NEMA STANDARDS PUBLICATION NO. ICS 3

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Industrial Control and Systems Factory Built Assemblies

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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NEMA Standards Publication No. ICS 3-1993

INDUSTRIAL CONTROL AND SYSTEMS
FACTORY BUILT ASSEMBLIES

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FOREWORD

This Standards Publication was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes the indicated NEMA Standards Publication.

Replacement: The three parts of ICS 3-1993 supersede the following parts of ICS 2-1988:
Part 1 supersedes Part ICS 2-322
Part 2 supersedes Part ICS 2-324
Part 3 supersedes Part ICS 2-325

In 1988, unrevised portions of all NEMA Standards Publications for Industrial Controls and Systems (the ICS series) were reaffirmed.

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital to a safe installation:

a. Environmental conditions
b. System design
c. Equipment selection and application
d. Installation
e. Operating practices
f. Maintenance

This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users of Industrial Control and Systems equipment, the Industrial Control and Systems Section is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

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NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions.

Proposed revisions to this Standards Publication should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037-1526

INTRODUCTION

The standards pertaining to factory built assemblies in NEMA Standards Publication ICS 3 are subdivided into the following clauses:

1 General
  Referenced Standards
  Scope
  Normative References
2 Definitions
  Terms which supplement the IEEE Standard Dictionary of Electrical and Electronics Terms (Std 100) or assist in clarifying the product standard.
3 Classification
  Product classifications where they have been established.
4 Characteristics and Ratings
  Descriptions of the kinds of ratings applicable to the product and tables of standard ratings for the product where they have been established.
5 Product Marking, Installation and Maintenance Information
  Product information to be provided to assist the user in the installation, use and maintenance of the devices.
6 Service and Storage Conditions
  A description of service and storage conditions for which the devices are intended.
7 Construction
  Marking, color coding and similar production requirements to be incorporated into the product as manufactured, as well as production test requirements where they have been established, i.e., the rules that the manufacturer follows in producing the product.
8 Performance Requirements and Tests
  The performance required to pass each design test specified for the product.
9 Application
  Information and performance considerations of importance to those who specify or use the product.

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The standards for the products included within the scope of the Industrial Control and Systems Section are organized as follows:

NEMA Standards Title
Publication No.

ICS 1-1993 Industrial Control and Systems
General Requirements

ICS 2-1993 Industrial Control and Systems
Controllers, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC

Part 1: *General Standards for Manual and Magnetic Controllers*
Part 2: *AC Noncombination Magnetic Motor Controllers, Rated 600 Volts*
Part 3: *Nonmagnetic Motor Controllers*
Part 4: *Overload Relays*
Part 5: *DC General-Purpose Constant-Voltage Controllers*
Part 6: *AC Combination Motor Controllers*
Part 7: *Magnetic Lighting Contactors*

ICS 3-1993 Industrial Control and Systems
Factory-built Assemblies

Part 1: *Motor Control Centers Rated Not More Than 600 Volts AC*
Part 2: *Medium Voltage Controllers Rated 2001 to 7200 Volts AC*
Part 3: *AC General-Purpose Controllers for Synchronous Motors*

ICS 4-1993 Industrial Control and Systems
Terminal Blocks

ICS 5-1993 Industrial Control and Systems
Control Circuit and Pilot Devices

Part 1: *General Standards for Control Circuit and Pilot Devices*
Part 2: *Industrial Control Relays*
Part 3: *Industrial Control Input Devices Actuated by Force, Temperature and Pressure*
Part 4: *Proximity Switches*
Part 5: *Pushbuttons, Selector Switches, Indicating Lights and Pushbutton Stations*

ICS 6-1993 Industrial Control and Systems
Enclosures

ICS 7-1993 Industrial Control and Systems
Adjustable Speed Drives

Part 1: *General Standards for Drive Converters, Drives, and Drive Systems*
Part 2: *Loop Position and Tension Control Drive Systems*
Part 3: *Wind and Unwind Drive Systems*
Part 4: *Variable-Frequency, Three-Phase Controllers, Rated Not More Than 600 Volts*
Part 5: *Adjustable-Voltage Packaged-Drive Systems (Where DC Armature Power Is Obtained from AC Lines Using Controlled Semiconductor Rectifiers)*
Part 6: *Variable-Frequency Drive Systems Rated Not More Than 600 Volts Using Semiconductor Power Conversion*
Part 7: *Variable-Frequency, Three-Phase Drives, Rated 601 to 7,200 Volts*

ICS 8-1993 Industrial Control and Systems
Crane and Hoist Controllers

Part 1: *General Standards for Crane Controllers Rated 600 Volts or Less AC and DC*
Part 2: *Constant-Voltage DC Magnetic Controllers for Motors on Cranes*
Part 3: *Adjustable-Voltage DC Controllers for Motors on Cranes*
Part 4: *Magnetic Controllers for AC Wound-Rotor Motors on Cranes*
Part 5: *Static Controllers for AC Wound-Rotor Motors on Cranes*

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Part 6: *Crane and Hoist Power-Circuit Limit Switches*
Part 7: *Heavy-Duty DC Magnetic Contactors Rated 600 Volts*

ICS 9-1993 Industrial Control and Systems
Power-Circuit Accessories

Part 1: *Electromagnetic Brakes*
Part 2: *Resistors and Rheostats*
Part 3: *Autotransformers and Reactors*

ICS 10-1993 Industrial Control and Systems
AC Transfer Switch Equipment

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Part 1
MOTOR CONTROL CENTERS RATED NOT MORE THAN 600 VOLTS AC

1 General

1.1 Reference Standards

In this NEMA Standards Publication reference is made to the following standards listed below. Copies are available from the indicated sources.

American National Standards Institute
11 West 42nd Street
New York, NY 10036

ANSI C37.50-1989*	*Switchgear – Low-Voltage AC Power Circuit*

*Also available from NEMA

National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

ICS 1-1993	*Industrial Control and Systems*
ICS 1.3-1991	*Preventive Maintenance of Industrial Control and Systems Equipment*
ICS 2-1993	*Industrial Control and Systems* *Controllers, Contactors and Overload Relays,* *Rated Not More Than 2000 Volts AC or 750 Volts DC*
ICS 2.3-1989	*Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers*
ICS 6-1993	*Industrial Control and Systems* *Enclosures*
NEMA 250-1991	*Enclosures for Electricla Equipment (1000 Volt Maximum)*

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 845 (1988)	*Motor Control Centers*

Institute of Electrical and Electronics Engineers
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855

IEEE C37.09-1979 (R1989)	*Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*
IEEE C37.26-1991	*Methods of Power-Factor Measurement for Low-Voltage Inductive Test Circuits*

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IEEE C62.2-1987	*Guide for Application of Gapped Silicon-Carbide Surge Arresters for Alternating-Current Systems*
IEEE 4-1978	*Standard Techniques for High Voltage Testing*
IEEE 141-1986	*Recommended Practices for Electric Power Distribution for Industrial Plants*
IEEE 100-1992	*Standard Dictionary of Electrical and Electronics Terms*

1.2 Scope

The standards in this part apply to three phase 50 and 60 hertz motor control centers rated not more than 600 volts AC.

1.3 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1, ICS 6 and portions of ICS 2 also apply to this part.

1.4 Equipment

A motor control center may contain any combination of equipment such as the following:

a. Full-voltage reversing or nonreversing combination motor-control units
b. Full-voltage multispeed combination motor-control units
c. Reduced-voltage part-winding, wye-delta or auto-transformer combination motor-control units
d. Solid-state industrial controllers such as adjustable-speed drives, programmable controllers, protective relays, etc.
e. Lighting or distribution panelboards
f. Feeder-tap units
g. Incoming-line equipment, such as main lugs, fusible switch, isolation switch, or air circuit breaker
h. Control or lighting transformers
i. Special equipment assemblies

The foregoing equipment may contain such items as pushbuttons, selector switches, indicating lights, control transformers, control circuit fuses and auxiliary contacts incorporated as an integral part of the above units.

2 Definitions

For the purposes of this part, the following definitions apply:

blank unit space: Unit space not equipped to accept a future unit.

combination motor-control unit: A control unit that includes an externally operable circuit disconnecting means, motor branch-circuit overcurrent protection and a motor controller with associated auxiliary devices when used.

The disconnecting means and motor branch-circuit overcurrent protection consist of a fusible disconnecting device or circuit breaker. If the latter is used, it is either an inverse time (thermal-magnetic or dual magnetic) or an instantaneous magnetic-trip-only circuit breaker.

The motor controller includes motor overload protection unless equivalent protection is otherwise provided.

Two sets of externally operable circuit disconnecting means, each with branch-circuit overcurrent protection and magnetic motor controller, may be mounted in a single compartment to form a dual unit.

custom drawings (motor control centers): Manufacturer's drawings made to meet user custom requirements.

feeder-tap unit: A unit that includes an externally operable circuit disconnecting means and branch-circuit overcurrent protection, principally used for nonmotor loads.

Two sets of externally operable circuit means, each with branch-circuit overcurrent protection, may be mounted in a single compartment to form a dual unit.

future unit space: Unit space specified and equipped to accept a future unit.

motor control center: A floor-mounted assembly of one or more enclosed vertical sections typically having a horizontal common power bus and principally containing combination motor-control units.

These units are mounted one above the other in the vertical sections. The sections normally incorporate vertical buses connected to the common power bus, thus extending the common power supply to the individual units. Power may be supplied to the individual units by bus bar connections, by stab connection, or by suitable wiring.

standard drawings (motor control centers): Arrangement drawings and wiring diagrams prepared using manufacturer's standard drawing sizes, device symbols, and identification and numbering designation.

unusable unit space: Unit space not suitable to accept a future unit.

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3 Classifications

3.1 Classes and Types

Motor control centers are provided as either Class I or Class II assemblies. Each class may be supplied with standard or custom drawings. Motor control centers are factory wired as either Type A, B, or C.

3.2 Classes of Motor Control Centers

Motor control centers shall be provided as either Class I or Class II assemblies. With either class the user may specify the physical arrangement of units within the motor control center subject to the design parameters of the manufacturer.

Equipment described in 3.2.1 and 3.2.2 shall be supplied with the manufacturer's standard drawings and shall be designated as Class I or Class II, as selected by the user.

Equipment described in paragraph 3.2.3 shall be supplied with the manufacturer's custom drawings and shall be designated as Class I-S or Class II-S, as selected by the purchaser.

3.2.1 Class I—Independent Units

Class I motor control centers shall consist of mechanical groupings of combination motor-control units, feeder-tap units, other units and electrical devices arranged in a convenient assembly. The manufacturer shall furnish drawings that include:

a. Overall dimensions of the motor control center, identification of units and their location in the motor control center, locations of incoming line terminals, mounting dimensions, available conduit entrance areas, and the location of the master terminal board if required (Type C wiring only)

b. Manufacturer's standard diagrams for individual units, and master terminal boards (Type C wiring only), consisting of drawings that:

1. Identify electrical devices

2. Indicate electrical connections

3. Indicate terminal numbering designations

NOTE—Where a combination schematic or wiring diagram, or both, for a unit is supplied showing optional devices, the manufacturer shall provide information to indicate which devices are actually furnished.

3.2.2 Class II—Interconnected Units

Class II motor control centers shall be the same as Class I motor control centers except with the addition of manufacturer-furnished electrical interlocking and wiring between units as specifically described in overall control system diagrams supplied by the user.

In addition to the drawings furnished for Class I motor control centers, the manufacturer shall furnish drawings that indicate factory interconnections within the motor control center.

3.2.3 Class I-S & II-S—Motor Control Centers with Custom Drawing Requirements

Class I-S and II-S motor control centers shall be the same as Class I and II motor control centers except custom drawings shall be provided in lieu of standard drawings as specified by the user.

Examples of custom drawings are:

a. Special identifications for electrical devices

b. Special terminal numbering designations

c. Special sizes of drawings

The drawings supplied by the manufacturer shall convey the same information as drawings provided with Class I and II motor control centers, additionally modified as specified by the user.

3.3 Circuit Wiring

All circuit components within each unit shall be factory wired.

3.3.1 Types of Wiring

3.3.1.1 Type A Wiring

With Type A wiring user field wiring connects directly to device terminals internal to the unit. Type A wiring shall be provided only on Class I motor control centers.

3.3.1.2 Type B Wiring

Type B user (field) load wiring for combination motor-control units Size 3 and smaller shall be designated as Type B-D or B-T, according to the following:

a. For Type B-D, the user connects directly to the device terminals, which are located immediately adjacent, and readily accessible, to the vertical wireway.

b. For Type B-T, the user connects to a load terminal block in, or adjacent to, the unit.

With Type B load wiring for combination motor-control units larger than Size 3, and for feeder-tap units, the user connects directly to unit device terminals.

With Type B control wiring the user connects to unit terminal blocks located in or adjacent to each combination motor-control unit.

3.3.1.3 Type C Wiring

With Type C wiring user (field) control wiring connects to master terminal blocks mounted at the top or bottom of those vertical sections that contain combination motor-control units or control assemblies. Combination motor-control units and control assemblies shall be factory wired to their master terminal blocks.

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With Type C wiring, load wiring for combination motor-control units Size 3 and smaller connects to master terminal blocks mounted at the top or bottom of vertical sections. Motor-control unit load wiring for these units shall be factory wired to the master terminal blocks.

With Type C wiring, load wiring for combination motor-control units larger than Size 3, and for feeder-tap units, the user connects directly to unit device terminals.

4 Characteristics and Ratings

4.1 Voltage Ratings

Motor control center voltage ratings shall be in accordance with ICS 1 and ICS 2. The rated voltage is the voltage to which the performance characteristics of motor control centers are related.

4.2 Combination Motor-Control Unit Ratings

The ratings of magnetic motor controllers of the combination motor control units shall be in accordance with Part 2 of ICS 2.

4.3 Continuous-Current Ratings of Buses

The horizontal common power bus shall have a continuous-current rating of 600, 800, 1000, 1200 amperes or higher as required by a particular application. Vertical bus extensions installed in a section shall have a minimum continuous-current rating of 300 amperes.

4.4 Basis for Short-Circuit Current Rating of Motor Control Centers

4.4.1 Available Short-Circuit Current

The available short-circuit current is the short-circuit current available at the motor control center line terminals plus motor contribution. The available short-circuit current shall be expressed in rms symmetrical amperes.

4.4.2 Short-Circuit Current Rating

Unless a current limiting means is used in a series combination (as defined in 4.4.3) with a motor control center, the short-circuit current rating shall be the lowest of the following:

a. The short-circuit current rating of the bus structure

b. The lowest short-circuit current rating of any installed combination motor control unit

c. The short-circuit current rating of any installed feeder tap unit.

4.4.3 Series Combination Rating

A series combination short-circuit rating is a higher short-circuit current rating, obtained by adding an internal or external current-limiting means in series with a lower-rated motor-control center.

Table 1-4-1
SHORT-CIRCUIT CURRENT RATINGS

RMS Symmetrical Amperes	
5,000	30,000
7,500	35,000
10,000	42,000
14,000	50,000
18,000	65,000
22,000	85,000
25,000	100,000

Examples of current-limiting means include current-limiting circuit breakers, current-limiting fuses, and current-limiting reactors.

The series combination rating shall not exceed the rating of the current-limiting device and shall be selected from Table 1-4-1.

For motor control centers with short-circuit current ratings over 100,000 amperes, a current-limiting means limiting the current to 100,000 amperes or less is recommended.

4.5 Standard Short-Circuit Ratings of Motor Control Centers

4.5.1 Ratings of Combination Motor-Control Unit and Feeder-Tap Units

Each combination motor-control unit and feeder-tap unit of a motor control center shall have a short-circuit current rating. The rating shall be selected from Table 1-4-1.

A combination motor-control unit shall be permitted to have a short-circuit rating greater than the short-circuit current rating of any individual component as determined by design tests.

4.5.2 Units Not Containing a Short-Circuit Protective Device

a. A unit not containing any short-circuit protective device shall not be connected directly to the power bus (with the exception of lightning and surge arresters) and shall not be assigned a unit short-circuit current rating.

b. Absence of a short-circuit current rating on such a unit does not affect the short-circuit current rating of the motor control center.

4.5.3 Separately Derived Systems

Motor control centers short-circuit current rating are not affected by units connected to a separately derived system in a motor control center.

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Table 1-4-2
BUS STRUCTURE SHORT-CIRCUIT CURRENT RATINGS

rms Symmetrical Amperes	
22,000	65,000
25,000	85,000
42,000	100,000
50,000	

The short-circuit current rating for such a unit should be appropriate for the short-circuit current capacity of the separately derived system

4.5.4 Rating of Bus Structure

The bus structure (horizontal and vertical bus) of a motor control center shall have a short-circuit current rating. The rating shall be selected from Table 1-4-2.

All short-circuit current ratings shall be based upon the test procedures, performance, and criteria described in 8.3.

4.6 Range of Operating Voltage

The range of operating voltage of a control center shall be in accordance with Part 1 of ICS 2.

5 Product Marking, Installation and Maintenance Information

5.1 Preventative Maintenance

See NEMA Standards Publication ICS 1.3 for general preventative maintenance instructions.

5.2 Handling, Installation, Operation and Maintenance

See NEMA Standard Publication ICS 2.3 for recommended procedures in handling, installing, operating and maintaining motor control centers.

5.3 Marking and Labelling

5.3.1 Units

A motor-control unit shall be marked with the following information, as applicable:

a. Manufacturer's identity
b. Required power supply (voltage, phase, frequency)
c. Load (any of: HP, Amps, kW, kVA, kvar)
d. Short-circuit current rating expressed in rms symmetrical amperes. A unit subject to the conditions in 4.5.2 a) shall be marked N/A
e. Wiring diagrams or tables, or their location in the motor control center
f. Service disconnect

5.3.2 Section(s)

A motor control center (when all sections are of similar construction) or each motor control center section (when the sections are not of similar construction) shall be marked with the following information, if applicable:

a. Manufacturer's identity
b. Required power supply (voltage, phase, frequency)
c. Horizontal and vertical bus ampacity
d. Short-circuit current rating expressed in rms symmetrical amperes
e. Enclosure type
f. Suitability to serve as service equipment

5.3.3 Marking Exception

Motor control center sections not containing power bus or power cabling shall be marked with a short-circuit rating of N/A.

6 Service and Storage Conditions

Clause 6 of ICS 1 applies.

7 Construction

7.1 Vertical Section

The function of a vertical section is to support the vertical and horizontal buses, the units, the doors and covers. Nominal installed height is 90 inches (2.29 m), excluding floor sills or mounting channels.

A vertical section is self-supporting when properly bolted to the floor or otherwise secured. These sections may be assembled into a group to which additional sections may be readily added.

7.2 Wiring Space

Within each section there shall be space for horizontal wiring between vertical sections at the top or bottom, or both. There shall be vertical wiring space within each section for wiring to the units.

7.3 Unit Mounting

Provision shall be made so that each combination motor-control unit and feeder-tap unit may be readily removed as a unit for rearrangement, replacement or repair. Exceptions are permitted where the size or weight of the unit makes its removal impracticable.

Unit doors shall be hinged and attached either to the vertical section or to the unit. Where the door is mounted on the unit, removal of the unit shall not leave the bus so exposed that accidental contact with it is likely.

7.4 Interlocking of Doors

Access to each combination motor-control unit or feeder tap unit shall be provided by a single separate

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hinged door, interlocked with its associated disconnecting device so that the door cannot be opened without first opening the disconnecting device.

Where two sets of circuit disconnecting means are mounted in a single compartment to form a dual feeder-tap unit, each disconnecting device shall be interlocked with its associated door. Provision shall be made for locking the disconnecting device in the open position when the door is closed.

Where required by the particular application, a deactivating means (defeater) shall be provided to permit entry into the enclosure when the disconnecting device is closed.

7.5 Spacings

Spacings of bare bus bars of the horizontal common power bus and of the bus extensions in the vertical sections, including stabs or bolted connectors, shall provide the following minimum clearances:

a. To parts of opposite polarity through air—1 inch (25.4 mm)

b. Between live parts and ground through air or across surfaces—1 inch (25.4 mm)

c. To parts of opposite polarity across surfaces—2 inches (50.8 mm)

Spacings within units shall be in accordance with the basic requirements for industrial control equipment for the rated voltage (See Clause 7 of ICS 1).

7.6 Control Circuit Protection

a. Control circuits shall be protected in accordance with Clause 7 of ICS 1.

b. A control circuit supplied by a source separate from the unit shall be considered to be an external source for purposes of overcurrent protection.

7.7 Lighting Panel and Auxiliary Control Panel Protection

Lighting panels and auxiliary control panels, where connected directly to the common power bus, shall include, or be protected by, protective devices having interrupting ratings not less than the available short-circuit current at the protective device location in the circuit.

Where these panels are supplied from transformers in the motor control center, the transformer primaries shall be protected for not less than the short-circuit rating of the motor control center. Those panels connected to the secondary of such transformers shall be protected for not less than the maximum available short-circuit current of the transformer.

8 Performance Requirements and Tests

8.1 Design Test Concept

Design tests are those tests made to determine the adequacy of the design of a particular type, style, or model of motor control center to meet its assigned ratings and to operate satisfactorily under normal service application conditions or under special conditions, if specified. Design tests are made only on representative motor control centers to substantiate the ratings assigned and are not contemplated in normal production.

8.2 Test Methods

All design tests shall be made by the manufacturer using a three-phase power supply for the tests specified in 8.3 and 8.4.

8.3 Horizontal Common Power Bus and Vertical Bus Extension Short-Circuit Withstand Test

8.3.1 Tests

Short-circuit current tests shall be conducted in accordance with the procedures and requirements of UL 845, on both the horizontal bus structure and vertical bus structure.

Each motor control center section shall have a short-circuit rating expressed in maximum rms symmetrical amperes and maximum voltage.

8.3.2 Performance Criteria

Performance shall be acceptable if the motor control center complies with the requirements in UL 845.

Criteria for acceptable performance may be summarized as follows.

a. There is no permanent dislocation of the bus bars or cable that would affect the normal functioning of the assembly.

b. There is no distortion of the vertical buses that would impair normal insertion of a unit.

c. There is no cracking or breaking of an insulating base that would impair the support of live parts.

d. The ground fuse is not opened.

e. There is no damage due to arcing.

f. Stab-in assemblies (if used) and vertical buses at the point of contact are in essentially the same mechanical and electrical condition as before the test.

g. The enclosure or a part of the enclosure has not been damaged or displaced to the extent that a live part is accessible.

h. There is no dielectric breakdown between live parts of opposite polarity and between live parts and the enclosure.

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8.4 Combination Motor-Control Units and Feeder-Tap Units Short-Circuit Interrupting Tests

8.4.1 Tests

Short-circuit current tests shall be conducted to verify the compatibility of the overcurrent devices and other involved components such as stab-in assembly line-side wiring, enclosure, door or cover and load-side terminals. The short-circuit tests shall be conducted in accordance with the procedures and requirements of UL 845.

Each combination motor-control unit and each feeder-tap unit shall have a short-circuit rating expressed in maximum rms symmetrical amperes and maximum voltage.

8.4.2 Performance Criteria

Performance shall be acceptable if the combination motor-control unit or feeder-tap unit complies with the requirements of UL 845.

Criteria for acceptable performance may be summarized as follows.

a. There is no dielectric breakdown at the unit disconnect and the fault current is interrupted by the branch- circuit protective device.

b. There is no discharge of parts outside the unit.

c. There is no damage to a conductor or terminal connector and the conductor has not pulled out of the terminal connector.

d. The unit door or cover has not blown open and the operating mechanism for the disconnect and the door interlocks shall permit the opening of the door.

e. The disconnecting means is capable of being opened manually with normal operation of the operating handle.

f. Stab-in assemblies (if used) and vertical buses at the point of contact are in essentially the same mechanical and electrical condition as before the test.

8.4.3 Location of Units

Units shall be tested while installed in a motor control center section in a location as close as practicable to the motor control center incoming line terminals.

8.4.4 Unit Fault Connection

The fault connection shall be made at the load terminals of the unit. It shall consist of three insulated conductors, each not more than 4 feet (1.22 meters) long and with ampacity appropriate for the maximum horsepower or maximum current rating of the unit.

8.4.5 Enclosure Ground Circuit

The unit enclosure shall be solidly connected to the test circuit conductor which supplies the center pole (L2) of the unit.

8.4.6 Test Voltage and Frequency

Units shall be tested at the three-phase 60 hertz rated voltage of the motor control center in which they are to be applied. The test voltage shall be determined at the line terminals of the motor control center by measuring the open-circuit line-to-line voltage immediately before the test.

8.4.7 Test Current

The available short-circuit current at the line terminals of the motor control center in which the unit is tested shall be not less than the short-circuit current rating of the motor control center in which the unit is to be applied.

8.4.8 Test Circuit Calibration

The available rms symmetrical short-circuit current shall be determined by measuring the current with the motor control center line terminals short-circuited. The current shall be determined at an instant one-half cycle at 60 hertz after the short circuit occurs and shall be calculated per ANSI C37.09. The test circuit power factor shall be in accordance with Table 1-8-1.

Table 1-8-1
TEST CIRCUIT POWER FACTOR

Short-Circuit Current Rating, rms Symmetrical Amperes	Maximum Power Factor, Percent
10,000	50
14,000	30
22,000 and above	20

Resistance and reactance components of the test circuits shall not be connected in parallel, except that an air-core reactor in any phase may be shunted by resistance in which the voltampere loss is approximately 0.6 percent of the reactive voltamperes of the air-core reactor in that phase.

8.4.9 Test Duty Cycle

Each combination motor-control unit tested shall have one open (O) test. The unit disconnecting means and controller contactor shall be closed prior to the test. The operating coil of the contactor shall be energized from a separate source.

Each feeder-tap unit shall have one open (O) test. The disconnecting means shall be closed prior to the test.

Short-circuit current shall be initiated by random closing of the test circuit.

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8.4.10 Performance Criteria

After completion of the short-circuit test, the condition of the unit shall be as follows.

a. The fault current shall have been interrupted by the unit branch-circuit protective device.

b. Immediately following the short-circuit test, the unit shall withstand a dielectric test of twice rated voltage at 60 hertz for 1 minute on the line side of the disconnecting means from line to line and from each line to ground. In this test, circuit breakers shall be left in the tripped position and fusible disconnect devices shall be left closed with the fuses left in their holders.

c. In a fusible disconnect device, contact welding is acceptable if normal operation of the operating mechanism will break the weld.

Table 1-8-2
ALLOWABLE TEMPERATURE RISE

	Degrees of Temperature Rise
a. Horizontal bus	65°C (117°F)
b. Vertical bus, at the location of the first plug-in connector from the horizontal bus	50°C (90°F)
c. Plug-in connector to the vertical bus	50°C (90°F)
d. Unit field terminals unmarked	50°C (90°F)
e. Unit field terminals marked for use with 75°C wire	65°C (117°F)

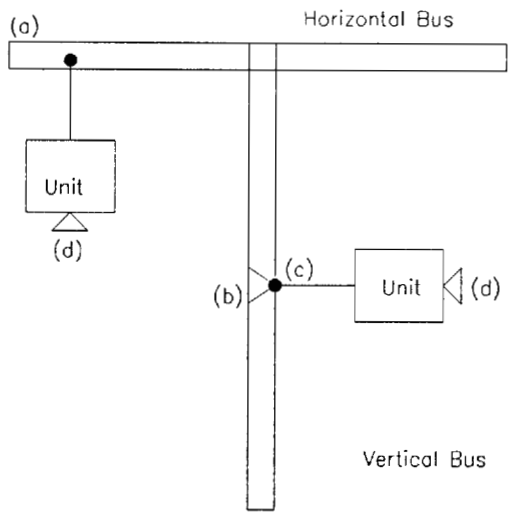


Figure 1-8-1
TEMPERATURE RISE TEST

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d. A combination motor-control unit or feeder-tap unit may require repair or replacement.

e. The operating mechanism for the disconnect device and the door interlocks shall permit opening of the door.

f. Stab-in assemblies (when employed) and vertical buses at the point of contact shall be in essentially the same mechanical and electrical condition as before the test.

g. The unit door must remain closed in its normal position and shall operate normally.

8.5 Temperature Rise Test

The temperature rise above ambient of current carrying parts shall not exceed the values stated in Table 1-8-2 when tested in accordance with UL 845, as indicated in Figure 1-8-1.

9 Application

9.1 Technical Information Needed to Supply a Motor Control Center

The technical information furnished to the motor control center supplier should include the following, as applicable.

a. Rating of power supply:
   1. Voltage
   2. Frequency
   3. Number of Phases
   4. Horizontal and vertical bus rating in amperes
   5. Available fault current at the line terminals of the control center in rms symmetrical amperes

b. Size, type (aluminum or copper), number and location of incoming cables, or busway

c. Enclosure:
   1. Type
   2. Accessibility (front or rear, or both)
   3. Clearance for door swing
   4. Restriction on height
   5. Requirements for bottom plates

d. Types of combination motor-control units, feeder-tap units, main disconnect devices, etc., to be coordinated with step a

e. Service entrance requirements per local codes, utilities, etc., for incoming line section

f. Class and type of motor control center

g. Preferred layout of units

h. Special features

9.2 Application of Short-Circuit Current Ratings

The motor control center short-circuit current rating shall be the maximum available rms symmetrical current in amperes permissible at its line terminals. It shall be computed as the sum of the short-circuit current contributions of the motors connected to the motor control center and the maximum available current, including all other short-circuit current contributions of the supply system at the point of connection to the motor control center.

Some simplified methods of determining available short-circuit currents treat all contributions to short-circuit current as due to motors and concentrated at the transformer terminals.

The maximum available current is taken as the sum of the maximum available current of the transformer and a motor contribution based on the transformer continuous-current rating.

Such methods are not consistently applicable for motor control center installations. Under some conditions, as where the installation involves relatively long or high-impedance (possibly current-limiting) feeders, those methods may be unsafe. In such instances, the short-circuit current within the control centers may exceed the predicted value because the short-circuit current contributions of the motors connected to the control center are not diminished by the feeder impedance, as contemplated by the method.

In all circumstances, the maximum available current at the line terminals of the motor control center should be computed as the sum of the maximum available current of the system at the point of connection and the short-circuit current contribution of the motors connected to the control center. (In the absence of more precise information, it is usual to assume that the short-circuit contribution of these motors equals four times the continuous current rating of the motor control center.)

The current thus determined must not exceed the short-circuit rating of the motor control center.

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Part 2
MEDIUM VOLTAGE CONTROLLERS RATED 2001 TO 7200 VOLTS AC

1 General

1.1 Scope

This part applies to AC general-purpose contactors and Class E magnetic controllers rated 2001–7200 volts, three phase, 50 and 60 hertz.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1 and ICS 6 also apply to this part.

2 Definitions

For the purpose of this section, the following definitions apply:

class E controller: AC air-break, vacuum, and oil-immersed magnetic controllers for service on voltages from 2200 to 6600 volts.

They are capable of interrupting short-circuit faults beyond operating overloads.

medium voltage: AC voltage in the range of 2001 to 7200 volts.

medium-voltage compartment: A compartment containing one or more medium-voltage components rated 2001 to 7200 volts.

3 Classifications

3.1 Class E1 Controllers

Class E1 controllers employ their contacts for both starting and stopping the motor and interrupting short circuits or faults exceeding operating overloads.

3.2 Class E2 Controllers

Class E2 controllers employ their contacts for starting and stopping the motor and employ fuses for interrupting short circuits or faults exceeding operating overloads.

4 Characteristics and Ratings

4.1 Continuous Current and Interrupting Ratings

4.1.1 General

Continuous current and fault interrupting ratings of controllers for nonplugging and nonjogging, reversing and nonreversing duty, when mounted in any type of enclosure and whether or not provided with running overcurrent (overload) protection or other auxiliary devices, shall be in accordance with Tables 2-4-1 and 2-4-2A and 2-4-2B.

Table 2-4-1 lists continuous current ratings of Class E controllers and contactors; Table 2-4-2A lists interrupting ratings of Class E1 controllers; Table 2-4-2B lists voltage and interrupting ratings of Class E2 controllers.

Class E controllers shall not be used with motors whose full-load current exceeds the continuous current rating given in Table 2-4-1. The continuous current ratings shown in Table 2-4-1 represent the maximum rms current, in amperes, which the controller may be expected to carry continuously without exceeding the temperature rises given in Clause 8 of ICS 1.

A Class E controller intended for use with nonmotor loads, such as capacitors or transformers, may require special consideration.

4.1.2 Service-Limit Current Rating

The service-limit current ratings shown in Table 2-4-1 represent the maximum rms current, in amperes, which the controller may be expected to carry for protracted periods in normal service.

The ultimate-trip current rating of overcurrent (overload) relays or of other motor protective devices used shall not exceed the service-limit current rating of the controller.

When controllers are operated above the continuous current rating and up to the service-limit current rating, temperature rises will exceed those obtained by testing the controller at its continuous current rating.

4.2 Basis of Interrupting Rating

The interrupting rating of a Class E controller is expressed in terms of the maximum symmetrical MVA (megavoltamperes) or maximum rms symmetrical fault current and specific line-to-line voltage it can interrupt at the controller incoming line terminals.

The symmetrical MVA rating is equal to the product of the rms symmetrical current that the controller can interrupt, the line-to-line open-circuit voltage, and a phase factor which is 1.73×10^{-6} for three-phase applications.

4.3 Coordination within the Controller

Class E Controllers should be provided with protection coordinated to meet specific load characteristics. Coordination consists of setting or selecting the characteristics of the various protective devices in the controller such that they operate only under the abnormal circuit condition for which they are intended.

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Table 2-4-1
CONTINUOUS CURRENT RATINGS OF CLASS E CONTROLLERS AND CONTACTORS

Size of Controller and Contactor	Enclosed Current Ratings Amperes		**Horsepower Ratings at Utilization Voltages								
			2300 Volts, Three-Phase			4000 Volts Three-Phase			6600 Volts, Three-Phase		
				Synchronous Motors			Synchronous Motors			Synchronous Motors	
	Continuous	Service Limit*	Induction Motors	80% Power Factor	100% Power Factor	Induction Motors	80% Power Factor	100% Power Factor	Induction Motors	80% Power Factor	100% Power Factor
H2	180	207	700	700	900	1250	1250	1500	2000	2000	2500
H3	360	414	1500	1500	1750	2500	2500	3000	4000	4000	5000
H4	540	621	2250	2250	2500	4000	4000	4500	6000	6000	7500
H5	630	724	2500	2500	3000	4500	4500	5000	7000	7000	8250
H6	720	828	3000	3000	3500	5500	5500	6000	8000	8000	10000

* 1.15 times the continuous current.
**Horsepower ratings are shown only for reference.

Table 2-4-2A
INTERRUPTING RATINGS OF CLASS E1 CONTROLLERS

Size of Controller	Class E1 Interrupting Ratings (Unfused)*	
	Three-Phase Symmetrical MVA	Volts, Amperes
H2	25 or 50	**
H3	50	**
H4	60	**
H5	75	**
H6	Future	**

* Class E1 ratings may be specified from either column (2) or (3).

**To be specified by manufacturer.

Table 2-4-2B
VOLTAGE AND INTERRUPTING RATINGS OF CLASS E2 CONTROLLERS

Rated Insulation Voltage	Range of Utilization Voltages at which Interrupting Rating Applies		Class E2 Interrupting Ratings (Fused)			
Volts, rms	Maximum	Minimum	Amperes (rms), Symmetrical*		Three-Phase Symmetrical MVA at Nominal Utilization Voltage	
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2500	2500	2200	40,000	or 50,000	160 or	200 at 2300V
5000	5000	3800	40,000	or 50,000	280 or	350 at 4000V
5000	5000	3800	40,000	or 50,000	320 or	400 at 4600V
7200	7200	6200	40,000	or 50,000	460 or	570 at 6600V

*The asymmetrical interrupting rating is 1.6 times the symmetrical values shown.

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The relationship of individual devices (of similar function) to each other, should be such that the device intended to protect against the abnormal lowest circuit condition operates first.

4.3.1 Characteristics of Class E1 Controllers

Running overcurrent protective units for Class E1 controllers should be selected to:

a. Prevent continuous operation above the service limit of the controller

b. Prevent excessive heating of branch circuit conductors and connected load

Contactors should be selected to be able to:

a. Continuously carry overload relay ultimate trip current

b. Interrupt normal running currents, operating overload currents, and faults occurring at or beyond the controller load terminals

4.3.2 Characteristics of Class E2 Controllers

Running overcurrent protective units for Class E2 controllers should be selected to:

a. Prevent continuous operation above the service-limit current of the controller

b. Prevent excessive heating of branch circuit conductors and connected load

c. Operate before any fuse melts at all currents below the minimum interrupting current of the power circuit fuses

Power circuit fuses should be selected to be able to:

a. Permit repetitive switching of the load, with consideration given to inrush current and time, without damaging a fuse

b. Interrupt faults at or beyond the controller load terminals

c. Continuously carry overload relay ultimate trip current

Contactors should be selected to:

a. Continuously carry overload relay ultimate-trip current

b. Interrupt normal running currents and operating overload currents up to the minimum interrupting current of the power circuit fuses

5 Product Marking, Installation and Maintenance Information

5.1 Marking

Class E controllers shall be legibly marked with the following:

a. Manufacturer's name or trademark

b. Catalog or manufacturer's identification

c. Class E1 or E2 controller, as appropriate

d. Number of phases

e. Frequency

f. Continuous-current rating, rms amperes

g. Interrupting rating (MVA or volts and rms symmetrical amperes)

h. Maximum voltage

i. Power circuit fuse size for Class E2 controller

j. Continuous-current rating of horizontal bus system where supplied

k. BIL test level

l. Control voltage

m. Volt-ampere rating or the equivalent of any operating coil circuit which requires a remote control device with a sealed rating or more than 125 volt-amperes

Marking is not required to be located on the outside of an enclosure provided it is readily visible by opening a door or removing a cover after installation. Other markings may be used to meet other applicable requirements.

5.2 Preventive Maintenance

5.2.1 General

See ICS 1.3 for preventive maintenance instructions.

5.2.2 Precautions

All maintenance should be performed by trained, qualified personnel, using safety practices and protective equipment applicable to systems over 600 Volts.

5.2.3 Condensation

If moisture condensation occurs inside an enclosure, corrective action, such as the installation of a space heater, should be taken. Refer to the manufacturer for the recommended heater size for the circuit.

5.2.4 Contacts

Contact wear allowance (overtravel) and contact spring pressures should be checked against the manufacturer's recommendation in the specific instruction literature.

Vacuum interrupters (bottles) in a vacuum contactor should be checked for adequate vacuum level periodically by performing a dielectric test across the open contacts in accordance with the manufacturer's recommendations.

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5.3 Maintenance after a Fault Condition

After the opening of any power circuit fuse(s) the controller should be inspected in accordance with manufacturer's instructions for mechanical damage, dielectric strength and contact wear. See Annex A of ICS 2 for further information on maintenance after a fault condition.

6 Service and Storage Conditions

Clause 6 of ICS 1 applies.

7 Construction

7.1 General

Class E controllers shall be wired and assembled as complete, totally-enclosed and self-supporting units.

Controllers shall be provided with means for electrical connection to ground; such means shall have contact with the bare metal of the permanent portion of the cubicle.

7.2 Power-Circuit Isolating Means

Externally-operable gang-operated medium-voltage isolating means with position indication shall be included and shall be capable of interrupting the no-load current of the control-circuit transformer supplied with the controller. The isolating means shall be permitted to be any one of the following:

a. Three-pole isolating switch

b. Three-pole isolating switch in mechanical combination with current-limiting fuses

c. Drawout contactor

7.3 Interlocking

Interlocking shall be provided by mechanical means or by combination of mechanical and electrical means and shall provide the following features:

a. Prevent the isolating means from being opened or closed unless all contactors are open

b. Prevent the opening of a door to a medium-voltage compartment when the isolating means is closed

c. Prevent the isolating means from being closed when the door of any medium-voltage compartment of the controller is open

The reversing contactors of reversing controllers shall be electrically and mechanically interlocked. When required by the particular application, interlocking functions governed by current or voltage sensing, or other means, shall be provided to guard against creating a short circuit through arcs at the contacts.

Where required by the particular application, means shall be provided to permit locking the doors of medium-voltage compartments.

Where a dynamic-braking contactor of the normally-open type is used, the dynamic-braking contactor shall be mechanically or electrically interlocked with the related contactor or contactors. Where the dynamic-braking contactor is normally closed, it shall be mechanically interlocked with the related contactor or contactors.

Where a means for circumventing the interlock described in 7.3(b) is provided for inspection or maintenance purposes, some degree of difficulty shall be required to bypass the interlock. The degree of difficulty shall involve a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty.

7.4 Arrangement for Field Inspection

Where required for the particular application, provisions shall be made to operate the controllers for testing only, with the medium-voltage isolating means open. The interlocking shall be so arranged for this test that power cannot be applied to the motor. Also, the control circuit shall be disconnected from the normal control transformer and connected to a separate source of control power supplied by the user.

7.5 Equipment Protection

Medium-voltage Class E controllers shall be provided with the following protective features:

a. Under-voltage protection, or under-voltage release (two-wire control); except for latched contactors in special applications

b. A minimum of three motor-running overcurrent protective units

c. A control-circuit transformer provided with primary overcurrent protection. The transformer secondary shall be insulated from the primary and provided with an overcurrent device in each ungrounded leg to which control circuit devices, e.g., pushbuttons, limit switches, etc. are connected.

d. Primary overcurrent protection for instrument potential transformers where such transformers are supplied

e. For Class E1 controllers, instantaneous-fault overcurrent protection in each ungrounded conductor of the power supply in addition to the foregoing motor-running overload protection

f. For Class E2 controllers, power circuit fuses for interrupting faults exceeding operating overloads.

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8 Performance Requirements and Tests

8.1 Verification of Fault Interrupting Rating

Tests made to verify the interrupting rating of a Class E controller shall be made over the range of 2200–2500 volts, 3800–5000 volts, or 6200–7200 volts, as applicable, with an available symmetrical short-circuit MVA (megavoltamperes) at least equal to the interrupting rating of the controller. The tests shall be made in accordance with 8.1.1 through 8.1.6. During the test, the controller shall meet the performance requirements of 8.1.6 and 8.1.7.

Interrupting tests are intended to prove the interrupting performance of a given controller design and are not to be considered production tests.

8.1.1 Fault Interruption Test Circuit

The test circuit (see Figures 2-8-1 and 2-8-2), with the controller short-circuited at its line terminals, shall be capable of producing a three-phase short circuit with an MVA value at least equal to the interrupting rating of the controller. This MVA value is based on the average symmetrical current in the three phases (i.e., omitting any DC component). Also, the test circuit shall be capable of producing in one of the three phases a total rms current, including the DC component, not less than that shown in Table 2-8-1.

The test circuit shall be capable of producing currents not less than those indicated in Table 2-8-1 from the instant of initiation of the short circuit to the instant of interruption.

The test circuit shall be permitted to be ungrounded or neutral-grounded and include current-limiting reactors, resistors, and transformers in addition to the generating system. In setting up the test circuit, the leads between the reactors and the controllers shall be made as short as practicable so as to keep the capacitance to ground at the controller terminals small. No capacitance shall be added in the circuit.

Table 2-8-1
DC COMPONENT CONTRIBUTION

Time after Initiation of Short Circuit, (Cycles at 60 hertz)	Ratio of Total RMS Current in the Phase with the Maximum DC Component to the RMS Symmetrical Current Corresponding to the Interrupting Rating
1/2	1.6
1	1.4
2	1.2
3	1.1
4 or more	1.0

The normal-frequency recovery voltage shall be not less than the rated voltage of the controller when measured in accordance with IEEE Standard C37.09.

8.1.2 Power Factor of Fault Interruption Test Circuit

The power factor of the test circuit shall not exceed 15 percent lagging. The power factor shall be determined from the design constants of the generator and the measured AC resistance and reactance of the remainder of the circuit, from oscillograph records, or by any other appropriate method.

8.1.3 Fault Interruption Test Preparation

a. Calibration of Test Circuit—The test circuit described in 8.1.1 shall be used for the test. In order to obtain the total rms current specified, it may be necessary to use a larger symmetrical component than that corresponding to the symmetrical interrupting rating in MVA.

   The circuit shall be tested and oscillograms shall be taken to record the three line-to-line voltages to assure compliance with 8.1.1.

   Measurements of the currents shall be made on the calibration oscillograms at each of the time intervals specified in Table 2-8-1. The available symmetrical short-circuit test current in each phase shall be the AC component as determined by drawing the envelope of the current wave, measuring the peak-to-peak values at the appropriate instant, and dividing them by 2.828 as illustrated in IEEE Standard C37.09.

b. Controller Test Circuit—The controller test circuit shall be identical to the calibration test circuit, except that the short circuit shall be placed at the load terminals of the controller, and the short circuit shall be interrupted by the controller.

c. Grounding of Controller and Test Circuit—The controller structure shall be grounded through a 3-ampere fuse or smaller of appropriate voltage rating.

d. Size of Fuses Used in Test—Class E2 controllers shall be tested with fuses of the highest current rating for which the controller is intended to be used.

8.1.4 Measurements to Be Taken During the Fault Interruption Test

Measurements shall be made by oscillograph unless otherwise specified in the following paragraphs. Data giving the voltage and current values of the circuit and a description of the operation of the controller during and after the test shall be prepared.

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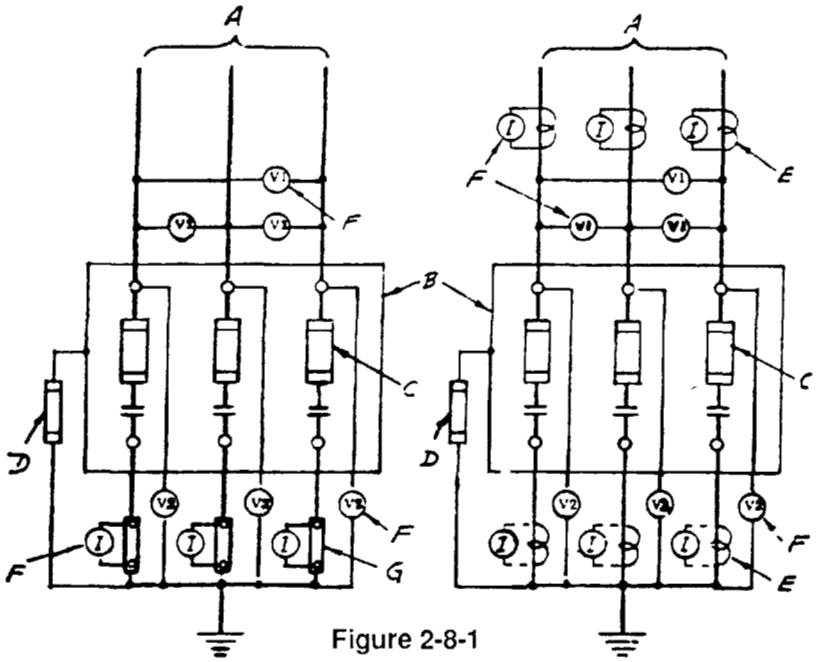


Figure 2-8-1
UNGROUNDED SUPPLY TEST CIRCUIT

A = Power supply (current-limiting reactors, resistors or transformers are not shown)

B = Controller under test

C = Main fuses (omitted in test of Class E1 controller)

D = 3-ampere 5000-volt fuse

E = Current transformers (alternate location shown by dotted lines)

F = Oscillograph elements

G = Current shunts

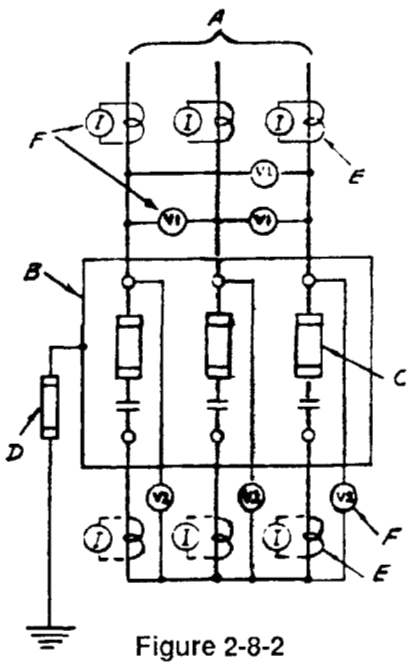


Figure 2-8-2
NEUTRAL-GROUNDED SUPPLY TEST CIRCUIT

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Data to be recorded during the test shall include the following information:

a. Measurements to be made in calibrating the test circuit:
   1. Open-circuit line-to-line voltages of all three phases by voltmeter or oscillograph immediately before the short circuit is created
   2. Short-circuit current in each line
b. Measurements to be made with the controller in the circuit:
   1. Line-to-line voltages (V1) of all three phases before the short circuit is created
   2. Voltage, V2, between controller line and load terminals before, during, and immediately following the short circuit
   3. Currents through controller during the test

8.1.5 Fault Interruption Test Cycle

A Class E controller shall be subjected to a test cycle consisting of a specified number of unit operations at stated intervals. A unit operation consists of a closing, followed immediately by an opening, of the circuit without purposely delayed action. This operation is designated by the letters CO signifying closing, then opening. Random switching shall be used.

8.1.5.1 Class E1 Controllers

The test cycle of a Class E1 controller shall be three CO unit operations at intervals of 2 minutes.

8.1.5.2 Class E2 Controllers

The test cycle of a Class E2 controller shall be three CO unit operations separated by the interval required to renew the fuses, to inspect and, if necessary, replace any renewable contacts. Replacement of a vacuum, or any other sealed type interrupter is not permitted.

8.1.6 Interrupting Performance

The controller shall interrupt the short-circuit current, including any DC component.

At the end of any test cycle, the controller shall be in the following condition:

a. The controller, with the exception of the blowing of power circuit fuses, shall be in substantially the same mechanical condition as at the beginning of the test.
b. The controller shall be capable of withstanding rated voltage in the open position and of carrying rated current at rated voltage for a limited time but not necessarily without exceeding the rated temperature rise. After a test cycle at or near its interrupting rating, it is not to be inferred that the controller can again meet its interrupting rating without minor repairs such as the replacement of contacts.
c. A controller shall perform without the emission of flame or oil from its enclosure. For Class E2 controllers the welding of contacts under the specified test duty cycle shall not be considered a failure. For Class E2 controllers, it is not necessary for the contacts to remain closed during the interrupting cycle.
d. The 3-ampere fuse between the controller enclosure and ground shall not have opened.

8.1.7 Fault Withstandability

A Class E controller shall withstand, without damage, except as noted in 8.1.6 (c), the thermal and electromagnetic effects imposed on it during the interval which the controller requires to open a short circuit on a system having the available short-circuit MVA at which the controller is rated.

8.2 Basic Impulse Insulation Level (BIL) Tests

Impulse dielectric tests on the controller medium-voltage circuits shall be made with a full wave in accordance with IEEE 4.

The impulse dielectric test is intended to prove the Basic Insulation Level (BIL) rating of a given controller design and is not to be considered a production test.

The impulse dielectric tests are independent of the interrupting tests, and a controller is not required to meet the impulse dielectric tests after being subjected to interrupting tests.

8.2.1 Impulse Test Voltage

Securing adequate insulation surge voltage protection depends upon a combination of good design practices with the selection of appropriate surge voltage protective devices. Manufacturers shall be permitted to assign one of two levels of surge voltage withstandability.

The choice between Level A and Level B is made by considering the likely degree of exposure to lightning surge voltage, the type of system grounding, and the type and location of any surge arrester on the source side.

Incoming surge voltages should be evaluated considering wave form variations and reflections. For approximating a worst case peak voltage, multiply the sparkover voltage of the surge arrester by 260 percent.

For a proper protective margin, the test voltage from Table 2-8-2 should be at least 20 percent more than the calculated worst case of incoming overvoltage.

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Table 2-8-2
IMPULSE TEST VOLTAGE

Controller Rating Line-to-Line rms Voltage	Impulse Test Voltage, Test 1 and 2		Peak Kilovolts Test 3*	
	Level A	Level B	Level A	Level B
2001–3600	30	45	33	49.5
3601–7200	45	60	49.5	66

* See 8.2.2 for reduction of the test voltage where the isolating means has provision for automatically grounding its load side when in the fully-opened position.

Table 2-8-3 shows example calculations for approximating a worst case of incoming overvoltage with resultant multipliers leading to the selection of Level A and Level B BIL rated equipment.

8.2.2 Impulse Test Sequence

a. *Test 1*: With the controller bus installed, the isolating means closed, the medium-voltage motor circuit fuses (in case of Class E2 controllers) and control circuit fuses in place, and the contactor in the open position, the impulse test voltage shall be applied between each electric circuit and grounded metal parts, and between each principal electric circuit and all other principal circuits, except that the impulse voltage need not be applied across the open gap of the contactor.

b. *Test 2*: Test 1 shall be repeated except that the contactor shall be closed.

c. *Test 3*: With the isolating means open, the impulse voltage shown in Table 2-8-2 for Test 3 shall be applied in each phase individually between the contacts of the isolating means across the isolating gap. Where the isolating means has provision for automatically grounding its load side when in the fully opened position, the test voltage shall be the value specified for Tests 1 and 2.

8.2.3 Test Procedure

The test samples shall be subjected to the sequence of tests described above. In each of these tests, three positive and three negative impulses shall be applied to each phase individually without causing disruptive damage or flashover.

Exception No. 1. If flashover occurs on only one test during any group of three consecutive tests, three more tests shall be made. If the equipment successfully withstands all three of the second group of tests, the flashover in the first group shall be considered as a random flashover and the equipment shall be considered as having successfully completed the test.

Exception No. 2. Flashover may occur at an integrally mounted surge arrester.

Dry-type core and coil assemblies, such as reduced-voltage-starting reactors and autotransformers and control-circuit transformers, are to be disconnected for this test.

8.3 Power Frequency Dielectric Voltage Withstand Test

8.3.1 General

A Class E controller shall be capable of withstanding for 1 minute without breakdown the application of a 60 hertz essentially sinusoidal potential as indicated in Table 2-8-4 in the following cases:

a. Between uninsulated live parts of each electric circuit and the grounded metal parts with the controller contacts both open and closed

b. Between uninsulated line parts of each medium-voltage circuit and all other medium-voltage circuits

c. Between terminals of opposite polarity with the controller contacts closed

d. Across the open contacts of the power circuit isolating means

A transformer, a coil, or a similar device normally connected between lines of opposite polarity shall be disconnected from one side of the line during test between terminals of opposite polarity, item c.

Where a controller includes a meter or meters, such instruments shall be disconnected from the circuit. The meter or meters shall be tested separately for dielectric voltage withstand, with an applied potential of 1000 volts in the case of an ammeter, and 1000 volts plus twice rated voltage in the case of any other instrument applied at line voltage. The test voltage shall be applied between live parts and the mounting panel, including the meter face and zero adjuster.

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Table 2-8-3
EXAMPLE CALCULATIONS FOR WORSE–CASE INCOMING OVERVOLTAGE

V Line-to-Line = 4.16kV (Grounded System)

Type of Lightning Arrester	Arrester Continuous Voltage (kV-rms)	Max Discharge Voltage of Arrester* (kV Crest)	Arrester Discharge Voltage ×2.6** (kV Crest)	Value of Column No. 4 ×1.2† (kV Crest)	Required Equipment BIL Level
Station	2.54	6.4	16.6	20	Level A (45KV)
Intermediate	2.54	9.9	25.7	31	Level A (45KV)
Distribution	3.00	11.0	28.6	34.3	Level A (45KV)

V Line-to-Line = 4.16kV (Ungrounded System)

Type of Lightning Arrester	Arrester Continuous Voltage (kV-rms)	Max. Discharge Voltage of Arrester* (kV Crest)	Arrester Discharge Voltage ×2.6** (kV Crest)	Value of Column No. 4 ×1.2† (kV Crest)	Required Equipment BIL Level
Station	4.20	10.4	27.0	32.0	Level A (45KV)
Intermediate	4.50	15.0	39.0	46.8	Level B (60KV)
Distribution	4.50	17.0	44.2	53.0	Level B (60KV)

* Typical data for selected arrester.

** Allowance for wavefront variations and reflected wave.

† Additional allowance for temperature, humidity, aging, and contamination of insulation.

8.3.2 Test Procedures

Test procedures shall be in accordance with Clause 8 of ICS 1 except for points of application (see above).

The controller shall be tested by means of a 500 volt-ampere or larger capacity transformer, whose output is essentially sinusoidal and can be varied. For definition of the applied wave shape see IEEE 4.

Care should be taken not to apply a test voltage across the open contacts of a vacuum interrupter that exceeds the manufacturer's recommendation, to avoid generating harmful x-rays.

8.3.3 Relation to BIL Rating

Power frequency dielectric tests are related to basic impulse insulation (BIL) levels. See Clause 8 of ICS 1.

8.4 Temperature Test

Temperature tests shall be conducted in accordance with Clause 8 of ICS 1.

8.5 Range of Operating Voltage Test

AC contactors shall withstand 110 percent of their rated voltage without injury to the operating coils and shall close successfully at 85 percent of their rated voltage.

For the test at 110 percent of rated control voltage, the operating coil shall be energized at 110 percent of rated control voltage until constant temperature is reached and then tested immediately to demonstrate that full closure results when rated control voltage is reapplied.

For the test at 85 percent of rated control voltage, the operating coil shall be energized at rated control voltage until constant temperature is reached and then tested immediately to demonstrate that full closure results when 85 percent of rated control voltage is applied.

Where the contactors of an AC controller are operated from the secondary of a control-circuit transformer which has its primary winding connected to the controller supply circuit, the controller shall operate successfully at 90 percent of rated primary voltage.

8.6 Make and Break Capability

8.6.1 Basic Requirement

A contactor that is part of a class E controller shall be capable of making and breaking the maximum current at which the overload relays alone cause current interruption (cross-over current). The cross-over point shall be determined from the characteristic curves of the overload relays and the total clearing time curves of the medium-voltage circuit fuses.

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Table 2-8-4
POWER FREQUENCY DIELECTRIC TEST VOLTAGES

Voltage Rating Volts (rms)	Test Voltage (rms)
0–600	1000 volts + (2 × nominal voltage rating)
601–7200	2000 volts + (2-1/4 × nominal voltage rating)

8.6.2 Procedure

To determine compliance a contactor shall be subjected to ten make and break operations at the crossover current or ten times the continuous current rating of the contactor whichever is greater. The operations shall be conducted in a single continuous test without intervening maintenance or service.

a. The contactor shall be operated at the rate of one operation per minute for contactors rated 400 amperes and less, and one operation per five minutes for contactors rated greater than 400 amperes, with an ON time of not less than 0.1 seconds. The test may be conducted at a faster rate if agreeable to those concerned.

b. Except as indicated above, the conditions for this test shall be the same as for the overload test described in 8.8.

c. This test shall be permitted to be performed on a separate sample, or in combination with the overload test described in 8.8.

8.6.3 Test Criteria

When the make and break test is performed on a separate sample, the contactor shall be in substantially the same mechanical condition at the conclusion of the test as at the beginning and shall be capable of withstanding applied dielectric test voltages except that the applied test voltage shall be two times the rated voltage. The ground fuse shall not have opened.

8.6.4 Combined Test

When the make and break test is combined with the overload test, the first ten operations shall be performed in accordance with 8.6.1 and 8.6.2. The remaining 40 operations (without the contactor being serviced) shall be performed in accordance with 8.8

8.7 Short-Time Capability

A new Class E contactor or controller shall be capable of meeting the short-time capability requirements shown below at 15 times rated current for 1 second and six times rated current for 30 seconds.

Separate tests shall be conducted to establish short-time operating capability and short-time surge capability. The test current shall be passed through the closed contacts for the specified period of time, and must be supplied at a voltage sufficient to maintain the current. At the end of the tests:

a. The motor controller must be capable of withstanding the dielectric tests described in ICS 1.

b. The contacts must be capable of being opened by normal operation.

For Class E2 controllers, the power circuit fuses shall be shunted during these tests.

A separate source of power may be supplied to the coils of magnetically operated devices.

8.8 Overload Test

8.8.1 Overload Test Procedure—General

A contactor shall be capable of making and breaking six times its rated continuous current for 50 operations in a continuous test, without intervening maintenance or servicing. When combined with the make and break test see 8.6.4.

The test shall be performed at the rated maximum voltage and a lagging power factor not greater than 0.35. The open-circuit voltage of the supply circuit shall be not less than 100 percent of the rated maximum voltage of the controller.

The closed-circuit voltage is not specified, but the normal-frequency recovery voltage shall be not less than the rated voltage of the controller when measured in accordance with ANSI/IEEE C37.09. Circuit characteristics shall be determined using either laboratory type meters or oscillographic means. When oscillographic means are employed, the method indicated in ANSI/IEEE C37.26 shall be used for determining power factor.

The controller shall be mounted with the door or cover closed. Any other openings, except intentional ventilation openings, shall be closed.

Open contactors shall be mounted in an enclosure whose dimensions shall be permitted to be approximately 150 percent of the dimensions of the contactor, or the contactor shall be permitted to be mounted in an enclosure whose dimensions are representative of the size enclosure in which the contactor will be mounted in actual service.

The controller structure and enclosure shall be grounded through a 3 ampere or smaller fuse of appropriate voltage rating or the equivalent, connected as shown in Figure 2-8-1 or 2-8-2.

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The controller shall be connected as shown in Figure 2-8-1 or 2-8-2. All or part of the limiting impedance shall be permitted to be connected on the load side. The test circuit shall be permitted to include current-limiting reactors, resistors and transformers in addition to the generating system. No capacitance shall be added in the circuit. The medium-voltage motor-circuit fuses shall be permitted to be shunted or replaced with dummy fuses.

In setting up the test circuit, the leads between the reactors and the controller should be made as short as practicable so as to keep the capacitance to ground at the controller terminals small.

Reactive components shall be permitted to be paralleled if of the air-core type but no reactance shall be connected in parallel with resistance except that an air-core reactor in any phase shall be permitted to be shunted by resistance, the volt-ampere loss of which is approximately 0.6 percent of the reactive volt-amperes in the air-core reactor in that phase.

The shunting resistance used with an air-core reactor having negligible resistance may be calculated from the formula:

$$R = 167\frac{E}{I}$$

where E is the voltage across the air-core reactor with current I flowing as determined by oscillographic measurement during the short-circuit calibration or, by proportion, from meter measurements at some lower current.

The controller shall be operated at the rate of one operation per minute. These operations shall be permitted to be conducted in groups of five with 15 minutes maximum OFF time between groups. During each operation the ON time shall be not less than four electrical cycles before contact parting commences as determined by oscillographic or equivalent measurements.

8.8.2 Overload Test Procedure—Reversing Controllers

For a reversing controller, the ON period shall consist of a forward operation immediately followed by a reverse operation.

The ON time for each total operation (forward operation and reverse operation) shall be as specified above.

Where the reversing circuit arrangement is such that both operating coils can be energized simultaneously, ten additional test cycles of operation shall be conducted with both coils energized simultaneously.

8.8.3 Overload Test Criteria

At the conclusion of the overload test, the controller shall be in substantially the same mechanical condition as at the beginning and the medium-voltage circuit fuses, if used, and the ground circuit fuse specified in 8.7.1 shall not have opened.

8.9 Production Tests

8.9.1 Power Frequency Dielectric Test

Production dielectric tests on controllers shall be made at power frequency in accordance with Clause 8 of ICS 1 except for points of application which shall be in accordance with 8.3.1.

9 Application

9.1 Typical Methods of Motor Starting

Typical methods of starting AC motors are shown in Figures 2-9-1 through 2-9-4. An "X" in the contactor sequence chart indicates closed contacts. The "DC FIELD" shown applies only to synchronous motors. For additional information on controllers for synchronous motors see Part 3.

9.2 Determination of Motor Starting Current

The starting current values for the various methods of motor starting shown in Figures 2-9-1 through 2-9-4 may be determined as follows.

9.2.1 Full-Voltage Starting (Figure 2-9-1)

The starting current is equal to the locked-rotor current at full voltage.

9.2.2 Resistor or Reactor Reduced-Voltage Starting (Figure 2-9-2)

The starting current is determined from the sum of the impedances of the starting reactor or resistor and of the motor under locked-rotor conditions.

9.2.3 Autotransformer Reduced-Voltage Starting (Figure 2-9-3)

The starting current drawn from the line is

$$I \times p^2 + 0.25\ I_m$$

The starting current taken by the motor is

$$I \times p$$

The autotransformer neutral current is

$$I \times p - (I \times p^2 + 0.25\ I_m)$$

Where:

I = Locked-rotor amperes at full voltage

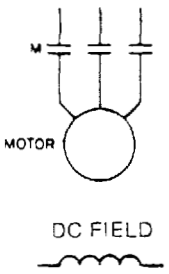
p = Transformer tap used (fraction of full voltage)

I_m = Rated full-load current of the motor. The term "0.25 I_m" is introduced to allow for transformer magnetizing current.

9.2.4 Part-Winding Starting (Figure 2-9-4)

The starting current is the locked-rotor current of the motor connected for starting.

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CONTACTOR SEQUENCE	
CONTACTOR	START AND RUN
M	X

Figure 2-9-1
FULL-VOLTAGE STARTING
(DC field is applicable only to synchronous motors.)

9.3 Coordination with Power Systems

9.3.1 Considerations

In applying medium voltage equipment consideration should be given by the user to coordination with upstream equipment, including, but not limited to:

a. The range of system voltage to which the equipment will be connected

b. Maximum available fault current of the system at the point of installation of the controller

c. The anticipated connected load, i.e., motor starting and full-load currents, motor acceleration time, and motor starting method (full-voltage or reduced-voltage)

d. Upstream protection devices and settings

e. Lightning and switching surges

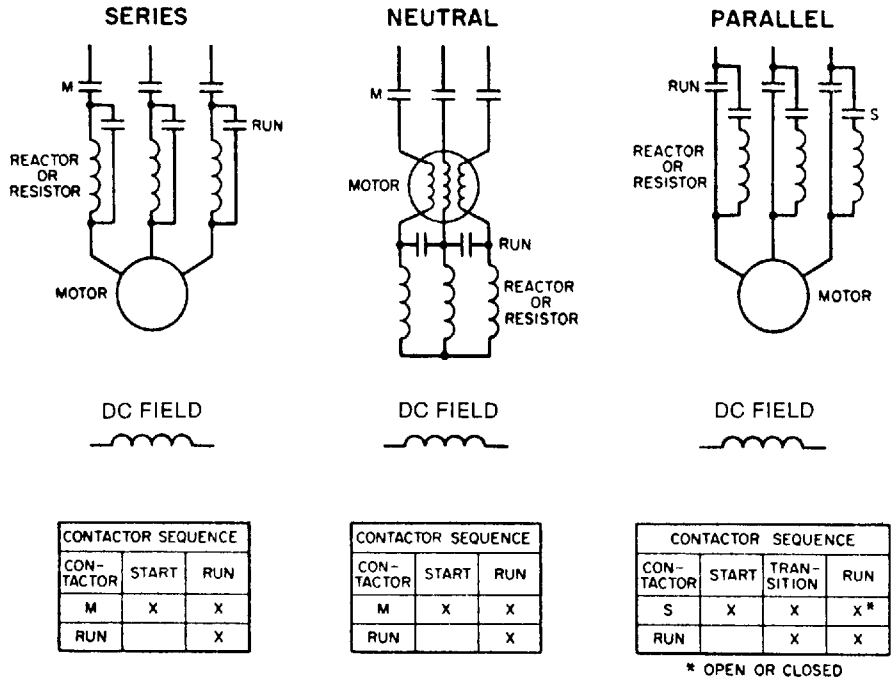
9.3.2 Voltage Coordination With Upstream Devices

The controller should have a continuous voltage rating at least as high as the highest system voltage to which it will be connected. For information on coordination of Basic Insulation Level (BIL) rating, see 8.2.1. For more BIL information on the application of surge arresters to safeguard electric power equipment against the hazards of abnormally high voltage surges of various origins, see ANSI/IEEE C62.2 and ANSI/IEEE Standard 141.

9.3.3 Current Coordination With Upstream Devices

The controller, as installed, should have a short-circuit rating at least as high as the available fault capacity of the system to which it is connected. For power system integrity the overcurrent protection characteristics of the controller should coordinate with the upstream equipment.

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CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE		
CON-TACTOR	START	RUN
M	X	X
RUN		X

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
S	X	X	X*
RUN		X	X

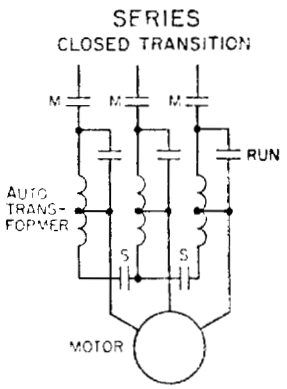
* OPEN OR CLOSED

Figure 2-9-2
REDUCED-VOLTAGE REACTOR OR RESISTOR STARTING
(DC field is applicable only to synchronous motors.)

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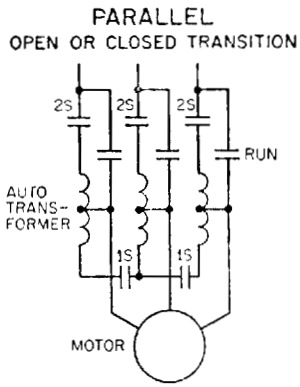
THREE-COIL TRANSFORMER



A

CONTACTOR SEQUENCE			
CON TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X

CLOSED TRANSITION

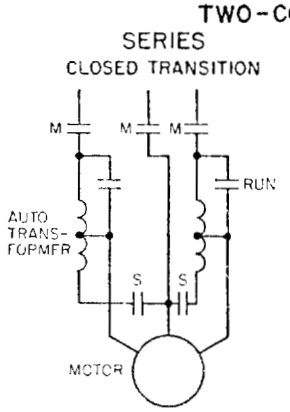


B

CONTACTOR SEQUENCE					
CON - TACTOR	START	OPEN TRAN-SITION	CLOSED TRAN-SITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

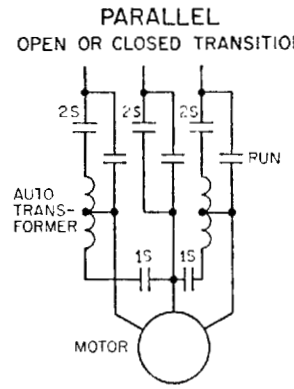
FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

TWO-COIL TRANSFORMER



C

CONTACTOR SEQUENCE			
CON-TACTOR	START	TRAN-SITION	RUN
M	X	X	X
S	X		
RUN			X



D

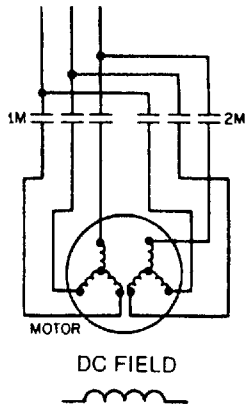
CONTACTOR SEQUENCE					
CON - TACTOR	START	OPEN TRAN-SITION	CLOSED TRAN-SITION		RUN
			1	2	
1S	X				
2S	X		X	X	
RUN				X	X

FOR OPEN TRANSITION 1S AND 2S MAY BE CONTACTS OF SAME CONTACTOR

Figure 2-9-3
REDUCED-VOLTAGE AUTOTRANSFORMER STARTING
(DC field is applicable only to synchronous motors.)

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CONTACTOR SEQUENCE		
CONTACTOR	START	RUN
1M	X	X
2M		X

Figure 2-9-4
PART-WINDING STARTING
(DC field is applicable only to synchronous motors.)

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Part 3
AC GENERAL-PURPOSE CONTROLLERS FOR SYNCHRONOUS MOTORS

1 General

1.1 Scope

This part applies to AC magnetic controllers for use with synchronous motors rated up to 7200 volts, 50 and 60 hertz.

1.2 Normative References

The definitions and standards of NEMA Standards Publication No. 250, ICS 1 and ICS 6 also apply to this part.

2 Definitions

For the purposes of this part, the following definitions apply:

(* indicates definition form ANSI/IEEE Standard 100)

brushless exciter:* An alternator-rectifier field exciter employing rotating rectifiers with a direct connection to the synchronous machine field winding, thus eliminating the need for field brushes.

field exciter:* The source of all or part of the field current for the excitation of an electric machine.

3 Classifications

3.1 Field Exciters

Synchonous motor field exciters are either of the brush or brushless type. Brushless type feed DC into the field winding of the motor without the use of brushes. Brush type exciters feed DC into the field winding of the motor via brushes and slip rings.

4 Characteristics and Ratings

For synchronous motor controllers rated 2001–7200 volts see Part 2. There are no standard ratings for low-voltage synchronous motor controllers.

5 Product Marking, Installation and Maintenance Information

See ICS 1.3 for preventative maintenance instructions.

6 Service and Storage Conditions

Clause 6 of ICS 1 applies.

7 Construction

7.1 General

Each synchronous motor controller shall include the following components:

a. One START and STOP pushbutton station integrally mounted on enclosed controllers. Provision for connecting one separately mounted START and STOP pushbutton station when required by the particular application

b. Necessary current transformers

c. Alternating current line ammeter

d. Unless integral to the machine, means which automatically applies field excitation at the proper time

e. In the case of a separately excited machine, a DC ammeter.

7.2 Protection Means

Unless integral to the machine, protective functions for synchronous motor controllers shall be as follows:

a. Means to automatically remove field excitation in event of pull-out

b. When required by the particular application, field loss protection shall be included to disconnect the motor from the line in the event of excitation failure.

Field loss protection is recommended for motors provided with controllers arranged for re-synchronizing when pull-out conditions are encountered.

c. Means to protect the field against excessive induced voltage during normal operation out of synchronism

d. Means to protect the squirrel-cage windings during operation out of synchronism

e. Means to automatically disconnect the motor from the line in case of pull-out, when required by the particular application.

f. Three motor running overcurrent (overload) protective units unless the motor, the motor control apparatus, and the branch circuit conductors are otherwise adequately protected.

g. Instantaneous undervoltage protection. When required by the particular application, time-delay undervoltage protection shall be included in lieu of instantaneous undervoltage protection.

h. When required by the particular application, the DC control bus supplying field excitation shall have a suitable two-pole disconnect

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means and short-circuit protection. Field discharge means shall be permanently connected across the load side of this protective device and disconnecting means.

7.3 Additional Features

When required by the application additional features may include the following:

a. Dynamic-braking contactor(s) shall be normally open and magnetically closed or normally closed and magnetically opened, and mechanically or mechanically and electrically interlocked with the line contactor(s).

b. Dynamic braking, when provided for emergency stopping, shall be effective under all normal conditions of operation and for all stops.

CAUTION—Dynamic braking will be ineffective under conditions of field failure.

c. Provision for connecting a two-pole emergency STOP switch. When tripped, this switch shall open both sides of the control circuit. This shall not hamper the conditions of paragraph b).

d. Means to prevent restarting of the motor during an emergency stop until the dynamic-braking cycle has been completed and field excitation removed.

e. Drilling for exciter field rheostat.

f. Mounting provision for a tapped resistor for the motor field.

g. Means to re-synchronize in event of pull-out.

h. An exciter rectifier unit for the motor field.

8 Performance and Tests

This part contains no performance and test requirements

9 Application

This part contains no application information.

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SUPPLEMENT 1
SCOPE OF THE INDUSTRIAL CONTROL AND SYSTEMS SECTION

The NEMA Standards Publications for Industrial Control and Systems cover the requirements for all industrial control apparatus except as modified below. These standards cover all devices, whether electric, magnetic, mechanical, or electronic (except those devices intended specifically for marine auxiliaries and propulsion control apparatus, mine locomotive control apparatus, and railway and railroad locomotion) which, individually or grouped, serve to govern in some predetermined manner the electric power delivered to the apparatus to which they are connected, and which are intended to function on commercial voltages of 750 volts or less, direct current and 7200 volts or less, alternating current.

Industrial Control and Systems Section equipment comprises, but is not limited to, mechanical, electromechanical and solid state devices, components, and controls.

The equipment is principally used in industrial applications for the control, or regulation, or both, of power utilization apparatus, including motors. Such equipment is rated not more than 750 volts DC or 7,200 volts AC.

These devices, components, and controls may be arranged to include one or more feedback loops. Functional elements in such arrangements include, sensors, programmable controllers, operational amplifiers, encoders, tape readers, gauging equipment and computer elements. Computer elements for the readout, logging, processing, and programming input and monitoring output of data may or may not be in the feedback loop. Devices, components and controls so arranged are used in functions such as:

a. Computer control of machines
b. Industrial process regulation
c. Integrated mill control
d. Energy management
e. Emergency and standby power control
f. Control of the cogeneration of electric power

The Industrial Control and Systems Section scope specifically includes, but is not limited to, products principally used:

a. To start, stop, protect, accelerate, decelerate, reverse, or control the speed of electric motors.
b. To automatically disconnect, connect, or transfer all classes of loads fed by primary or alternate power sources.
c. To provide some mechanical movement through the action of magnets or solenoids.
d. To start, stop and control AC or DC adjustable speed drives, whether unregulated, regulated, or automatically regulated, including semiconductor power converters and inverters for adjustable speed drives, and providing such functions as: regulating speed, tension, current, frequency and voltage.
e. To start, stop and control the function and operation of machine tools, including feedback control and speed, position and torque.
f. To start, stop and control the operation of automatic warehouses, including control of conveyors, stackers, and the like.
g. To start, stop and control the operation of cranes and hoists.
h. To start, stop and control the operation of AC motors applied to fans, pumps, and blowers, including provision for feedback control of speed by sensors such as for temperature, flow, and pressure.
i. To control the management of energy under normal and emergency conditions including peak load shaving.
j. To control generator equipment used in dispersed power generation systems for cogeneration, emergency, or stand-by electric power.

Also included, but not limited to, are:

a. Motor controllers
b. Motor control centers
c. Medium-voltage controllers
d. Programs and related documentation making up the software that is furnished with programmable devices for industrial control and systems equipment
e. Register and synchronizing controls
f. Digital display devices
g. Analog-digital convertors and transducers
h. Programmable controllers
i. Functional elements of systems, such as:
   Operational amplifiers
   Computer elements
   Encoders
   Tape readers
   Sensors

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Man-machine interface devices

Gaging equipment

j. Renewal parts for Industrial Control and System products.

Examples of Industrial Control and System products are:

a. Manual, magnetic and solid-state (static) starters and controllers

b. Relays and contactors

c. Automatic transfer switches and controllers, and associated by-pass isolation switches

d. Drum switches

e. Overload devices intended primarily for the starting and running protection of electric motors, including inherent overload protective devices

f. Rheostats and resistors

g. Autotransformers and reactors of the type principally used in reduced-voltage starters

h. Control-circuit and pilot devices including, but not limited to, timers, pushbuttons, indicating (pilot) lights, solenoids, photoelectric relays, and plugging switches, speed switches, domestic water pump pressure switches

i. limit, pressure, vacuum, temperature and liquid-level switches.

j. AC and DC brakes, clutches, and electrical operators

k. Resistance dimmers, autotransformer dimmers, reactor dimmers, and solid-state (static) dimmer systems

l. Solid-state logic devices

m. Control panels for machine tool and similar machines

n. Terminal blocks of the molded barrier or sectional type and terminal strips used for the connection of conductors, electrical and electronic circuits and equipment. These include, but are not limited to, terminal blocks using, wire binding screws, pressure wire connectors, stud and nut, quick connect, solder lug, and solderless wrapped terminations, and terminal blocks which incorporate fuse holders, test/disconnect features, indicator lamps, diodes, etc.

o. Automatically regulated adjustable speed drive systems such as: rolling mill drives, paper mill drives, slasher drives

p. Programmable controllers and their accessories devices used for the supervision, or control or command of industrial machines and processes Exclusions:

Excluded from the product scope are:

a. Specific components and systems covered by the product scopes of other NEMA sections

b. Automatic and manual temperature and humidity controls and panels that are in the scope of the Residential Controls Section of the types principally used in air conditioning, refrigeration, and comfort heating of nonindustrial areas

c. Motors, generators and motor-generators, which function as control when constituting part of adjustable speed drives.

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NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

Categories of Standards

National Electrical Manufacturers Association Standards are of three classes, which have received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture.
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development.
3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

Identification of Status

Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

The material identified as "Authorized Engineering Information" is designated similarly. Statements incorporating other auxiliary verbs such as "should," "may," etc. refer to the authorized engineering information and not to procedures required for compliance with the standard.

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INDUSTRIAL CONTROL AND SYSTEMS SECTION OF THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

ABB Control, Inc.
Wichita Falls, TX 76306

AEG Automation
Systems Corporation
Pittsburgh, PA 15238-0830

Allen-Bradley Company
Milwaukee, WI 53204

Amerace Electronic Components
Punta Gorda, FL 33950

Automatic Switch Company
Florham Park, NJ 07932

Balluff, Inc.
Florence, KY 41042

USD Products
Bussman, Div. of Cooper Ind.
Chicago, IL 60656

CEGELEC Automation Inc.
Macon, GA 31206

Challenger Electrical Equipment Corp.
Raleigh, NC 27609

Eaton Corporation
Cutler Hammer Products
Milwaukee, WI 53216

Electrical Power Systems Inc.
Tulsa, OK 74131

Electro Switch Corporation
Weymouth, MA 02189-2103

Elliott Control Company
Hollister, CA 95024-1329

Emerson Electric Company
Grand Island, NY 14072

Entrelec, Inc.
Irving, TX 75038-4312

Firetrol, Inc.
Cary, NC 27512

Furnas Electric Company
Batavia, IL 60510

GE
Plainville, CT 06062

General Equipment & Manufacturing
Company, Inc.
Louisville, KY 40213

Gettys Corporation
Racine, WI 53404

Giddings & Lewis, Inc.
Fond du Lac, WI 54936-1658

Halmar Robicon Group
Pittsburgh, PA 15239-2982

Harnischfeger Corporation
Milwaukee, WI 53215-1707

Honeywell, Inc.
Ft. Washington, PA 19034

Hubbell Incorporated
Madison, OH 44057

Joslyn Clark Controls, Inc.
Lancaster, SC 29720

Killark-Stahl, Inc.
St. Louis, MO 63115

Klockner Moeller Corporation
Franklin, MA 02038

Lexington Switch & Controls
Madison, OH 44057

Master Controls Systems, Inc.
Lake Bluff, IL 60044

Metron, Inc.
Denver, CO 80223

Micro Switch (Div. of Honeywell)
Freeport, IL 61032

Modicon Inc.
No. Andover, MA 01845

NAMCO Controls
An Acme Cleveland Corporation
Mentor, OH 44060

Omron Electronics, Inc.
Schaumburg, IL 60173

Onan Corporation
Minneapolis, MN 55432

OZ Gedney
Unit of General
Signal Corporation
Brooklyn, NY 11208

Pepperl + Fuchs, Inc.
Twinsburg, OH 44087

Phoenix Contact, Inc.
Harrisburg, PA 17111

Reliance Electric Company
Cleveland, OH 44117

Russelectric, Inc.
Hingham, MA 02043

Siemens Energy & Automation,Inc.
Alpharetta, GA 30201

Siemens Industrial Automation, Inc.
Johnson City, TN 37601

Square D Company
Palatine, IL 60067

R. Stahl, Inc.
Woburn, MA 01801

Texas Instruments, Inc.
Attleboro, MA 02703

Toshiba International Corporation
Houston, TX 77041

Turck, Inc.
Minneapolis, MC 55441-2656

Weidmuller Inc.
Richmond, VA 23236

Westinghouse Electric Corporation
Pittsburgh, PA 15220

Zenith Controls, Incorporated
Chicago, Il 60609

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