





Guide Form Specification

For

MV Variable Frequency Drive

Rated 300-10000 HP

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# GENERAL

## **DOCUMENT AND EQUIPMENT SCOPE**

1. This document specifies required features of a Medium Voltage Variable Frequency Drive (VFD) System design, control, manufacturing and testing. This VFD system is to have 2.3kV ~13.8kV, 3Ph, 60Hz supply for its input and 2.3kV~4.16kV, 100Hz variable frequency output to control an induction motor with or without a speed encoder for speed feedback.
2. For procurement of a motor and a VFD as one package, the Purchaser shall provide relevant motor specifications with specific applications requirements. Preference will be given to suppliers that manufacture, guarantees and provides service for the motor and the VFD.
3. VFD shall be completely assembled, pre-wired and tested by the VFD supplier. Project specific data shall be used during factory testing.

## **CODES AND STANDARDS**

1. Applicable requirements in the latest edition of the following industry standards and industry practices shall be considered an integral part of this Specification.
   * + 1. IEEE 519 Guide for Harmonic Control and Reactive Compensation of Static Power Converters
     1. IEEE 1100 – Powering and Grounding Sensitive Electronic Equipment
     2. NEMA ICS 6 – Industrial Control and Systems Enclosures
     3. International Electrotechnical Commission (IEC) 61800-5 AC Drives Standard
     4. NFPA 70 – National Electrical Code (NEC)
     5. UL 347 – High Voltage Industrial Control Equipment Standard
     6. UL 347A – Medium Voltage Power Conversion Equipment – preliminary standard
2. Any conflicts between this specification and the Bidder’s documents shall be identified in writing to Purchaser for resolution.
3. Any deviations to specifications given here will be clearly stated in writing at the time of submittal of proposal/quotation documents.

## **VFD COMPONENTS AND CONFIGURATION**

VFD shall consist of following major components:

1. Fused Disconnect Switch for incoming power
2. Multi-secondary Isolation Transformer for Rectifier
3. Variable Frequency Inverter
4. Electronic Motor Protection
5. Output filter or reactor – per motor or installation requirements
6. Output Disconnect or bypass – as specified or required by the application.
7. Control and Diagnostic Circuits.
8. This specification covers an VFD driving a single motor. When more than one motor is to be run in parallel or more than one motor needs to be run in alternate mode, additional information regarding process/operation will have to be specified in a separate document.
9. All components and material shall be new and of the latest field proven design and in current production. Obsolete components or components scheduled for immediate discontinuation shall not be used.
10. If it becomes necessary to disassemble various units of VFD for ease of transportation then adequate instructions shall be provided for easy field reassembly of the system.

## **SUBMITTALS**

1. VFD Manufacturer shall submit drawings and data as specified below as part of bid information;
2. Basic description of all major components and basic control and protection features of VFD
3. Outline drawings showing outside dimensions, weights for switchgear, transformer and VFD equipment.
4. Single-line diagrams showing all major components within the system
5. Recommended spare parts list
6. Rate schedule for field service
7. Terms of standard warranty

Following drawings and data will be submitted for engineering review per agreed project schedule;

1. Control schematic for the system
2. Control schematic for the VFD equipment
3. Installation, Operation, Programming, and Maintenance Manual(s)

Test reports will be supplied as part of factory testing for inspection and testing results.

## **INSPECTION AND TESTING**

1. Following minimum testing will be performed in addition to Manufacturer’s standard testing;
2. Individual IGBT power cells shall undergo a visual inspection, an electrical inspection, and a complete full load test including temperature rise test, prior to the final assembly into the VFD.
3. Mechanical checks and tests shall be performed for each VFD to verify satisfactory assembly and safety locking operation.
4. Electrical functions including Instrumentation check, software, and monitoring tests shall be performed. Tests shall be performed to ensure proper operation of all devices and components including operation of the VFD at full load conditions – using a dynamometer.
5. Final VFD assembly shall be tested for full load using an electrical dynamometer system where a regenerative power supply returns drive output power to the power line.
6. A test record for each VFD shall be furnished as part of the final data requirements.

## **RELIABILITY**

* + 1. VFD shall be designed for a Mean Time Between Failure of at least 10 years. The mean time to replace power cells shall not exceed 15 minutes after DC buss discharges. Spare power cells shall have a minimum of 20 year shelf –life without the need to power up cell periodically.
    2. The VFD shall be designed for availability of 99.9%

## **WARRANTY**

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A. Seller shall warrant the equipment for a period of 3 years from date of shipment for equipment to be installed and operated in North America. For North American installations, warranty shall cover both parts and labor for required repairs.

B For equipment to be installed and operated in other regions of the world, warranty shall extend for a minimum of 12 months after startup, 18 months after shipment. Inclusion of labor for repairs may vary depending on location.

C. Seller must state clearly the details of warranty offered with his equipment.

# PRODUCTS

## **ACCEPTABLE MANUFACTURER**

* + - * 1. The variable frequency drives shall be WEG Electric MVW01.
        2. The VFD supplier shall have a minimum of 10 years of experience in supplying medium voltage variable frequency drives.

## **PRODUCT DESCRIPTION**

### **MECHANICAL**

#### ENCLOSURE CONSTRUCTION

##### The VFD assembly and its enclosure protection class (NEMA 1G – IEC IP 21) should allow indoor installation within unclassified area. Door vents shall have louvered panel assemblies that can be removed from the front to allow cleaning and/or replacement of air filters.

##### All doors on the IGBT power sections shall be kirk-key interlocked with the door on the control cabinet, thus preventing opening of any door by bypassing electrical interlocking signals.

##### All control boards used within VFD shall be coated such that there can be no damage from moisture or dust in the ambient environment.

##### A “loss of cooling” fault shall be generated by an air pressure sensor within the enclosure. In the event of clogged filters or fan failure, the VFD shall produce an alarm and then shutdown safely without causing failure of any electronic component.

##### If specified on the data sheet, optional redundant fans shall be supplied.

##### An arc detection monitor shall be provided to detect any arcing in the power section of the VFD

##### The IGBT power section shall contain individual draw-out power unit with stab connections for each phase. A cart designed for removing and inserting IGBT power modules shall be supplied.

##### Air filters shall be of reusable type that can be easily cleaned. Air exhaust from cooling fans will be at the top of the enclosure.

* 1. Fan motors shall be protected by an input circuit breaker. Fan power will be supplied from a separate control transformer and is not tapped from the main drive isolation transformer.
  2. The maximum noise level of the unit shall not exceed 75 dBA at a distance of 3.3 feet (1 meter) from the unit and at a height of 5 feet (1.5 meters) from the floor.
  3. All enclosures will have manufacturer’s standard finish unless otherwise specified by the purchaser.
  4. Enclosures shall be designed to accommodate power cable entry from either top or bottom.

1. ENCLOSURE AUXILIARY COMPONENTS  
   * 1. Space heater elements shall be supplied to avoid any condensation inside the enclosure.
     2. The space heater circuit shall turn on when the drive is not operating. Thermostatic control cannot determine the dew point.
     3. A circuit breaker for the space heater circuit shall be provided for overload protection and as a disconnecting means.
     4. Enclosures shall be equipped with lighting, fluorescent or incandescent, as specified by the purchaser.
2. ENCLOSURE nameplates
   1. Engraved, laminated plastic nameplates with characters 1/2 inch (12.7 mm) high, or larger, shall be provided for each VFD to identify the load it serves.
3. Nameplates shall have black letters on a white background, unless otherwise specified on the Data Sheet.
4. Meters, relays, switches, and other devices within the VFD shall be permanently identified using the same name as those appearing on the schematic diagrams.

### **ELECTRICAL**

1. Power Requirements

* + 1. The VFD shall be capable of providing rated output for continuous input voltage deviations of +10% to -15% from the nominal.
    2. The power transistors used in the VFD power section shall be rated for a minimum of 6.5kV thereby avoiding any series connection of IGBTs. Series connected IGBTs for output power devices are not acceptable.
    3. Output power transistors shall default to open without additional circuitry in the event of a motor short circuit
    4. The VFD shall be able to ride through voltage dips down to 80% of its nominal voltage rating, such as those experienced during motor starting.
    5. The VFD shall have ride-through capability upon loss of incoming power for 2 seconds.
    6. The VFD one-minute overload current rating shall be 115% of rated current for variable torque applications and 150% of rated current for constant torque applications.
    7. The IGBT power devices will be switched using Optimum Pulse Pattern technique. Optimum Pulse Pattern technique searches for best switching frequency for IGBTs that optimize the harmonics in the output voltage/current waveform.
    8. Output filters, as required, shall be integral to the drive cabinet.
    9. The VFD shall comply with the latest revision of IEEE 519 for total harmonic current and voltage distortion measurement and calculation. Current distortion shall not exceed 5% and voltage distortion shall not exceed 3% at the point of common coupling. Individual harmonics shall not exceed the limits given by IEEE 519, 2014 Guidelines.
  1. Power DISCONNECT and bypass DEVICES
     1. If a suitable disconnect device for incoming power is not available at site, then VFD manufacturer shall include a fused disconnect device with an interlocked and/or padlocked handle mechanism. The disconnect switch will feed a MV vacuum contactor. The MV contactor will be controlled by the VFD logic, to switch in upon completion of pre-charge cycle for power capacitors.
     2. If specified on the Data Sheet, the VFD supplier shall supply an output disconnect device to be able to electrically isolate the motor for maintenance purpose.
     3. If specified by the Purchaser the VFD shall include a bypass feature. A “maintenance bypass" shall allow servicing of the VFD components while the motor is operating at fixed speed
     4. If the VFD is used as a motor starter that limits the motor starting current to 100%~150%, then a synchronous by-pass scheme using contactors will be provided, to accommodate a closed transition bypass, to run the motor up to synchronous speed and then connect it to the power line for DOL running.
  2. Input Power Transformer and Rectifier  
     1. The VFD supplier shall provide a dry type isolation transformer whose primary voltage shall be as specified by the purchaser.
     2. The isolation transformer shall phase shifted secondary windings that feed phase shifted, 3 phase power to a minimum 12 or 18 pulse rectification section. The secondary of the phase shifting transformer should NEVER be grounded to prevent excessive common mode voltage on motor bearings.

* + 1. The system shall allow for either an indoor dry type or outdoor dry type or oil filled isolation transformer that can be mounted away from the VFD in order to minimize heat generated around the VFD location.
    2. The transformer shall have an electrostatic shield for protection from voltage transients.
    3. The rectifiers shall be fuse-less design
    4. Pre-charge of the DC bus capacitors shall be accomplished by use of low voltage internal step up transformer and shall be interlocked with the main power such that the drive cannot be energized until the bus is fully charged.
    5. Long life dry type, plastic film capacitors shall be used for the DC rectifier section. Electrolytic or oil filled capacitors are not permitted in the MV DC bus energy storage power circuit.
  1. Power Bus  
     1. Bus bars shall be braced to withstand short circuit currents with a minimum of 50KAIC.
     2. As specified, input and output connections shall be either top or bottom access.
     3. If specified bus-bars shall be nickel plated to avoid corrosion.
  2. Inverter Section
  3. The VFD inverter section shall consist of three modular IGBT assemblies with snubber circuit and energy storage dry type, plastic film capacitors (DC bus capacitors) and fed from a single DC power supply.
  4. IGBT Cell assembly shall be done with sandwich bus-bar assembly in order to reduce inductance value in connecting conductors and help reduce total losses within the cell structure
  5. The IGBTs are designed in a bridge connection such that when used in combination with the other bridges, a multi-level output motor voltage waveform of minimum 3/5 level is constructed.

##### Each IGBT cell shall communicate to the controller through optical communications. No other isolation method is permitted.

##### The power and control sections of the VFD shall be isolated by use of fiber optic connections. IGBT trigger control as well as feedback signals such as measurement of incoming voltage, frequency, DC bus voltage and heat-sink temperatures and output current shall be done via optical signals.

* 1. A high resistance ground detection circuit at the neutral point shall be included for alarm or warning in the event the load develops a ground leakage current or fault.
  2. The VFD output 3/5 level wave-form shall be generated by switching of IGBTs via Optimum Pulse Pattern algorithm that selects a optimum carrier frequency to achieve minimum output waveform distortion, minimum torque pulsations and noise in the motor.
  3. Wiring and Terminations  
     1. Bus terminations with standard four-hole pattern shall be supplied for input and output connection for external power cable connections and shall be conveniently located, clearly numbered, and identified.
     2. Control wire terminal blocks for field wiring termination shall be compression screw type, designed to accommodate stripped insulation bare wire ends.
     3. Connection points for inputs and outputs of different voltage levels shall be separated to reduce possibility of electrical noise.
     4. Where wiring is run through sheet metal or any barrier, bushings, grommets or other mechanical protection around the sheet or barrier opening shall be provided.
     5. All internal wiring shall be terminated with no more than two (2) conductors per terminal point.
     6. The VFD shall have an internal mechanical ground connection suitable for terminating a stranded copper ground conductor of the same size as the incoming phase conductors. Ground connections shall be near the incoming and outgoing power cable termination points and control wiring connections.
     7. Minimum wire bending space shall meet or exceed the value shown in NEC Table 430‑10(b) for termination of the power cable.

### **CONTROL**

1. CONFIGURATION   
   * 1. The VFD Supplier shall supply a software tool to configure, monitor and troubleshoot the VFD system. The software tool shall have a trending feature where up to six VFD signals can be displayed in real time.
     2. The software tool shall have a multilevel access feature for configuration of parameter settings.

1. Operator Panel, Instruments, Displays, and Indicating Lights  
   * 1. A door-mounted graphic key pad will be provided for local control and monitoring of the VFD system. The keypad shall be removable type and can also be remotely mounted. Remote mounted keypad can be available in NEMA 4 protection case.
     2. The removable keypad display shall:
        1. have configurable bar charts and intuitive icons
        2. have soft-keys for selection of menu items
        3. have drive control functions and allow local operation of the motor from the keypad
        4. have full access to all parameters and variables.
     3. The operator keypad shall be used to read and write parameter data, to present operational information, to produce first fault and device indication, to show alarms, and to allow metering of parameters.
     4. The operator keypad shall include a level of security.
     5. The operator keypad shall have analog input information.
     6. Meters, displays, and keypads shall be accessible and visible from the front without opening the enclosure.
2. OPERATIONAL CONTROLS  
   * 1. The VFD shall include the following basic operating adjustments:

##### Start/Stop

##### Acceleration/Deceleration Time (Ramp and S Ramp Setting)

##### Current Limit

##### Minimum/Maximum frequency or speed set points

##### Selectable skip frequencies

##### V/Hz ratio setup

##### Sensor-less Vector and Close loop Vector Control with encoder parameter settings

1. Jog, Forward/Reverse, Local/Remote selection  
   * 1. The removable graphic keypad shall allow activation of self diagnostic tests for checking status of control boards and IGBT power devices.
     2. The VFD shall include necessary instrumentation to monitor the power devices and the motor against overload, internal faults of the motor or the VFD and disturbances in the incoming power supply.
     3. The VFD shall be equipped with relays for temperature monitoring of motor windings and isolation transformer windings via RTDs. The relays shall be capable of measuring up to 8 RTD signals.
     4. VFD fault that results in tripping out shutting down of VFD operation shall be annunciated on the removable graphic LCD keypad. The VFD will shut down safely with the output voltage reduced to zero for the following conditions;

##### Short circuit in the output of the VFD

##### Instantaneous over current or motor overload (i x t)

##### DC link voltage imbalance

##### Under voltage or overvoltage on the incoming AC line

##### Single phasing of the AC incoming line

##### Over temperature within VFD electronics from a component or ventilation failure

##### Gate driver power supply or control power supply under voltage

##### VFD output open circuit during operation

##### Overvoltage or ground fault at VFD output

1. Power cell fault identifying the failed device.  
   * 1. If specified, the VFD shall return the motor to operating speed upon restoration of power following a voltage interruption on the AC incoming line.
     2. If specified, the VFD shall be able to reaccelerate a rotating motor (catch a spinning load). If this feature is not specified, the manufacturer shall ensure that the VFD will not restart until the motor has slowed sufficiently and/or stopped.
     3. If specified on the Data Sheet, the VFD shall have the ability to provide dynamic braking to slow the motor down.
     4. The VFD shall be equipped with an auto tune-up wizard that includes off-line programming feature. This function will allow the VFD control to be run in off-line mode without connecting the motor.
2. Control Power Transformers (CPT)  
   * 1. A control power transformer (CPT) shall be provided within the enclosure. Depending upon site requirements, the CPT shall be capable of accepting either 220V, 380V or 460V, 3Ph, 50/60 Hz input.

* + 1. The KVA rating of the CPT shall be determined by the Manufacturer and shall have a minimum of 25% spare capacity.
    2. The CPT primary shall fed via circuit breaker equipped with an over-current trip mechanism.
    3. Separate control transformers will be supplied for supplying power to the electronic control boards and for supplying power to auxiliary circuits such as cooling fans, enclosure lighting etc.

1. Input and Output Controls   
   * 1. Discrete Interface to field controls and field signals shall be furnished by the VFD supplier.
     2. VFD control system shall be capable of following INPUT signal interface;

Analog INPUTS:   
2 Programmable Differential Inputs (10 bits): 0...10V, 0...20mA or 4...20mA

1 Programmable Isolated Input (10 bits): 0...10V, 0...20mA or 4...20mA

1 Programmable Bipolar Input (14 bits): -10 ... +10 V, 0...20mA or 4...20mA \*

1 Programmable Isolated Input (10 bits): 0...10V, 0...20mA or 4...20mA \*

Digital INPUTS:

8 Programmable Isolated Inputs: 24Vdc

1 Programmable Isolated Input: 24Vdc \*

1 Programmable Isolated Input: 24Vdc (for Motor PTC Thermistor) \*

\* OPTIONAL

* + 1. VFD control system shall be capable of following OUTPUT signal interface;

Analog OUTPUTS:

2 Programmable Outputs (11 bits): 0...10V

2 Programmable Isolated Outputs (11 bits): 0 ... 20mA or 4 ... 20mA

2 Programmable Bipolar Outputs (14 bits): -10 ... +10V \*

2 Programmable Isolated Outputs (11 bits): 0 ... 20mA or 4 ... 20mA \*

Relay OUTPUTS:

5 Programmable Outputs, Form C Contacts (NO/NC): 240Vac, 1A

Transistor OUTPUTS:

2 Programmable Isolated Outputs (Open Collector): 24Vdc, 50mA \*

\* OPTIONAL

* + 1. If specified, a communication network to the Purchaser’s network shall be MODBUS, DeviceNet or Profibus.
  1. FAULTS and Alarms  
     1. The latest 100 faults and alarms are logged and time stamped with date record. The trace for each alarm is started 50 ms before the fault and ends 100 ms after the fault. This trace data can be uploaded to PC tool for display/analysis in the trend window.
     2. The VFD shall include an alarm contact that will be closed during normal operation and will open on VFD fault conditions. Contacts shall be rated 1A at 240 VAC. If specified by the Purchaser, additional diagnostic contacts shall be provided.

### **CONTROL PERFORMANCE**

1. Efficiency & Power Factor
2. The efficiency of the VFD excluding the transformer shall be higher than 98.5% at 60 hertz output frequency and rated load.
3. The overall power factor of the VFD shall be 97% over a speed range of 30% to 100% rated speed. The power factor should never be leading.

1. SPEED CONTROL
2. Sensor-less vector control shall have speed regulation of 0.5% of rated speed.
3. Vector control with a speed feedback encoder shall have speed regulation between 0.5% and 0.01%.
4. torque control
5. VFD shall not cause higher than 1% torque ripple over a 20 to 1 speed range on the motor.

# EXECUTION

## **SITE PREPARATION**

1. The VFD shall be installed in an indoor, unclassified area. Ambient factors such as maximum temperature, humidity, air quality etc. shall not exceed maximum ambient values as listed in the VFD specification and/or manuals.
2. A stable foundation/base shall be prepared for installation of the VFD equipment. Cable entry exit points are to be setup either via conduit installation or cable tray/cable guide installation.
3. Appropriate low voltage power for auxiliary controls shall be made available at the site.
4. All power wiring and control wiring shall be done by the installation contractor per manufacturers drawing.
   1. **shipping**
5. Unless specified otherwise, preparation for shipment shall be in accordance with Manufacturer's standards.
6. Loose parts and components shall be properly packaged and secured for shipment inside the enclosure or shipping container. These items shall be properly tagged for easy identification.
7. VFD shipping units can be export packaged when required
   1. **SYSTEM STARTUP AND COMMISSIONING**
8. Commissioning and Startup Services must be available from the supplier’s local field engineering service group. A field service engineer shall be available 24 hours per day, 365 days per year.
9. Supplier shall provide a start-up and commission plan for the supplied VFD system. The startup plan shall include check of installation, check of power and field signal wiring, power-up / no-load testing (load uncoupled) and load testing (coupled testing).
10. The Supplier shall provide a software tool with operational, maintenance and diagnostic features. Using a Purchaser supplied IBM compatible PC, this software shall permit the programming of parameters, display block diagrams, show bar graphs, report adjustment data, display trends, provide troubleshooting using first fault data and trace back data.