Switchgear and Control Handbook

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Preface

This Handbook was written to provide practical engineering data for assisting engineers in selecting and specifying switchgear and control. It also provides installation and maintenance information for plant and maintenance engineers and for technicians and electricians who install and care for this equipment.

Through this Handbook, eminently qualified engineers give the reader the benefit of their many years of practical experience. The thirty-four contributors have become widely known through their published books, technical articles, engineering papers, and through committee activities in their engineering societies.

Sections 1, 2, and 3 cover fundamental information on switchgear, its classifications and arrangements, control standards, general purpose motor starters, and control circuit devices used with both switchgear and control.

System considerations affecting switchgear and control selection are given in Sections 4 through 7.

Sections 8 and 9 cover installation and service requirements, including earthquake considerations, that must be understood when specifying switchgear and control.

An important background on load and motor characteristics affecting control selection is given in Sections 10 and 11.

Sections 12 through 15 provide an excellent guide to the coordination of system protection and instrumentation.

Plant engineers and engineering consultants are given information in Sections 16 through 21 for planning and specifying distribution and utilization systems which may include switchgear, control, substation, bus duct, distribution panelboards and switchboards.

Process design and application engineers are provided a wide variety of control system information in Sections 22 through 29, enabling them to specify controls from standardized polyphase motor

control and control centers to the very complex automated control systems.

Section 30 provides plant engineers and management with comprehensive safety planning information.

Maintenance engineers and technicians are given valuable information on the care of power distribution equipment in Section 31.

SAFETY

Since switchgear and control govern and protect electrical systems and equipment operating on voltages which can be dangerous to personnel, safety is a prime consideration in their application and maintenance. A thorough understanding of safe procedures in installation and servicing of electrical equipment by those who design, specify, apply, and work with this equipment will greatly reduce accidents. Some facet of safe practice is covered in almost every section of this book. Section 30, which is concerned with plant safety in general, should be carefully studied by all who work with electrical equipment, their supervision and management.

STANDARDS

Because modern electric machines are precisely designed to exact ratings, their control and protection require careful adherence to up-to-date standards of the electrical industry.

The IEEE, ANSI, and NEMA standards, the National Electrical Codes, and Underwriters Laboratory Codes are continually improved and updated by the addition of new requirements or by changes in existing requirements. It is, therefore, recommended that those specifying, applying, and maintaining electrical equipment avail themselves of the latest applicable standards and codes and note the changes as they are made. This Handbook will help the reader to understand and apply these standards and codes when using or specifying switchgear and control.

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Robert W. Smeaton

Switchgear and Control Handbook

Contents

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1

Functions of Industrial Switchgear

A. EWY *

FOREWORD

Industrial switchgear consists of assemblies of switchgear devices such as circuit breakers, switches, protective equipment, metering, instrumentation, control and associated equipment for power generation, transmission, and distribution. This section outlines the basic application information and terminology involving this equipment.

PURPOSE AND TYPES

Switchgear provides protection for such equipment as generators, transformers, motors, and transmission lines. It also performs certain switching functions for the proper operation of generating and industrial plants.

Switchgear equipment comes in various forms and ratings depending on the particular functions it is to perform (Table 1). The components used in this equipment are

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TABLE 1. Switchgear Assemblies

Metal-enclosed power switchgear	Metal-enclosed bus	Switchboards	
		Power	Control
Metal-clad	Nonsegregated	Enclosed	Enclosed
Low-voltage power circuit breaker	Segregated phase	Dead front	Dual
Metal-enclosed interrupter	Isolated phase	Live front	Duplex
Station-type cubicle			Control desk
			Benchboard
			Dual benchboard
			Duplex benchboard
			Vertical panel

covered in other sections of this handbook. More details on switchgear selection are found in Sec. 17.

1. Metal-clad switchgear is metal-enclosed and has the following features:

1. The circuit breaker is removable and can be moved into the operating position, test position, and disconnect position.
2. The primary and secondary contacts are self-aligning and self-coupling.
3. The primary circuit such as the circuit breaker, buses, and potential transformers are enclosed in metal grounded compartments.
4. Insulating materials cover the primary bus conductors and connections (Table 2).

TABLE 2. Rated Voltages and Insulation Levels, Ac Switchgear Assemblies

Rated voltages, rms		Insulation levels, kV	
Rated nominal voltage	Rated max voltage	60-Hz withstand 1 min, rms *	Impulse withstand
Metal-enclosed Low-voltage Power-Circuit-Breaker Switchgear			
240 volts	250 volts	2.2	
480	500	2.2	
600	630	2.2	
Metal-clad Switchgear			
4.16 kV	4.76 kV	19	60
7.2	8.25	36	95
13.8	15.0	36	95
34.5	38.0	80	150
Interrupter Switchgear			
4.16 kV	4.76 kV	19	60
7.2	8.25	26	75
13.8	15.0	36	95
14.4	15.5	50	110
23.0	25.8	60	125
34.5	38.0	80	150
Station-Type Cubicle Switchgear			
14.4 kV	15.5 kV	50	110
34.5	38.0	80	150
69.0	72.5	160	350

* When switchgear is installed in the field and a 60-Hz, 1-min withstand test is applied, 75% of these values should be used.

5. When the circuit breaker is removed, automatic shutters close off and prevent exposure of the primary conductors.

6. Interlocks are provided for safe removal and insertion of the circuit breaker into the structure.

7. The door or panel through which the circuit breaker enters the structure may be used to mount instruments and panels. The instruments, relays, and their wiring are isolated from high voltage by grounded metal barriers.

Some typical circuits and arrangements of metal-clad switchgear are given in Figs. 1 through 11. Device numbers used in the figures are given in Table 3. Metal-clad-switchgear ratings are given in Table 4.

2. Metal-enclosed low-voltage switchgear is an assembly of equipment rated 600 V ac. It is completely enclosed on all sides and top with sheet metal (Table 5). The assembly contains primary power circuit breakers, switching or interrupting devices,

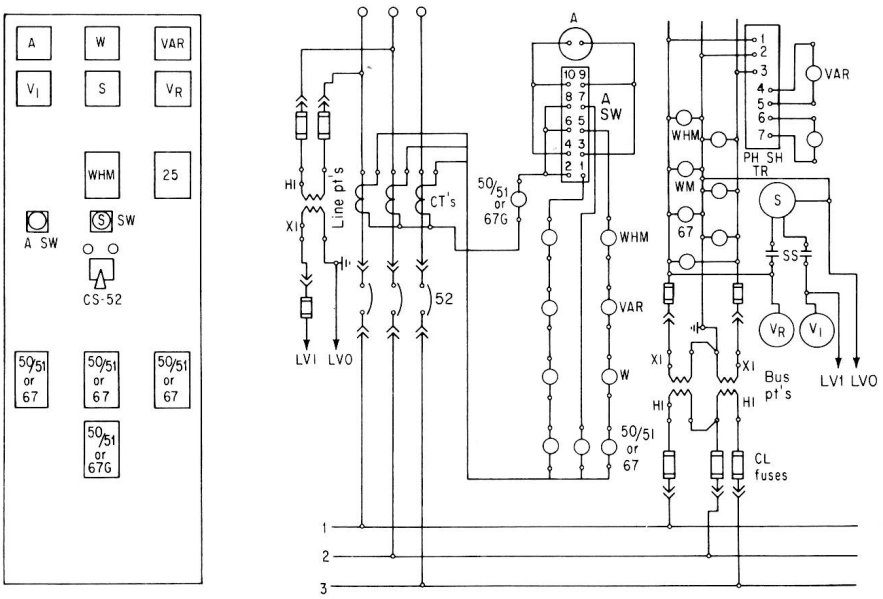

Fig. 1 Incoming-line panel and typical diagram.

with buses and connections. It may contain control, measuring, or protective devices (Fig. 12).

Metal-enclosed low-voltage switchgear includes the following equipment and features:

1. Low-voltage power circuit breakers that are mounted stationary or removable and contained in individual grounded metal compartments.
2. Bus bars and connections.
3. Instrument and control transformers.
4. Instruments, meters, and protective relays.
5. Control wiring and accessory devices.
6. Circuit breakers may be controlled at the switchgear or from a remote point.
7. When the circuit breakers are removable, interlocks are provided so circuit breakers may be removed or inserted safely.

3. Metal-enclosed interrupter switchgear is metal-enclosed power switchgear which may include the following equipment:

1. Interrupter switches
2. Power fuses
3. Bare buses and connections
4. Instrument transformers
5. Control wiring and accessory devices

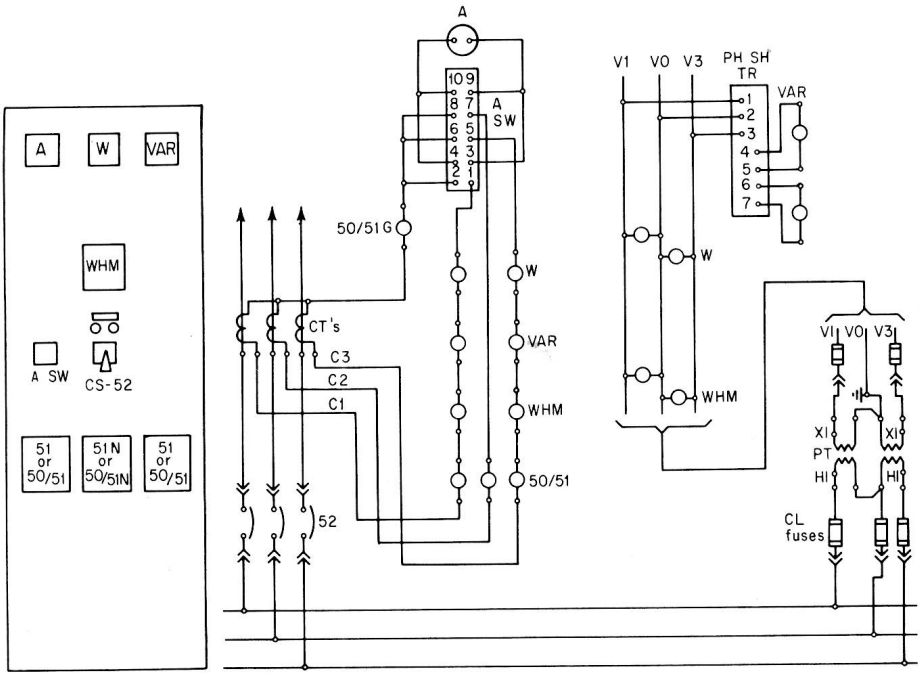

Fig. 2 Feeder panel and typical diagram.

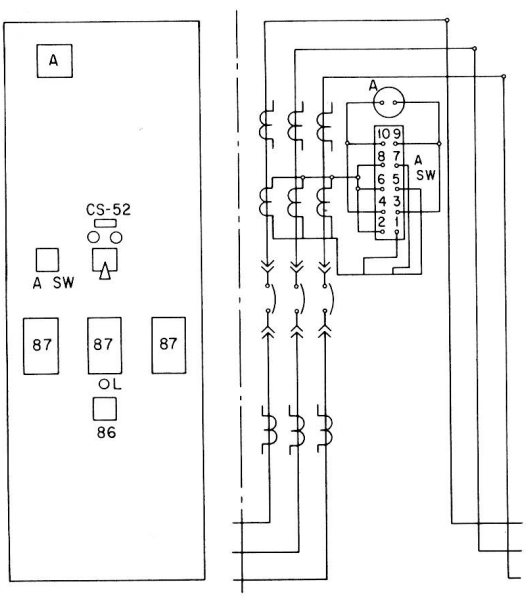

Fig. 3 Bus-tie panel and typical diagram.