MEDIUM VOLTAGE VARIABLE FREQUENCY DRIVE SPECIFICATION

MVH2 Series

Abstract

This specification defines the requirements for Medium Voltage Variable Frequency Drive for the operation of medium voltage motors.

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1 GENERAL

1.1. SCOPE

A. This specification defines a complete Medium Voltage Variable Frequency Drive, MV VFD or MV drive in short.
B. VFDs are also identified as Adjustable Frequency Drives, AFDs in short, or motor controllers in general.
C. This specification covers the requirements for design, manufacturing, testing, supply, installation and performance of MV drives.
D. The MV drive manufacturer shall supply the drive and all necessary controls as herein specified in this document.

1.2. CODES AND STANDARDS

A. Provide MV drive in accordance with the latest applicable rules, regulations, codes and standards of:
   - International Organization for Standardization (ISO)
   - Occupational Safety and Health Act (OSHA)
   - American National Standards Institute (ANSI)
   - Institute of Electrical and Electronics Engineers (IEEE)
   - National Electrical Manufactures Association (NEMA)
   - North American 3rd Party Nationally Recognized Test Lab, e.g., Underwriters' Laboratories (UL/cUL)

1.3. ACCEPTABLE MANUFACTURES

A. Drive shall be manufactured by the MV VFD supplier at its own facility which has a quality assurance program that is certified in conformance with ISO Standard 9001.
B. Drive shall be MVH2 Series or approved equal meeting the exact requirements of this specification. Any proposed exceptions must clearly be stated at bid time citing the reason for non-compliance.
C. The drive manufacturer shall have at least 20 years of experience in manufacturing Medium Voltage products.
D. The manufacturer or their representative shall have service, repair and technical support services available on a 24/7 basis.
E. A drive that is manufactured by a third party and/or "brand labeled" shall not be acceptable.
F. The drive manufacturer shall be one of the following:
   - Benshaw
   - ----------
   - ----------
G. All named manufacturers above are obligated to meet the detailed requirements of this specification. Any proposed exceptions must clearly be stated at bid time, citing the reason and justification for noncompliance.

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1.4. DOCUMENTATION AND SUBMITTALS

A. Documentation shall be custom prepared for this application and shall cover sufficient information to determine compliance with the project specifications and contract documents.
B. Deviations to this specification shall be indicated within the submittal documents accompanied by a detailed written justification for the deviation.
C. Proposal submittal documents shall include, but not be limited to:
   - Certification of compliance with this specification
   - Drive's electrical, mechanical and performance specifications including current and voltage rating, applicable deratings, efficiency, power factor and harmonics
   - Drive's mechanical specifications including preliminary dimensions and weight estimation, required clearances, cooling requirements and environmental considerations
   - External interconnection one-line diagram showing all power, control, signal, monitoring, protection, and communication connections (also known as customer connections)
   - Warranty
   - Preliminary spare parts list
D. After order (after purchase order and before delivery) submittal documents shall include, but not be limited to:
   - Drive's electrical specifications as detailed as required by project
   - Detailed customer power and I/O connections
   - Drive's mechanical specifications including dimension and weight estimation for shipping splits and lifting, handling and transportation requirements
   - Applicable certifications
   - Warranty
   - Spare parts list
E. Final (delivery and after delivery) submittal documents shall include, but not be limited to:
   - As-built drawings
   - Operating instructions
   - Maintenance instructions
   - Manufacturer, supplier, support, service and repair contact information
   - Spare parts list

2 PERFORMANCE REQUIREMENTS

2.1 GENERAL FUNCTION AND FEATURES

A. The MV drive shall be suitable for speed regulation and control of medium voltage three-phase AC motors.
B. It shall include the following motor control methods: scaler volts to hertz control, vector control, sensorless vector control and synchronous motor control.
C. The MV drive shall include optional power cell bypass technology with mechanical bypass and electronic bypass optional.
D. The drive shall be designed around neutral point shift technology.

E. Features should include but not be limited to the following: auto restart after power loss, synchronous transfer switch function (with optional synchronous switch cabinet), leader-follower control function, VFD dual or multi-motor operation of process PID control function.

2.2 RATINGS

A. The MV drive shall be available in ratings from 2.3-13.8kV (-10% to +5%)
B. The drive shall have a rated input frequency of 50/60Hz (-10% to +10%)
C. Control power shall be 240VAC, single phase, 10kVA
D. Rated input power factor shall be ≥0.96%
E. Efficiency shall be ≥96%
F. Output frequency range shall be 0-80Hz
G. Speed accuracy shall be ±0.5% (open loop vector) or ±0.1% (closed loop vector)
H. Instantaneous overcurrent protection shall be adjustable (up to 150%)
I. Overload capacity shall be a minimum of 120% load for 120 seconds

2.3 OUTPUT CAPABILITY

A. The MV drive shall be capable of producing a 3-phase variable AC voltage and frequency output to provide continuous AC motor operation, with equivalent horsepower and speed rating, over the specified speed and torque range.
B. The drive shall operate standard AC motors without compromising the motor insulation system or motor life expectancy.
C. The drive shall have a normal duty of 100% continuous current. Short time duty rating overload (current and torque) shall be available to meet process / application requirements.
D. The drive shall utilize multi-level pulse width modulation (PWM) with low voltage IGBT power modules and dry film capacitors.
E. The drive shall be capable of producing output voltage waveforms with low harmonic distortion. In the case of 4160 VAC, 60 Hz applications, the drive shall be capable of producing minimum 7-level line to neutral (phase to neutral) and resultant 13-level line to line (phase to phase) voltages. Drives not capable of this feature are not acceptable as they reduce a motor's life and increase its failure rate and total cost of ownership.
F. The output voltage dv/dt shall not exceed 4000 V/µs to minimize undesired motor heating and motor insulation stress.
G. The maximum step size on output voltage waveform shall not exceed 1200 V under nominal conditions.
H. Use of output sine filter or dv/dt filters in standard applications is not allowed as they reduce system efficiency and introduce risk of electrical and mechanical resonances.
I. The drive shall be capable of producing near sinusoidal current waveforms to the motor at all speeds and load levels.
J. The drive shall not utilize or rely upon output transformers and / or output filters for typical AC motor applications.
K. The drive shall not generate unbalanced output voltages.
L. The drive shall not generate DC output current during normal operation.

M. Motor cable voltage reflections shall not result in any performance restrictions and / or insulation stress on motor side for cable lengths up to 1000 ft. (approximately 300 m). Use of an output filter for cables longer than 1000 ft. is allowable to meet this requirement.
N. As a commissioning and troubleshooting feature, the drive shall be capable of operating without a motor connected to the output.
O. The drive shall include synchronous transfer function using phase lock loop technology to adjust the output of the drive, making the frequency, phase position and amplitude match those of the network.
P. Multi-motor synchronous transfer function shall allow users to start up to four (4) MV motors sequentially in drive mode and control the last motor speed.

2.4 INPUT CAPABILITY

A. The drive shall utilize 3 phase AC input supply voltage within -10 /+5 of the nominal line voltage on a continuous basis.
B. The drive shall be of a design with features to account for electrical grid imperfections, to certain limits of magnitude and duration. The imperfections may include temporary power outage and voltage transients, sags, swells, and brownouts.
C. The drive shall maintain operation under input frequency transient tolerances within ±10%.
D. The drive shall comply with and exceed the input power quality requirements defined within latest version of IEEE 519.
E. The drive shall maintain input power factor of minimum 0.95 throughout the full speed range. This value shall exceed 0.96 at full load and full speed operation. The drive shall be able to maintain this power factor without the use of any power factor correction equipment (capacitors).
F. The drive converter shall be at least 18-pulse to eliminate the need for harmonic filters.

2.5 EFFICIENCY

A. The drive system efficiency shall be a minimum of 96% at rated speed and full load. System efficiency shall include inverter power cells, input transformer or reactors (if applicable), input and / or output filters (if applicable), control power and cooling fans.

2.6 RELIABILITY

A. The drive shall be of a topology which does not utilize unreliable power components including but not limited to:
    - High voltage IGBTs (3300 V and higher)
    - Electrolytic capacitors
B. Life expectancy of the DC capacitors shall be a minimum of 20 years.

2.7 SAFETY

A. The drive shall protect motor and itself under undesired circumstances including but not limited to damaged motor, output short-circuit, overload, and internal power component failure.
B. The drive shall provide ground fault protection during starting, acceleration, running and deceleration. The preferred method of detection is monitoring the leakage current in a high impedance ground circuit. Drives with no ground fault protection during running are not acceptable.

C. The fault currents and arc flash potential shall be minimized by utilizing distributed DC energy storage and localizing any rare catastrophic fault to individual power cell(s). Drives that utilize or rely upon a centralized DC link capacitor bank are not acceptable.
D. The drive's arc flash boundary shall be limited to low voltage distances during testing, start-up, or maintenance exercises. To meet this critical requirement, the design shall allow testing of the control section using low voltage (i.e., 240 VAC) power, without energizing the medium voltage input transformer. This feature shall allow for checks of the drive system functions, microprocessor control, communications, and I/Os with no medium voltage present.

2.8 SERVICEABILITY

A. The drive shall be of a modular design providing easy and fast serviceability and maintenance.
B. The drive shall not specifically require (nor depend upon) the use of a direct employee of the manufacturer for servicing or support.
C. Rear access shall not be required for service and maintenance of the power cells and / or control section.
D. The inverter section shall be modular in design and constituted of individually removable power cells in order to, in rare cases, facilitate replacement of a failed power cell.
E. Drives that employ a single integrated power conversion module that is not site-repairable or easily accessible by site maintenance personnel is not acceptable.
F. The maximum Mean Time to Repair (MTTR) to replace a failed power cell shall be ten (10) minutes or less after the power cell capacitors have discharged to a safe voltage level.
G. The maximum wait time for capacitors to discharge to a safe voltage level shall be twenty (20) minutes or less.

2.9 ENVIRONMENTAL CONDITIONS

A. The drive shall be suitable for operation in the following environment:
    - Ambient Temperature: -5 °C (no frost) to 45 °C (23 °F to 113 °F)
    - Relative Humidity: Up to 95%, non-condensing
    - Air quality: Degree 2 per UL 840 and IEC 61010-1, no corrosive gases
    - Altitude: 0m to 1000 m (0 to 3300 ft.) above sea level, no derating
B. The manufacturer shall provide the required derating(s) if the ambient temperature is higher than 45 °C (113 °F) and / or if the installation altitude is higher than 1000 m (3300 ft).
    - This derating factor(s) shall be clearly identified within the submittals.
    - The derating factor(s) shall not adversely affect the lifetime, performance, or the reliability of the drive.
C. The drive shall be suitable for being transported or stored in an ambient temperature range of -20 °C to 65 °C (-4 °F to 149 °F).

3 CONTROL REQUIREMENTS

3.1 MOTOR SPEED CONTROL FEATURES

A. Motor control functions shall include but not limited to:

- Volts/Hertz (V/Hz)
- Sensor-less vector control (SVC)
- Sensored vector control (VC)

B. Frequency resolution shall be 0.01Hz (0-80Hz)
C. Speed regulation shall be less than +/-0.5%.
D. Start functions shall include but not be limited to:
   - Accelerate from zero speed: Drive follows the acceleration profile from zero speed.
   - Flying start / restart: Drive catches a spinning motor and bring it to a commanded speed.
E. Acceleration functions shall include but not be limited to:
   - Linear profile with adjustable acceleration ramp time (5-6000sec, load dependent)
F. Stop functions shall include but not be limited to:
   - Decelerate: Drive follows the deceleration profile to zero speed.
   - Coast to stop: Drive disables the output, allowing the motor to coast to a stop.
G. Deceleration functions shall include but not be limited to:
   - Linear profile with adjustable deceleration ramp time (5-6000sec, load dependent)
H. Advanced functions shall include but not be limited to:
   - Skip frequency: Certain frequencies that can cause resonance in the driven equipment may be selected and locked out. The drive will accelerate and decelerate through these frequencies but will not sit at the locked-out speeds.

3.2 FAULT & ALARM FEATURES

A. The following motor and drive protection features shall be included:

Fault	Alarm
• VFD overcurrent	• Motor overload
• Over voltage fault	• Parameter setting error
• High voltage power loss fault	• Transformer door alarm
• Power cell over-heat fault	• Power cell door alarm
• Cabinet over-heat fault	• Power cell cabinet overheat alarm
• Transformer cabinet temperature fault	• Transformer over-heat alarm
• Unit cabinet temperature	• Fan alarm
• Power supply fault	• Power cell bypass
• Three-phase output unbalance	• Controller communication
• Output short circuit to ground	• Fan loss of power
• Input imbalance	
• Analog line drop	
• System overspeed	
• Overtemperature	
• Excitation fault	

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4 CONSTRUCTION REQUIREMENTS

4.1 GENERAL

A. The MV drive shall use power cells in a series connection using H-bridge multilevel overlapping PWM technology to provide for an output waveform with low harmonic content.

B. The MV drive shall not require any extra motor output filtering

C. The MV drive shall be able to operate in PWM mode without derating the motor.

D. The drive shall not have any cable length limitations providing the cable voltage drop is less than 3%

E. The drive shall be forced air cooled

F. The MV drive enclosure shall provide Type 1 protection

G. Standard enclosure will be painted ANSI 61 grey (other paint colors optional)

4.2 INPUT TRANSFORMER

A. The drive shall have an isolation transformer providing secondary phase shifting to rectifier. This transformer is referred to as the input transformer in this document.
B. The input transformer shall accommodate 3-phase primary voltage ranging from 480 VAC to 13.8 kVAC.
C. The input transformer shall provide primary connections with -5% / 0 / +5% taps.
D. The input transformer shall be a multiple pulse design
E. Use of 12-pulse or lower transformers is not acceptable, unless specifically specified by customer, due to its higher input current harmonic content.
F. The input transformer shall have appropriate voltage rated distribution class surge arrestors as standard and connected to the input power terminals.
G. The input connection to the drive shall have a minimum basic impulse level (BIL) as following:
   - 60 kV, for primary voltages ≤7.2 kVAC.
   - 75 kV, for primary voltages >7.2 kVAC.
H. The input transformer shall be of a high efficiency type with full load losses no greater than 4.0% (96% efficiency).
I. The input transformer shall have either standard Aluminum or optional Copper conductors.
J. The input transformer, if installed indoor, shall have a class H insulation system (220 °C rated) to operate at an average temperature rise of maximum 130 °C at full load conditions. The hot spot temperature rise shall not exceed 30 °C.
K. The input transformer, if installed outdoors, shall be designed to operate in an ambient temperature range of 0 °C to 45 °C with mean monthly average of 30 °C.
L. The transformer design shall include thermal detection devices monitoring winding temperature with warning and trip indications.
M. Special designed transformer shall be available to meet customer specific requirements if not within the ranges specified above.

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4.3 POWER CELLS

4.3.1 Rectifier Section

A. The rectifier section of the power cells shall be three phase full wave diode rectifier providing a single DC bus supply internal to the power cell.
B. The rectifier diodes shall be protected by fuses on all three phases in the event of a short circuit or prolonged overload. Protection schemes using fuses on two phases is not acceptable.
C. The power cell shall detect if an input fuse has opened.
D. DC capacitors shall be incorporated into the inverter power cells to provide a distributed energy storage configuration. Use of centralized energy storage capacitors on the DC link is not allowed. Topologies utilizing centralized energy storage capacitors on the DC link are not acceptable as this practice increases the fault currents, energy, and arc flash potential. The capacitors shall be of dry, self-healing, polypropylene type.

4.3.2 Inverter Section

A. The inverter shall be multi-level pulse width modulated (PWM) type utilizing modular power cells.
B. The modular design shall provide easy and fast power cell replacement to minimize downtime and increase availability in rare event of inverter failure.
The inverter power assembly shall be supplied DC power from the power cell's internal rectifier.
C. Power cells shall utilize conventional 1700 V rated Insulated Gate Bipolar Transistors (IGBT) devices. These IGBTs are being produced in volume for low voltage (LV) drive industry with proven high reliability and low failure rates. Inverters that utilize (or rely upon) medium voltage (such as 3300 V or 6500 V) IGBTs or highly specialized semiconductors (such as IGCTs or SGCTs) are not acceptable. These components, with their high FIT rate, negatively impact the reliability and availability of the drive.
D. The IGBTs shall be available from multiple vendors to eliminate any dependency upon a sole source supplier or vendor.
E. The latest in IGBT designs shall be utilized for minimum losses.
F. The DC capacitors shall be integral to the inverter power cells.
G. The inverter assembly shall consist of an inherent arc flash resistant topology, consisting of a distributed energy storage arrangement that intrinsically minimizes fault currents and arc flash potential. Catastrophic inverter faults shall be localized to individual power cell(s). Drives that utilize or rely upon a centralized DC link capacitor bank are not acceptable.
H. Self-healing dry film type capacitors, which do not require reforming, shall be utilized in the inverter power section design. Life expectancy of the main power DC capacitors shall be a minimum of 20 years. Inverters utilizing electrolytic or liquid / oil filled capacitors in the power section are not acceptable. Use of electrolytic bus capacitors negatively impacts the reliability and failure rate of the inverter.
I. Upon application of main power, inrush currents to the inverter shall be eliminated by executing a pre-charge of the DC capacitors in the power cells. When the proper DC voltage is attained, the pre-charge circuit shall turn off.
J. The power cells shall be intelligent and communicate with the main controller via a serial protocol and use Plastic Optical Fiber (POF) cables to provide electrical isolation.

K. A high resistance grounding circuit with detection devices shall be included for protection in the event the load develops a ground leakage current or fault.

4.4 CONTROL

A. The drive shall consist of a fully digital and robust modern control platform.
B. Internal communication between the main controller and individual power cells shall be via a serial protocol and use high speed plastic optical fiber.
C. A RS485/Modbus RTU connection shall exist as standard on the controller.
D. The following industry standard field buses and communication protocols shall be available at a minimum:
    - Ethernet Modbus TCP/IP
    - Ethernet / IP
    - RS485/Modbus RTU
    - Profibus DP
    - ProfiNet
E. A historical log shall record all pertinent operational data in order to evaluate operational trends and performance. The historical trend data shall be accessible via a USB flash drive.
F. The historical event log shall record all faults.
G. All events stored in event log shall be accessible via a USB flash drive.
H. The drive shall contain a Built-in-Self-Test (BIST) or Debug mode feature. The drive shall be designed with a mode that inherently reduces the arc flash boundary to low voltage distances during testing, start-up, or maintenance exercises. The mode shall allow testing of the inverter section using low voltage (i.e., 230 VAC) power, without energizing the medium voltage input transformer. The mode shall allow for checks of the drive system functions, microprocessor control, and communications.
I. A flexible, customizable I/O system shall be utilized within the drive to support customer's application and process control.
J. The drive shall provide, at minimum, fourteen (14) digital inputs.
    - Run
    - Stop
    - Fault reset
    - Local / Remote
    - Drive enable / disable
    - Speed 1 input
    - Speed 2 input
    - Speed 3 input
    - Medium Voltage Trip input
    - Sync to Line activated
    - Field ready
    - Field applied
    - Field faulted
    - Fan feedback
    - Inverter cabinet door feedback

- Transformer cabinet door feedback
- Transformer OT trip feedback
- Transformer overheat alarm feedback

K. The drive shall provide, at minimum, twenty-two (22) digital outputs.
   - Run
   - Fault – non fail safe
   - Fault – fail safe
   - Ready
   - At Speed
   - Forward / reverse
   - Local / remote control source active
   - Stopped
   - Alarm
   - Overcurrent / undercurrent warning
   - Motor overload warning / trip
   - Drive overload warning / trip
   - Bus overvoltage / undervoltage trip
   - Cell fault
   - Ground fault trip

L. The drive shall provide, at minimum, three (3) analog inputs. The following functions shall be available:
   - Speed reference input
   - Customer process value input
   - Field current feedback input

M. The drive shall provide, at minimum, four (4) 4-20mA analog outputs. One output dedicated to output frequency and one output dedicated to output current.

N. Following functions shall be selectable for the other two analog outputs:
   - Output frequency
   - Output current
   - Power cell temperature
   - Field excitation current
   - Output power
   - Output power factor
   - Output voltage

4.5 OPERATOR INTERFACE

A. The drive shall have an intuitive user-friendly operator interface for local and / or remote control and monitoring.

B. HMI, displays, signal lights, meters and any other locally mounted operator interface shall be accessible and visible from the front without opening the enclosure.

C. The drive shall have a standard HMI interface with the following minimum features:
   - The HMI shall be minimum 10” and support multiple languages.

- The HMI shall provide drive control functions and allow local or remote operation of the motor.
- The HMI shall present operational information including but not be limited to meter values / trending, set points, and faults / alarms.
- The HMI shall provide read / write access to drive parameters.
- The HMI shall be capable of being mounted locally on the inverter enclosure or remotely at any location of the customer's preference (for example, remotely wall-mounted and/or mounted to facilitate gloved maintenance personnel).
- The HMI shall use an Ethernet (ProfiNet) based communication protocol interface.
- The HMI shall be equipped with a security passcode system that can be enabled or disabled only by designated personnel. This feature shall provide limiting of access and adjustment of any system parameters by unauthorized persons.
- The HMI shall display all messages and values in plain language and engineering units.
- The HMI shall clearly indicate drive's real time status including Start, Stop, Running Forward, Running Reverse and Stopped.
- The HMI shall display real time values of output current, output line to line voltage, motor real power in kW, motor power factor, and cabinet temperature.
- The HMI shall display trending graphs of output current, output frequency, and motor real power in kW.
- The HMI shall provide access to parameters. Parameters shall be organized in meaningful groups such as Drive parameters, Function parameters and I/O parameters.
- The HMI shall include a dedicated cell status section which indicates the real time status and existence of any fault / alarm at each power cell.
- An appropriate indicator on the HMI shall illuminate when a Fault, or Alarm occurs. HMI shall display name of the respective condition.

D. The drive shall be compatible with a PC based tool with the following minimum features:
   - A Windows-based graphical PC tool shall be available for connectivity between a PC and the drive.
   - The PC tool shall present operational information including but not be limited to meter values / trending, set points, and faults / alarms.
   - The PC tool shall provide read / write access to parameters.
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4.6 COOLING

A. The drive shall be forced air-cooled unless otherwise specified.
B. The cooling system shall be oversized for the amount of total airflow required to cool the drive. The loss of a single fan shall not prevent operation of the drive at nominal load. N+1 redundancy in other words, adequate airflow and cooling capacity shall be maintained by the remaining fans.
C. The drive shall use single phase 240 VAC backward curved centrifugal fans.
D. The fans shall be supplied from a power source independent from medium voltage source of supply (not tapped from the converter's input transformer).
E. The air filters shall be standard commercial sized filters.
F. The air filters shall be accessible and removable for cleaning or replacement.

G. The air filters screens/barriers shall be designed to prevent drawing a straight line from any point outside the enclosure to any medium voltage live parts including insulated parts.

4.7 ENCLOSURE

A. The drive enclosure(s) shall be NEMA 1 for indoor installation.
B. The enclosure shall provide front access to all components.
C. The enclosure shall have bolt-on access panels which prohibit unauthorized access to the medium voltage compartments. In case of use of doors instead of bolt-on panels, each door shall be equipped with two mechanical methods needed to open the door. interlock.
D. The enclosure shall provide safe access to control components without exposure of any high voltages. All low voltage wiring shall be fully isolated from medium voltage compartments by barriers.
E. All the bolt-on panels and doors shall be fully gasketed.
F. The standard exterior paint color for the enclosure shall be ANSI 61 (gray) in color.
G. The enclosure shall be designed to accommodate power cable entry from either top or bottom, and cable exit top, bottom, and bottom left and right sides.

4.8 NAMEPLATES AND LABELS

A. Nameplates shall be minimum 1.00” high (per line of text) x 7.5” wide.
B. Nameplates shall have black letters on a white background, unless otherwise specified by customer.
C. Each section of the enclosure shall include a label which clearly specifies the function of that section such as transformer and inverter.
D. Each section of the enclosure shall include a label which clearly specifies the highest voltage available behind that section. Proper “danger” labels shall be used in case of existence of medium or high voltage.

5 TESTING

A. Factory acceptance test (FAT) or factory test in short shall follow the drive manufacturer’s standard test procedures unless otherwise specified.
B. The factory test shall take place at the same facility where the drive is being manufactured.
C. The factory test shall help ensure proper operation of the drive including but not limited to electrical circuitry, mechanical assembly, software, and control and, instrumentation and monitoring.
D. The factory test shall, at minimum, include following:
    - Visual inspection / check to verify physical dimensions and degree of protection for enclosures, mechanical assembly of components, hardware torquing marks and marking of cables, wires and terminals
    - Point-to-point electrical resistance (ohm) check or voltage check (using a digital voltmeter) to verify all the electrical connections
    - Verification of programming on computer card, PLC and boards

- Verification of proper operation of all fans
- Functional tests to verify proper functionality of the drive

E. When specified, the testing shall include an optional loaded run that operates the drive on a dynamometer.
F. The test results shall be submitted to customer as part of O&M manuals.
G. When specified, customer witness test shall be provided by the manufacturer.
   - The witness test shall take place at the facility where the drive is manufactured.
   - Witness test shall test and demonstrate the functionality and operation of the drive and well as the operator interface.
   - A projected test schedule and a copy of proposed test procedures shall be provided by manufacturer in advance of test date.

6 SHIPMENT AND DELIVERY

A. The drive shall be shipped as one unit or properly defined shipping splits.
B. The shipping unit(s) shall be adequately packaged for shipment per the drive manufacture's standard practice.
C. For international shipment, the shipping unit(s) shall be crated for export per the drive manufacturer's standard export practice.
D. Exposed sections of the shipping unit(s) shall be covered and protected from damage during shipment.
E. The drive shall be delivered to the customer's site pre-assembled and wired. Required hardware and cables for connection across shipping splits (if any) shall be identified and provided by drive's manufacturer.
F. Instructions for handling and storage shall be provided prior to delivery of the drive.
G. All shipping units shall have adequate provisions for handling by overhead crane or forklift truck.

7 COMMISSIONING

A. Commissioning shall be performed at customer's site.
B. The drive manufacturer shall provide the field services of engineers and technicians, as necessary, to supervise and inspect installation, perform start-up of the drive and complete functional testing.
C. Commissioning shall confirm installation requirements, operating parameters and motor performance.

8 STANDARDS

Standard	Definition
UL347A (pending)	Safety of Medium Voltage Power Conversion Equipment
UL50/50E	Safety of Enclosures for Electrical Equipment, Non-Environmental Considerations and Environmental Considerations
UL508A	Safety of Industrial Control Panels

UL61800-5-1	Safety for Adjustable Speed Electrical Power Drive Systems, Part 5-1
CSA C22.2 NO. 274	Safety for Adjustable Speed Drives
ANSI/IEEE C57.12.01	Standard General Requirements for Dry-Type Distribution and Power Transformers
ANSI/IEEE C57.12.91	Standard for Testing of Dry-Type Distribution and Power Transformers
ANSI/IEEE C57.12.51	Standard for Ventilated Dry-Type Power Transformers – General Requirements
ANSI/IEEE C57.18.10	Standard Practices and Requirements for Semiconductor Power Rectifier Transformers
UL 1562	Safety of Transformers, Distribution, Dry-Type – Over 600 Volts
NEMA - ICS1	Industrial Control and Systems: General Requirements
NEMA - ICS3	Standards for Medium Voltage Controllers
NEMA - ICS6	Standard for Industrial Control and System Enclosures
NFPA - 70	U.S. National Electric Code
IEEE Std 519 - 2014	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

9 WARRANTY

A. The drive manufacturer shall state clearly the details of terms and conditions of warranty offered with the drive.
B. The drive shall be warranted against defects in material and workmanship for a period of 18 months after delivery or 12 months after installation, whichever occurs first.
C. The drive shall be warranted against defects in material and workmanship for an extended period of 36 months from the start-up date if manufacturer authorized commissioning service is performed upon initial start-up.

10 TRAINING

A. When specified by the customer, training shall be performed by a direct employee of the manufacturer.
B. Training shall be performed at the manufacturer's facility or at an alternate location as specified by the customer.

11 SPARE PARTS

A. The drive manufacturer shall provide a complete list of spare parts.
B. The drive manufacturer shall provide a list of recommended and critical spare parts.
C. As a minimum, the drive manufacturer shall include following spare parts:
    - Three (3) spare power cells
    - One (1) of each main controller circuit boards

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- One (1) of each control power supplies
- One (1) replacement modular cooling fan assembly
- One (1) set of replacement air filters

D. All spare parts shall be properly marked and packaged for long-term storage.

E. All circuit boards shall be contained and handled in anti-static ESD safe packaging.