MIL-HDBK-1004/3
NOTICE 1
30 December 1991

MILITARY HANDBOOK
SWITCHGEAR AND RELAYING

TO ALL HOLDERS OF MIL-HDBK-1004/3

1. THE FOLLOWING PAGES OF MIL-HDBK-1004/3 HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
v	30 December 1991	v	Reprinted w/o Change
vi	30 December 1991	vi	13 October 1987
vii	30 December 1991	vii	13 October 1987
viii	30 December 1991	viii	13 October 1987
ix	30 December 1991	ix	13 October 1987
x	30 December 1991	x	13 October 1987
xi	30 December 1991	xi	13 October 1987
xii	30 December 1991	xii	13 October 1987
9	30 December 1991	9	13 October 1987
10	30 December 1991	10	13 October 1987
11	30 December 1991	11	13 October 1987
12	30 December 1991	12	13 October 1987
13	30 December 1991	13	13 October 1987
14	30 December 1991	14	13 October 1987
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2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-HDBK-1004/3 will verify that all changes indicated above have been made. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the Military Handbook is completely revised or cancelled.

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FOREWORD

This military handbook has been developed from an extensive evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies and the private sector. This handbook was prepared using, to the maximum extent feasible, national professional society, association, and institute standards. Deviations from this criteria, in the planning, engineering, design and construction of naval shore facilities, cannot be made without prior approval of NAVFACENGCOM Code 04.

Design cannot remain static any more than the functions it serves or the technologies it uses. Accordingly, recommendations for improvement are encouraged and should be furnished to Commanding Officer, Naval Facilities Engineering Command, Chesapeake Division, Code 406, Washington Navy Yard, Washington, DC 20374; telephone (202) 433-3314.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

ELECTRICAL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	PA
MIL-HDBK-1004/1	Preliminary Design Considerations	CHESDIV
MIL-HDBK-1004/2	Power Distribution Systems	PACDIV
MIL-HDBK-1004/3	Switchgear and Relaying	CHESDIV
MIL-HDBK-1004/4	Electrical Utilization Systems	CHESDIV
DM-4.05	400-Hz Medium-Voltage Conversion and Low-Voltage Utilization Systems	SOUTHDIV
MIL-HDBK-1004/6	Lightning Protection	CHESDIV
MIL-HDBK-1004/7	Wire Communication and Signal Systems	CHESDIV
DM-4.9	Energy Monitoring and Control Systems	ARMY
MIL-HDBK-1004/10	Cathodic Protection	NCEL

SWITCHGEAR AND RELAYING

CONTENTS

Page

APPENDICES

FIGURES

TABLES

2.4.1.3 Basic Impulse Insulation Level. Determine the basic impulse insulation level of system equipment as well as that of the protective equipment in use.

2.4.1.4 Types of System Grounding. System grounding includes the isolated, neutral, and effectively grounded types (refer to MIL-HDBK-1004/1, Preliminary Design Considerations, and IEEE 142, Recommended Practice for Grounding Industrial and Commercial Power Systems, for systems grounding criteria).

2.4.1.5 Station Shielding. Station shielding is determined by the number of ground wires, ground mat or counterpoise details, tower footing resistance, location of surge arresters, and associated protective equipment (refer to IEEE 80, Guide for Safety in Substation Grounding, and IEEE 81, Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System).

2.4.1.6 System Voltage. Some of the factors affecting the selection of protective devices include normal voltage, rated voltage for continuous operation, and maximum voltage that the system insulation must withstand.

2.4.1.7 Past Performance. Ascertain the performance elsewhere of this type of system against lightning and switching surges.

2.4.2 Traveling Waves. Determine the magnitudes and shapes of traveling waves that may occur on the system as a result of a surge impulse. The procedures are described in paras. 2.4.2.1 through 2.4.2.5 of this section.

2.4.2.1 Surge Impedance. Compute the values of surge impedance at strategic locations on the system.

2.4.2.2 Reflection and Refraction Constants. Calculate the reflection and refraction constants at the junctions of equipment having different surge impedance values.

2.4.2.3 Equipment Resistance. Determine the attenuation of the equipment resistance on a traveling wave.

2.4.2.4 Natural Frequency. Determine the natural frequency at which the traveling wave will propagate.

2.4.2.5 Lattice Network. With the aforementioned information, construct a lattice network and compute the values of voltage at the various surge impulse points on the system. An example of a lattice network is given in the Westinghouse, Electrical Transmission and distribution Reference Book.

2.4.3 Equipment Selection. Select equipment with respect to the advantages and limitations of the different types that may be used to protect the system from surges. The characteristics of the selected equipment must be related to protective level, tolerances, operating life, and effects on system relaying and fuses.

2.4.3.1 Arresters. Arresters are the preferred method of surge protection. (Refer to MIL-HDBK-1004/2, Power Distribution Systems, for characteristics and applications of arresters.)

2.4.3.2 Gaps. Characteristics of rod and sphere types of protective gaps are that they:

a) not be capable of interrupting power flow current,
b) are relatively large,
c) are affected by surrounding bodies and weather, and
d) have large tolerance in withstand-time curve.

2.4.4 Coordination. The insulation level of the protective equipment must be coordinated with the insulation level of the system equipment. Refer to IEEE 142 and perform the following:

a) Protective Voltage Level. Establish a protective voltage level to correlate with the system voltage level at which protective equipment (such as surge arresters) is expected to operate.

b) Level of Insulation of System. Determine the level of insulation of the system equipment.

c) Atmospheric Conditions. Check the effect of atmospheric conditions on the flashover characteristics of the equipment insulation.

d) Arrester Separation. Determine the effect of arrester separation from the equipment to be protected. This separation shall be kept to a minimum.

e) Volt-Time Withstand Characteristics. Compare volt-time withstand characteristics of the system equipment insulation with the volt-time withstand characteristics of the protective equipment.

f) Margin Between Levels. Determine the margin between the protective voltage levels and equipment withstand voltage.

Section 3: LOW-VOLTAGE SWITCHGEAR AND DISTRIBUTION EQUIPMENT

3.1 Circuit-interrupting Devices. Specify low-voltage equipment to meet atmospheric conditions or climatic requirements.

3.1.1 Circuit Breakers. Circuit breakers are preferred since they cannot single phase, do no require fuse replacement, and are more difficult to modify for carrying currents greater than originally intended. Circuit breakers rather than fusible switches shall be used for circuit protection, except for special applications, such as critical technical load panelboards (refer to MIL-HDBK-1004/1). In the selection of circuit breakers, refer to paras. 3.1.1.1 through 3.1.1.5.

3.1.1.1 Voltage Rating. Determine the maximum operating voltage at which the breaker will be used.

3.1.1.2 Frequency. Determine the breaker rating at the frequency to which it will be applied. Standard frequency is 60 Hz. When used for other frequencies, such as 50 or 400 Hz., the manufacturer shall be consulted for a derating factor. Most manufacturers do not derate when frequencies are at 50 Hz.

3.1.1.3 Continuous Current. Compute the maximum continuous current flow through the breaker for normal and contingency conditions. Also consider provisions for future load growth, where required.

3.1.1.4 Interrupting Duty. A complete fault analysis may be necessary to select the proper circuit breaker interrupting duty under normal and contingency conditions. Use criteria in IEEE 242, Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems, and IEEE 141. In cases where there is less than 25-percent motor load, fault current calculations by the simplified graphic method (refer to Appendix A) are sufficiently accurate. Determine if provisions for future system design will affect the interrupting duty of the circuit breakers. Cascading is not permitted, except as covered in Section 4 of this handbook. NAVFAC computer programs available for calculating fault currents include Computer-Assisted Power System Engineering (CAPSE) and VICTOR.

3.1.1.5 Breaker Selection. Of the breakers described in a) through e), specify breakers of the required rating with due consideration of initial cost, maintenance, and similar items (refer to MIL-HDBK-1004/2):

a) Molded-Case Circuit Breakers. Molded-case circuit breakers shall be used for normal duty only. This type of circuit breaker is generally equipped with noninterchangeable-thermal and adjustable-magnetic or solid-state trip elements. Interchangeable trip elements are available from circuit breakers of more than 225 A frame size. Current-limiting breakers are available in most sizes. Molded-case circuit breakers are suitable for mounting in panelboards and switchboards. Derate thermal tripping setting, depending on ambient temperature (refer to NEMA AB-1, Molded Case Circuit Breakers, and National Fire Protection Association (NFPA), NFPA-70, National Electrical Code).

b) Integrally Fused Molded-Case Circuit Breakers. Integrally fused. molded-case circuit breakers shall be used to protect small loads connected to systems with high available short-circuit currents. Various current-limiting fuses are available.

c) Power Circuit Breakers. Power circuit breakers shall be used in accordance with IEEE 242. For low-voltage AC power circuit breakers used in enclosures, refer to the application guide in IEEE C37.13, Low-Voltage AC Power Circuit Breakers Used in Enclosures.

d) Current-Limiting Circuit Breakers. Current-limiting circuit breakers are used in lieu of current-limiting fuses only where economically feasible. Current-limiting circuit breakers are defined in Underwriters Laboratories, Inc., (UL), UL 489, Molded-Case Circuit Breakers and Circuit Breaker Enclosures.

e) Insulated-Case Circuit Breakers. Insulated-case circuit breakers shall be used to the maximum extent feasible in lieu of more expensive open-type air circuit breakers. Insulated-case circuit breakers shall conform to NAVFACENGCOM Guide Specification (NFGS) NFGS-16335, Transformers, Substations and Switchgear, Exterior; NFGS-16462, Pad-Mounted Transformers (75 kVA to 500 kVA); NFGS-16465, Interior Substations; or NFGS-16475, Interior Switchgear and Switchboards, Low-Voltage, as applicable.

3.1.2 Switches. Generally, use switches only where necessary for isolation purposes. Switches for Heating, Ventilating, and Air-Conditioning (HVAC) systems must be installed in conformance with NFPA-70.

3.1.2.1 Enclosures. Select enclosures of electrical equipment according to NEMA-type designations to ensure safe and reliable operation for the applicable external conditions (refer to NEMA ISC6 Series, Enclosures for Industrial Controls and Systems).

3.1.2.2 Switch Duty. Switch equipment duty is defined by NEMA KS-1, Enclosed Switches. Use general-duty equipment for nonessential applications and where equipment is subject to infrequent operation. General duty equipment is intended for use on circuits of 240 V or less; therefore, heavy-duty equipment is required for higher voltages. Use heavy-duty equipment for industrial application where reliability and continuity of service are prime factors and where equipment is subject to frequent operation. It is intended for use on circuits of 600 V or less and where available fault current of more than 10,000 amperes are likely to be encountered.

3.1.2.3 Rating. To determine ratings, follow the basic procedure outlined for circuit breakers in para. 3.1.1. Motor disconnect switches shall have an ampere rating of at least 115 percent of the full-load current rating of the motor to meet the requirements of NFPA-70; however, 125-percent capacity is not considered excessive.

3.1.2.4 Fusible Switches. Fusible switches combine isolation with protection of a particular component of the circuit.

3.1.2.5 Selection. Specify a switch of the appropriate rating and enclosure (refer to NFPA-70 and NEMA KS-1) and select from the following:

a) Safety (disconnect) switches can be fused or nonfused units operable up to 600 volts and 1,200 amperes of maximum continuous current and are normally used for motor isolation or protection.

b) Other switches such as heavy-duty switches operable up to 600 volts and 1,200 amperes of continuous current and load-break pressure switches operable up to 600 volts and 5,000 amperes of continuous current shall only be used for application where circuit breakers are not appropriate.

3.1.2.6 Transfer Switches. Automatic transfer (and bypass/isolation) switches shall conform to NFGS-16262, Automatic Transfer (and Bypass/Isolation) Switches.

3.1.3 Fuses. Generally fuses will be used only when required to provide adequate interrupting duty for short-circuit conditions.

3.1.3.1 Rating. Determine the rating of fuses based on voltage, current-carrying capacity, and interrupting requirements. Take into consideration motor-starting and other forms of inrush current.

3.1.3.2 Coordination. Fuses shall be coordinated with all other circuit protective equipment that operates in series with them in the system. Use the time-current curves of devices.

3.1.3.3 Selection. Specify a set of fuses of the calculated rating; select fuses from Table 4. The 10,000-ampere interrupting capacity shall only be used for critical technical-load panelboards where circuit breakers are not permitted. Higher interrupting capacities are usually used in conjunction with circuit breakers.

3.1.4 Protection. Protection devices shall be selectively coordinated to provide maximum system reliability.

3.1.4.1 Service-Entrance Protection. Service-entrance protection shall consist of a nonautomatic load interrupter with a current limiter for services with high available short-circuit currents.

3.1.4.2 Network Protectors. Use network protectors to prevent damage in network transformers. Specify associated reverse-current relays which are sufficiently sensitive to trip the main breaker upon loss of transformer magnetizing current (refer to NEMA SG-3, Low-Voltage Power Circuit Breakers. and Section 4 of this handbook).

Table 4
Fuse Selection

Type	Maximum continuous current amperes	Interrupting capacity amperes
Single element.......	600	10,000
Dual element:		
Low interrupting capacity.........	600	10,000
High interrupting capacity.........	600	100,000
Current limiting....	600	200,000
Current limiting....	6,000	200,000

3.1.4.3 Low-Voltage Ground-Fault Protection. NFPA-70 requires ground-fault protection at the service disconnecting means for circuits rated 1,000 amperes or more and for circuits having a voltage-to-ground in excess of 150 volts. Where such protection is required, current transformers connected in residual or a zero sequence current transformer shall be applied as shown in Figure 1. The use of a single current transformer on the grounding electrode conductor is not acceptable because grounding of the service transformer provides a second point of ground-fault current which is not sensed when this system is used.

3.1.4.4 Surge Protection. Provide arresters and metal-oxide varistors as required by the equipment being protected (refer to MIL-HDBK-1004/2 and MIL-HDBK-419, Grounding, Bonding, and Shielding for Electronic Equipments and Facilities).

3.2 Grouped Devices. Switchboards, power distribution panelboards, and branch-circuit panelboards are included and shall be provided spare capacity for normal load growth.

3.2.1 Switchboards. Place switchboards as close as possible to the center of the load to be served. Select utility areas and avoid locations near heat-dissipating equipment.

3.2.1.1 Clearances. Follow the procedure outlined for indoor unit substations in MIL-HDBK-1004/2 and NFPA-70.

3.2.1.2 Spare Capacity. Provide 25-percent additional spare empty compartments for future circuit-interrupting devices, only where the nature of the project indicates the necessity, and 25-percent spare bus capacity.

3.2.2 Power Distribution Panelboards. In general, panelboards serving three-phase motors and power equipment shall be of the circuit breaker type.

3.2.2.1 Mounting. Use wall-mounted panelboards where possible; otherwise, adopt a freestanding type.

3.2.2.2 Location. Place the power and distribution panelboard as near as possible to the center of the load.

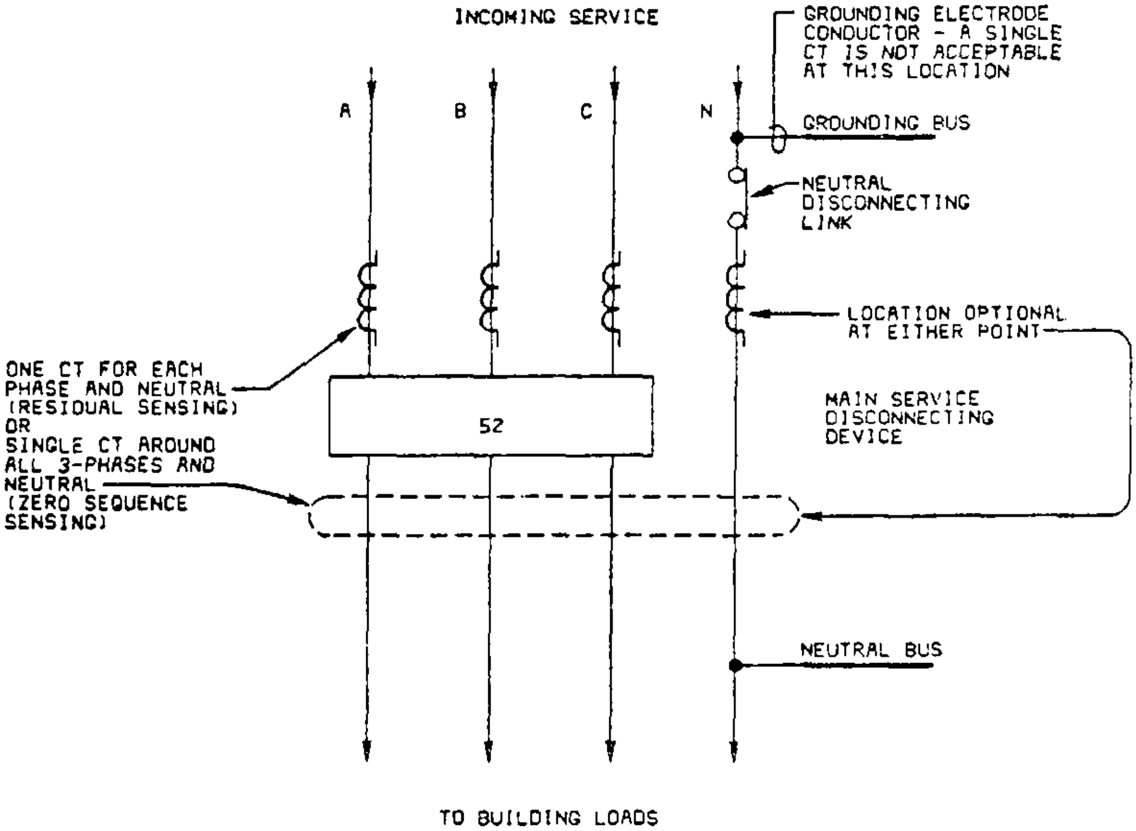

Figure 1
Low-Voltage Ground-Fault Protection

3.2.2.3 Limitations. In establishing design limitations, consider the maximum height of the upper breaker, the maximum number of breakers in one panelboard, the maximum capacity of the lugs, and the maximum capacity of the mains. Normally, panelboards with more than two lugs per phase shall not be used. Where more than 1,200-ampere mains are used, switchboard construction shall be provided.

3.2.2.4 Spare Capacity. A spare bus capacity of 25-percent shall be provided, 20-percent spare circuit breakers, and 5-percent spare empty spaces as a minimum.

3.2.3 Branch-Circuit Panelboards. Branch protective devices in panelboards shall be circuit breakers unless fuses are required because of available fault currents or limitations on critical load outage times. Consider the difficulty of stocking fuses at remote installations.

3.2.3.1 Location. Panelboards shall be located as near as possible to the center of the load. For panelboards serving one type of load, sacrifice ease of accessibility when large-scale economy of branch circuits is possible. However, do not provide an installation which would necessitate a reconnaissance mission to locate the panelboard.

3.2.3.2 Main Circuit Breaker. Main circuit breakers shall be used for isolation purposes and for short-circuit protection (refer to NFPA-70). Main circuit breakers must be UL listed as suitable for service-entrance use.

3.2.3.3 Limitations. Limitations shall be the same as those for power distribution panelboards.

3.2.3.4 Spare Capacity. The spare capacity shall be the same as that for power distribution panelboards.

3.3 Busways. Busways shall be used to carry large current loads through minimum physical space and for system flexibility (refer to NEMA BU-1, Busways, and UL 857, Electric Busways and Associated Fittings).

3.3.1 Rating. The ratings of busways shall be used on maximum current under normal and contingency conditions.

3.3.2 Duty. Determine maximum symmetrical short-circuit current available at the connecting point of the bus duct. Specify bracing to withstand mechanical stresses produced by such current.

3.3.3 Voltage Drop. Voltage drops shall not exceed the limits imposed by NFPA-70.

3.3.4 Selection

3.3.4.1 Feeder Busway. Feeder busways shall be used to supply heavy loads to panelboards, with minimum losses and voltage drops. Specify low-impedance busways.

3.3.4.2 High-Impedance Busway. High-impedance busways can be used to reduce short-circuit duty of switchboard equipment connected at the busway load end, but such use is not recommended because of energy losses; current-limiting fuses or circuit breakers with higher interrupting duties shall be used instead.

3.3.4.3 Plug-In Busway. Plug-in busways shall be used for multiple tapping and for system flexibility.

3.3.4.4 High-Frequency Busway. High-frequency busways shall be used where the system frequency is 180 Hz and above.

3.3.4.5 Trolley Duct. Trolley ducts shall be used for supply of overhead cranes, hoists, and moving loads in general and for industrial lighting.

3.4 System Corrective Equipment. System corrective equipment includes voltage regulators and capacitors. This equipment shall comply with the criteria in paras. 3.4.1 and 3.4.20.

3.4.1 Voltage Regulation. Voltage regulators shall be used to maintain a constant load voltage from the available source or a constant utilization voltage with a variable load on a weak source of supply (refer to ANSI C57 Series, Transformers). The regulator kVA can be calculated by multiplying the line current by the rated range of regulation in kilovolts or by multiplying the line current times the line kilovolts times the per unit regulation (percent regulation in decimal equivalent). When using single-phase regulators to serve three-phase loads, provide regulators connected in a grounded wye, ungrounded delta, or ungrounded open-delta configuration.

3.4.2 Power Factor. Capacitors shall be used to correct the low power factor. An overall load power factor of not less than 90 percent shall be achieved. When power factor correction capacitors have been installed and the calculated power factor exceeds 95 percent, switched capacitor banks shall be used to prevent overvoltages during off-peak hours. Capacitors on inductive loads shall be provided as near to the loads as is practical. Capacitors for large inductive loads shall be switches that are simultaneous with the load. Install capacitors close to the loads to reduce reactive current through feeders, improve voltage regulation, and reduce losses (refer to Standard Handbook for Electrical Engineers, Donald G. Fink and H. Wayne Beaty, subsection entitled Power Distribution and subsection entitled Application of Capacitors).

3.5 Current-Converting Equipment. If rectifiers are to be used, determine the rectifier duty and select from the types described in paras. 3.5.1 through 3.5.4.

3.5.1 Silicon-Controlled Rectifiers. Silicon-Controlled Rectifiers (SCRs) or thyristors shall be used where high efficiency and accurate voltage control are required. This type is suitable for practically all load ranges.

Section 5: ELECTRONIC POWER MONITORING SYSTEM AND SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) SYSTEM

5.1 Introduction. Power monitoring systems are used to monitor electrical distribution systems or portions of distribution systems. Power monitoring is done by installing individual meters such as ammeter, voltmeter, watt-hour meter, etc., on the desired electrical metering points or on the power equipment being monitored. State-of-the-art electronic power monitors have multiple metering and status monitoring functions which replaces the need of installing individual meters and monitors. Use power monitors instead of individual meters as standard power metering devices. The power monitors can be fully interfaced with a computer. When monitors are interfaced with a computer equipped with a power monitoring software historical, as well as instant information of the status of the power distribution system can be obtained at operator request.

A Supervisory Control and Data Acquisition (SCADA) system is a fully centralized system which is used for supervisory control of protective and switching devices, including generator operation, as well as providing power monitoring system functions.

The power monitoring system and the SCADA system described in this section relate to 15 kV medium and 600 V low voltage power systems. Both systems are microprocessor based.

5.2 Power Monitoring Systems. Power monitoring systems are used for metering and power device/system status monitoring purposes as described in paragraph 5.2.1.

5.2.1 Monitoring Functions. Generally, a power monitor is capable of monitoring a part or all of the following:

a) Phase currents
b) Line-to-line voltages
c) Line-to-neutral voltages
d) 3-phase real power
e) 3-phase reactive power
f) Average demand real power
h) Peak demand power
i) Predicted demand real power
j) Average demand currents
k) Peak demand current
l) Power accumulated
m) Reactive power accumulated
n) Power factor
o) Frequency
p) Temperature
q) Device operations and their trip status
r) Recording monitored data

5.2.2 Components of Power Monitoring Systems. Components of fully centralized monitoring systems include power circuit monitors, circuit monitor display, master station with system software, communication links, system network interface controller and line printer. A master station is a centralized display terminal (usually a personal computer terminal) capable of interfacing with all circuit monitors through network interface.

5.2.3 Power Monitoring System Types. Power Monitoring Systems are categorized as one of the following types:

a) Decentralized Power Monitoring System;
b) Group Centralized Power Monitoring System; or,
c) Master Centralized Power Monitoring System.

5.2.3.1 Decentralized Power Monitoring System. Use a decentralized power monitoring system to monitor a dedicated individual power device or a power line, one monitor for one device. It is comprised of a power monitor connected directly to a device to be monitored. It is the simplest type of power monitoring system and is mainly used as a multi-metering device and/or as a breaker trip status monitor.

5.2.3.2 Group Centralized Power Monitoring System. The group centralized power monitoring system is equipped with a circuit monitor capable of monitoring multiple devices or other decentralized power monitors. It is comprised of a power monitor interconnected to different individual devices including metering monitors in a loop configuration. Metering and/or circuit breaker trip or started status information can be obtained from the display at the monitor or the information can be relayed to a computer terminal for display. The computer terminal is specially useful when remote monitoring is required. With the computer terminal as an option, this type of monitoring system is suitable for use in a large scale integrated switchgear, switchboards, and motor control center assemblies in a group configuration.

5.2.3.3 Master Centralized Power Monitoring System. For a large scale facility monitoring, when a centralized system display terminal is derived for monitoring purposes, a master centralized power monitoring system can be used by interconnecting all monitors in a facility, including decentralized and/or group centralized system, thus providing master monitoring at a centralized terminal. This system is recommended for a large power facility system requiring a central monitoring of more than 60 devices.

5.3 SCADA System. A SCADA system is capable of power monitoring as indicated in paragraph 5.2 and also, of operating power system devices, mainly switching or motor starting, individually or sequentially, in automatic mode or manually via keyboard. Device operation is carried out by means of sending electrical signals, which make the operating mechanism of the device operate. Automatic operations of selective devices are performed by preprogrammed settings via a master station. A manual operation, though not recommended, is carried out by commands at the master station at an instant when an operation is desired. The system monitoring and controls are run by a system software/hardware package included in the SCADA system. SCADA systems are recommended in large facilities requiring critical power reliability, facility-wide power system monitoring and automated power system operation.

5.3.1 Control Functions. Operating control functions may include a part or all of the following:

a) Operation of breakers and switches
b) Transfer switches and/or generator start-up operations
c) Load-shedding and sequencing operations
d) Power factor correction via capacitor switching
e) System diagnostics

5.3.2 SCADA System Components. In general, SCADA systems are comprised of the following components: circuit monitors, master station with system software and network interface controller, line printer, and system links.

5.4 Surge Protections. Protect all equipment against power line surges as recommended by IEEE C62.41 and against surges induced on communication signal circuits. Protect computer equipment with surge protectors. Do not use fuses for surge protection.

5.5 Backup Power Supply. Provide 15 to 30 minute battery backup for both centralized power monitoring and SCADA systems.

5.6 System Configuration. Configuration of a monitoring and control system should be such that future addition or modification will be at a minimum cost. Usually, system components of various manufacturers do not interface with one another. Make sure to design new systems incorporating components capable of interfacing and future expansion. When expanding or modifying an existing system, make sure that new components are fully compatible with existing system components. Specify installation and operational testing of centralized systems shall be under supervision of a technical representative of the manufacturer supplying the monitoring or the SCADA system.

REFERENCES

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

C37.06	Preferred Ratings and Related Required Capabilities for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
C57 Series	Transformers
C62.2	Guide for the Application of Valve-Type Lightning Arresters for AC Systems
C84.1	Voltage Ratings for Electric Power Systems and Equipment (60 Hz)

The Art and Science of Protective Relaying, General Electric Engineering Practice Series, C. Russell Mason, John Wiley & Sons, Inc., New York, NY 10036.

IEEE Publications, Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017.

80	Guide for Safety in Substation Grounding
81	Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
141	Recommended Practice for Electric Power Distribution for Industrial Plants
142	Recommended Practice for Grounding Industrial and Commercial Power Systems
242	Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
399	Recommended Practice for Industrial and Commercial Power System Analysis

IEEE/ANSI Publications, Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017.

C37.010	Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

C37.011	Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
C37.04	American National Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
C37.13	Low-Voltage AC Power Circuit Breakers Used in Enclosures
C37.2	Standard Electrical Power System Device Function Numbers
C37.20	Switchgard Assemblies Including Metal-Enclosed Bus
C62.41	Guide for Surge Voltages in Low-Voltage AC Power Circuits

Military Handbooks, available from the Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipments and Facilities
MIL-HDBK-1004/1	Preliminary Design Considerations
MIL-HDBK-1004/2	Power Distribution Systems
MIL-HDBK-1008	Fire Protection for Facilities Engineering, Design, and Construction

NFPA Publications, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

NFPA-70	National Electrical Code

NAVFAC Guide Specifications, available from Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

NFGS-16262	Automatic Transfer (and Bypass/Isolation) Switches
NFGS-16335	Transformers, Substations and Switchgear, Exterior
NFGS-16462	Pad-Mounted Transformers (75 kVA to 500 kVA)

NFGS-16465	Interior Substations
NFGS-16475	Interior Switchgear and Switchboards, Low-Voltage

NEMA Standards, National Electrical Manufacturers Association, 2101 L Street, NW., Washington, DC.

AB-1	Molded Case Circuit Breakers
BU-1	Busways
ICS 6	Enclosures for Industrial Controls and Systems
KS-1	Enclosed Switches
SG-3	Low-Voltage Power Circuit Breakers
SG-4	Alternating-Current High-Voltage Power Circuit Breakers

Standard Handbook for Electrical Engineers, 12th Edition, Donald G. Fink and H. Wayne Beaty, McGraw-Hill Book Company, Inc., New York, NY 10036.

UL Standards, Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062.

489	Molded-Case Circuit Breakers and Circuit Breaker Enclosures
857	Electric Busways and Associated Fittings

Westinghouse Electric Corporation:

Applied Protective Relaying; Relay and Telecommunications Instrument Division, Coral Springs, FL 33065.

Electrical Transmission and Distribution Reference Book; 777 Penn Center Boulevard, Pittsburgh, PA 15235.

CUSTODIAN:
NAVY - YD

PREPARING ACTIVITY
NAVY - YD

PROJECT NO.
FACR-0194