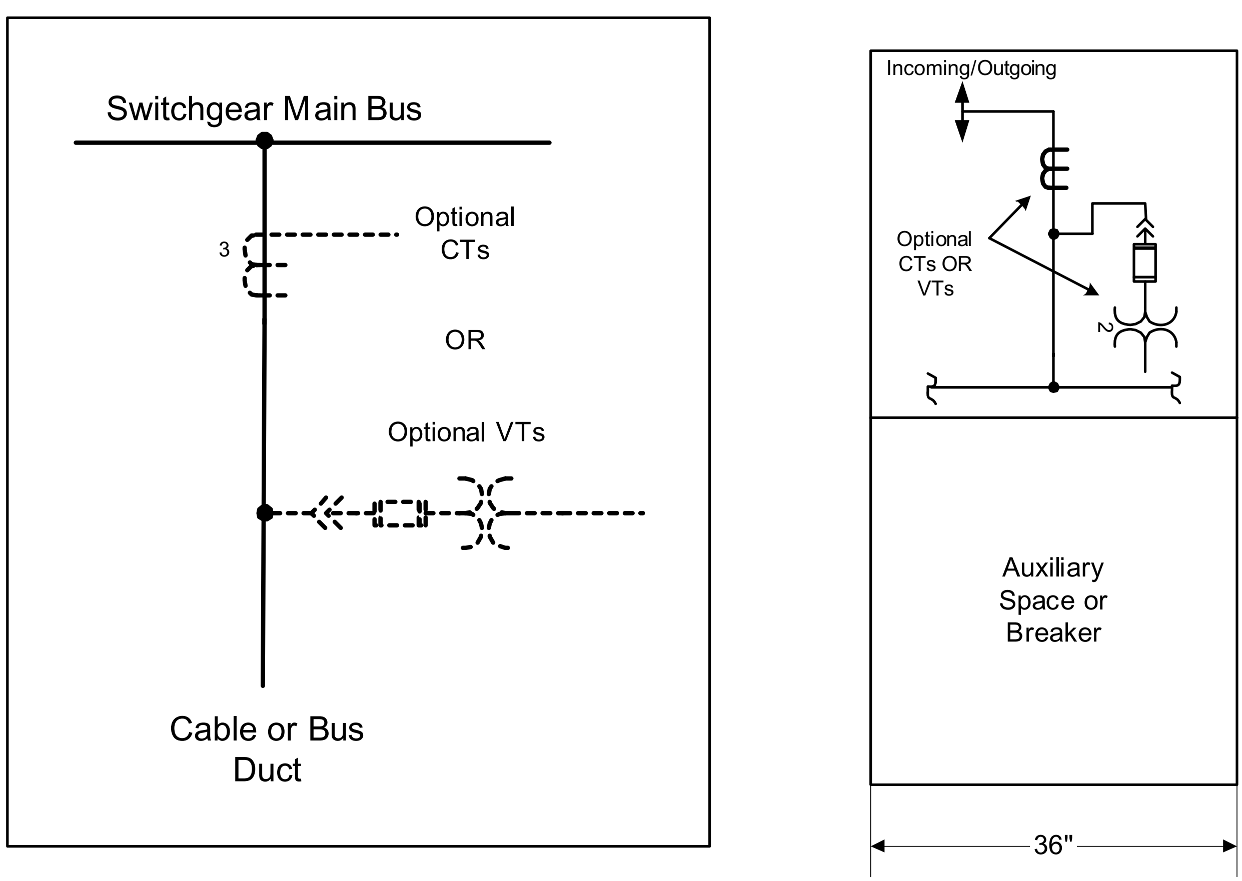
OPTIONAL EQUIPMENT SELECTION

Indication

INSTRUMENTATION AND METERING - For circuits requiring the indication or metering of electrical quantities, add three current transformers or two voltage transformers. Cannot locate both a set of CTs and VTs in a Bus Entrance. Select instrumentation and metering required as necessary.

TEST BLOCKS - For circuits that require the provisions for insertion of portable recording meters or other similar devices, add current and voltage test blocks. Basic current block is wired to maintain the circuit when the test plug is removed.

Figure 6-7 Bus Entrance



INDUCTION MOTOR FEEDERS, FULL-VOLTAGE-START,

DEFINITION

These metalclad feeder equipments (IMF) are used for controlling and protecting full-voltage-start motors and are designated as "branch circuit" protective equipment. Economics usually preclude protecting a motor smaller than 1500 hp (IMF1) with a device package as complete as that used for larger motors (IMF2). The equipment is specified for use on impedance grounded or solidly grounded systems. See "Optional Equipment Selection" for modifications of this equipment for use on systems with other types of grounding. Also see IEEE C37.96-2000 IEEE Guide for AC Motor Protection for relaying recommendations.

PROTECTIVE SCHEME SELECTION

IMF1 Basic equipment for and IMF1 includes three-phase running overload, locked rotor, and short-circuit protection (49/50); undervoltage protection with time delay (27, 62) (only one required per lineup); zero-sequence ground-fault protection (50GS); and load current indication. The overcurrent relays operate from a three CT's, one in each phase, and a ground-sensor CT.

IMF2 Basic equipment for an IMF2 is a digital motor protection relay which includes (26/50/83) for locked rotor and short-circuit protection; over temperature (49); undervoltage with time delay (27, 62); 3-phase self-balancing machine differential (87M); one lockout relay (86M); zero-sequence ground fault (50GS); and full function metering.

IMFE These metalclad feeder equipments (IMFE) are used for controlling and protecting full-voltage-start, essential-service motors and are designated as motor "branch circuit" protective equipment. Such motor feeders sound an alarm only for motor overload, but trip the circuit breaker for locked rotor and short-circuit conditions. Basic equipment for an IMFE include a 239 digital motor protection relay which provides three-phase overload indication, locked-rotor tripping, short-circuit tripping (49/50/83), zero-sequence ground-fault protection and load current indication. No undervoltage protection is included.

OPTIONAL EQUIPMENT SELECTION (For IMFE, IMF1, IMF2)

Protection

For ungrounded systems, omit the ground-sensor overcurrent relay and the current transformer.

When equipment is used to feed more than one motor from the same bus, only one undervoltage relay is required. However, for multiple motors, add auxiliary relay(s) (27X), with sufficient contacts to trip each additional motor feeder breaker.

On smaller motors, where economically justified to include motor differential protection, 3-element, instantaneous overcurrent relay operating from the three current transformers (mounted at the motor terminals) and

connected for balanced-current motor differential protection (87M).
For larger motors (greater than 1500HP), complete protection including motor differential can be obtained by using (with motor mounted CTs).

The CT's located at the motor and used for the motor differential (87M) circuit, are typically furnished by the motor manufacturer. They are not supplied with the switchgear.

For lineups with bus differential protection, add three current transformers.

Control

REMOTE CONTROL — For circuit breakers controlled from a remote location, choose the remote control scheme from those listed in Table 5-1 (page 5-7 of this guide). From this table, Scheme C is recommended, since it provides maximum operating flexibility. It requires the use of a breaker control switch to provide the permissive function. With Scheme C, remote close and trip is possible only with the breaker in the "connected" position; local close with the breaker in the "test" position; and local trip with the breaker in the "connected" or "test position.

In addition, remote control for motors requires a lockout relay (86), which prevents breaker closing (after a relay-initiated trip) until the lockout device is manually reset. (The 86 device specified on IMF2 may be used for both 87M and remote control.)

Location of Optional Devices

If several optional devices are added to a motor feeder equipment, there may not be sufficient space to mount them all. In this case, specify that the excess relays are to be mounted on an adjacent auxiliary compartment. This makes the vertical section a custom section.

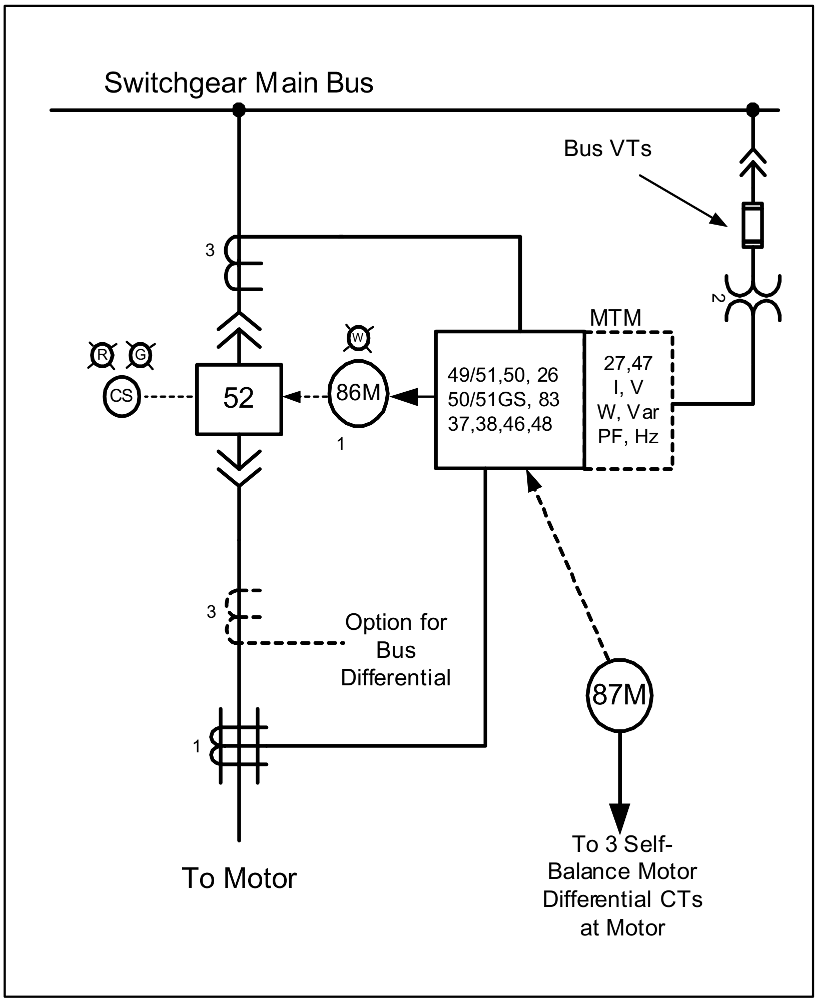
Reduced Voltage Starting

Power distribution system voltage regulation requirements sometimes mandate reduced current starting to minimize the current inrush and voltage sag when starting large motors. Inserting a reactor and then bypassing it as the motor comes up to speed is one method of accomplishing this objective.

An auto transformer connection is an alternate method of reduced voltage starting. This method applies a reduced voltage via the autotransformer, which is shorted out as the motor comes up to speed.

Figures 6-9 through 6-10 illustrate the typical POWER/VAC circuits and arrangements for these special motor starting requirements.

Figure 6-8 Induction Motor Feeder



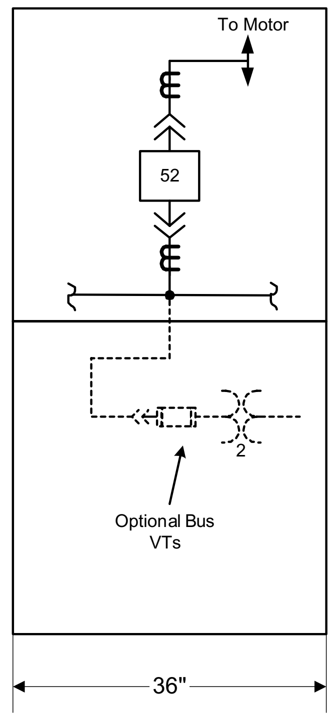
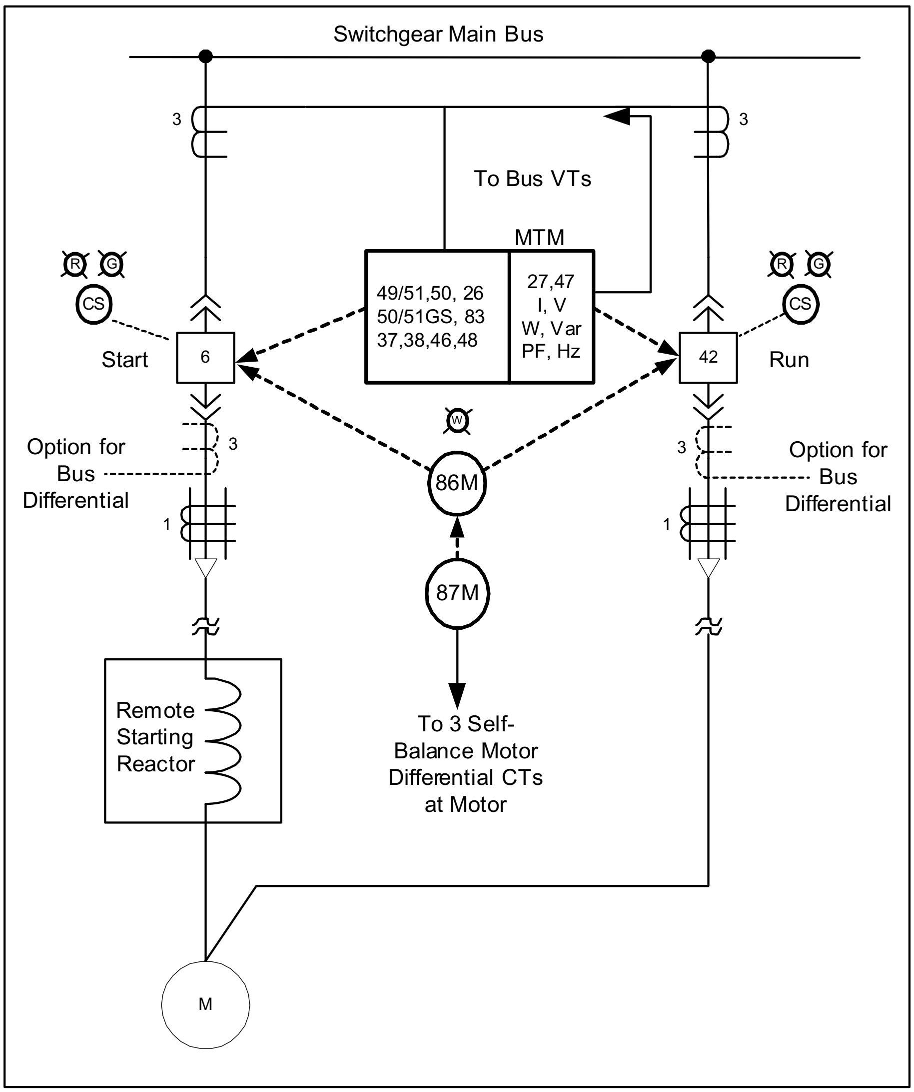


Figure 6-9 IMF, Reduced Voltage Reactor Start



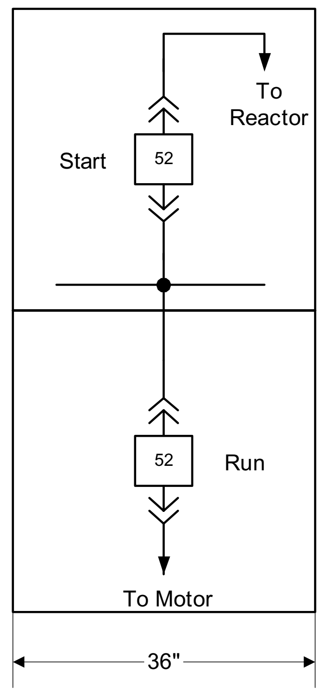


Figure 6-10 IMF Reduced Voltage Autotransformer Start

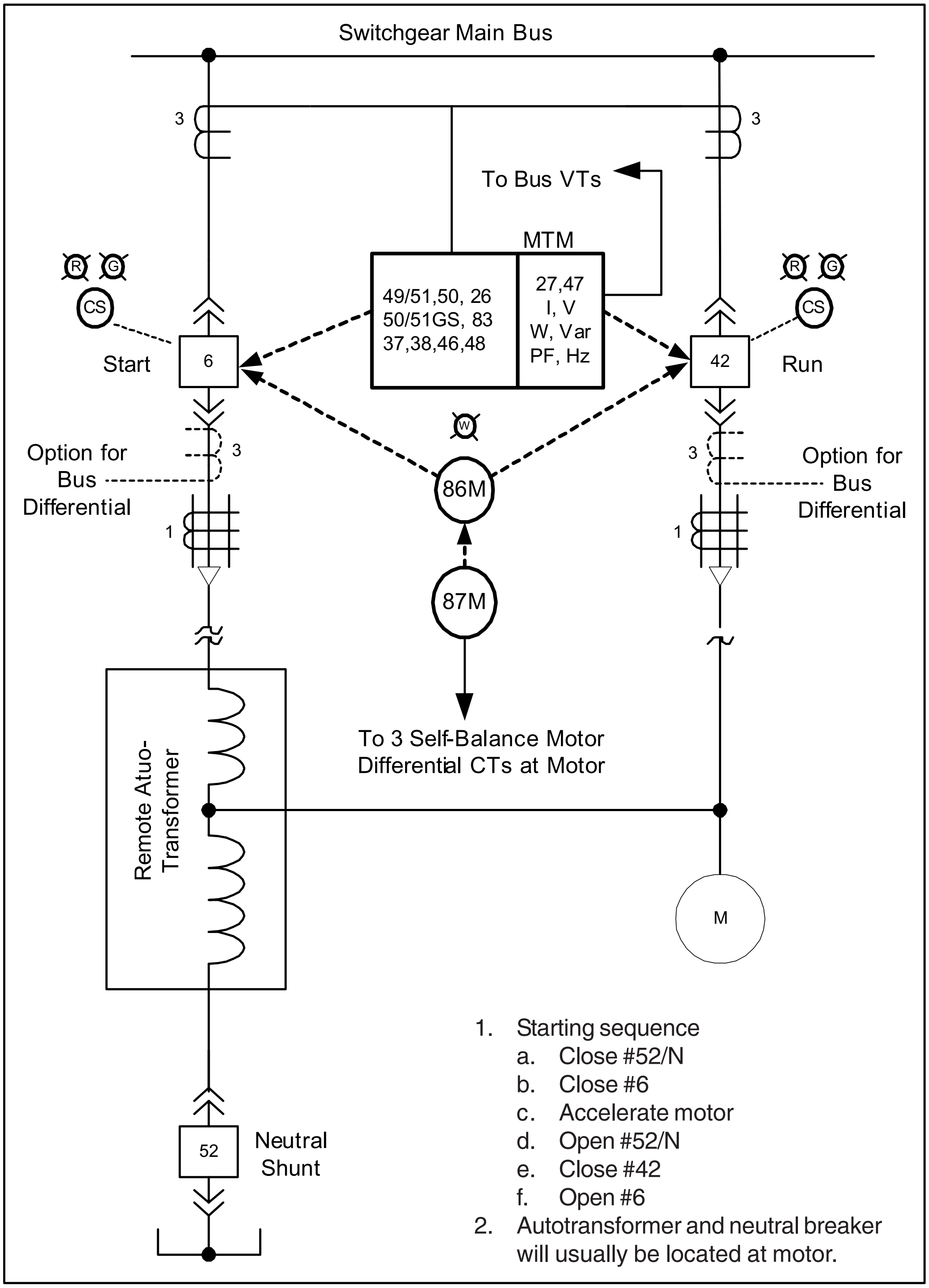
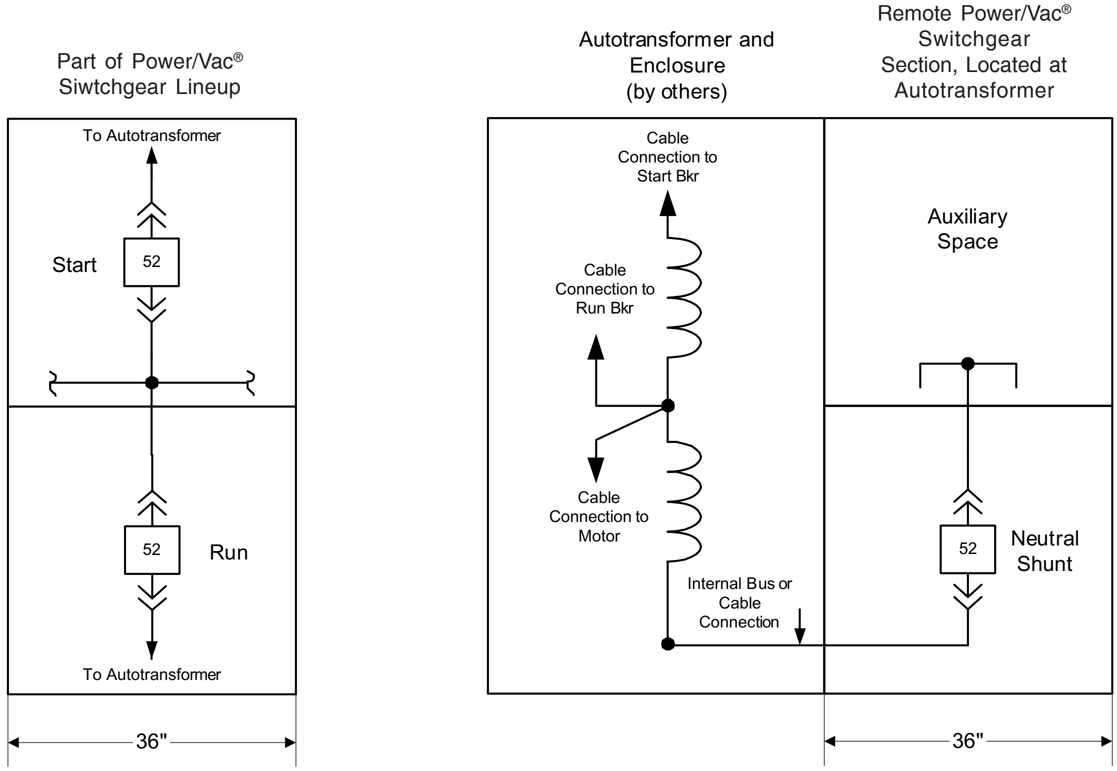
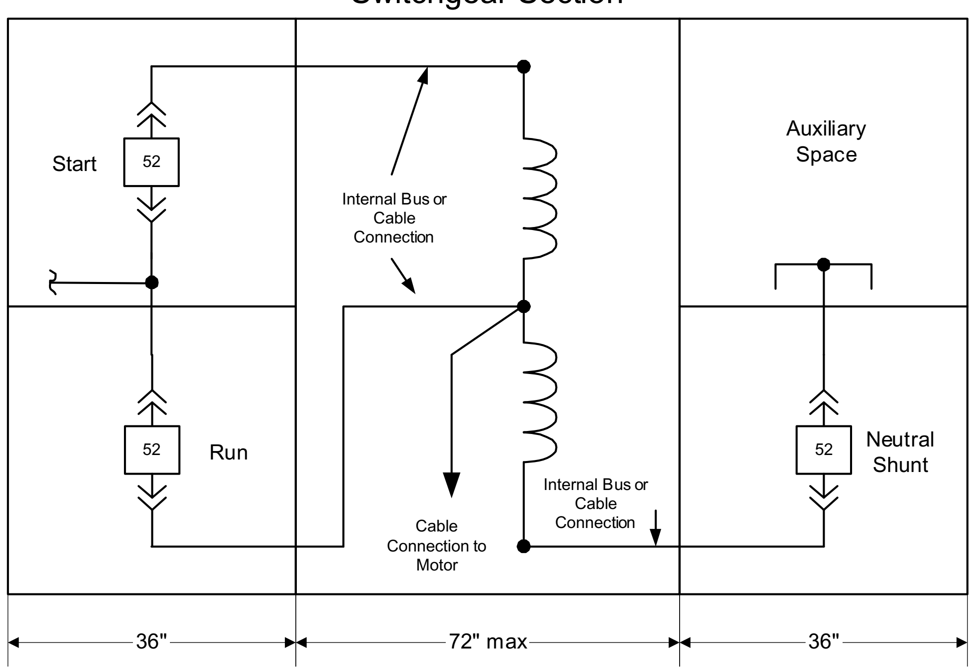


Figure 6-11 Remote Mounted Autotransformer (Standard)



Autotransformer Mounted in Custom
Switchgear Section



This option only available for small auto transformers. No extension of main bus available for future add-on.

SYNCHRONOUS MOTOR FEEDERS, FULL-VOLTAGE START, DIRECT-CONNECTED EXCITERS

DEFINITION

These metalclad feeder equipments (SMF) are used for controlling and protecting full-voltage-start synchronous motors and are designated as motor "branch circuit" protective equipment. Economics usually preclude protecting a motor smaller than 1500 hp (SMF1) with a device package as complete as that used for larger motors (SMF2). Also see IEEE C37.96-2000 IEEE Guide for AC Motor Protection for relaying recommendations.

PROTECTIVE SCHEME SELECTION

SMF1 Basic equipment for and SMF-1 (1500 HP and less) includes three-phase running overload, locked rotor, and short-circuit protection (49/50); undervoltage protection with time delay (27, 62) (only one required per lineup); zero-sequence ground-fault protection (50GS); load current indication. The overcurrent relays operate from a three CT's, one in each phase, and a ground-sensor CT.

The equipment is specified for use on impedance grounded or solidly grounded systems. See "Optional Equipment Selection" for modifications of this equipment for use on systems with other types of grounding or having motors with other types of excitation.

SMF2 Basic equipment for an SMF2 (greater than 1500 HP) is a digital motor protection relay which in-cludes three-phase running overload, locked rotor, and short-circuit protec-tion (49/50); undervoltage protection with time delay (27, 62) (only one re-quired per lineup); 3-phase self-balancing machine differential (87M); one lockout relay (86M); zero-sequence ground fault (50GS); and full function metering. The protection relay operates from three current transformers, one in each phase, a ground sensor CT and three current transformers located at the motor.

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OPTIONAL EQUIPMENT SELECTION (For SMF1 and SMF2)

Protection

If six-CT machine differential relaying (87M) is desired, omit the three-phase instantaneous relay (if used) and three CT's (supplied by motor manufacturer) at the ma-chine terminals. Use the relay and six CT's (three in machine neutral leads and three in metalclad switchgear.) Specify the relay be wired for current summation differential in lieu of self-balance.

For ungrounded systems, omit the ground-sensor overcurrent relay (50GS) and the current transformer.

When equipment is used to feed more than one motor from the same bus, only one undervoltage relay is required. However, for multiple motors, add auxiliary relay(s) (27X), with sufficient contacts to trip each additional motor feeder breaker.

On smaller motors, where economically justified to include motor differential protection, add one, 3-element, instantaneous overcurrent relay operating from the three current transformers (mounted at the motor terminals) and connected for balanced-current motor differential protection (87M).

For larger motors (greater than 1500HP), complete protection including motor differential can be obtained by using the motor protection relay (with motor mounted CTs).

Excitation

Field application equipment or exciter packages for a synchronous motor are typically furnished with the motor package. Excitation packages and panels can be sourced and mounted in a switchgear compartment or section. These application panels are considered custom design.

Control

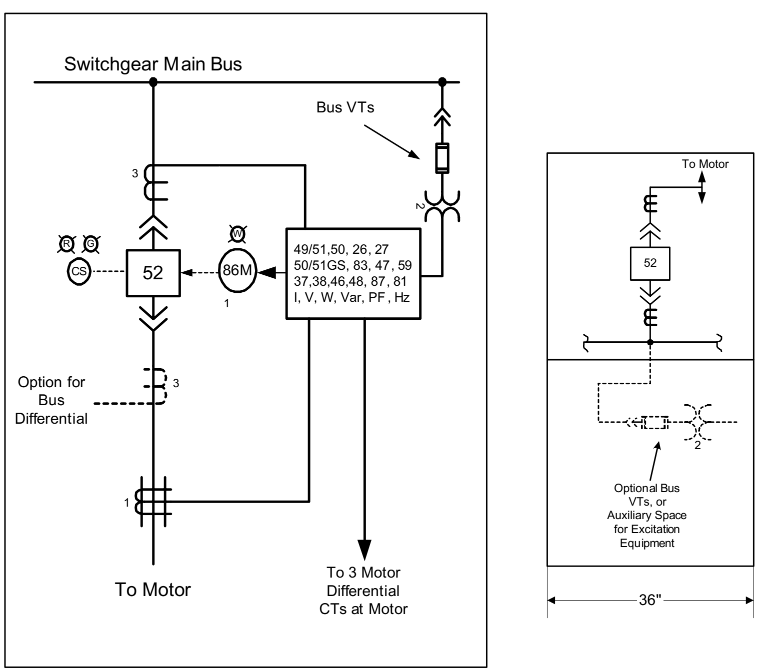
REMOTE CONTROL - For circuit breakers controlled from a remote location, choose the remote control scheme from those listed in Section 5, Table 5-1. From this table, Scheme C is recommended, since it provides maximum operating flexibility. If requires the use of a breaker position switch in conjunction with the breaker control switch to provide the permissive function. With Scheme C. remote close and trip is possible only with the breaker in the “connected” position; local close with the breaker in the “test” position; and local trip with the breaker in the “connected” or “test” position.

In addition, remote control for motors requires a lockout relay (86), which prevents breaker closing (after a relay-initiated trip) until the lockout device is manually reset. (The 86 device specified on SMF2 may be used for both 87M and remote control.)

Location of Optional Devices

If several optional devices are added to a motor feeder equipment, there may not be sufficient space to mount them all. In this case, specify that the excess relays are to be mounted on an adjacent auxiliary compartment. This makes the vertical section a custom section.

Figure 6-12 Synchronous Motor Feeder



GENERATORS

DEFINITION

Generator metalclad equipment (GEN) controls and protects a synchronous generator driven by a steam turbine, gas turbine, a diesel engine, a gasoline engine, a water-wheel turbine, or a motor. The generator may be operated as an isolated system source or in parallel with other power sources. The basic equipment specified here is adaptable to any of these circumstances with the addition of the proper optional equipment. Most generator equipments are custom.

BASIC PROTECTIVE SCHEME

The basic equipment includes no field control or voltage regulator equipment, since this equipment is normally supplied with the generator and located in a separate cubicle either adjacent to the generator or near the switchgear.

Basic GEN protection utilizes a digital generator protection relay, which includes three-phase voltage-restrained overcurrent (51V), ground overcurrent (51G or 50G), reverse power/anti-motoring protection (32) and generator differential (87G). Include one lockout relay (86G). The relay operates from three switchgear mounted CT's, one in each phase, three CTs located at the generator (furnished by the generator manufacturer) and a set of VTs con-nected to the generator side of the circuit breaker.

Field Control and Voltage Regulation

To obtain field control for remote-mounted field application equipment, add one motor-operated rheostat control switch and one field ammeter.

For generators with brushless exciters and without remote SC-VT regulators, add one metalclad equipment vertical section containing provisions for mounting a voltage regulator, brushless exciter field control, mounting for an exciter field rheostat, and an exciter field ammeter. Add one or two VT's and one CT to the generator circuit breaker vertical section for use with the voltage regulator, if required.

Protection

FOR GENERATORS ON GROUNDED SYSTEMS - Use ground overcurrent relay connection (51G).

FOR GENERATORS OPERATING IN PARALLEL WITH OTHER POWER SOURCES ON GROUNDED SYSTEMS

FOR LARGE GENERATORS (larger than 5000 kW) - Add loss-of-field relay (40), negative sequence current relay (46), and voltage-balance relay (60).

Synchronizing

For manual synchronization of machine to bus, specify a synchronizing panel with two voltmeters, a frequency meter, a synchroscope, and two indicating lamps.

Isolated Systems

Omit the synchronizing switch and add one frequency meter and a voltmeter.

Current Transformers

Add three current transformers for lineups that include bus differential protection.

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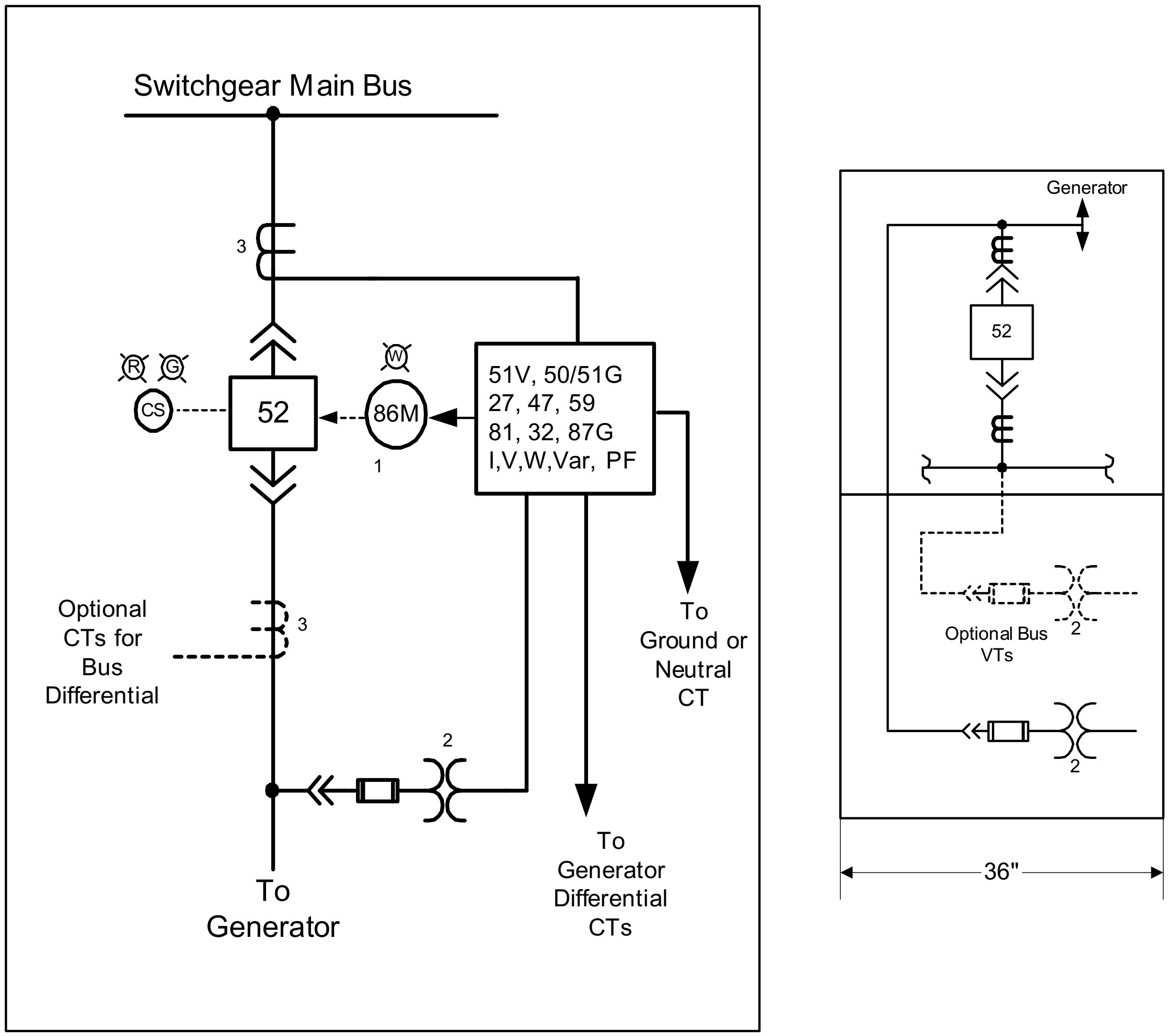
Figure 6-13 Generator



POWER COMPANY METERING

DEFINITION

Metalclad equipment that contains Utility owned metering transformers and meters. These sections are custom, and designed to meet the specific requirements of the specified Utility. Sections are dedicated for Utility use, therefore cannot contain any Owner/Customer equipment. Standard designs utilize either 36" wide or 48" wide sections. Some Utilities require a separate cable entry or pull section for the incoming cables, in addition to the metering section. Section designs can be for "Hot Sequence" (metering before main disconnect/breaker) or "Cold Sequence" (metering after main disconnect/breaker) as shown in Figure 6-14.

Consult the serving Utility on your project, for their specific requirements regarding metering section design and construction. All metering section designs must be approved by the Utility, prior to manufacture.

Figure 6-14. Utility Metering Arrangements

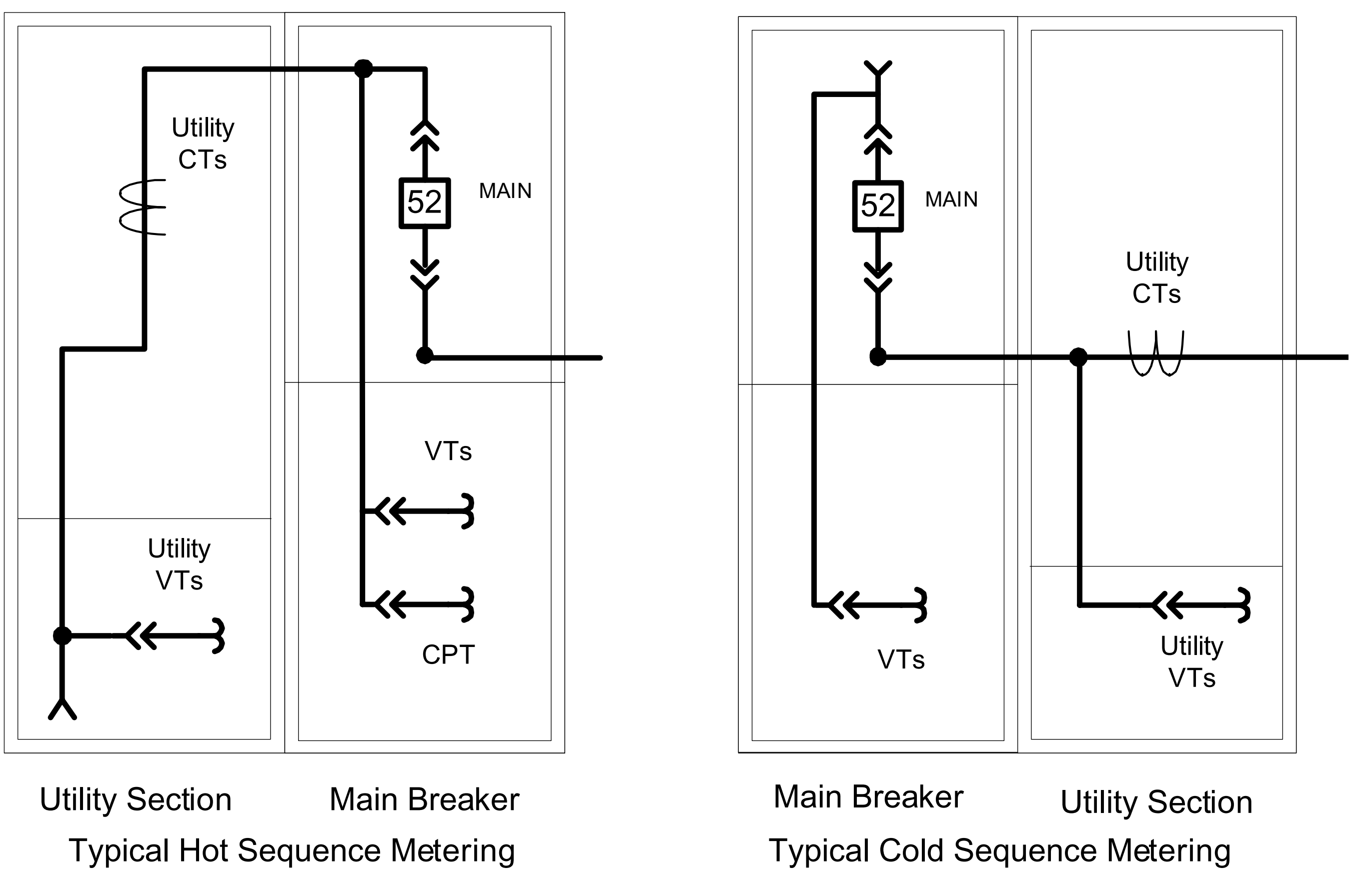
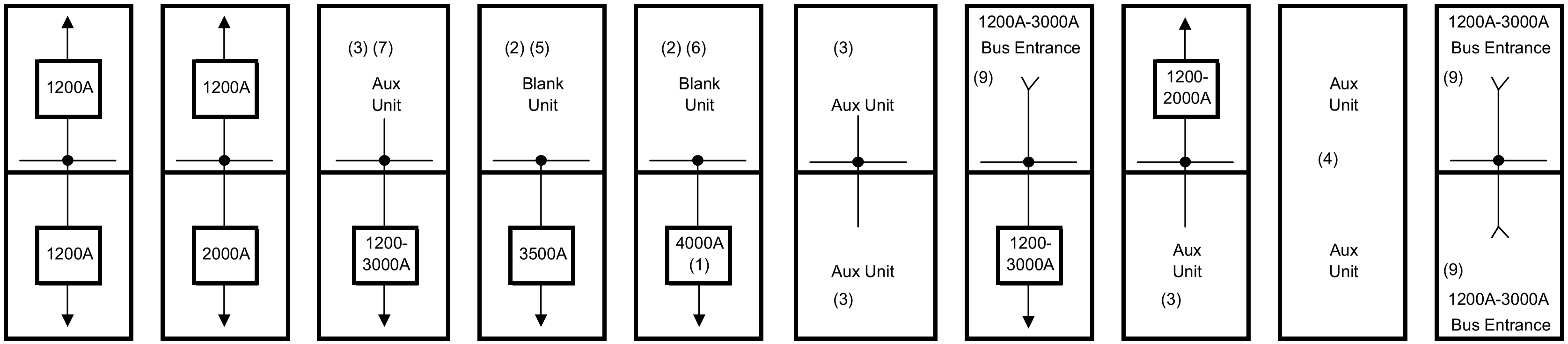
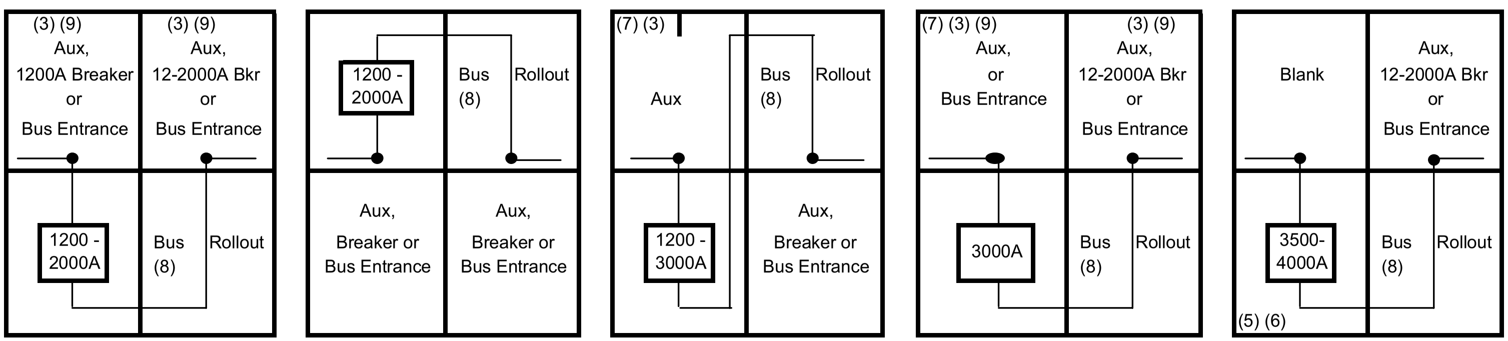


Figure 6-15.

Standard Power/Vac® Breaker Stacking Configurations



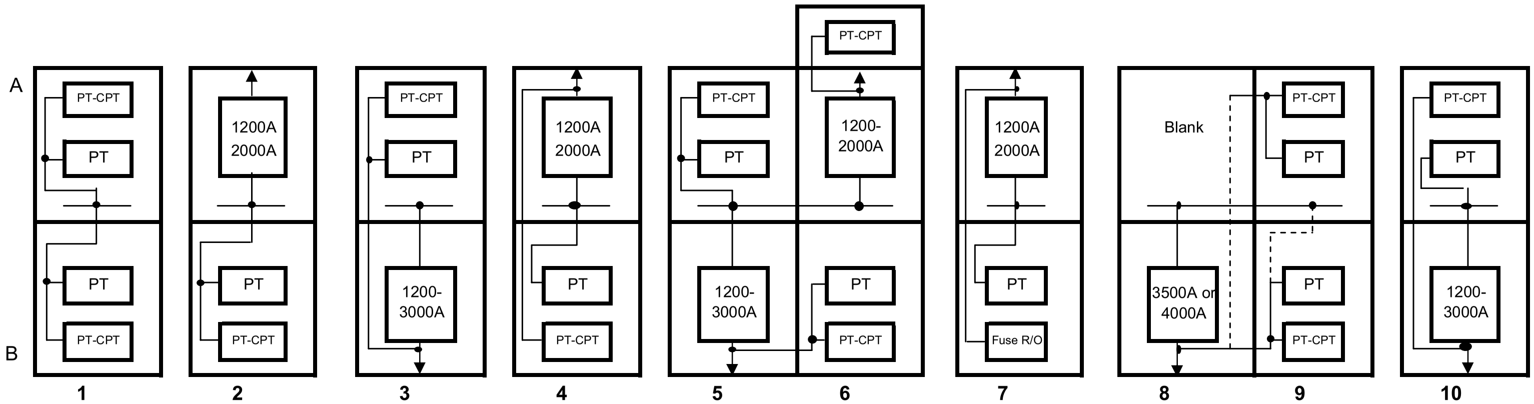
Standard Power/Vac® Bus Tie Breaker Stacking Configurations



(1) 4000A breakers require fans on top of structure for forced air cooling.
(2) Blank Unit above 3500A & 4000A breakers have room for device mounting .
(3) Auxiliary Units can contain rollout tray for VTs & CPTs, or additional device mounting.
(4) Full height Auxiliary Units can contain additional device mounting or be used for material storage .
(5) 3500A must be derated to 3250A in outdoor construction.
(6) 4000A is not available in outdoor construction.
(7) Rollouts located above a 3000A breaker, are only available on indoor construction.
(8) Auxilary Bus Ties can contain 1 bus connected rollout tray.
(9) Bus Entrance can also contain a VT rollout tray, or CTs (not both)

Each section in standard indoor construction is 36" W x 95" H x 94" D.

Figure 6-16.



Standard Power/Vac® Auxiliary Compartment Configurations

1. 4 high auxiliaries capability
2. 1200A/2000A breaker in A, two bus connected rollouts in B
3. 1200A, 2000A or 3000A breaker in B, two line connected rollouts in A (rollouts above 3000A Bkr on indoor construction only)
4. 1200A/2000A breaker in A, two rollouts in B, one line & one bus connected
5. 1200A, 2000A or 3000A breaker in B, two bus connected rollouts in A (rollouts above 3000A Bkr on indoor construction only)
6. 1200A/2000A breaker in A, with line connected rollout in superstructure. Two rollouts in B, line connected from adjacent section (1200A, 2000A or 3000A breaker)
7. 1200A/2000A breaker in A, two rollouts in B, one line connected fused R/O, with large CPT mounted in rear
8. 3500A/4000A breaker in B compartment with line connection to adjacent section 9. A compartment must beblank
9. Two rollouts in A or B compartments, line connected to 3500A/4000A breaker in adjacent section 8, Rollouts can be combination of line or bus connected.
10. 1200A, 2000A or 3000A breaker in B, one line and one bus connected rollouts in A (rollouts above 3000A Bkr on indoor construction only)

NOTE: ALL ROLLOUT TRAYS ARE HARD BUS CONNECTED. NO CABLE CONNECTED TRAYS.

Rollout Unit	Devices	Ratings	A Compartment		B Compartment	
			Lower	Upper	Lower	Upper
VT	2 - VTs (1)	5KV through 15KV	Yes	Yes	Yes	Yes
VT	3 - VTs (1)	5KV through 15KV	Yes	Yes	Yes	Yes
CPT	1 - CPT (1)	5, 10, 15KVA	No	Yes	Yes	No
Fused Unit	1 - CPT (2)	25, 37.5KVA (4)	Yes	N/A	Yes	N/A
Fused Unit	CPT Fuses (3)	Remote 225kVA Max	Yes	N/A	Yes	N/A

(1) Fuses are an integral part of VT or CPT. CPTs are single phase
(2) CPT is installed in the rear cable compartment. CPT fuses are installed in a key interlocked fuse rollout in the Lower A or Lower B compartment
(3) Fused rollout tray must be key interlocked with remote CPT secondary breaker
(4) Contact your Powell representative for availability of larger CPTs or 3-phase bank.

Section 7

Standard Power/Vac® Construction Features, Equipment and Installation Information

INTRODUCTION

This section of the Application Guide provides basic construction information for Power/Vac vacuum metalclad switchgear; standard equipment construction features, weights and dimensions, floor plan details, and installation details for floor or pad installations.

Since Power/Vac is a highly structured design, one basic floor plan detail, with three sets of dimensions, provides complete floor plan information, regardless of rating. Control and power conduit entrances remain in one specified location for all units in a lineup. In addition, anchor bolt locations are the same for each unit. These benefits of product design structuring simplify layout planning, sited construction, and equipment installation.

STANDARD EQUIPMENT FEATURES

GENERAL

This specification describes standard Power/Vac vacuum metalclad switchgear with ratings listed in Sections 1 and 3 of this guide.

DOCUMENTATION

Standard documentation provided consists of the following computer-generated diagrams and documents:

- Device summary
- Elementary diagram (power and control circuits showing each contact, coil, wire and terminal point)
- Connection/Interconnection diagram (shows physical location of devices, terminal blocks and internal wiring)
- Arrangement drawing (includes simple one-line diagram, front view, side views, and floor plan)

Standard documentation does not include special drawing formats, special nomenclature for terminal points, special location or sequencing of customer terminal points, or preparation of composite drawings showing equipment other than the switchgear and essential customer connections.

INDUSTRY STANDARDS

Power/Vac metalclad switchgear is designed, built and tested in accordance with applicable ANSI, IEEE and NEMA standards as listed in Section 1 of this guide.

SERVICE CONDITIONS

Power/Vac metalclad switchgear assemblies are suitable for operation at their standard nameplate ratings (See ANSI-C37.20.2):

- Where continuous ambient temperature is not above 40°C or below -30°C (104°F and -22°F)
- Where the altitude is not above 1000 meters (3300 feet)
- Where the effect of solar radiation is not significant

SEISMIC INSTALLATIONS

Power/Vac Medium Voltage Switchgear has been qualified to the seismic requirements of IBC-2003 and IEEE-693-1997 through shake table testing. Several samples representative of the most seismically vulnerable product configurations were tested to certify the entire product line. Equipment remained structurally sound and devices functioned properly during and after the seismic event.

Power/Vac Medium Voltage Switchgear is certified to the following IBC-2003 levels:

Ip = 1.5
Sds = 1.77 g at z/h = 0
Sds = 1.1 at z/h > 0

Power/Vac Medium Voltage Switchgear is certified to the following IEEE-693-1997 levels:

Moderate with 2.5 amplification factor, and High with 1.4 amplification factor

IBC-2003 and IEEE-693-1997 do not use seismic Zones to specify performance levels as UBC and CBC do. IBC-2003 requirements are specified using three key variables:

Sds - A measure of equipment base acceleration. Sds values range from 0 to 2.0 and are multiples of g-force.

Ip - An importance factor. Ip levels range from 1.0 to 1.5. All Power/Vac equipment with IBC-2003 certification is qualified to an Ip level of 1.5, indicating the equipment will be fully functional during and after a seismic event.

z/h - A measure of the equipment mounting location inside or outside a building. Z/h ranges from 0 to 1, where h is the total building height and z is the vertical distance between ground level and the equipment installation location. Ground and roof mounted equipment, for example, would have z/h levels of 0 and 1, respectively.

Equipment is certified to the IBC-2003 levels listed above for all Seismic Use Groups, Occupancy Importance Factors, and Seismic Design Categories.

IEEE-693-1997 uses two performance levels: Moderate and High. Recent IEEE-693-1997 certifications also carry an amplification factor analogous to the z/h value of IBC-2003 to specify the installation level within a building. Amplification factors of 1 and 2.5 correspond to equipment mounting at ground and roof levels, respectively.

CONSTRUCTION

INDOOR EQUIPMENT

Indoor Power/Vac switchgear consists of one or more vertical sections mounted side by side, and connected electrically and mechanically to form a complete lineup of equipment.

Each vertical section is a self-supporting structure including a formed steel frame, bolted together (with reinforcing gussets) to which 11 gauge steel front doors, top, side and rear covers are assembled. (or equivalent thickness if covers consist of two sheets). A vertical section will accommodate a maximum of two circuit breakers or four VT/CPT fuse rollout trays, or certain combinations thereof (see Section 1, Section 6 Figures 6-15 and 6-16).

Breakers are removable from the equipment by means of a portable lifting device (lift truck). An optional lower compartment roll-in breaker design is available on Indoor or Outdoor Protected-Aisle construction. As a breaker is removed, grounded metal safety shutters isolate the primary contacts from the rest of the compartment and are fronted by a glastic safety barrier.

Grounded metal barriers isolate the primary compartments of each circuit. Primary compartments include the breaker compartment, main bus compartment, power termination compartment, and auxiliary compartment. In addition, each breaker and rollout tray is furnished with an 11 gauge steel front plate that isolates the secondary control from the primary compartment. Secondary control circuit wires will be armored where they pass through primary compartments.

Power termination compartments are located at the rear of the equipment, accessible through bolted covers equipped with lifting handles. Hinged rear covers are an option as well as padlock provisions. Barriers and a cable pass-through box are furnished to isolate the two separate termination compartments in 2-high vertical sections, to maintain ANSI Metalclad standards.

Two front doors (upper and lower) are mounted on each vertical section utilizing full-length hinges, doorstops, and two hex-knob closing screws. T-handle type door latching as well as padlock provisions are optional. Each breaker door will typically contain only those control, instrumentation and protection devices associated with the breaker in that compartment. Fuse blocks, terminal blocks and other surface-mounted accessories will be mounted in locations dedicated for that purpose within the associated breaker compartment.

Required ventilation is provided by air intake through slots in the bottom flange of each front door and louvers in the rear covers. Exhaust is through "basket weave" openings in the top covers (not used for power control cable entry). Top cover exhaust vents are equipped with dust guards to keep dirt from entering the top of the switchgear.

Indoor Drip Proof Construction

Indoor drip proof construction is used to prevent dripping liquids from entering the top of the switchgear, such as from overhead pipes or sprinkler systems. It has the same design as the standard indoor construction, but with the addition of our standard sloped outdoor roof. Door gasketing can be added, to provide construction similar to that described as NEMA 12 in the NEMA 250 Standard. See Figure 7-2.

OUTDOOR EQUIPMENT

Outdoor construction begins with basic indoor equipment and is weatherproofed by gasketing and sealing the end covers and rear covers, adding filters to ventilation louvers and adding a sloped weatherproof roof. In addition, weatherproof doors or a maintenance aisle are added to the front. A three-inch box frame is provided under each vertical section and the equipment is painted and undercoated for outdoor service.

Airflow for convection cooling is assisted by the addition of standard equipment strip heaters with guards. Each heater is rated 300W at 240VAC, but applied at half voltage for long life which provide 75 watts for each heater equipment. Four heaters are mounted in each section, for a total of 300 watts per vertical section. These should remain energized at all times (no switch or thermostat is provided unless specified) to guard against internal condensation when wide ambient temperature excursions occur.

Standard Outdoor (non walk-in) Construction - For standard outdoor construction, full-height, gasketed, padlockable doors are provided on the front of the basic weatherproofed equipment to protect the device doors. Grounded 120-volt convenience outlets are provided on each lower device door. In addition, a light socket and switch (120-volt, 100-watt) for an incandescent lamp is mounted on the inside of each unit. See Figure 7-3.

Power Control Isle - A 75" deep weatherproof aisle of 11-gauge steel is added to the front of basic weatherproofed equipment to provide “protected-aisle” convenience. Doors with padlocks and panic latches are located at each end of the aisle. Space (36") is required at the left end of the lineup to allow for device door swing of the left-end units. This space can be either a full 36" wide “blank section” used for a work area, batteries and battery charger, or for equipment storage, or can be an extension of the aisle alone. On the right end of the lineup, a minimum 12" aisle extension is typically required for clearance to operate the breaker lift truck. The aisle is shipped “knocked down” for job site assembly. Factory preassembly of aisle sections is an option. See Figure 7-4 and 7-29.

Inlet ventilation openings for the aisle are louvered, equipped with filters, and located on the aisle doors. Exhaust is through screened openings designed into the roof perimeter overhang. Note that the protected aisle cannot be furnished with HVAC systems or insulated; though roof mounted ventilation fans can be provided. For projects requiring a controlled environment for the switchgear installation, due to temperature extremes, corrosive atmospheres or other harsh conditions, a Power Control Room should be considered.

A grounding-type receptacle, rated 250 volts ac, 20 amperes, is provided at each end of the aisle for portable comfort heaters. (Comfort heaters to be furnished by Purchaser.) A 120-volt grounding, duplex convenience outlet and a three-way switch for ceiling lights are also provided at each end of the aisle. Ceiling-mounted light sockets for 120-volt, 100-watt, incandescent bulbs are furnished (one per vertical section).

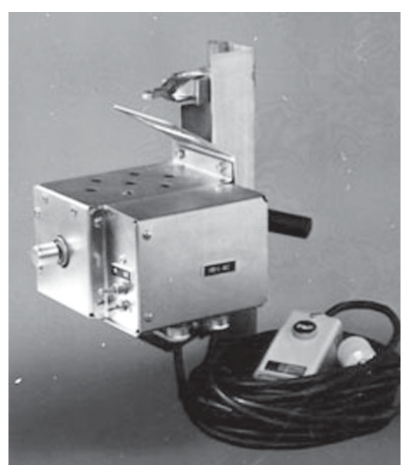
Common-Aisle Construction - To provide common-aisle construction, the space between facing lineups of weatherproofed gear is spanned; by a “common” weatherproof aisle. Space (36") is provided at the left end of each lineup to allow for device-door swing. Otherwise, all construction details are the same as those for protected-aisle construction. See Figure 7-5.

HARDWARE

All standard assembly hardware is high tensile-strength steel (SAE grade 5), which is plated to resist corrosion. On outdoor construction, exposed hardware is stainless steel.

BREAKER COMPARTMENT

Each Power/Vac circuit breaker rolls on horizontal guide rails and has self-coupling primary and secondary contacts. The breaker is continuously grounded while in the compartment, via a breaker mounted copper ground bar and a ground shoe located in the compartment. A manually operated jackscrew racking mechanism is provided in each breaker compartment to move the breaker between the “connected” and “test/disconnected” positions. The equipment is of closed-door-drawout design, to allow the breaker to be racked between positions with the front door closed for safety. Breaker position indicator is viewable from the front with the compartment door closed and latched. An optional motor driven, remote racking operator is available for racking the breaker in and out of the cubicle. This device can be used to provide enhanced operator Arc Flash Safety as described in NFPA 70E-2004.



Remote Racking Device

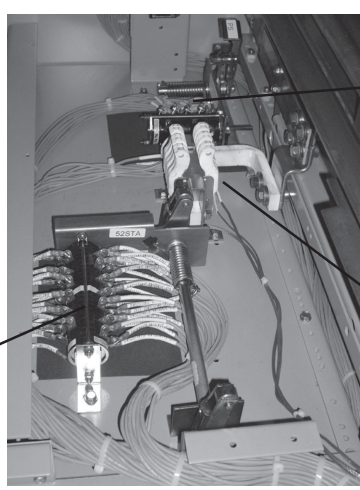
Grounded-metal safety shutters, mechanically linked to the racking mechanism are actuated to cover the stationary primary disconnects when the breaker is moved from the connected position.

The standard racking mechanism provides two positions with up to 3 padlocks each (padlocks with a 3/8-inch shackle are recommended). The front position keeps the breaker from closing in the "Test" and "Connect" position. This gives the same interlocking functions as the optional key lock described below, and but does not block the motion of the racking mechanism. The second position for padlocks will prevent any motion of the racking mechanism by blocking access to the hexagonal racking shaft.

The breaker racking mechanism track also has a provision for an optional key lock. The purpose of this lock is to keep the breaker from closing in the "Test" and "Connect" positions by operating the negative interlock and prevents the breaker from closing. The key lock does not prevent motion of the racking mechanism. A special racking mechanism track is available, that when used with the keylock, will lock the mechanism, blocking racking.

An optional stationary (breaker cell mounted) auxiliary switch (52STA or MOC = mechanism operated contact) is available in a 3-stage (3 "a" and 3 "b"), a 6-stage (6 "a" and 6 "b"), or a 10-stage (10 "a" and 10 "b") configuration. This switch changes state with the breaker opening and closing, and normally will operate with the breaker in either the "Connect" or "Test/Disconnect" positions. It may also be supplied to operate with the breaker in only the "Connect" or "Test" positions.

An optional breaker cell mounted position switch (52POS or TOC = truck operated contact) is also available in a 3-stage (3 "a" and 3 "b"), or a 6-stage (6 "a" and 6 "b") configuration. This switch changes state as the breaker is moved between the "Connected" and "Test/Disconnected" positions. Note switch contacts are not convertible.



52 STA, 52POS and Ground Shoe in Breaker Cell

AUXILIARY COMPARTMENT

Rollout trays are provided in primary auxiliary compartments for mounting voltage transformers (VT's), control power transformers (CPT's) or CPT fuses. Two rollout trays can be accommodated in the bottom primary auxiliary compartment and two in the top compartment. See Section 1, Figure 1-5 and Section 6, Figure 6-16.

Optional 'top hats' or "superstructures" are offered for VT's or CPT's in areas with restricted space. See Figure 7-20. Auxiliary compartments can also be utilized to mount control power distribution or transfer panels, exciter equipment for motor starter applications, or as a storage compartment for a spare breaker or ground & test device.

TRANSITIONS

Power/Vac has standard bus coordination details and drawings. See Figures 7-17 thru 7-19. The main switchgear bus is extended out the side 10 inches, and the side sheet is provided with standard drilling pattern to allow the mating equipment to bolt up to the Power/Vac switchgear.

The standard transition section furnished by Powell is 29 inches in width. It is full height and full depth, matching up to the Power/Vac on one side and equipment on the other side. See Figure 7-17.

Transition to a transformer is very similar. The transformer vendor provides the transition section, and the Power/Vac provides a 6" throat welded to the switchgear end sheet, which then can be bolted to the transformer transition section. See Figure 7-18 and 7-19.

SAFETY INTERLOCKS

Power/Vac switchgear is provided with mechanical interlocks to:

- Inhibit moving the breaker to or from the "Connected" position when the breaker contacts are in the "closed" position;
- Block closing the breaker, unless the primary disconnects are fully engaged or the breaker is in the "Test/Disconnect" position.

- Automatically discharge the closing springs when the breaker is moved between the “Connected” and “Test” positions or when it is inserted into or withdrawn from the compartment.

  In addition, the breaker racking mechanism is a jackscrew type, which positively holds the breaker when it is in either the “Connected” or “Test/Disconnected” position. Finally, control power transformer primary fuses, whether located on the CPT or on the separate rollout trays, are not accessible unless the CPT primary and secondary circuits are open.

  Additional safety design features include:

- The rating interference plate, which allows only a breaker of the correct type and rating to be inserted into any specific breaker compartment.
- Closed-door drawout design, which allows breaker racking to and from the “Connected” position with the front door closed.
- Grounded metal shutters which automatically close to cover the stationary primary disconnects when the breaker is moved from the “Connected” position.
- An additional insulated safety barrier is installed in front of the metal shutters.

MAIN BUS

The main bus is completely enclosed by grounded, metal barriers and feeds both the upper and lower compartment in a vertical section. Main bus materials are copper ASTM B187 for 1200-ampere rating (3/16-inch by 6-inch bar) and 2000-ampere rating (3/8-inch x 6-inch bar), and ASTM B187 Type ETP copper for the 3000 ampere rating (2 - 0.38" x 6.0" bars) and 3500 and 4000 ampere ratings have (2 - 0.625" x 6.0" bars). All main bus joints are silver plated (tin plating is an option) and utilize at least two ½-inch Grade 5 plated steel bolts per joint. Provision for future extension of the main bus is standard.

Bus bars are mounted edgewise and are insulated with flame retardant, track-resistant to a thickness that withstands the dielectric tests specified in ANSI-C37.20.2. The bus bars are supported on track-resistant, molded-polyester-glass supports, which also serve as inter-section bus barriers. Bus supports have strength suitable to withstand the forces caused by a 50kA RMS symmetrical short-circuit (80kA RMS asymmetrical, 130kA Peak). Enhanced bus bracing for 63kA symmetrical short-circuit is also available. All main bus joints are insulated with pre-formed vinyl boots secured by nylon hardware as a standard practice. Some custom bus joints may require taping.

Porcelain insulation to ground is optional. This includes porcelain inserts in the bus-support barriers, porcelain standoff insulators where required, and porcelain sleeves for the stationary primary disconnects.

SECONDARY CONTROL

Door-mounted Devices

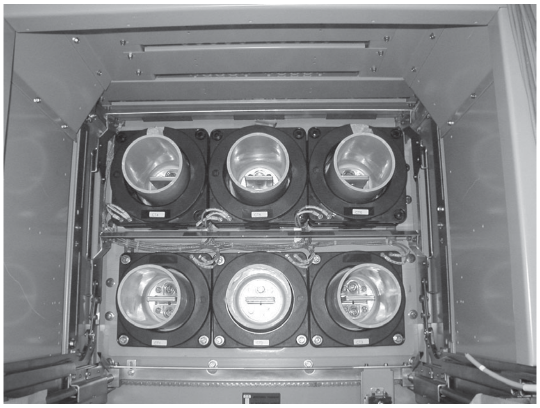
Protection, instrumentation, and control devices, which provide indication or manual control, are mounted on the enclosure front doors. Typical door-mounted devices include protective and relays, meters, instruments, control switches indicating lights, and test blocks.

The devices required for a particular breaker are typically mounted on the compartment door associated with that breaker. For cases in which all devices cannot be accommodated on the breaker compartment door, the additional devices can be mounted on an auxiliary compartment door of an adjacent vertical section.

Equipment-mounted Devices

Secondary control devices, which are not door-mounted, are surface-mounted in suitable locations inside the compartment. Included in this class are fuse blocks, terminal blocks, most auxiliary relays, and timers. All control circuits are properly protected using fuses in dead front, draw-out or tilt-out blocks.

Ring-type current transformers are mounted over the stationary primary disconnect bushings and are accessible through the front of the breaker compartment. A maximum of four (4) CTs with standard accuracy class can be mounted per phase. If CTs are optional high accuracy class, only two (2) can be mounted per phase. Wound primary CT’s (bar type) when required, are mounted in the power termination compartment. See Section 5, Table 5-2 for typical ring type CT ratios.



Typical CTs mounted in Power/Vac® breaker cell

Voltage transformers, and their associated fuses, are mounted on rollout trays. Standard voltage transformers are mounted three per tray for wye connection transformers and two per tray for open-delta connected transformers.

Typical VT Drawout tray

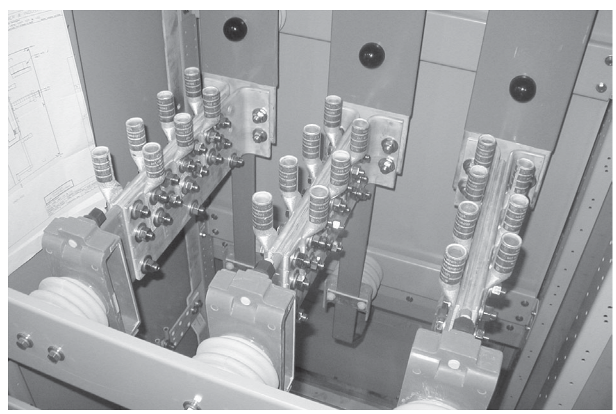
Control power transformers are epoxy-cast, dry-type transformers. A rollout tray can accommodate one single-phase control power transformer, up to 15-kVA maximum. Larger control power transformers must be stationary-mounted in the power termination compartment and only the fuses are mounted in the rollout tray. A secondary non-automatic MCB is provided, key interlocked with the primary fuse tray, to prevent withdrawing the fuses under load. Transformer size in the rear termination compartment is limited to one 75 KVA single-phase transformer or a 75 KVA three-phase bank using three individual 25 KVA transformers (see Sections 1 and 6).

Wiring

Secondary control wiring is No. 14 extra flexible, 41 strand, tinned-copper control wire, Type SIS (Vulkene), rated 600 volts, except for some specific circuits for which a larger wire size is required. Crimp-type, uninsulated spade terminals and sleeve type wire markers are furnished on all wire ends, except where non-insulated ring terminals are used to connect CT circuit connections. Secondary control wires are armored or enclosed in grounded metal troughs where they pass through primary compartments.

POWER TERMINATION COMPARTMENT

Cable termination compartments for incoming and load cables are located at the rear of the equipment and are accessible through rear covers. Barriers and cable pass-through boxes of 11-gauge steel are provided to isolate the circuit terminations in the event there are two cable termination compartments in the same vertical section. Each cable termination pad can accommodate up to two 750 KCMIL cables per phase as standard. With the addition of optional adapters, or a rear depth extension, various combinations can be accommodated up to ten1000 KCMIL cables per phase maximum.



Cable adapter bars for up to 10 cables per phase

Standard Power/Vac switchgear includes only NEMA 2-hole drilling for terminations. Terminal lugs are optional. Connections to roof entrance bushings (REB), pothead terminations, non-seg bus duct or cable bus are also available.

As required, the power-termination compartment may be used for mounting stationary CPT's, wound-primary CT's, ground-sensor CT's, surge arrestors, and other auxiliary devices.

Additional options include:
- Rear cover mounted infrared sightglasses
- Hinged Rear Covers
- Padlock Provisions
- Grounding studs
- Glow tubes for voltage indication

GROUND BUS

The standard ground bus is 0.25-inch by 2-inch bare copper, and has a short-circuit rating of 50 kA symmetrical for 2 seconds. For 63kA short circuit applications, the ground bus is 0.40-inch by 2-inch copper to achieve a 63 kA symmetrical 2 second rating.

The ground bus extends throughout the lineup with connections to each breaker grounding contact and each cable compartment ground terminal. All joints are made with at least two 3/8-inch, plated steel bolts per joint. Station ground connection points are located in each end section.

EQUIPMENT HEATERS

Indoor equipment does not include equipment heaters and thermostats as a standard offering. They may be supplied as an option. Each heater is rated 300W at 240VAC, but applied at half voltage for long life which provide 75 watts for each heater element. Four heaters are mounted in each section, 2 front and 2 rear, for a total of 300 watts per vertical section.

On outdoor designs, heaters are supplied as standard to minimize moisture condensation. Heaters are applied at half-voltage for extended life and are protected by perforated metal guards to prevent inadvertent contact with the heater element. Heaters should be energized at all times to guard against condensation caused by wide ambient temperature excursions; accordingly, no switch or thermostat is typically provided in the heater circuit.

FINISH AND PAINT

Switchgear enclosure parts are protected after pretreatment of the metal, with an electrostatically applied, baked on, polyester powdercoat of Light Gray ANSI 61.

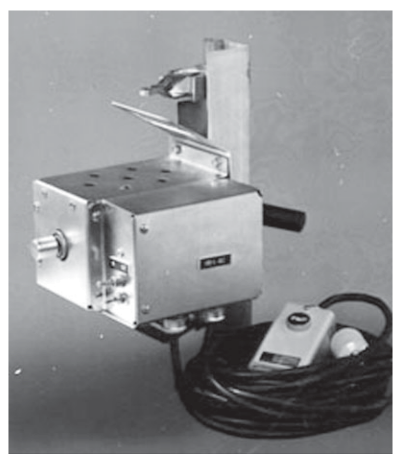
Other exterior colors such as Dark Gray (ANSI 24), Sky Gray (ANSI 70) or Berkshire Medium Green (ANSI 45) are optional.

UNIT NAMEPLATES

Provided on each unit door is a 4" X 1" laminated plastic engraved nameplate. Either black on white or white on black will be furnished, as specified (white on black if not specified by Purchaser), with the designated customer unit name engraved on the nameplate in 3/6-inch letters, two lines and sixteen letters per line, maximum. A blank nameplate will be provided if unit designations are not specified. Device and component nameplates are optional.

ACCESSORIES

Remote Racking Operator – This is an optional motor-driven racking tool, which can be used to move the circuit breaker between disconnect and connected position, in lieu of the standard hand operated crank. The device attaches to the front of the closed breaker compartment door, and is controlled by a hand-held station on the end of a 30 foot cord. Devices are available for either 120VAC or 240VAC supply. Two models are offered: Type 0177D8399 offers a quick connect/disconnect door attachment design, and is used for closed door racking of circuit breakers only; Type 0144D2856 uses door studs and a clamping mechanism which allows use for racking circuit breakers and Ground & Test Devices with the compartment door open, and breakers with the door closed.

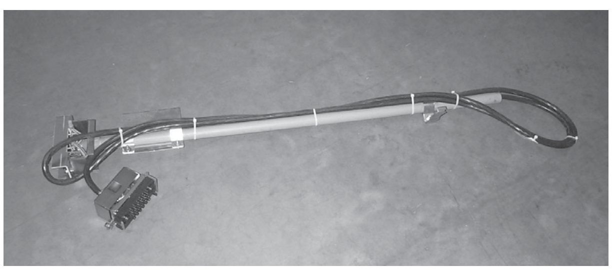


Remote Racking Device

Breaker Test Cabinet – A Test Cabinet is used to electrically operate the Power/Vac breaker when out of the breaker cell, typically at a test or repair bench. It provides a convenient means to access the breaker trip and close circuits during maintenance and inspection procedures. The Test Cabinet contains trip and close pushbuttons, on-off switch, control power fuses and a 10 foot secondary coupler for connection to the Power/Vac breaker.

Breaker Test Cabinet

Breaker Test Coupler – For operating Power/Vac breakers removed from the breaker cell, but using the local switchgear controls, the Breaker Test Coupler is available. The Test Coupler has a 20 foot cord that is used to connect the breaker secondary disconnect block of a breaker removed from the compartment, to the mating block in the breaker cell. This allows for the use of the internal switchgear control power and local breaker controls to test or operate the breaker outside of the breaker cell.



Power/Vac® Test Coupler

Ground and Test Devices – Powell offers both manually operated and electrically operated Grounding and Testing Devices for use in Power/Vac switchgear. See Section 8 for complete descriptions.

INSTALLATION INFORMATION

Typical estimating weights and dimensions are given in Table 7-1. Figures 7-1 thru 7-5 provide typical equipment envelopes for layout and planning. Figures 7- 6 thru 7-8 provide floor plan details showing anchor bolt locations.

Typical equipment anchoring details are provided in Figures 7-9 thru 7-13. Power conductor and secondary conduit entrance locations are found in Figures 7-14 thru 7-16.

SHIPPING SPLITS

Most metalclad switchgear lineups require many vertical sections, or stacks. These multi-section lineups are broken down into shipping splits of four stacks or less after the lineup is assembled and tested at the factory. For confined spaces at jobsite, individual stack shipping sections are available, but must be specified prior to engineering. Each shipping section is bolted to wooden skids, which can be moved with a fork truck. A four stack shipping section will be approximately 14 feet long, 8 feet high and 9 feet deep, weighing 16,000 pounds. These shipping sections must be reassembled, in the correct order, when received at the job site.

POWER/VAC® SWITCHGEAR INDOOR FOUNDATION PREPARATION

Power/Vac switchgear can be mounted directly on a flat level floor, however imbedded steel floor channels are recommended for supporting the equipment. The use of steel floor channels is at the option of the Purchaser, and must be furnished by the Purchaser. Switchgear is anchored to the floor or channels with a minimum of 1/2 inch Grade 5 bolts at the specified locations. Plug welding can also be utilized at the same locations if desired. See Figure 7-9.

The foundation must be strong enough to prevent sagging due to the weight of the switchgear structure and to withstand the shock stress caused by the opening of the breakers under fault conditions. The shock loading is approximately 1-1/2 times the static load. The finished floor must extend 78 inches beyond the front of the equipment, to provide operating clearance for the breaker lift truck. If a housekeeping pad is utilized, the pad must extend no more than 3 inches beyond the front of the switchgear, and be no more than 7 inches tall to allow the use of the breaker lift truck. The finished floor beyond the pad must be the same as noted above.

For Seismic installations, steel floor channels are required (furnished by the Purchaser), and the anchoring options as detailed in the furnished Seismic Installation Drawings must be followed.

The foundation must be flat and level in all planes, perpendicular on both axes to within 0.25 in. in 10 ft. span. We must be concerned with how much the pad is out of level and to what degree this varies over the installation. A foundation pad that is not flat and level can result in problems with breaker alignment and the racking mechanism operation as well as placing unusual stresses on insulators and supporting structures. Minor adjustments can be corrected with shims. When used, shims should be placed beneath all vertical frame posts (located 33 or 36 inches from the front of the equipment, and runback support posts. The acceptance of the pad and the use of shims is the customer's responsibility

FLAT—Surface of pad must lie between two parallel, level planes spaced 1/8 in. apart.

LEVEL—Planes must be perpendicular to plumb line

Table 7-1 Power/Vac® Estimating Weights and Dimensions

Equipment Rating		Indoor Equipment						Outdoor Equipment								Indoor & Outdoor		
4.76KV, 8.25KV & 15KV				2-High Breaker Vertical Section (less breakers)		Auxiliary Vertical Section				2-High Breaker Vertical Section (less breakers)		Auxiliary Vertical Section		For Protected Aisle, Add to Each Vertical Section (2)			Front & Rear Clearances	
Current Rating (Amps)	Breaker Weights (lbs)	Height (in)	Depth (in) (1)	Width (in)	Weight (lbs)	Width (in)	Weight (lbs)	Height (in)	Depth (in)	Width (in)	Weight (lbs)	Width (in)	Weight (lbs)	Depth (in)	Weight (lbs)	Roll-out Weight (W/VT-CPT)	Front Aisle (min)	Rear aisle (min)
1200	550	95 (6)	94	36	3050	36	2950	111 O/D 112 P/A or C/A	109 O/D 181 P/A 272 C/A	36	3550	36	3450	75	1100	500	78 (3)	26 (5)
2000	650				3100		3000				3600		3500					
3000	780				3180		3080				3680		3580					
3500	850		106		3280		3180				3780		3680					
4000	860				3300		3200				3800		3700					

(1) An optional 82" depth may be available for some indoor applications. Consult Factory.
(2) For Power Control Aisle construction, add 1500 lbs to weight of 2 indoor vertical sections.
(3) Reduced minimum front aisle space of 58" is available on indoor construction or outdoor aisle type construction, with the use of bottom roll-in breakers only (1-high).
(4) Weights listed are for estimating purposes only, and should not be used for foundation construction.
(5) If hinged rear covers are supplied, rear aisle space must be 35" minimum. Consult NFPA 70 (NEC) for necessary safety clearances which may be greater.
(6) Height over cooling fans on 4000A breaker units is 106".

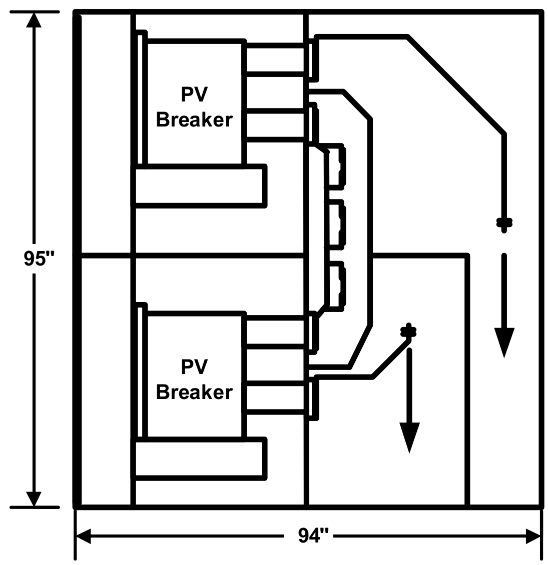


Figure 7-1
Indoor
Construction

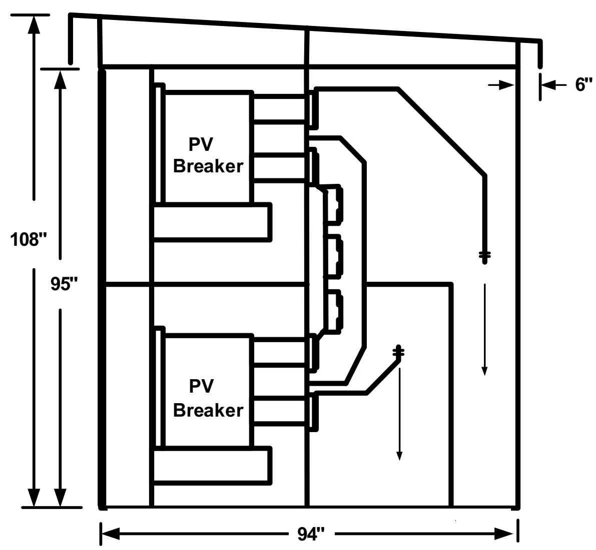


Figure 7-2
Indoor Drip Proof
Construction

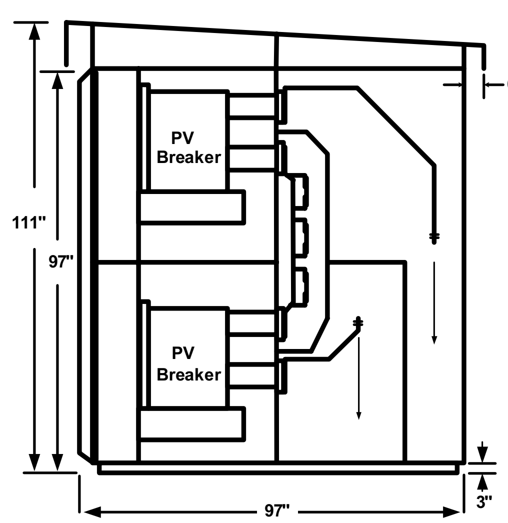


Figure 7-3
Outdoor Non-Walkin
Construction

Figure 7-4 Outdoor Power Control **Aisle Construction**

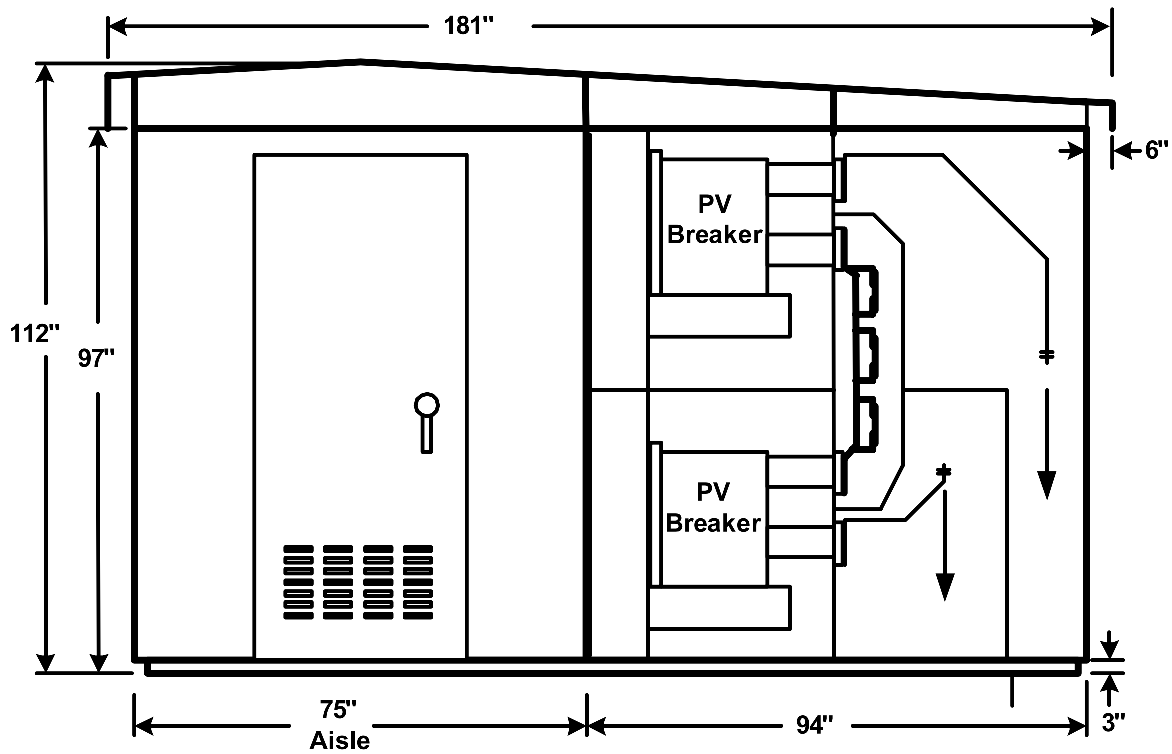


Figure 7-5 Power Control Aisle - Common **Aisle Construction**

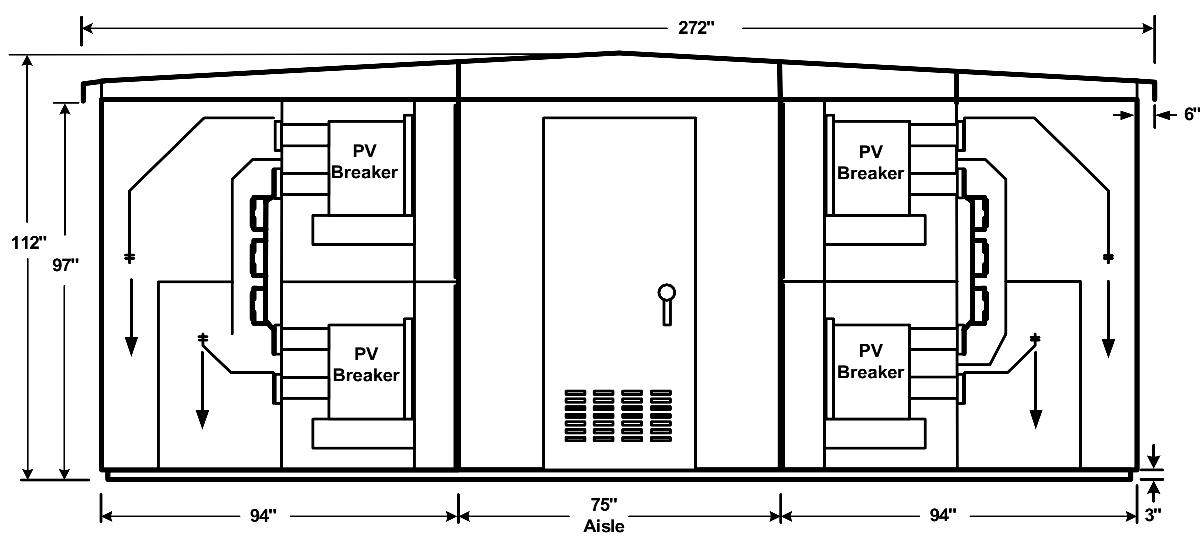
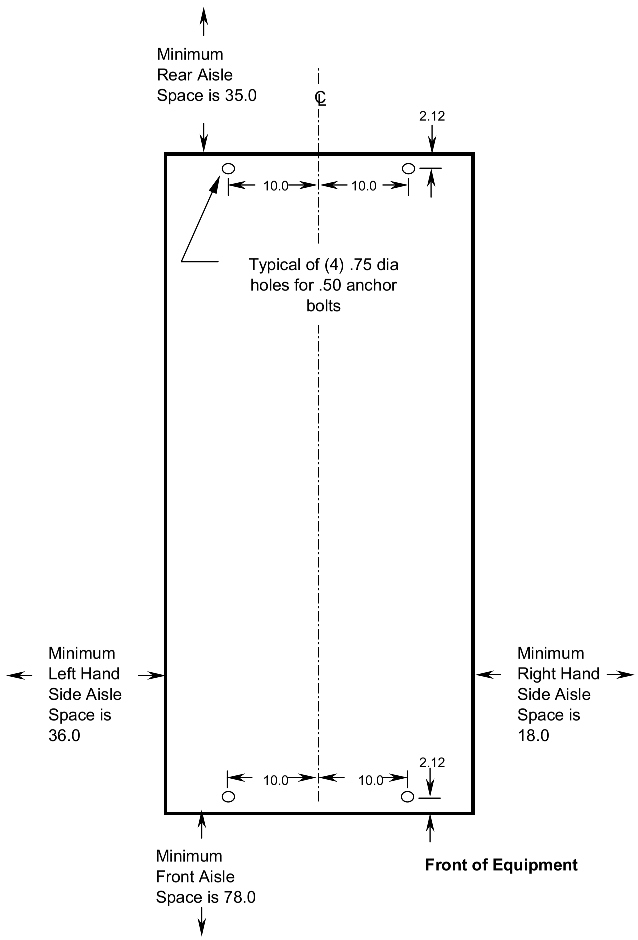
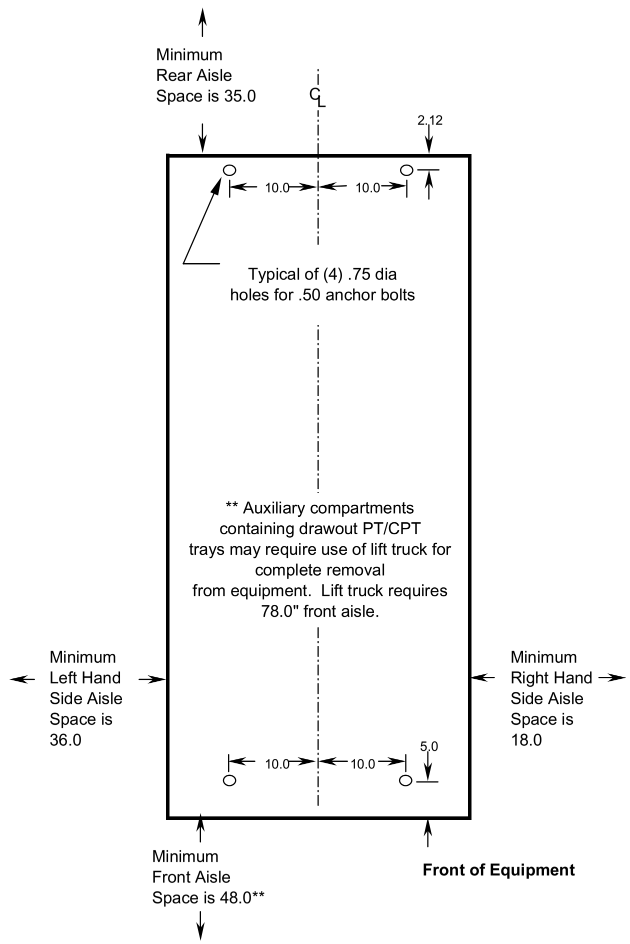


Figure 7-6



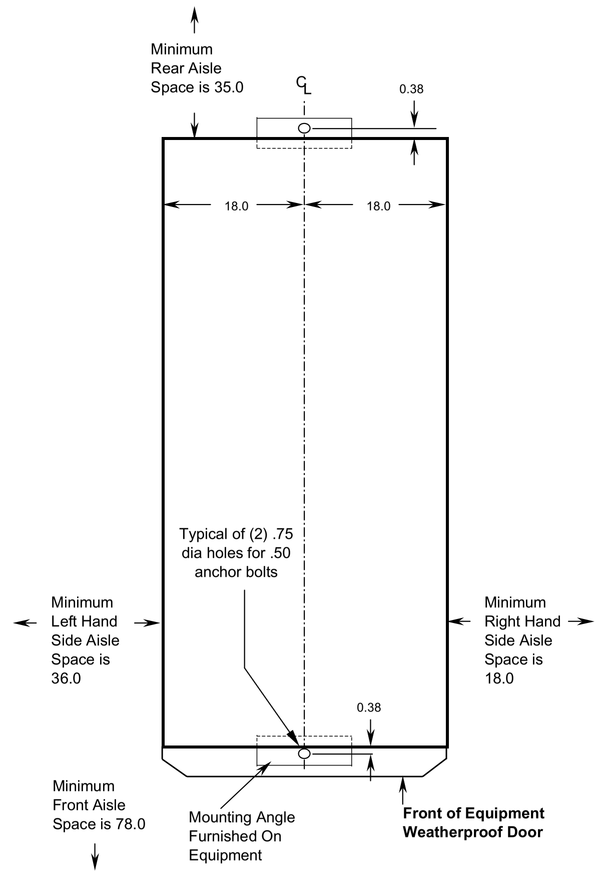
Standard Indoor Anchoring

Figure 7-7



Roll-in Breaker Indoor Anchoring

Figure 7-8



Standard Outdoor Anchoring

Anchoring Details

Figure 7-9 Typical Anchoring Methods

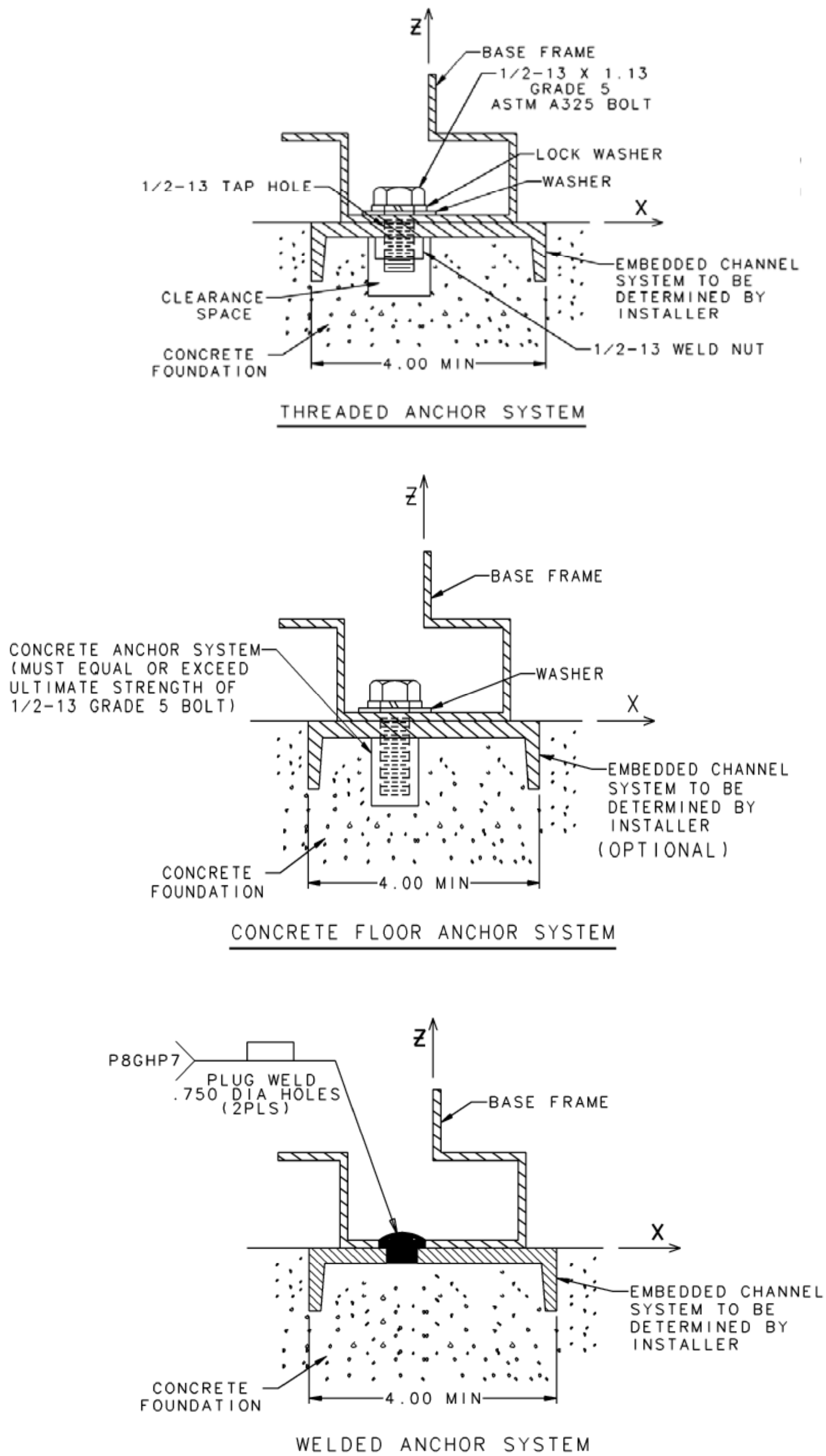


Figure 7-10 Typical Outdoor Anchoring Method—Flat Pad

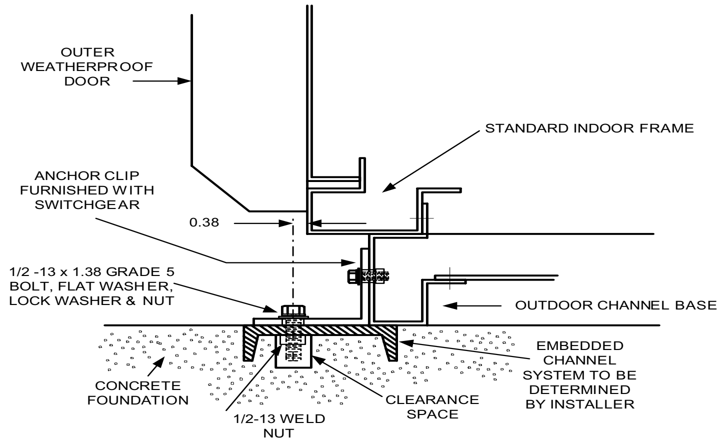


Figure 7-11 Alternate Outdoor Anchoring Method—Flat Pad

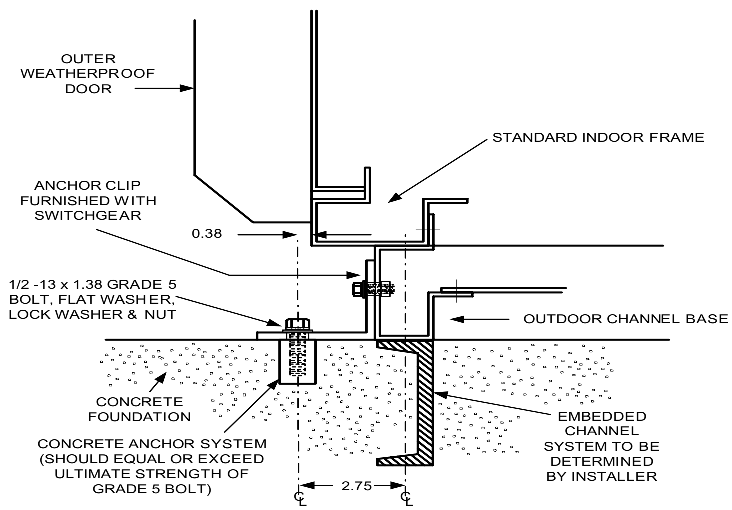


Figure 7-12 Alternate Outdoor Anchoring Method—Housekeeping Pad

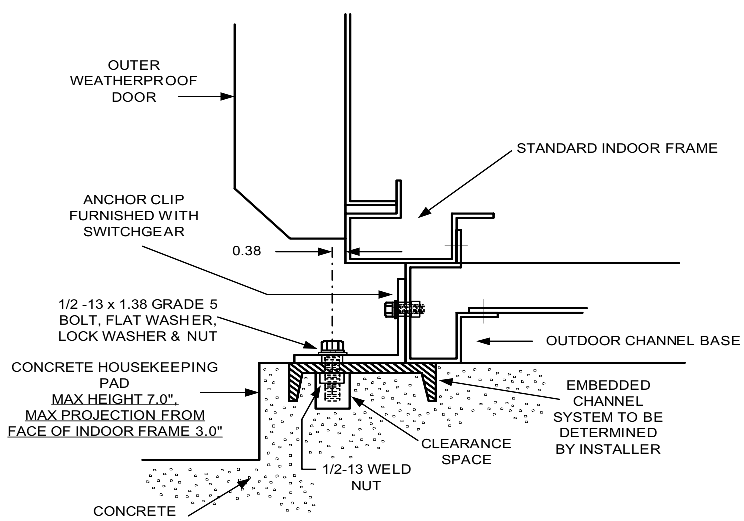


Figure 7-13

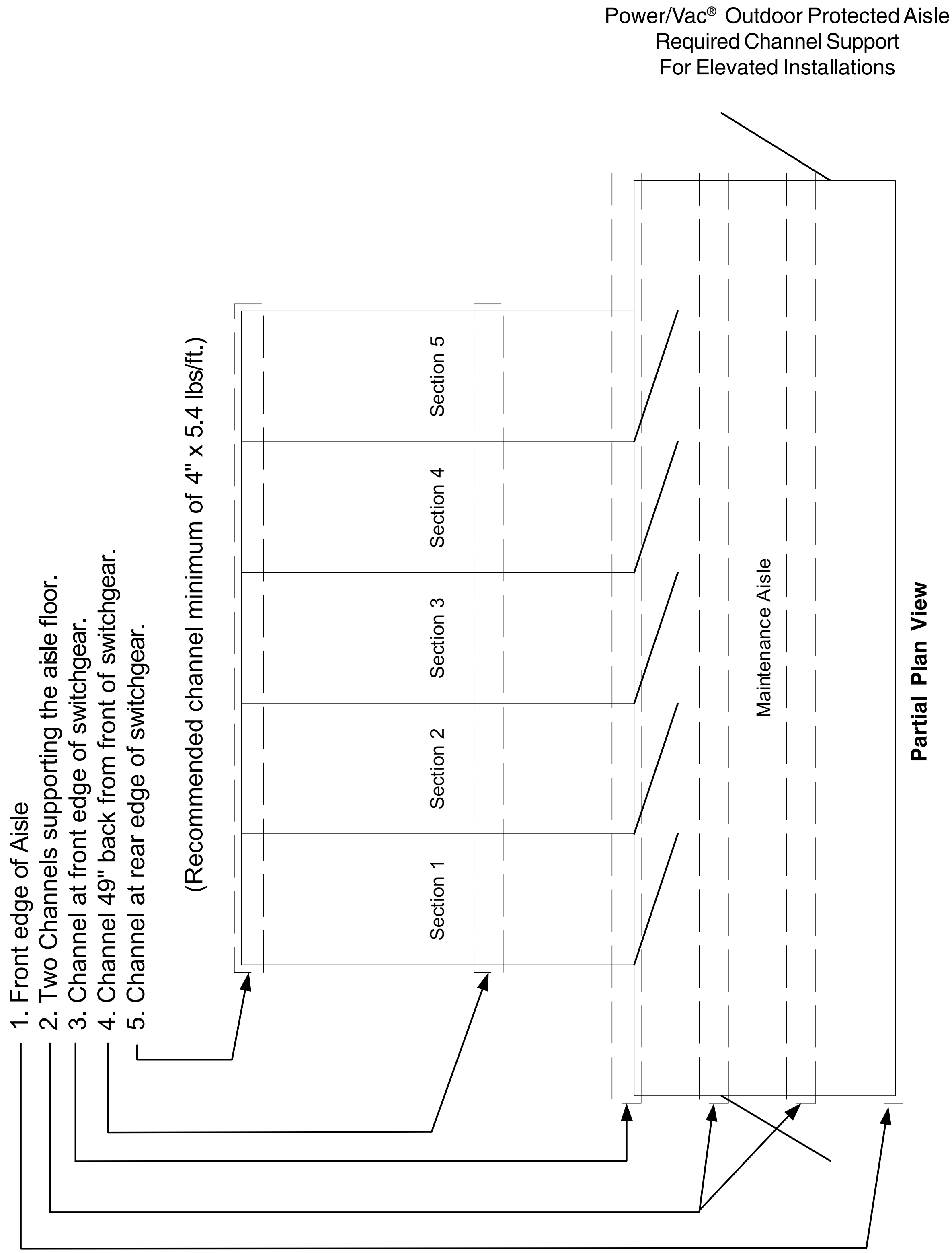
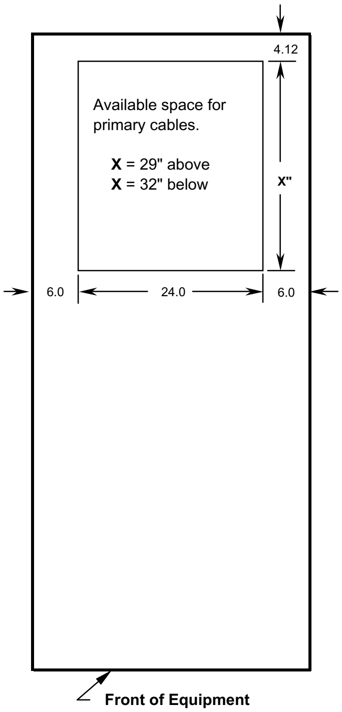
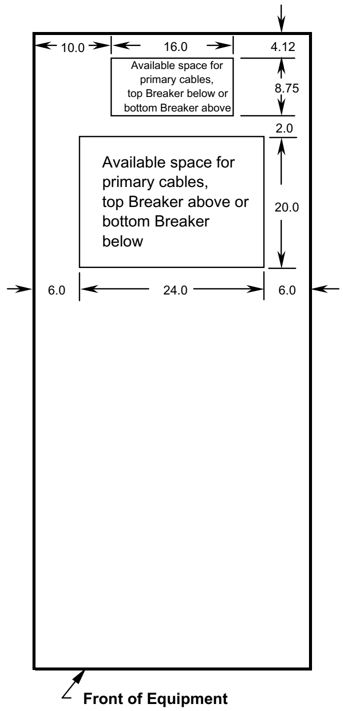

Power/Vac® Outdoor Protected Aisle
Required Channel Support
For Elevated Installations
1. Front edge of Aisle
2. Two Channels supporting the aisle floor.
3. Channel at front edge of switchgear.
4. Channel 49" back from front of switchgear.
5. Channel at rear edge of switchgear.
(Recommended channel minimum of 4" x 5.4 lbs/ft.)
Section 1
Section 2
Section 3
Section 4
Section 5
Maintenance Aisle
Partial Plan View

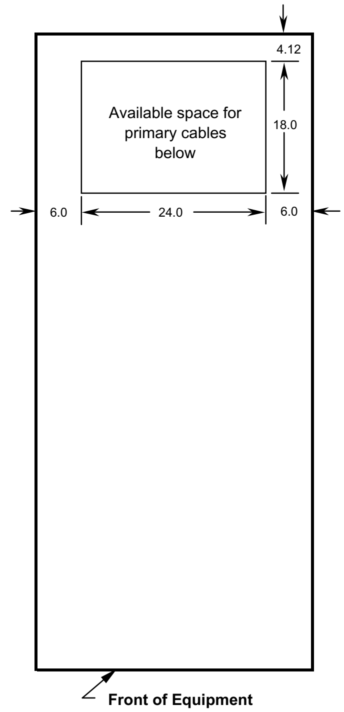
Figure 7-14 Primary Cable Entrance Floor Plan Details



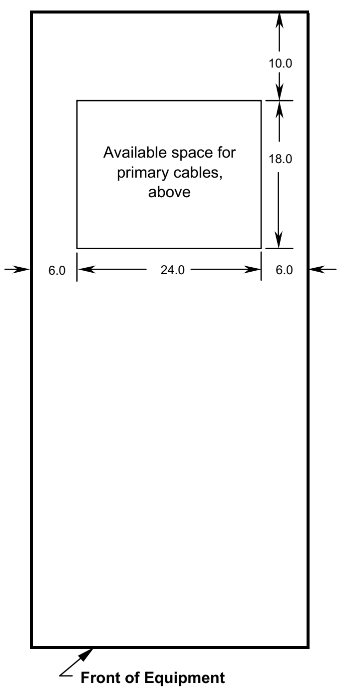
Standard 1-High Cable Space
1200A or 2000A Breakers
Above or Below



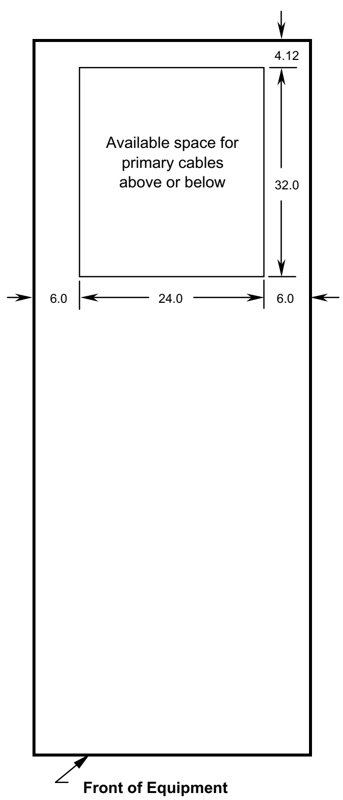
Standard 2-High Cable Space
1200A or 2000A Breakers
Above or Below



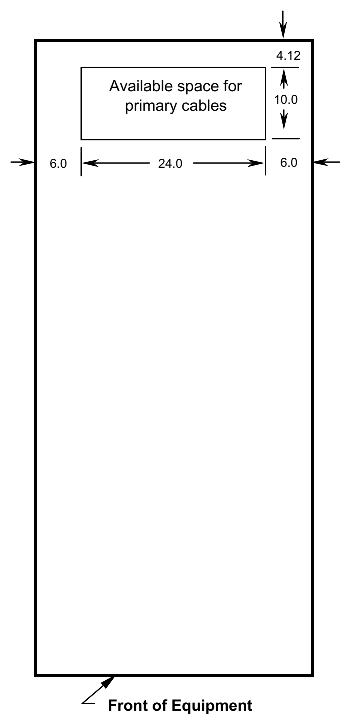
Standard 1- High Cable Space
3000A Breaker
Cables Below



Standard 1- High Cable Space
3000A Breaker
Cables Above

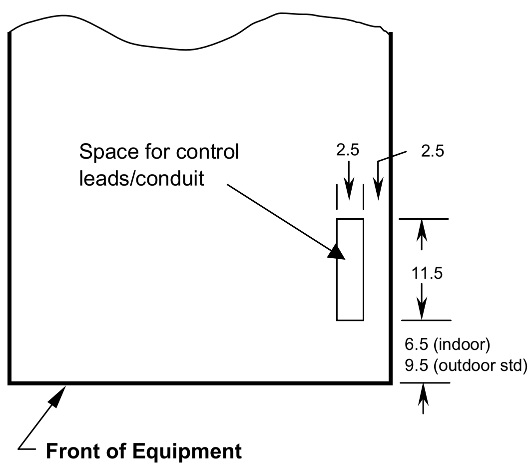


Standard 1- High Cable Space
3500/4000A Breakers, 106" depth,
Cables Above or Below



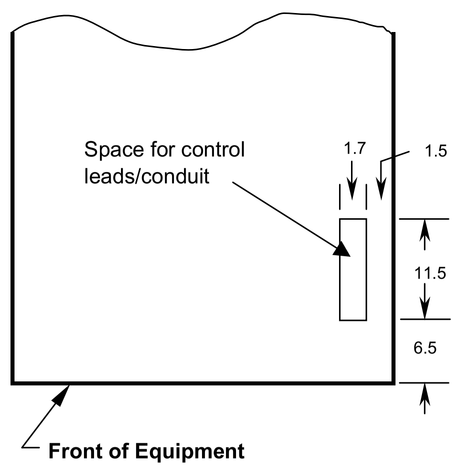
Standard 1- High Cable Space
1200A or 2000A Breaker,
Cables Passing Behind Rear Auxiliary Tie Bus

Figure 7-15



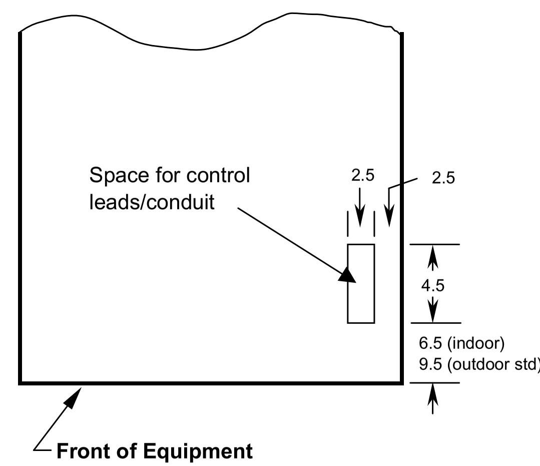
Recommended Location For Secondary Control Wire Entrance

Standard Breaker Compartment - Entry Above or Below
Roll-in Breaker Compartment - Entry Above



Recommended Location For Secondary Control Wire Entrance

Roll-in Breaker Compartment - Entry Below

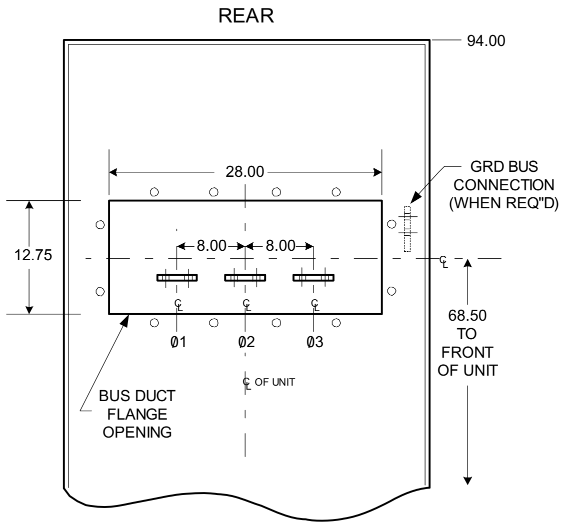


Recommended Location For Secondary Control Wire Entrance Into PT/CPT Rollout Compt

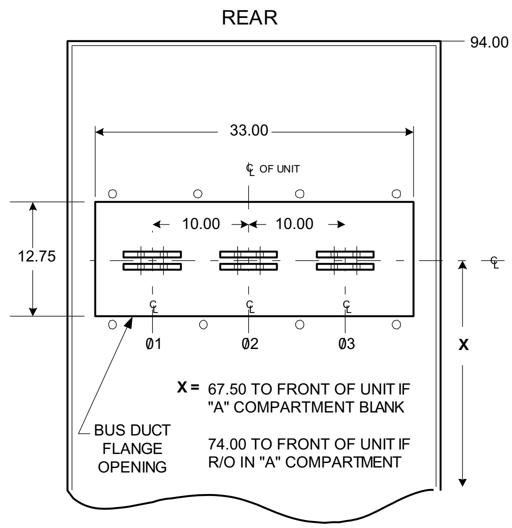
NOTES: Maximum conduit projection above pad, 1.0".
9.5" dimension for Outdoor Standard is from face of weatherproof outer door.

Secondary Conduit Entrance Floor Plan Details All Dimensions In Inches

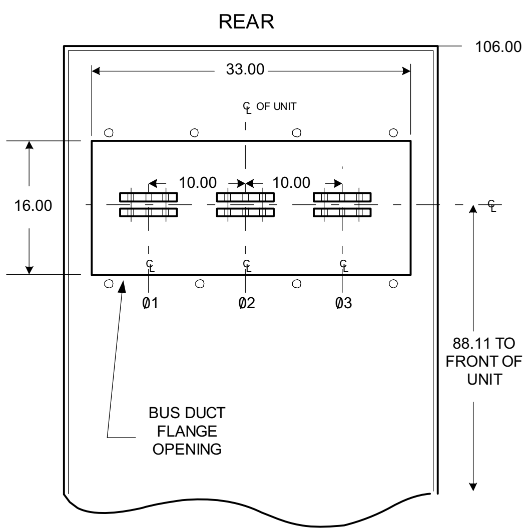
Figure 7-16 Standard Power/Vac® Indoor Non-Seg Bus Duct Interface



PARTIAL TOP VIEW
1200A & 2000A - ABOVE



PARTIAL TOP VIEW
3000A - ABOVE

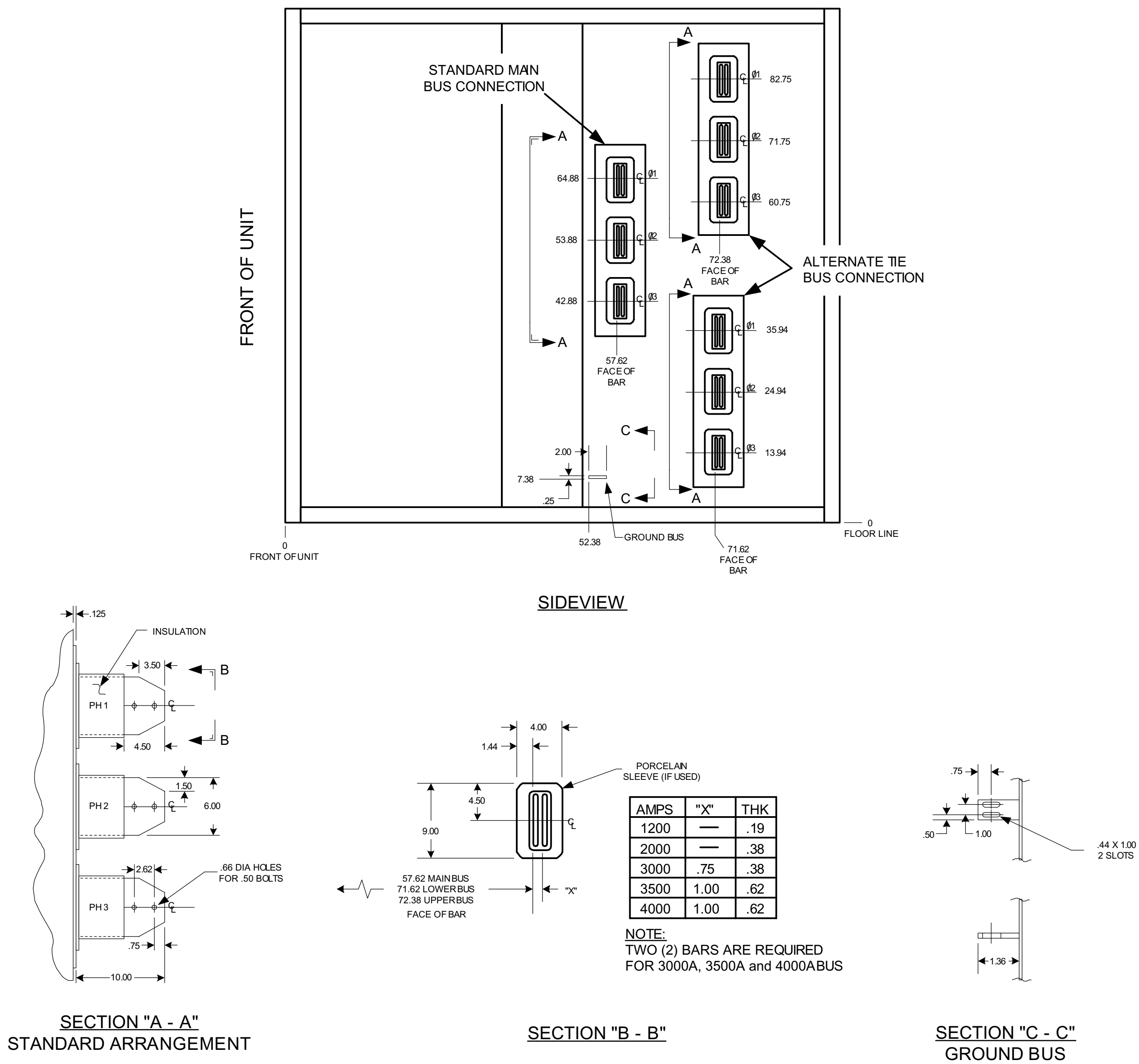


PARTIAL TOP VIEW
3500A & 4000A - ABOVE

NOTES:

1. BOOTS FOR SWGR TO BUS DUCT JOINT FURNISIHED BY BUS DUCT VENDOR, OR TAPE JOINTS PER INSTRUCTION BOOK GEK-39672.
2. FOR BOTTOM ENTRY OR OUTDOOR CONSTRUCTION, CONTACT YOUR POWELL REPRESENTATIVE
3. DIMENSIONS SHOWN ARE FOR ESTIAMTING PURPOSES ONLY.
4. GROUND OR NEUTRAL BUS CONNECTION FURNISHED WHEN REQUIRED, CAN BE LOCATED ON LEFT OR RIGHT SIDE.

Figure 7-17 Standard Indoor Power/Vac® Bus Extension For Connection to MV Motor Control and MV Load Interrupter Switches



AMPS	"X"	THK
1200	—	.19
2000	—	.38
3000	.75	.38
3500	1.00	.62
4000	1.00	.62

NOTE:
TWO (2) BARS ARE REQUIRED FOR 3000A, 3500A and 4000A BUS

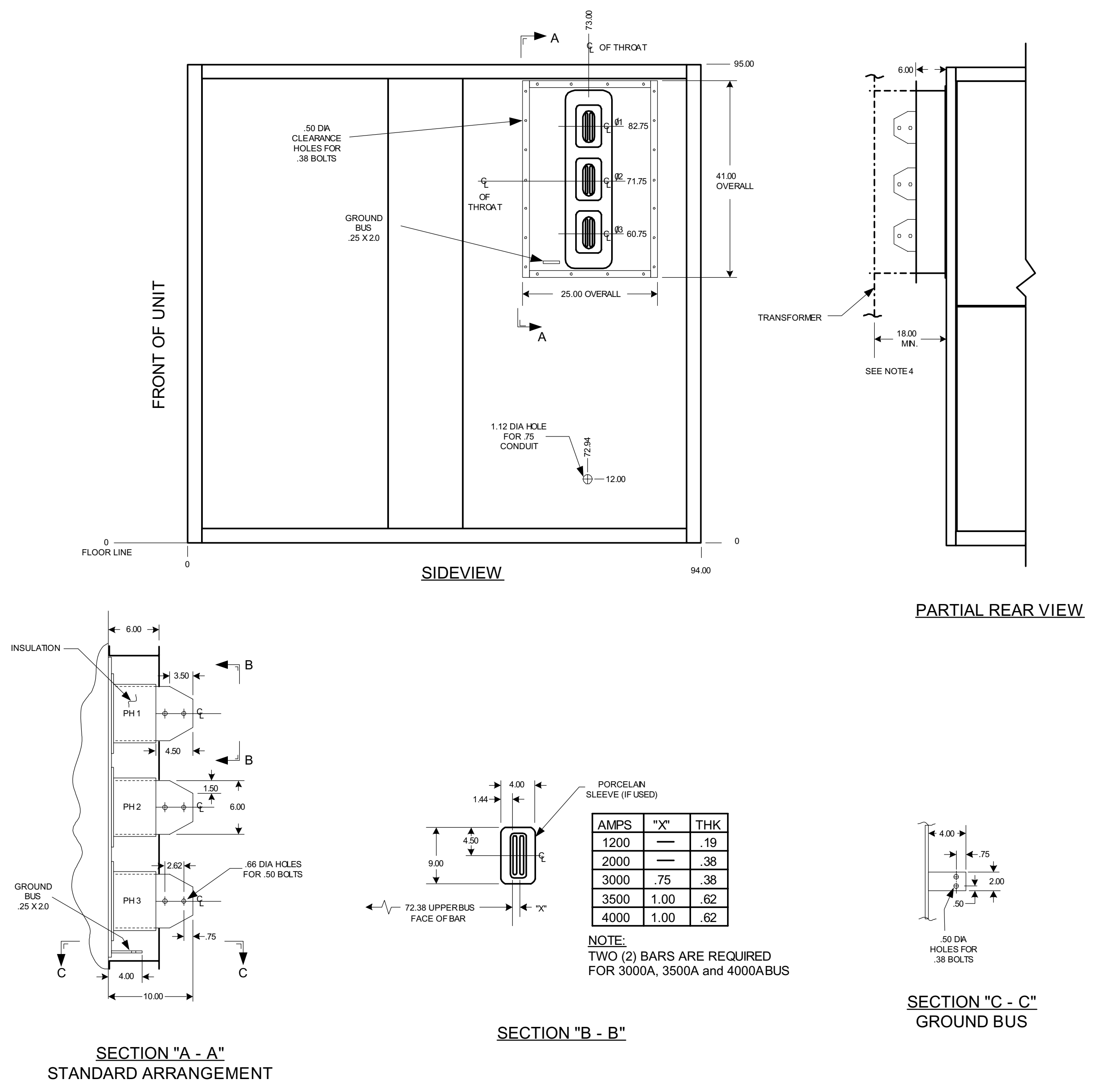
NOTES:

1. ALL DIMENSIONS SHOWN ARE THE SAME FOR STANDARD ARRANGEMEMNT (MATCHING EQP'T ON THE RIGHT) AND REVERSE ARRANGEMENT (MATCHING EQUIPMENT ON LEFT) IN RELATION TO FLOOR LINE AND FRONT OF UNIT.

2. TRANSITION SECTIONS (IF REQUIRED) ARE TO BE FURNISHED BY MATCHING EQUIPMENT MANUFACTURER.

Figure 7-18

STANDARD INDOOR Power/Vac®
TRANSFORMER THROAT CONNECTION

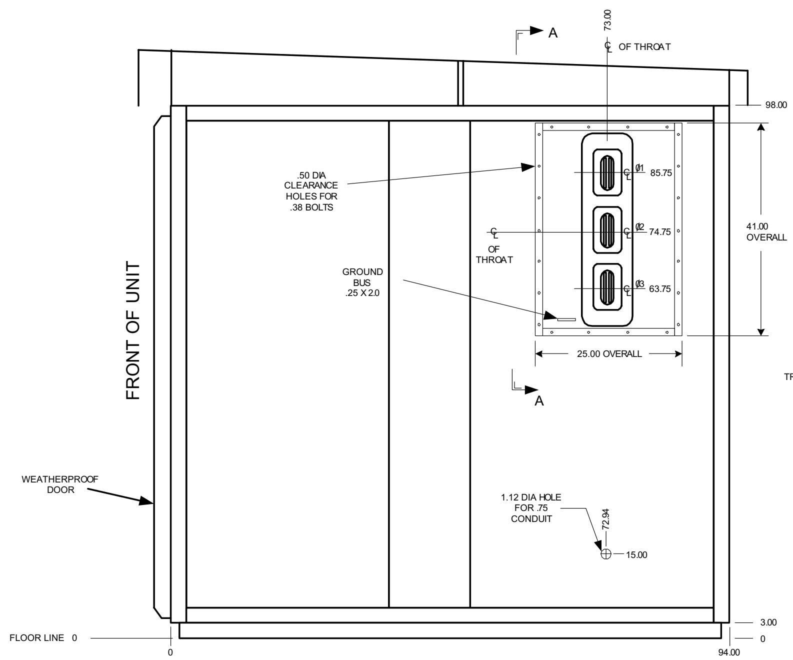


AMPS	"X"	THK
1200	—	.19
2000	—	.38
3000	.75	.38
3500	1.00	.62
4000	1.00	.62

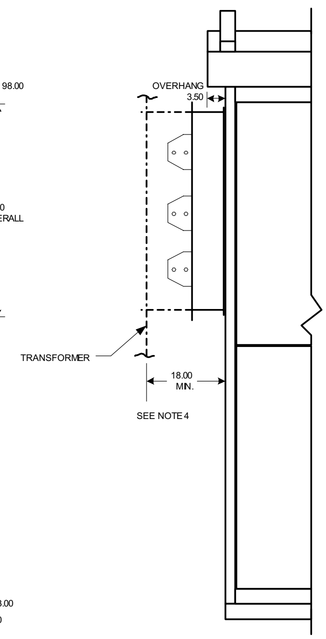
1. ALL HARDWARE FOR TRANSFORMER FLANGE TO POWER/VAC EQUIPMENT FLANGE & SWITCHGEAR FLEX-CONNECTIONS FURNISHED BY Powell.
2. ALL FLEX CONNECTORS AND INSULATION MATERIAL FOR ATTACHMENT TO POWER/VAC PHASE OR GROUND BUS IS TO BE FURNISHED BY TRANSFORMER SUPPLIER.
3. THE TRANSFORMER MANUFACTURER TO PROVIDE FLAN TO MATCHING POWER/VAC THROAT WHICH ALLOWS 18.0" MINIMUM WORK SPACE BETWEEN EQUIPMENT.
4. ALIGNMENT OF TRANSFORMER TO SWITCHGEAR, (CENTE LINE, FRONT OR REAR ALIGNMENT) TO BE PER TRANSFORM MANUFACTURER'S STANDARD UNLESS SPECIFIED OTHERW BY PURCHASE ORDER.
5. ALL DIMENSIONS SHOWN ARE THE SAME FOR STANDARD ARRANGEMEMNT (MATCHING EQP'T ON THE RIGHT) AND REVERSE ARRANGEMENT (MATCHING EQUIPMENT ON LEFT) RELATION TO FLOOR LINE AND FRONT OF UNIT.

Figure 7-19

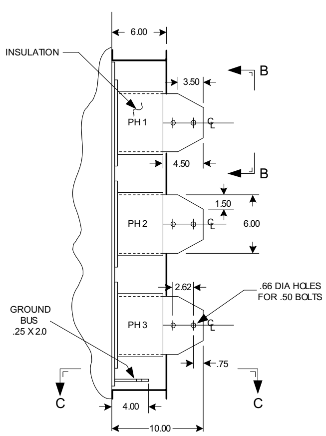
STANDARD OUTDOOR Power/Vac®
TRANSFORMER THROAT CONNECTION



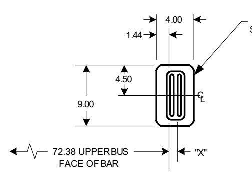
SIDE VIEW



PARTIAL REAR VIEW



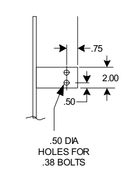
SECTION "A - A"
STANDARD ARRANGEMENT



AMPS	"X"	THK
1200	—	.19
2000	—	.38
3000	.75	.38
3500	1.00	.62
4000	1.00	.62

NOTE:
TWO (2) BARS ARE REQUIRED FOR 3000A, 3500A and 4000A BUS

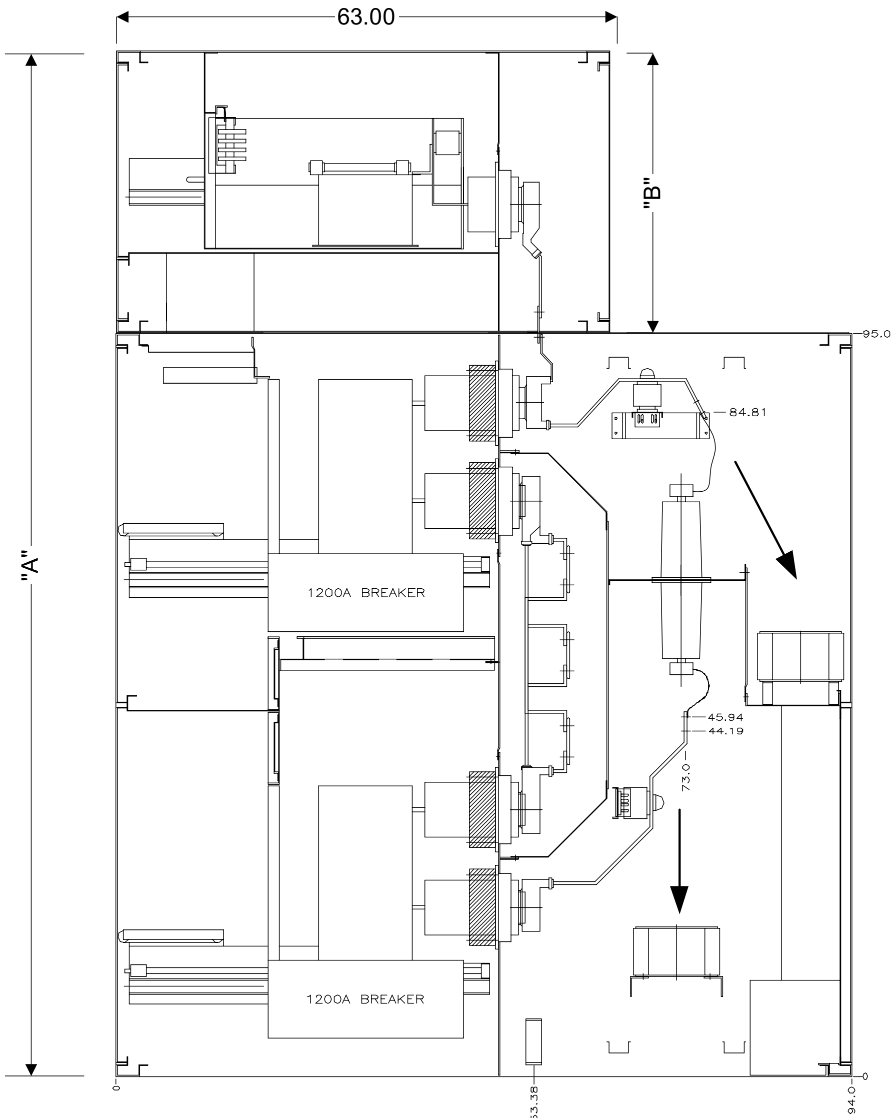
SECTION "B - B"



SECTION "C - C"
GROUND BUS

1. ALL HARDWARE FOR TRANSFORMER FLANGE TO POWER/VAC EQUIPMENT FLANGE & SWITCHGEAR FLEX-CONNECTIONS FURNISHED BY Powell.
2. ALL FLEX CONNECTORS, GASKETS AND INSULATION MATERIAL FOR ATTACHMENT TO POWER/VAC PHASE OR GROUND BUS IS TO BE FURNISHED BY TRANSFORMER SUPPLIER.
3. THE TRANSFORMER MANUFACTURER TO PROVIDE FLANGE TO MATCHING POWER/VAC THROAT WHICH ALLOWS 18.0" MINIMUM WORK SPACE BETWEEN EQUIPMENT.
4. ALIGNMENT OF TRANSFORMER TO SWITCHGEAR, (CENTER-LINE, FRONT OR REAR ALIGNMENT) TO BE PER TRANSFORMER MANUFACTURER'S STANDARD UNLESS SPECIFIED OTHERWISE BY PURCHASE ORDER.
5. ALL DIMENSIONS SHOWN ARE THE SAME FOR STANDARD ARRANGEMEMNT (MATCHING EQP'T ON THE RIGHT) AND REVERSE ARRANGEMENT (MATCHING EQUIPMENT ON LEFT) IN RELATION TO FLOOR LINE AND FRONT OF UNIT.

Figure 7-20
OPTIONAL SUPERSTRUCTURE



TYPE OF ROLLOUT	"A"	"B"
VT	131.00	36. 00
CPT	137.00	42 .00

Figure 7-20
2-high feedrer breaker with VT "Top Hat" connected to "A" compartment breaker cable connection.

NOTES:
ROLLOUT TRAY MAY BE SAME AS ANY OF OUR STANDARD CONFIGURATIONS. ROLLOUT MUST BE "LINE" CONNECTED TO "A' COMPARTMENT BREAKER ONLY

TOP HAT SUPERSTRUCTURE ONLY AVAILABLE ON INDOOR CONSTRUCTION.

SPECIAL LIFT TRUCK REQUIRED TO REMOVE TRAY FROM STRUCTURE ON TOP OF UNIT (0144D2911G005)

SUPERSTRUCTURE IS REMOVED FOR SHIPMENT

Figure 7-21

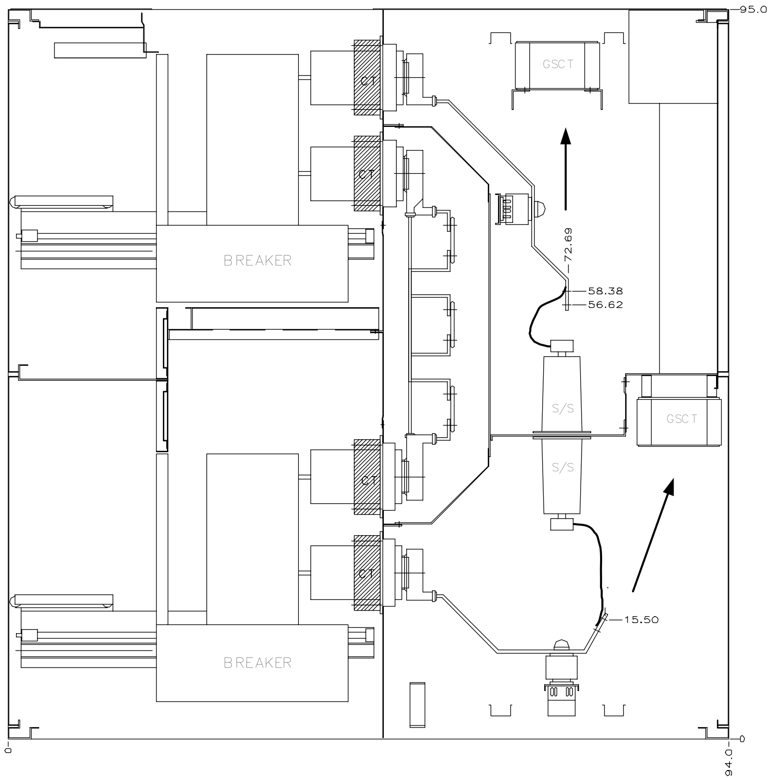


Figure 7-21
Standard 2-high breakers with cables exiting above.

Figure 7-22

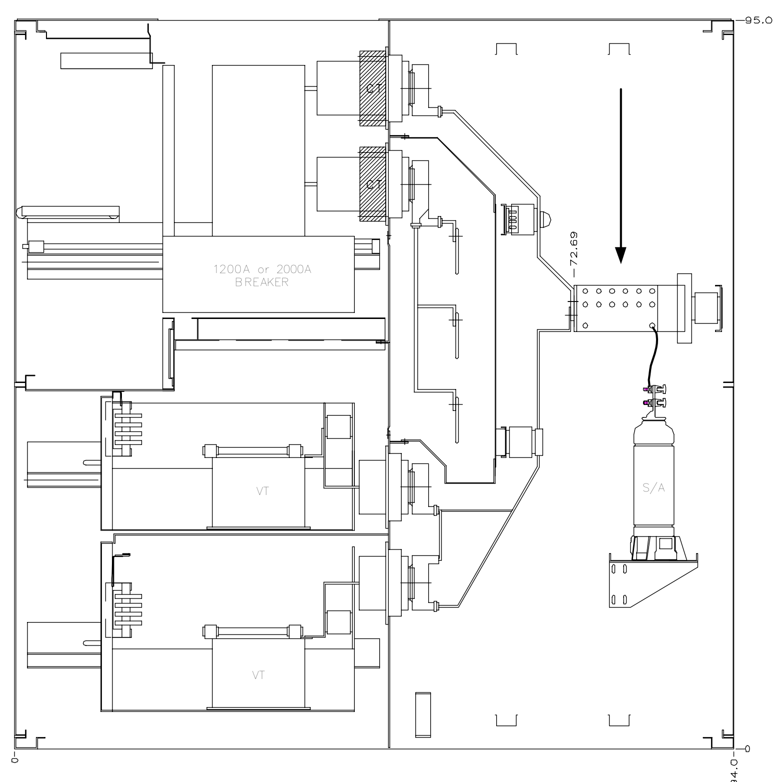


Figure 7-22
Main breaker with line connected VTs (2 sets), arrestors and provisions for 6 cables per phase above.

Figure 7-23

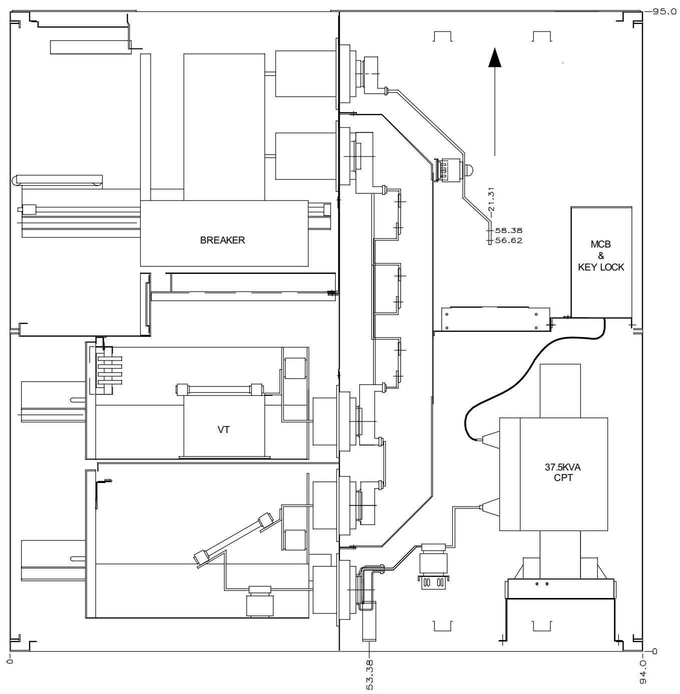


Figure 7-23
"A" compartment breaker with cables above. "B" compartment bus connected VTs and fused rollout. Large CPT mounted in rear compartment

Figure 7-24

Figure 7-24
3500A Main Breaker, with line connection bus to auxiliaries in adjacent section. Incoming cables from above, maximum 10 cables per phase with optional adaptors shown.

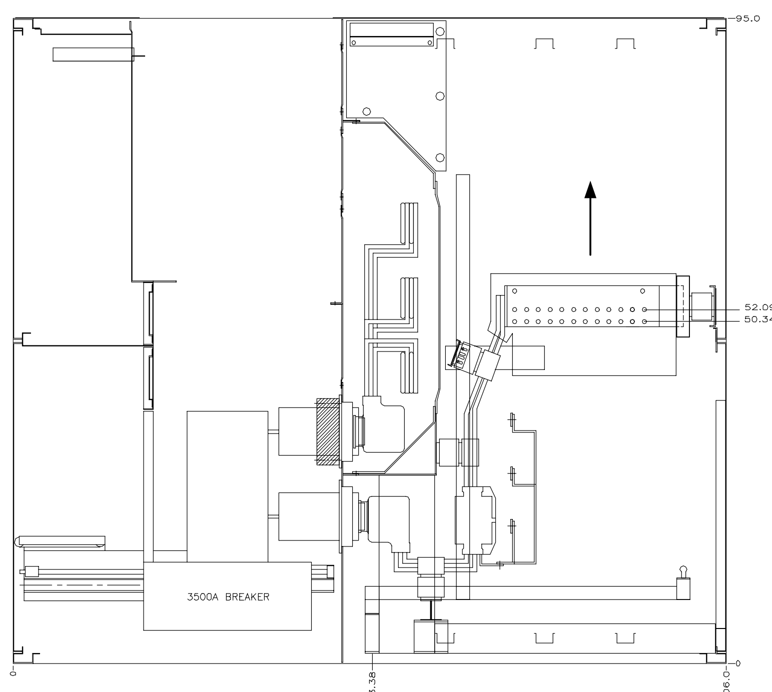


Figure 7-25

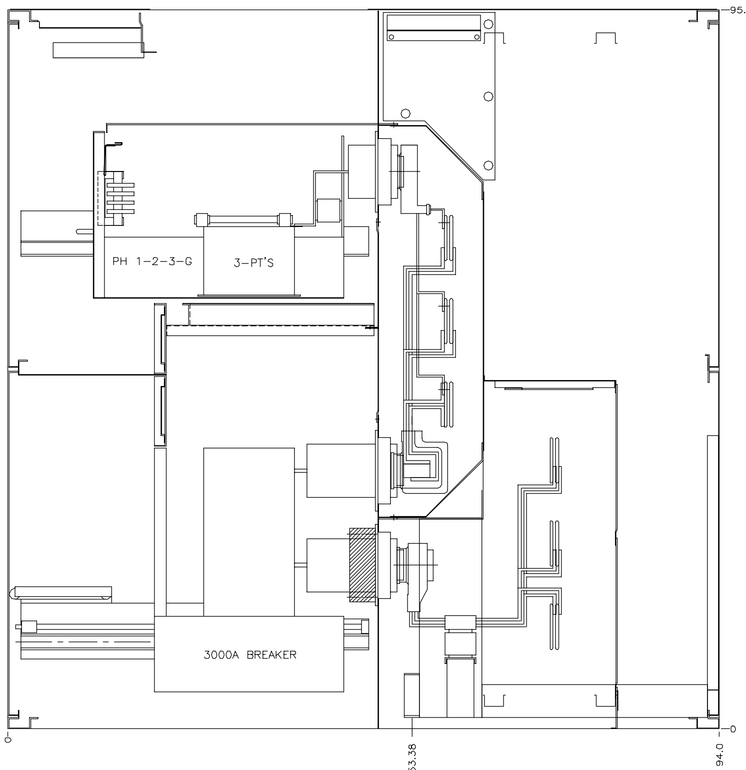


Figure 7-25
3000A Tie Breaker, with Bus connected VTs in upper compartment.

Figure 7-26

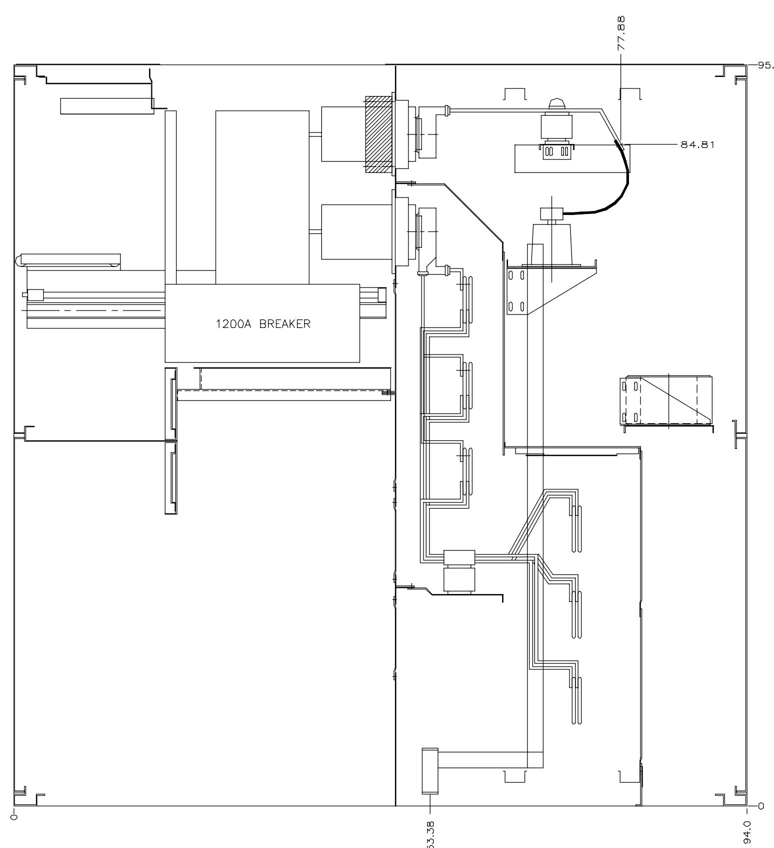


Figure 7-26
3000A Auxiliary Tie Bus with blank aux compartment. 1200A Feeder Breaker upper compartment, cables below past auxiliary tie bus.

Figure 7-27

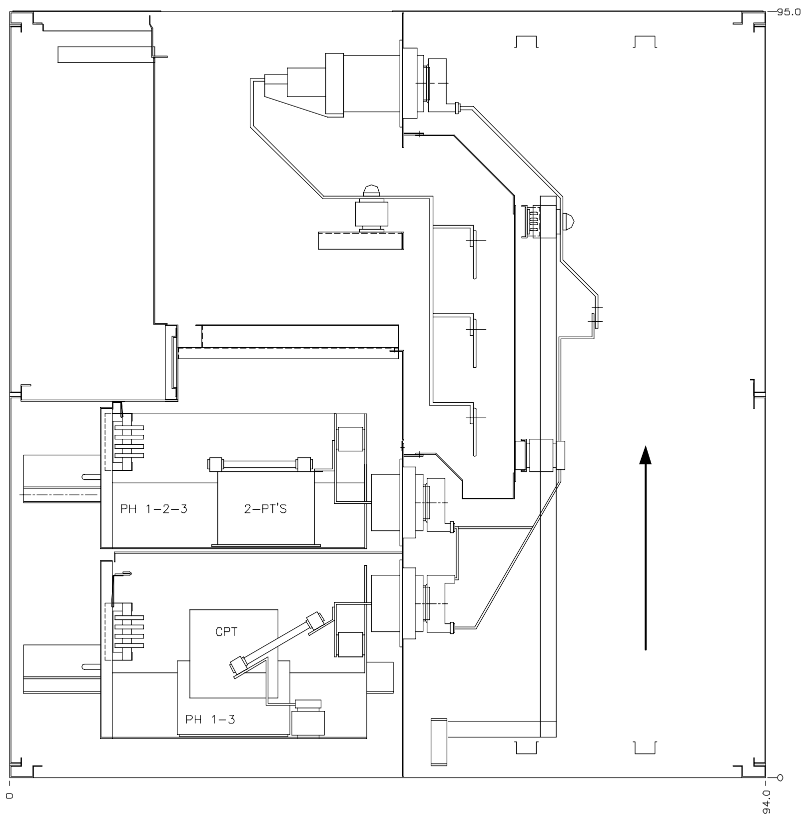


Figure 7-27
1200A Bus Entrance in upper compartment, with Line connected VTs and CPT in lower compartment.

Figure 7-28

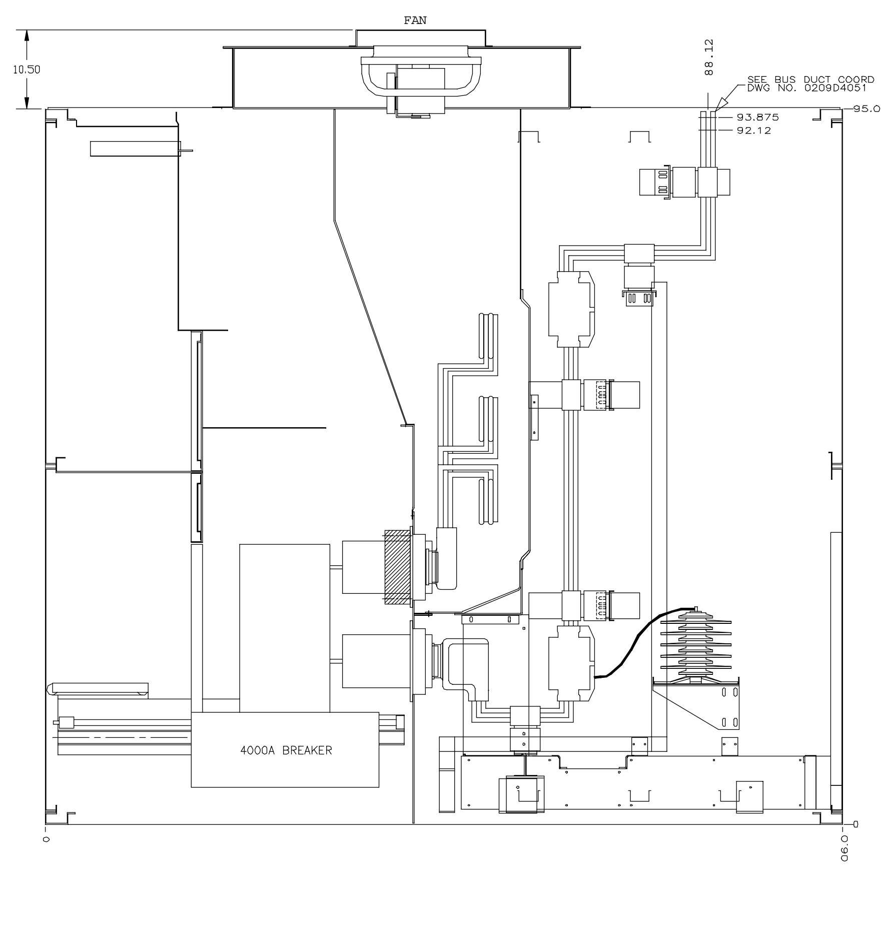
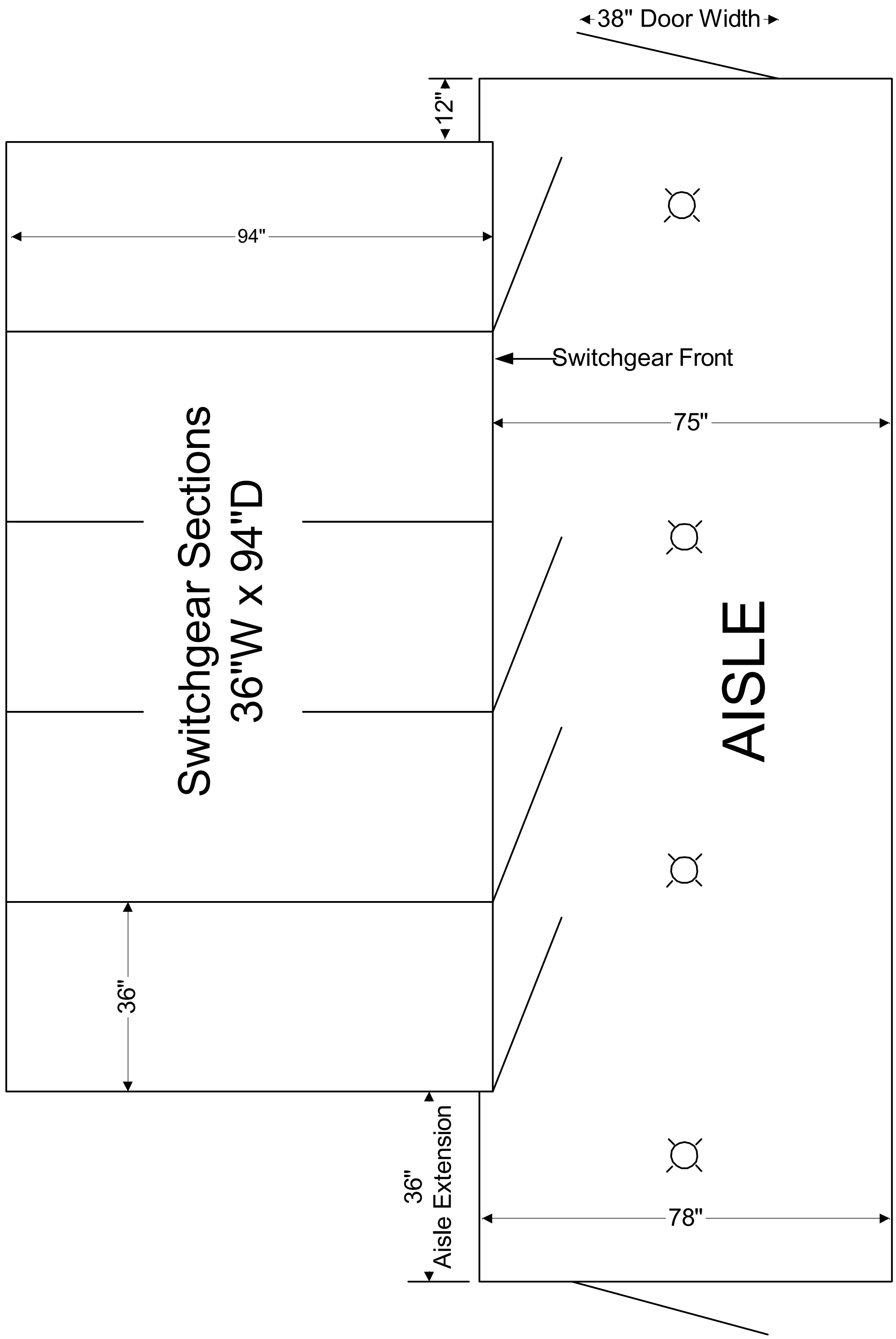


Figure 7-28
4000A Main Breaker, Bus Duct connection above.

Figure 7-29 Typical Power Control Aisle Plan View



Section 8

Ground And Test Devices and Dummy Elements

Ground And Test Devices

APPLICATION

A Ground and Test Device is an auxiliary removable device for use in Power/Vac metal-clad switchgear equipment during initial installation and at normal maintenance periods. The function of this device is to solidly ground the equipment manually as well as permit various types of tests. A convenient means of grounding a system is provided to safeguard personnel who may be working on the equipment. Exposed terminals can also be used for applying high-potential tests, measuring insulation resistance to ground, and phasing out cables.

DESCRIPTION

Ground and Test Devices can be provided in two types: A manually operated device and an electrically operated device. Different primary connection bar sets are required for each current rating of: 1200, 2000, and 3000/3500/4000 amperes. An optional Manual Ground and Test Device is available utilizing one unit for either current rating of 1200 amperes or 2000 amperes. In applying a Ground and Test Device to a metalclad unit, the current rating and the short-circuit rating of the equipment needs to be considered. Electrical insulation of the device has been designed to include voltage rating from 5 kV to 15 kV maximum system voltage. The Manual and Electrical Devices are designed to meet applicable ANSI/IEEE/NEMA standards.

Note that the use of the motor operated remote racking device to connecr or withdraw any ground or test device is strongly recommended. See Section 7, Accessories.

MANUAL GROUND & TEST DEVICE

The Manual Ground and Test Device is an auxiliary removable device for use in Power/Vac metal-clad switchgear equipment during initial installation and at normal maintenance periods. The Device does not have interrupters or a mechanism; therefore, it has no interrupting or closing capability. Note that for equipment rated for 63kA (1500MVA), only an Electrically Operated Ground & Test Device is available.

Figure 8-1 Standard Manual Ground & Test Device

The function of this device is to solidly ground the equipment manually as well as permit various types of tests. It provides a convenient means of grounding a system bus or cable connections to safeguard personnel who may be working on the equipment. Exposed Ground and Test Device terminals can also be used for applying a high-potential test, measuring insulation resistance to ground and phasing cables.

ELECTRICAL GROUND AND TEST DEVICE

The Power/Vac Electrical Ground and Test Device uses a sealed vacuum ground switch (vacuum interrupters) to make or break contact between the primary stud and the equipment ground. The standard Power/Vac spring-charged mechanism provides the vertical motion to move the lower contact of the ground switch to the open or closed position.

The Electrical Ground and Test Device has no interrupting rating, but is designed to close and latch against short circuit currents equivalent to the maximum momentary rating of the switchgear equipment.

It is composed of three major elements; the grounding switch, the selector switch and test receptacles, and the operating mechanism. The grounding switch, selector switch and test receptacles are composed of three similar pole assemblies mounted on top of the unit frame that contains the operating mechanism.

Figure 8-2 Direct Roll-in Electrical Ground & Test Device

The nameplate of the grounding device describes the control power requirements for the Electrical Ground and Test Device. Verify this is in agreement with the control voltage in the metal-clad switchgear via the nameplate on the circuit breaker it is replacing. On some units the control power may be supplied by an external power source via a cable connected to the front panel of the Grounding Device.

Various interlock arrangements are included within the device, where possible, to insure proper operation. Since the Electrical Device has been designed to serve many purposes and cover many ratings, it is not practical to interlock every element. Therefore, it is the responsibility of the user to properly set up the components for the particular requirements of the application.

A single Electrical Ground and Test Device with interchangeable primary contact fingers for 1200/2000 amperes, and 3000/3500/4000 amperes will cover all the metal-clad equipment ratings and can be installed in the upper or lower compartments.

With Electrical Ground and Test Devices for use in equipment rated 63kA (1500MVA), a separate device is required for upper or lower studs.

Proper installation and maintenance are necessary to insure continued satisfactory operation of the Electrical Ground and Test Device. A clear conception of the function of all parts, and the application of placing the device in test service or maintenance is helpful in understanding the safe operation during the periods of installation and maintenance.

SAFETY

The Ground and Test Device is often used during initial installation and for trouble shooting when the possibility of making an error is greatest. The Ground and Test Devices and the metalclad switchgear have interlocks to prevent unsafe operation. Unfortunately, it is not possible to eliminate every hazard with interlocks; therefore, is the responsibility of the person using this device to recognize the potential hazards while working on potentially energized equipment and take adequate precautions.

Interlocks are provided for the safety of the operator and correct operation of the device. If an interlock does not function as described in the Instruction Book, do not make any adjustment or force the device into position.

DUMMY ELEMENT

The Dummy Element is an auxiliary removable device for use with Power/Vac metal-clad switchgear equipment. It is designed to provide an economical means for making a connection between the bus and line or load terminations in a breaker cell.

The Dummy Element does not have interrupters nor does it have a mechanism; therefore, it has no interrupting or closing capability. The Dummy element and the related metal-clad switchgear must have mechanical and electrical interlocks to prevent unsafe operation. Main bus and load circuits must be de-energized prior to inserting or withdrawing a Dummy Element.

Safety is critical in the use of this device. Any potential hazards can be eliminated if the customer takes adequate safety precautions.

A separate device is required for each current rating of 1200, 2000, 3000, 3500/4000 amperes. In applying the Dummy Element to a switchgear unit, only the current rating needs to be considered. Electrical insulation for 5 kV to 15 kV and mechanical strength for 250 MVA to 1000 MVA have been designed into the Dummy Element for each current rating. The Dummy element is designed to meet applicable ANSI Standards.