

**SECTION 26 29 11
MOTOR CONTROLLERS****PART 1 - GENERAL****1.1 DESCRIPTION**

- A. This section specifies the furnishing, installation, connection, and testing of motor controllers, including all low-voltage motor controllers and manual motor controllers, indicated as motor controllers in this section, and low-voltage variable speed motor controllers.
- B. Motor controllers, whether furnished with the equipment specified in other sections or otherwise (with the exception of elevator motor controllers specified in Division 14), shall meet this specification and all related specifications.

1.2 RELATED WORK

- A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS:
Requirements that apply to all sections of Division 26.
- B. Section 26 05 19, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES:
Low-voltage conductors.
- C. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS:
Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.
- D. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits.

1.3 QUALITY ASSURANCE

- A. Refer to Paragraph, QUALIFICATIONS (PRODUCTS AND SERVICES), in Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

1.4 SUBMITTALS

- A. Submit six copies of the following in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
 - 1. Shop Drawings:
 - a. Submit sufficient information to demonstrate compliance with drawings and specifications.
 - b. Include electrical ratings, dimensions, weights, mounting details, materials, overcurrent protection devices, overload relays, sizes of enclosures, wiring diagrams, starting characteristics, interlocking, and accessories.
 - 2. Manuals:

- a. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals, including technical data sheets, wiring diagrams, and information for ordering replacement parts.
 - 1) Wiring diagrams shall have their terminals identified to facilitate installation, maintenance, and operation.
 - 2) Wiring diagrams shall indicate internal wiring for each item of equipment and interconnections between the items of equipment.
 - 3) Elementary schematic diagrams shall be provided for clarity of operation.
 - 4) Include the catalog numbers for the correct sizes of overload relays for the motor controllers.
 - b. If changes have been made to the maintenance and operating manuals originally submitted, submit updated maintenance and operating manuals two weeks prior to the final inspection.
3. Certifications: Two weeks prior to final inspection, submit the following.
- a. Certification by the manufacturer that the motor controllers conform to the requirements of the drawings and specifications.
 - b. Certification by the Contractor that the motor controllers have been properly installed, adjusted, and tested.

1.5 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by basic designation only.
- B. Institute of Electrical and Electronic Engineers (IEEE):
 - 519-92.....Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
 - C37.90.1-02.....Standard Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
- C. International Code Council (ICC):
 - IBC-12.....International Building Code
- D. National Electrical Manufacturers Association (NEMA):

- ICS 1-08.....Industrial Control and Systems: General Requirements
- ICS 1.1-09.....Safety Guidelines for the Application, Installation and Maintenance of Solid State Control
- ICS 2-05.....Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 Volts
- ICS 4-05.....Industrial Control and Systems: Terminal Blocks
- ICS 6-06.....Industrial Control and Systems: Enclosures
- ICS 7-06.....Industrial Control and Systems: Adjustable-Speed Drives
- ICS 7.1-06.....Safety Standards for Construction and Guide for Selection, Installation, and Operation of Adjustable-Speed Drive Systems
- MG 1 Part 31.....Inverter Fed Polyphase Motor Standards
- E. National Fire Protection Association (NFPA):
 - 70-11.....National Electrical Code (NEC)
- F. Underwriters Laboratories Inc. (UL):
 - 508A-07.....Industrial Control Panels
 - 508C-07.....Power Conversion Equipment
 - UL 1449-06.....Surge Protective Devices

PART 2 - PRODUCTS

2.1 MOTOR CONTROLLERS

- A. Motor controllers shall comply with IEEE, NEMA, NFPA, UL, and as shown on the drawings.
- B. Motor controllers shall be separately enclosed, unless part of another assembly. For installation in motor control centers, provide plug-in, draw-out type motor controllers up through NEMA size 4. NEMA size 5 and above require bolted connections.
- C. Motor controllers shall be combination type, with magnetic controller per Paragraph 2.3 below and with motor circuit protector disconnecting means, with external operating handle with lock-open padlocking positions and ON-OFF position indicator.
 - 1. Motor Circuit Protectors:
 - a. Magnetic trip only.
 - b. Bolt-on type with a minimum interrupting rating as indicated on the drawings.

c. Equipped with automatic, adjustable magnetic trip. Magnetic trip shall be adjustable up to 1300% of the motor full load amperes.

D. Enclosures:

1. Enclosures shall be NEMA-type rated 1, 3R, or 12 as indicated on the drawings or as required per the installed environment.
2. Enclosure doors shall be interlocked to prevent opening unless the disconnecting means is open. A "defeater" mechanism shall allow for inspection by qualified personnel with the disconnect means closed. Provide padlocking provisions.
3. All metal surfaces shall be thoroughly cleaned, phosphatized, and factory primed prior to applying light gray baked enamel finish.

E. Motor control circuits:

1. Shall operate at not more than 120 Volts.
2. Shall be grounded, except where the equipment manufacturer recommends that the control circuits be isolated.
3. For each motor operating over 120 Volts, incorporate a separate, heavy duty, control transformer within each motor controller enclosure.
4. Incorporate primary and secondary overcurrent protection for the control power transformers.

F. Overload relays:

1. Electronic type. Devices shall be NEMA type.
2. One for each pole.
3. External overload relay reset pushbutton on the door of each motor controller enclosure.
4. Overload relays shall be matched to nameplate full-load current of actual protected motor and with appropriate adjustment for duty cycle.
5. Electronic overload relays shall utilize internal current transformers and electro-mechanical components. The relays shall have ambient temperature compensation, single-phase protection, manual or automatic reset, and trip classes of 10, 15, 20 and 30. The relay shall provide fault cause indication, including jam/stall, ground fault, phase loss, and overload.

G. Hand-Off-Automatic (H-O-A) switch is required unless specifically stated on the drawings as not required for a particular controller. H-

O-A switch shall be operable without opening enclosure door. H-O-A switch is not required for manual motor controllers.

- H. Incorporate into each control circuit a 120 Volt, electronic time-delay relay (ON delay), minimum adjustable range from 0.3 to 10 minutes, with transient protection. Time-delay relay is not required where H-O-A switch is not required.
- I. Unless noted otherwise, equip each motor controller with not less than two normally open (N.O.) and two normally closed (N.C.) auxiliary contacts.
- J. Provide green (RUN) and red (STOP) pilot lights.
- K. Motor controllers incorporated within equipment assemblies shall also be designed for the specific requirements of the assemblies.
- L. Additional requirements for specific motor controllers, as indicated in other specification sections, shall also apply.

2.2 MANUAL MOTOR CONTROLLERS

- A. Shall be in accordance with applicable requirements of 2.1 above.
- B. Manual motor controllers shall have the following features:
 - 1. Controllers shall be general-purpose Class A, manually operated type with full voltage controller for induction motors, rated in horsepower.
 - 2. Units shall include thermal overload relays, on-off operator, red pilot light, normally open auxiliary contacts.
- C. Fractional horsepower manual motor controllers shall have the following features:
 - 1. Controllers shall be general-purpose Class A, manually operated type with full voltage controller for fractional horsepower induction motors.
 - 2. Units shall include thermal overload relays, red pilot light, and toggle operator.

2.3 MAGNETIC MOTOR CONTROLLERS

- A. Shall be in accordance with applicable requirements of 2.1 above.
- B. Controllers shall be general-purpose, Class A magnetic controllers for induction motors rated in horsepower. Minimum NEMA size 0.
- C. Where combination motor controllers are used, combine controller with protective or disconnect device in a common enclosure.
- D. Provide phase loss protection for each controller, with contacts to de-energize the controller upon loss of any phase.

- E. Unless otherwise indicated, provide full voltage non-reversing across-the-line mechanisms, closed by coil action and opened by gravity. Equip controllers with 120 VAC coils and individual control transformer unless otherwise noted.

2.4 LOW-VOLTAGE VARIABLE SPEED MOTOR CONTROLLERS (VSMC)

- A. VSMC shall be in accordance with applicable portions of 2.1 above.
- B. VSMC shall be electronic, with adjustable frequency and voltage, three phase output, capable of driving standard NEMA B three-phase induction motors at full rated speed. The control technique shall be pulse width modulation (PWM), where the VSMC utilizes a full wave bridge design incorporating diode rectifier circuitry. Silicon controlled rectifiers or other control techniques are not acceptable.
- C. VSMC shall be suitable for variable torque loads, and shall be capable of providing sufficient torque to allow the motor to break away from rest upon first application of power.
- D. VSMC shall be capable of operating within voltage parameters of plus 10 to minus 15 percent of line voltage, and be suitably rated for the full load amps of the maximum watts (HP) within its class.
- E. Minimum efficiency shall be 95 percent at 100 percent speed and 85 percent at 50 percent speed.
- F. The displacement power factor of the VSMC shall not be less than 95 percent under any speed or load condition.
- G. VSMC current and voltage harmonic distortion shall not exceed the values allowed by IEEE 519.
- H. Operating and Design Conditions:
1. Elevation: 500 feet Above Mean Sea Level (AMSL)
 2. Temperatures: Maximum +90°F, Minimum -10°F.
 3. Relative Humidity: 95%
 4. VSMC Location: Non-Air conditioned space.
- I. VSMC shall have the following features:
1. Isolated power for control circuits.
 2. Manually resettable overload protection for each phase.
 3. Adjustable current limiting circuitry to provide soft motor starting. Maximum starting current shall not exceed 200 percent of motor full load current.

4. Independent acceleration and deceleration time adjustment, manually adjustable from 2 to 2000 seconds. Set timers to the equipment manufacturer's recommended time in the above range.
5. Control input circuitry that will accept 4 to 20 mA current or 0-10 VDC voltage control signals from an external source.
6. Automatic frequency adjustment from 1 Hz to 300 Hz.
7. Circuitry to initiate an orderly shutdown when any of the conditions listed below occur. The VSMC shall not be damaged by any of these electrical disturbances and shall automatically restart when the conditions are corrected. The VSMC shall be able to restart into a rotating motor operating in either the forward or reverse direction and matching that frequency.
 - a. Incorrect phase sequence.
 - b. Single phasing.
 - c. Overvoltage in excess of 10 percent.
 - d. Undervoltage in excess of 15 percent.
 - e. Running overcurrent above 110 percent (VSMC shall not automatically reset for this condition.)
 - f. Instantaneous overcurrent above 150 percent (VSMC shall not automatically reset for this condition).
 - g. Short duration power outages of 12 cycles or less (i.e., distribution line switching, generator testing, and automatic transfer switch operations.)
8. Automatic Reset/Restart: Attempt three restarts after VSMC fault or on return of power after an interruption and before shutting down for manual reset or fault correction, with adjustable delay time between restart attempts.
- J. VSMC shall include an input circuit breaker which will disconnect all input power, interlocked with the door so that the door cannot be opened with the circuit breaker in the closed position.
- K. VSMC shall include a 5% line reactor and a RFI/EMI filter.
- L. Surge Suppression: Provide three-phase protection against damage from supply voltage surges in accordance with UL 1449.
- M. VSMC shall include front-accessible operator station, with sealed keypad and digital display, which allows complete programming, operating, monitoring, and diagnostic capabilities.
 1. Typical control functions shall include but not be limited to:

- a. HAND-OFF-AUTOMATIC-RESET, with manual speed control in HAND mode.
 - b. NORMAL-BYPASS.
 - c. NORMAL-TEST, which allows testing and adjusting of the VSMC while in bypass mode.
2. Typical monitoring functions shall include but not be limited to:
 - a. Output frequency (Hz).
 - b. Motor speed and status (run, stop, fault).
 - c. Output voltage and current.
3. Typical fault and alarm functions shall include but not be limited to:
 - a. Loss of input signal, under- and over-voltage, inverter overcurrent, motor overload, critical frequency rejection with selectable and adjustable deadbands, instantaneous line-to-line and line-to-ground overcurrent, loss-of-phase, reverse-phase, and short circuit.
 - b. System protection indicators indicating that the system has shutdown and will not automatically restart.
- N. VSMC shall include two N.O. and two N.C. dry contacts rated 120 Volts, 10 amperes, 60 Hz.
- O. Hardware, software, network interfaces, gateways, and programming to control and monitor the VSMC by control systems specified in other specification sections, including but not limited to Divisions 22 and 23.
- P. Network communications ports: As required for connectivity to control systems specified in other specification sections, including but not limited to Divisions 22 and 23.
- Q. Communications protocols: As required for communications with control systems specified in other specification sections, including but not limited to Divisions 22 and 23.
- R. Bypass controller: Provide contactor-style bypass, arranged to bypass the inverter.
 1. Inverter Output Contactor and Bypass Contactor: Load-break NEMA-rated contactor.
 2. Motor overload relays.
 3. HAND-OFF-AUTOMATIC bypass control.
- S. Bypass operation: Transfers motor between inverter output and bypass circuit, manually, automatically, or both. VSMC shall be capable of

stable operation (starting, stopping, and running), and control by fire alarm and detection systems, with motor completely disconnected from the inverter output. Transfer between inverter and bypass contactor and retransfer shall only be allowed with the motor at zero speed.

- T. Inverter Isolating Switch: Provide non-load-break switch arranged to isolate inverter and permit safe troubleshooting and testing of the inverter, both energized and de-energized, while motor is operating in bypass mode. Include padlockable, door-mounted handle mechanism.

2.5 DV/DT OUTPUT FILTER FOR VSMC'S

- A. Basis of Design: TCI model V1K series selected for the specified Voltage and Horsepower ratings.
- B. The filter shall be specifically designed for applications where VSMC's are installed 100ft or greater from the load server by the VSMC. It shall suppress voltage wave reflections which are damaging to cabling, motors, and VSMCs.
- C. Shall consist of a gapped, three phase, iron core inductor; AC-rated, polypropylene capacitors and wire-wound resistors.
- D. The filter shall be rated for application at a maximum fundamental system frequency of 60Hz at nominal system voltages up to 600V.
- E. The filter shall operate at a maximum carrier frequency of 8kHz at 40% of fundamental voltage.
- F. The three phase inductors shall be designed for harmonic filtering service and for slowing the rate of rapid current changes. The inductors shall be UL component-recognized and shall be built to comply with UL 508A standard. Construction shall be of copper wire wound on magnetic grade steel. Inductors shall be sized appropriately for the total connected load. The design maximum temperature rise for reactors shall be 115° C or 155° C depending on frame size at rated current.
- G. Windings shall consist of copper wire or of copper foil. Terminations shall be copper alloy ring lugs, UL-recognized terminal blocks, or solid copper bus.
- H. Inductors shall be air-gapped to control saturation. Inductance shall be measured under full load and shall be within 10% of design value.
- I. Completed inductors shall be impregnated with 100% solid epoxy resin. All insulation varnish systems shall be rated class R (220° C) or H(180°C), 600V.

- J. Inductance shall remain above 50% of nominal for any overload up to 200% of rated current. Inductors shall not sustain any thermal damage for levels up to 150% of rated current for a minimum period of five minutes. Inductors shall be Hi-Pot tested (2,640V, 60 Hz, 1 second) line-to-line and line-to ground.
- K. Capacitors shall be constructed of metallized polypropylene film material.
- L. Capacitors shall be Wye-connected and ungrounded neutral. Each capacitor element shall be rated at minimum of 700V AC.
- M. Resistors shall consist of wire-wound cement construction and incorporate thermal insulating terminations.
- N. Resistors shall be derated to operate at twice the calculated worst case requirements for watts loss.
- O. Enclosure shall be designed to conform to NEMA 1 standards. Enclosure shall be constructed from steel with enamel finish. Enclosure openings shall be provided to allow for air flow convection cooling. Provisions shall be made to allow for permanent conduit entry sites. Enclosure shall have a removable cover that shall not at any time disrupt the conduit connections.

PART 3 - EXECUTION

3.1 INSTALLATION

- A. Install motor controllers in accordance with the NEC, as shown on the drawings, and as recommended by the manufacturer.
- B. Install manual motor controllers in flush enclosures in finished areas.
- C. Set field-adjustable switches, auxiliary relays, time-delay relays, timers, and electronic overload relay pickup and trip ranges.
- D. Program variable speed motor controllers per the manufacturer's instructions and in coordination with other trades so that a complete and functional system is delivered.
- E. Adjust trip settings of circuit breakers and motor circuit protectors with adjustable instantaneous trip elements. Initially adjust at six times the motor nameplate full-load ampere ratings and attempt to start motors several times, allowing for motor cooldown between starts. If tripping occurs on motor inrush, adjust settings in increments until motors start without tripping. Do not exceed eight times the motor full-load amperes (or 11 times for NEMA Premium Efficiency motors if

required). Where these maximum settings do not allow starting of a motor, notify COR before increasing settings.

- F. Install DV/DT output filters for VSMCs within 20ft (conductor length) of VSMC.

3.2 ACCEPTANCE CHECKS AND TESTS

- A. Perform manufacturer's required field tests in accordance with the manufacturer's recommendations. In addition, include the following:

1. Visual Inspection and Tests:

- a. Compare equipment nameplate data with specifications and approved shop drawings.
- b. Inspect physical, electrical, and mechanical condition.
- c. Verify appropriate anchorage, required area clearances, and correct alignment.
- d. Verify that circuit breaker, motor circuit protector, and fuse sizes and types correspond to approved shop drawings.
- e. Verify overload relay ratings are correct.
- f. Vacuum-clean enclosure interior. Clean enclosure exterior.
- g. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
- h. Test all control and safety features of the motor controllers.
- i. For low-voltage variable speed motor controllers, final programming and connections shall be by a factory-trained technician. Set all programmable functions of the variable speed motor controllers to meet the requirements and conditions of use.

3.3 FOLLOW-UP VERIFICATION

- A. Upon completion of acceptance checks, settings, and tests, the Contractor shall show by demonstration in service that the motor controllers are in good operating condition and properly performing the intended functions.

3.4 SPARE PARTS

- A. Two weeks prior to the final inspection, provide one complete set of spare fuses for each motor controller.

3.5 INSTRUCTION

- A. Furnish the services of a factory-trained technician for two 4-hour training periods for instructing personnel in the maintenance and operation of the motor controllers, on the dates requested by the COR.

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