MEDIUM VOLTAGE AIR-COOLED VARIABLE FREQUENCY DRIVE SPECIFICATION
1.0 SCOPE

1.1 This specification covers the complete labor, materials, equipment, and incidentals required to place into operation an integrated medium voltage variable frequency drive (VFD) system. This specification may be applied to any type of medium voltage (MV) AC motor application.

1.2 Every variable frequency drive system shall meet the performance, protection, safety, testing, and certification criteria of this specification. This system may include incoming harmonic filter/power factor correction unit, input isolation transformer, VFD converter/DC link/inverter, and output filter.

1.3 The VFD system must:

   1.3.1 Represent a fully integrated and serviceable package.

   1.3.2 Include all material necessary to interconnect any VFD system elements, even if shipped separately.

1.4 Any modifications to a standard product provided to meet this specification shall be performed by the VFD manufacturer only.

1.5 The VFD system as defined (1.2 above) shall be completely factory pre-wired, assembled, and then tested as a complete package by the VFD manufacturer, before delivery, to assure a properly coordinated, fully integrated drive system.

1.6 Any 3rd party certification, safety, or protection requirements shall be applied to the VFD system as a whole. Certification or protection of system elements or individual components by themselves is not acceptable.

2.0 GENERAL

2.1 Codes and Standards

   2.1.1 Provide equipment in accordance with the latest applicable rules, regulations, and standards for medium voltage drives:

       2.1.1.1 American National Standards Institute (ANSI)

       2.1.1.2 National Electrical Manufacturers Association (NEMA)

       2.1.1.3 Institute of Electrical and Electronics Engineers (IEEE)

       2.1.1.4 International Electrotechnical Commission (IEC)

       2.1.1.5 North American 3rd Party Nationally Recognized Test Lab [e.g. Underwriters’ Laboratories (UL), Canadian Standards Association (CSA)]

   2.1.2 VFDs shall be manufactured, assembled, tested and designed in accordance with UL, CSA, or CE standards as applicable.

2.2 Quality Standards

   2.2.1 Variable frequency drives shall be manufactured by the VFD supplier at its own facility which has an Integrated Management System, certified in accordance with ISO Standard 9001, 14001 and OHSAS 18001.
2.3 Acceptable Manufacturers

2.3.1 Variable frequency drives shall be SINAMICS GH180 Series or approved equal, meeting the exact requirements of these specifications.

2.3.2 The VFD manufacturer shall be able to demonstrate at least 15 years of experience in manufacturing VFDs at medium voltage and their capability to provide parts and service support. A user’s list of similar design equipment, complete with contact names and telephone numbers, shall be furnished upon request.

2.3.3 To ensure timely onsite support, spare parts availability and product life cycle support drives that are manufactured by a third party and/or “brand labeled” shall not be acceptable.

2.4 Product Experience

2.4.1 It is the intention of this specification to purchase dependable and reliable equipment offering the best performance available from currently proven technology. All equipment furnished under this contract must, therefore, have documentation showing proof of actual operation for a minimum of 15 years in similar service.

3.0 PERFORMANCE

3.1 Operating Envelope

3.1.1 VFD shall meet the following speed and torque requirements:

3.1.1.1 The VFD shall be capable of producing a variable AC voltage/frequency output to provide continuous operation over the normal system 20-100% speed range. The VFD must be capable of operation at 1/10 speed to facilitate checkout and maintenance of the driven equipment. As a commissioning and troubleshooting feature, the VFD power circuit shall be capable of operating without a motor connected to the VFD output.

3.1.1.2 VFD shall be capable of operating any standard AC motor of equivalent rating (horsepower and speed) over the specified speed range.

3.1.1.3 The VFD shall be able to produce full rated torque at any speed in the operating range (constant torque capability).

3.1.1.4 If high breakaway/starting torque is required, the VFD shall provide full rated torque at breakaway.

3.1.1.5 One minute overload capability (1 minute every 10 minutes) shall be provided consistent with the application requirements defined in this specification.

3.2 Input Harmonics

3.2.1 VFDs shall comply with the latest edition of IEEE 519 for total harmonic current distortion, calculation and measurement, and meet the above distortion limits without causing the VFD to operate at a leading input power factor from 30% to 100% of rated speed.

3.2.2 Voltage Harmonics: individual or simultaneous operation of the VFDs shall not add more than 3% total harmonic voltage distortion while operating from the utility source, or more than 5% while operating from standby generator (if applicable).

3.2.3 Total harmonic current distortion limits for each individual VFD shall not exceed 5% as calculated and measured at the point of common coupling, defined as the input connection of each VFD.
3.2.4 The VFD converter section shall be 18 or more pulse to eliminate the need for harmonic filters. Harmonic filters are highly undesirable due to resonance problems, and they require tuning whenever other inductive/capacitive loads are placed on the system or when the power system changes.

3.2.5 Upon request compliance shall be verified by the VFD manufacturer with field measurements of harmonic distortion differences at point of common coupling with and without VFDs operating. The point of common coupling (PCC) for all harmonic calculations and field measurements for both voltage and current distortion shall be defined as the input connection of each VFD. In the event the initial field measurements do not meet the latest edition of IEEE-519, the VFD manufacturer shall be responsible for any additional equipment needed for compliance.

3.2.6 Power quality metering shall be inherent to the VFD system to continuously monitor and display input and output power quality. This will allow easy customer verification of power quality and efficiency for the VFD system. The power quality data shall include the following:

- 3.2.6.1 Input voltage (average rms value)
- 3.2.6.2 Input current (individual phase rms values and average rms value)
- 3.2.6.3 Input frequency
- 3.2.6.4 Input power factor
- 3.2.6.5 Input kW, kVAR
- 3.2.6.6 Input kWHR
- 3.2.6.7 Input current THD (average of 3 phases)
- 3.2.6.8 Calculation of total input current or voltage harmonic demand distortion
- 3.2.6.9 Drive efficiency
- 3.2.6.10 Motor voltage (rms)
- 3.2.6.11 Motor current (rms)
- 3.2.6.12 Motor speed (in RPM or %)
- 3.2.6.13 Motor flux (%)
- 3.2.6.14 Motor torque current (%)
- 3.2.6.15 Drive output power (kW)
- 3.2.6.16 Output kW-Hr

3.3 Motor Compatibility

3.3.1 VFD system shall provide an output waveform that will allow utilization of standard motors, without the need of any special insulation or de-rating. Motor life expectancy should not be compromised in any way by operation with the VFD system. The system must comply with all elements of the output harmonics section of this specification. The VFD must provide motor overload protection in any operating condition.

3.3.2 VFD output waveform shall be suitable for operating a squirrel cage induction motor without de-rating or requiring additional service factor. To ensure that there are no problems with motor heating, VFD output current waveform, as measured at the motor, shall be inherently sinusoidal at all speeds, with a total harmonic current distortion not exceeding 3% referenced to the full load output current fundamental between 10% and 100% speed.

3.3.3 The system design shall not have any inherent output harmonic resonance in the operating speed range.

3.3.4 The VFD output shall produce minimum electrically-induced pulsating torque to the output shaft (less than 1%) of the mechanical system eliminating the possibility of exciting a resonance caused by VFD induced torque pulsations. VFD systems, or other types which produce individual torque pulsations across speed range are <1% of rated w/out over-modulation and <3.5% of rated w/ over-modulation.
3.3.5 VFD shall inherently protect motor from high-voltage $\delta v/\delta t$ stress, independent of cable length to motor. VFD shall not require non-standard insulation systems or insulation ratings above the VFD output voltage rating. The VFD system shall be designed to produce no standing waves or over-voltage conditions based on cable lengths below 7500 feet (2300 m). This is a typical length which will cover most application requirements and allow for potential future cable run changes from VFD to motor. If the VFD requires an output filter to meet this requirement, it shall be an integral part of the VFD system.

3.3.6 An integral input transformer shall be included with the VFD system to provide common mode voltage protection and allow the use of a standard motor. Special high-voltage motor insulation is not an acceptable method for protection against common mode voltages. VFD systems that do not include an integral input transformer will not be accepted.

3.4 VFD System Efficiency

3.4.1 Guaranteed minimum VFD system efficiency ($\eta_{sys}$) shall be above 96% at 100% load, and above 95% in the 100% to 50% load range. Efficiency evaluation shall include input transformer, harmonic filters, and power factor correction (if applicable), VFD converter, and output filter, as indicated below.

The VFD system efficiency is as follows:

$$\eta_{sys} = \eta_{VFD} \times \eta_{xfmr} \times \eta_{pfc} \times \eta_{harm} \times \eta_{filter}$$

<table>
<thead>
<tr>
<th>Converter/Inverter (VFD)</th>
<th>$\eta_{VFD}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Transformer</td>
<td>$\eta_{xfmr}$</td>
</tr>
<tr>
<td>Power Factor Correction</td>
<td>$\eta_{pfc}$</td>
</tr>
<tr>
<td>Input Harmonic Filter</td>
<td>$\eta_{harm}$</td>
</tr>
<tr>
<td>Output Filter</td>
<td>$\eta_{filter}$</td>
</tr>
</tbody>
</table>

VFD System Efficiency ($\eta_{sys}$) must be 96.0% at full load and 95% at 50% load.

3.4.2 If required, a factory test shall be performed at the VFD manufacturer's facility certifying that efficiencies have been met. A penalty (in dollars per kW) will be assessed if efficiency is not achieved and will be deducted from the contracted price.

3.5 System Input Power Factor

3.5.1 VFD system shall maintain a 0.95 minimum power factor from 30% to 100% of rated speed. VFD system including power factor correction and/or harmonic filter shall never have a leading power factor under utility or generator operation. VFD manufacturer is to supply a power factor correction system, if required, to meet this requirement. Power factor correction unit shall include a separate input isolating contactor with fuses, power factor correction grade capacitors (voltage class shall be consistent with the VFD system input voltage), and series harmonic de-coupling reactors, all integrated into VFD system and mounted within the VFD enclosure.

3.5.2 For VFD systems employing a capacitive input filter, an electrical system analysis shall be performed by the VFD vendor to ensure the VFD will not create a leading power factor or a resonant condition while operating on utility or back-up generator power. This analysis shall be provided with the bid.
3.6 Speed Regulation

3.6.1 VFD control system speed regulation shall be ±0.5% without encoder or tachometer feedback.

4.0 DESIGN CALCULATIONS

4.1 Torsional Analysis

4.1.1 If a torsional analysis is required, as defined by the output waveform section (see Section 3.3), the price of the torsional analysis shall be included in the base price of the VFD system. The total rotating system shall be analyzed to determine its natural resonant frequencies. Stresses are to be calculated for elements of the rotating system, utilizing torsional excitation data from the drive and driven system, taking into account potential transient or fault conditions, and appropriate amplification and damping factors of the rotating system. A written report on the analysis shall detail the procedures used and the assumptions that were considered shall be provided. The results of the analysis must be presented in both detailed and summary form. Specific data presented shall include the following:

4.1.1.1 A diagram of the frequencies of the torque pulsations and the mechanical resonant frequencies showing their coincident points

4.1.1.2 A plot of total shaft stress versus operating speed for the most highly stressed areas of the rotating system

4.1.1.3 A diagram of the rotating system model and mode shapes for resonance(s) of interest

4.1.1.4 Tables summarizing total calculated stresses for each element of the rotating system at operating speeds where interference(s) exist between torsional excitations and torsional resonance

4.1.1.5 Details of the rotating system used in the analysis, including the specified or a recommended alternate coupling

4.2 Harmonic Study (Performed on request)

4.2.1 A preliminary harmonic calculation shall be performed by the VFD system manufacturer if required for specific project. A power system short circuit ratio of 10 shall be assumed, with all VFDs operating at maximum speed and maximum load.

4.2.1.1 The harmonic calculation, submitted by the VFD system manufacturer, should include all voltage and current harmonics up to the 99th. The point of common coupling for all harmonic calculations and field measurements for both voltage and current distortion shall be defined as the primary connection of each VFD.

4.2.1.2 A separate calculation shall be performed on the basis of the standby generator system data.

5.0 AVAILABILITY

5.1 Firing Signals

5.1.1 All internal firing signals and other communications with power components, such as status and diagnostic signals, must meet noise immunity and safety requirements as defined by the applicable standards referenced in Section 2.1.
5.2 Multi-cell H-bridge topology

5.2.1 Drives with multi-cell H-bridge topology shall have 750V cells for the nominal output voltage of 4kV and above to offer best reliability.

5.3 Failed Power Electronic Ride-Through Capability

5.3.1 If power-electronic bypass feature is included, the failure of any power switching device (SCR, diode, IGBT, IGCT, etc.) in both the converter and inverter sections and/or switching device control circuitry shall not result in a process trip and shall allow for continued operation of the VFD system. In the event of a device or device control failure, the VFD shall annunciate and identify the specific location of the failed device and allow for continued operation until such time as repairs can be scheduled.

5.3.2 The power-electronic bypass feature shall meet the following requirements:

5.3.2.1 Only mechanical bypass is acceptable to improve bypass reliability. If electronic bypass is offered, independent communication between the bypass system and the drive control is required.

5.3.2.2 In case of a fault bypass shall engage within 250 milliseconds or less.

5.3.3 With a single power module in bypass system shall maintain as a minimum 83% of output voltage without extra modules, the VFD shall maintain the required speed. Output voltage shall be optimized when VFD is in bypass without inducing torque pulsations.

5.3.4 Extra rank of cells/modules/section shall be available as an option to provide 100% of current and voltage.

5.3.5 The feature shall be demonstrated and documented during the factory acceptance testing of the VFD system.

5.4 Power Interrupt Ride-Through

5.4.1 In case of medium voltage line loss, the user shall be able to select either 0.5 seconds ride-through with all cells functional or to maintain flux on the machine to reduce restart time depending on customer application. The VFD system must be capable of continuous operation in the event of a power loss of a minimum of 5 cycles with 1 or more cells not functional.

5.4.2 The VFD system must be capable of automatically restarting in the event of a momentary loss of power. The VFD system shall provide the user with the choice of automatically restarting or not. A safety device (hard key or password) must be available to allow enabling, disabling, and setting changes to this feature only by authorized personnel. The user shall be able to selectively apply this feature and have the ability to set the allowable restart time applicable to some (but not necessarily all) conditions as determined by the user to be appropriate for the specific application.

5.5 Power Sag Ride-Through

5.5.1 The VFD system shall be capable of maintaining continuous operation with a 35% voltage sag on the input power line. Such operation shall be maintained as long as medium voltage is absent (or below 65%). If enabled, the control shall monitor the motor flux (both magnitude and phase) as it decays based on the motor open circuit time constant. If the drive is restarted and the motor flux is still above 4% of rated, the drive shall re-magnetize the motor and follow the speed ramp without any delay.
5.6 “Catch-A-Spinning-Load” Capability

5.6.1 The VFD system must be able to catch and take control of a spinning load if started while rotating equipment is already spinning in a forward direction. Appropriate safeguards must be included in this operation to prevent damaging torque(s), voltages, or currents from impacting any of the equipment. The user shall have the option of employing this feature or disabling it. This option shall be hard-key or password protected to avoid unwanted changes by unauthorized personnel.

5.7 Auto-Restart Capability

5.7.1 The VFD system must be capable of automatically restarting in the event of a process or drive trip as long as input MV is present. The VFD system shall provide the user with the choice of automatically restarting or not. The user shall be able to selectively apply this feature to some (but not necessarily all) conditions as determined by the user to be appropriate for the specific application. This option shall be hard-key or password protected to avoid unwanted changes by unauthorized personnel.

5.8 Ground Faults

5.8.1 In the event of an input or output ground fault, the VFD shall be capable of annunciating the ground fault condition, safely operating, and by user selection, either trip or continue operation.

5.8.2 The VFD shall be capable of detecting output ground fault of 10mA to ensure personal safety. The manufacturer shall provide a valid type test to show that protection and detection works as described.

5.8.3 In order to prevent erroneous operation of the site's ground fault relay protection system, the VFD system shall not contribute more than 0.3 amp input ground fault when operating under normal operation.
6.0 SERVICEABILITY / MAINTAINABILITY

6.1 Front Access

6.1.1 VFD system should be designed for front access only. VFD manufacturer shall state in their proposal if rear or side access is required. An explanation of reason and specified distance for any required rear or side access shall be given.

6.2 Power Component Accessibility

6.2.1 All power electronic components in the converter sections shall be designed for rack-out accessibility for ease of maintenance and to minimize repair downtime. Alternate access options must be described in the proposal for purchaser’s review and evaluation.

6.2.2 Those systems that employ a single integrated power conversion module that is not readily site-repairable or easily accessible by site maintenance personnel are not acceptable.

6.3 Voltage Isolation

6.3.1 All low voltage components, circuits, and wiring shall be separated with physical barriers from any sources of medium voltage and shall be compliant with IEC 61800-5-1.

6.4 Remote Diagnostics

6.4.1 The VFD system shall be provided with the capability for remote diagnostics via Ethernet link.

6.5 Marking/Labeling

6.5.1 Self-laminating vinyl labels or other acceptable means of permanent identification shall be applied to power and control wiring. Individual labels shall be provided for all major components of the VFD system. Labels shall match equipment drawings.

6.6 Mean Time To Repair (MTTR)

6.6.1 In the event of a power electronic failure, removal and replacement should take an average of 20 minutes, after capacitors have discharged and safe working conditions have been established.

7.0 PHYSICAL REQUIREMENTS

7.1 Environmental Requirements

7.1.1 VFD system shall be capable of continuous operation in an average ambient temperature between +5°C and 40°C at an elevation up to 3300 feet (1000 meters) above MSL without de-rating. The VFD system shall also be simultaneously suitable for continuous operation with the humidity between 0 and 95% non-condensing.

7.2 Heat Dissipation/Cooling System

7.2.1 VFD system shall be forced air-cooled and when required, shall be provided with fan redundancy and automatic switchover in the event of a fan failure for enhanced reliability. If a fan fails, the system must automatically switch to the alternate fan and generate an alarm to notify operator of initial fan system failure. During normal operation, the system must periodically cycle between the redundant fan systems to “exercise” them and prevent drying out of bearings, seals, etc., and to ensure availability of all systems. VFD system manufacturer shall provide heat dissipation data necessary to design all auxiliary HVAC systems.
7.3 Enclosure

7.3.1 All VFD system components, including transformer, shall be mounted and wired by the VFD system manufacturer in a grounded enclosure meeting the following requirements without exception:

7.3.1.1 Input filters, transformer, power conversion, and output filters shall be IP-21 design (or NEMA equivalent), or better degree of protection, with gasketed doors. Ventilated enclosure shall have cleanable filter media covering all air inlets. Inlet air filters shall be 100% washable with a corrosion-free media. Filters shall be front replaceable (for cleaning) while the VFD is in operation without exposing maintenance personnel to any of the power components. Cabinet color shall be ANSI 61 gray. Paint procedures and materials shall be manufacturer’s system, designed and proven for resistance to chemical attack in industrial power-house environments.

7.3.1.2 Microprocessor and control logic boards and their power supplies shall be safely accessible without exposure to high voltages and without drive shutdown. All low voltage wiring shall be fully isolated from medium voltage compartments by metal barriers.

7.3.1.3 Cabinets and doors shall be fabricated using heavy gauge formed or structural steel for sturdy construction for dimensional integrity to assure long-term fit and function. All doors shall be gasketed to provide environmental protection and secure fits.

7.3.1.4 Enclosures must be designed to avoid harmonic and inductive heating effects.

7.4 Installation/Cabling

7.4.1 Owner will provide labor to set equipment in place. All VFD system wiring (power, control, and protection) shall be located internally within the VFD system enclosure. All external power conductors (bus or cable) shall be insulated. Power wiring shall be isolated by voltage class. Control and protection wiring shall be isolated from power wiring.

No more than two wires shall be terminated at any terminal point.

7.5 Space Limitations - Footprint

7.5.1 The VFD system must fit in the space indicated on project drawings.

7.6 Interlocks

7.6.1 Mechanical key interlocks shall be provided on all MV hinged doors. Interlocking shall be fully coordinated to prevent access to all high voltage compartments, including transformer, filters, or any switchgear that is part of the supply, when line power is applied to the VFD system. Interlocks must be mechanical to provide positive lock-out prevention and safety.

7.6.2 If requested, electrical interlocks should be provided in addition to mechanical key interlocks, as added safety measure to prevent access to energized sections in the VFD.

7.7 Auxiliary Power

7.7.1 To power the VFD cooling system and control circuits, a 3-phase low-voltage auxiliary power will be provided by the customer. Means for isolation shall be provided to allow for isolation of this power supply source as needed. This auxiliary power voltage shall be determined by the customer and must be indicated at time of order.
7.8 Control Power

7.8.1 All VFD internal control circuits shall be 120 VAC single phase unless otherwise specified. VFD manufacturer shall provide provision for deriving control power from auxiliary power.

8.0 PROTECTIVE DEVICES / DIAGNOSTICS

8.1 Drive Short Circuit Protection

8.1.1 The VFD with integral transformer that has 9 secondaries and above shall have built-in short-circuit detection and protection. Software shall include protective functions which detect abnormal conditions due to an internal power circuit sub-component failure(s). And as such, VFD will fault if abnormal conditions are present. Protective functions shall include:

8.1.1.1 Excessive Input Reactive Current Detection (One Cycle Protection)

8.1.1.2 Excessive Drive Losses Protection

8.1.2 The manufacturer shall provide a valid type test to show that protection and detection works as described.

8.1.3 An upstream trippable device is required

8.2 Power Component Protection

8.2.1 VFD system shall include distribution class surge arrestors to protect the converter and its input transformer against voltage surges.

8.2.2 The VFD system shall include power fuses on the input to the converter devices to protect the secondary of the transformer from any potentially harmful fault currents.

8.3 Protective Features and Circuits

8.3.1 The controller shall include the following alarms and protective features:

8.3.1.1 Static instantaneous over-current and over-voltage trip

8.3.1.2 Under-voltage and power loss protection

8.3.1.3 Over-temperature protection

8.3.1.4 Electronic motor inverse time overload protection

8.3.1.5 Responsive action to motor winding temperature detectors or thermostatic switches, a dry contact (NC) input to the VFD is required motor protection relay is by the customer.

8.3.1.6 When power is restored after a complete power outage, the VFD shall be capable - if this function has been enabled - of catching the motor while it is still spinning in a forward direction and restoring it to proper operating speed without the use of an encoder

8.3.2 The VFD system shall be protected from damage due to the following, without requiring an output contactor:

8.3.2.1 Single-phase fault or 3-phase short circuit on VFD system output terminals
8.3.2.2 Power device failure to commutate/switch due to severe overload or other conditions

8.3.2.3 Loss of input power due to opening of VFD input disconnect device or utility power failure during VFD operation

8.3.2.4 Loss of one phase of input power

8.3.2.5 Induction motor regeneration due to backspin or loss of VFD input power

8.3.3 The VFD shall be able to withstand the following fault conditions without damage to the power circuit components:

8.3.3.1 Failure to connect a motor to the VFD output

8.3.3.2 VFD output open circuit that may occur during operation

8.3.3.3 VFD input or output ground fault

8.3.3.4 VFD input or output single-phase

8.3.4 The VFD shall be provided with integrated control provisions to operate or trip an incoming power disconnect device.

8.4 Data Displays

8.4.1 A door-mounted LCD display shall be furnished, capable of displaying the VFD operational status and drive parameters. The digital display must present all diagnostic message and parameter values in plain language/engineering units when accessed, without the use of codes. English is the default language unless noted otherwise.

8.4.2 As a minimum, the following door mounted digital indications with a resolution of at least ±0.01% and an accuracy of 1%, shall be supplied:

8.4.2.1 Speed demand in percent

8.4.2.2 Input current in amperes

8.4.2.3 Output current in amperes

8.4.2.4 Output frequency in Hertz

8.4.2.5 Input voltage

8.4.2.6 Output voltage

8.4.2.7 Total 3-phase kW output

8.4.2.8 Kilowatt hour meter

8.4.2.9 Elapsed time running meter

Note: A minimum of four indications must be displayed simultaneously and display indications must be available at the indication panel.
8.5 Diagnostics and Fault Recording

8.5.1 The control logic section shall be fully digital and not require analog adjustment pots or fixed selector resistors.

8.5.2 Fault log data storage memory shall be stored in non-volatile memory or be supported by a UPS sized to provide a minimum of 48 hour data retention.

8.5.3 The VFD shall include a comprehensive microprocessor based digital diagnostic system which monitors its own control functions and displays faults and operating conditions.

8.5.4 A “FAULT LOG” shall record, store, display, and print upon demand, the following for the 256 most recent events:

8.5.4.1 VFD mode (Auto/Manual)
8.5.4.2 Date and time of day
8.5.4.3 Type of fault
8.5.4.4 Reset mode (Auto/Manual)

8.5.5 A “HISTORIC LOG” shall record, store, display, and print upon demand, the following control variables at an adjustable time interval for the 50 intervals immediately preceding a fault trip and 100 intervals following such trip:

The historic log records operating data of the drive and is frozen upon detection of a fault. A new fault will overwrite the recorded historic log. The event log includes the option to copy and record the historic log so that all fault events are recorded. The historic log is stored in memory with a total of 512 records. Non-volatile memory is used to store the most recent 78 records. Snapshots are recorded at the slow cycle update rate:

- Most snapshots are recorded before a fault occurs.
- 20 snapshots are recorded after a fault occurs.

8.5.5.1 VFD mode (manual/auto/inhibited/tripped/etc.)
8.5.5.2 Speed demand
8.5.5.3 VFD output frequency
8.5.5.4 Demand (output) amps
8.5.5.5 Feedback (motor) amps
8.5.5.6 VFD output volts
8.5.5.7 Type of fault
8.5.5.8 Drive inhibit (On/Off)
8.5.5.9 The fault log record shall be accessible via an Ethernet port, as well as, line by line on the keypad display.
8.5.6 With the VFD, a Windows®-based graphical tool suite shall be provided at no additional charge to customer. This graphical PC tool shall be able to plot and display up to 8 different VFD parameters and have the ability to freeze plotting and print hard-copy versions of the plots. Capability to display at least 8 different VFD system parameters is required, and all parameters displayed on the PC tool shall be synchronized with the standard keypad display.

9.0 PROGRAMMING AND COMMUNICATIONS

9.1 User Input/Keypad

9.1.1 The door of each power unit shall include manual speed device, a mode selector marked "Manual/Automatic", a "POWER ON" light, a VFD "FAULT" light, a VFD "RUNNING" light, start pushbutton, stop pushbutton, and reset pushbutton.

9.1.2 A door-mounted keypad with integral digital LCD display shall be furnished, capable of controlling the VFD and setting drive parameters. The display must present all diagnostic message and parameter values in standard engineering units when accessed, without the use of codes. The keypad shall allow the operator to enter exact numerical settings in standard engineering units. A plain language (English or other language, as noted on the data sheet) user menu (rather than codes) shall be provided in software as a guide to parameter setting. This device shall be fully compliant with applicable Norms related to enclosures.

9.1.3 Drive parameters shall be factory set in non-volatile EEPROM registers and re-settable in the field through the keypad. A minimum of 6 levels of password security shall be available to protect drive parameters from unauthorized personnel. The EEPROM stored drive variables must be able to be transferred for programming of new or spare boards.

9.1.4 The VFD system shall have the user selectable option of programming up to 3 speed avoidance bands. This gives the user the ability to block out and prevent operation at any undesirable speed, such as one that may be coincident with a mechanical resonance condition. The loss of the keypad or display shall be annunciated as a fault but shall not result in a VFD trip.

9.2 Serial Communication/Protocols/Modem or Cable

9.2.1 VFD shall be capable of digital communication for setup of parameters, fault diagnostics, trending, and diagnostic log downloading. An Ethernet port shall be door-mounted.

9.2.2 The drive shall support duplicate communications channels without the use of protocol bridges. In case of failure, the use of bridges increases maintenance complexity as local expertise is required to reprogram the bridge.

9.2.3 The VFD shall be provided with digital communication capability to allow direct control and status communication with a PLC, SCADA, or other control system. Provisions for a redundant channel shall be provided as an option. The control system must be able to communicate with various protocols as determined by the customer.

10.0 COMPONENT REQUIREMENTS

10.1 Printed Circuit Boards

10.1.1 All printed circuit boards in the VFD power circuit shall be new. They shall be conformal coated for moisture and chemical resistance, in addition to any dielectric coating properties. All control boards must be tested in accordance with Section 11.1.1.
10.2 Power Bus and Wiring

10.2.1 Main power bus shall be high-conductivity and plated for chemical and corrosion resistance and low losses. Bus shall be appropriately sized for the VFD continuous current rating and braced to withstand the mechanical forces caused by a momentary short circuit current. All connections shall be bolted or continuously welded. Main grounding of the VFD system shall have a common loop consisting of copper cable placed in the enclosure base. This cable will ground the base and will be attached to stainless steel grounding pads welded to the base on two locations, one at each end of the enclosure.

10.2.2 All control wiring shall be physically separated from the power wiring. Low and high voltage cables shall be physically isolated from each other. The VFD system shall be pre-wired within the enclosure. Spade type connectors are not acceptable. No soldering shall be used in connection with any wiring. Wiring shall be adequately supported to avoid tension on conductors and terminations. All wiring shall be run in surface mounted conduit or wire-ways. Any section of wiring outside of conduit or wire-way shall be securely tied with cable ties at intervals not exceeding 6 inches. No cables shall be tied off to or in any way supported from power busses. Wherever wiring passes metal edges or through holes, suitable guards, grommets, or chamfers shall be provided to prevent cutting or chafing of the insulation.

10.2.3 All wiring shall be tagged with permanent labels at each termination, junction box, and device. Labels shall correspond to the schematic and wiring diagrams.

10.2.4 Standard corrosion resistant bus pads with NEMA hole patterns are provided for input/output customer connections.

10.3 Ground Connection

10.3.1 Corrosion resistant, stainless steel ground pads shall be provided in each power cabinet.

10.4 Input Isolation Transformer

10.4.1 The VFD system must be supplied with a drive isolation transformer to provide common mode voltage protection and phase shifting (for 18 pulse or higher converter bridge, if employed to meet the power quality requirements of Section 3.2). VFD systems utilizing input AC line reactors which require motors equipped with special higher voltage rated insulation systems are not acceptable and will not be allowed as an alternate bid.

10.4.2 Transformer design to be a rectifier grade isolation type with a K-Factor of 12 for variable torque loads or a K-Factor of 20 for constant torque loads when applied to a SCR converter, in accordance with current EPRI recommendations and ANSI/IEEE Standard C57.110. A K-Factor of 6 is required for diode rectifier converters. Transformers shall have a BIL rating in accordance with the requirements of ANSI/IEEE Standard C57.12.01-2005, C57.110-1998, and IEC 60076-11.

10.4.3 Isolation transformers shall be air-cooled dry type construction, insulation Class H (220°C insulation, 130°C rise), with over-temperature protection.

10.4.4 The requirements listed in this section shall be considered in conjunction with Section 3.4, VFD System Efficiency.
10.5 DC Link Inductors

10.5.1 DC link inductors, if required, shall be air core to prevent saturation. Separate inductors (split dual winding type) shall be provided in the positive and negative leg of the DC link to minimize stray magnetic fields. Inductors shall be Class H insulation (220°C insulation, 150°C rise) with over-temperature protection. To minimize cabling costs, the inductors shall be integral to the VFD system lineup. If it is not possible to integrate the inductors into the VFD system enclosure, the cabling and connecting must be entirely supplied and/or contracted by the VFD system supplier, and approved by the customer’s engineer. Inductors shall be designed to prevent saturation under maximum fault current conditions.

10.5.2 The requirements listed in this section shall be considered in conjunction with Section 3.4, VFD System Efficiency.

10.6 DC Link Capacitors

10.6.1 Capacitors used in the converter DC link shall be integral to the VFD system lineup to minimize cabling costs.

10.6.2 Capacitors used in the converter DC link shall contain discharge resistors and capable of reducing the residual charge to 50 volts or less within 10 minutes after the capacitor is disconnected from the source of supply.

10.7 Input Harmonic Filters

10.7.1 If, after meeting Section 3.2 above, harmonic filters are still required to meet power factor requirements, stricter local requirements, or telephone interference factor restrictions, the VFD manufacturer must provide the filter, upstream filter isolation, protection, and protection coordination. As harmonic filters are power system dependent, the VFD supplier is responsible for maintaining and providing any required upgrades required for the first 10 years of operation at zero cost to the owner. To minimize cabling costs, the harmonic filter components shall be integral to the VFD system lineup, but isolated from other components, such that they can be disconnected from the power source and accessed for maintenance/repair while the VFD is in operation. If it is not possible to integrate the filters into the VFD system enclosure, the cabling and connecting must be entirely supplied and/or contracted by the VFD system supplier, and approved by the customer’s engineer. Harmonic filters must be located on the primary side of the input isolation transformer and must be switchable with the VFD, to prevent their remaining on the power line in the event of a VFD trip which could create a damaging leading power factor condition. The complete filter must have independent protection for over-current, phase differential, and ground fault.

10.7.2 Capacitors used in any harmonic filter banks shall be provided with a method of shorting the phases to ground once power has been removed and the capacitors have been discharged to a safe voltage level. Where oil-filled capacitors are required and the total volume of oil exceeds 500 gallons or 2000 liters, the oil sump and containment provisions shall be supplied as part of the VFD system.

10.7.3 Any reactors used shall be iron-core with Class H (220°C insulation, 130°C rise) insulation and over-temperature protection. Reactors shall be designed to prevent saturation under maximum fault current conditions.

10.7.4 The requirements listed in this section shall be considered in conjunction with Section 3.4, VFD System Efficiency.
10.8 Output Filters

10.8.1 If an output filter is required to meet the output harmonics requirements of this specification or to meet any special requirements of the application, they must be fully incorporated into the VFD system design and added to overall VFD line-up. Cabling and connection of filter to VFD must be supplied and performed or contracted by the VFD system supplier and approved by the customer’s engineer.

10.8.2 Where potential exists for self-excitation between the output filter and the motor system, a fully (voltage and current) rated output contactor shall be provided by the VFD supplier as part of the VFD system delivery.

10.8.3 Any reactors used shall be iron-core with Class H (220°C insulation, 130°C rise) insulation and over-temperature protection. Reactors shall be designed to prevent saturation under maximum fault current conditions.

10.8.4 The requirements listed in this section shall be considered in conjunction with Section 3.4, VFD System Efficiency.

10.9 Input / Output Power Terminations

10.9.1 Input and output power connections shall be made to isolated, supported, and plated bus strap connections. Sufficient space shall be provided for termination connections from the top or the bottom of the VFD cabinet. Space provisions shall be provided for application of standard stress cones, and provisions shall be provided for grounding of shielded cabling.

11.0 TESTING

11.1 Subassembly Tests

11.1.1 Printed circuit boards shall be visually inspected and functionally tested. Boards must be tested individually prior to assembly to minimize any impact faulty boards may have on delivery schedules and system reliability. Boards shall be load and temperature cycled from no load to full load and from ambient to +60°C during a 48-hour burn-in test. Any board that changes function outside of design parameters shall be replaced with a properly functioning board.

11.1.2 Power module subassemblies shall be visually inspected and then HIPOT tested. Complete diagnostics and logic shall be tested. Each complete power conversion module shall be thoroughly tested at 100% load for a minimum of 15 minutes and then tested for 1 minute at momentary overload rating, to reduce potential problems in advance of final system testing.

11.2 System Level Tests

11.2.1 The system (as defined in Section Error! Reference source not found.) shall be given preliminary checks for verification of electrical connections, including ground connections and power and control wiring, and resistance checked point-to-point. E-prom and EE-prom shall be checked for correct revision level. Visual check shall be performed to verify degree of protection for cabinets, input isolation is lockable in the off-position, marking of terminals and wiring, space availability for cable termination, accessibility of components, and ease of maintenance and repair. The VFD system shall be fully checked against the approved drawings for compliance and correct physical dimensions.

11.2.2 Power circuit and all control circuits shall be HIPOT tested to ground.

11.2.3 All control voltage levels are to be checked and verified against stated acceptable levels.
11.2.4 A no load test is to be performed on the system. Drive is to be connected to an unloaded motor and feedback signals shall be verified. Output voltage shall be calibrated. All logic and interlocks, including customer logic and instrumentation, shall be tested.

11.2.5 Drive shall be given a full power test at rated current and rated voltage (simultaneously) for a minimum of 2 hours on a dynamometer or reactor load. This test shall be performed as an integrated system including all supplied input switchgear (if supplied), input transformer, input filter (if supplied), power section, and output filter (if supplied).

11.2.6 The VFD manufacturer shall offer an option for additional system level testing to measure the total system efficiency, power factor, and harmonic distortion, to ensure customer specified limits are met. Total system efficiency shall be measured on both the input and the output of the VFD system. System shall not be shipped unless specified performance criteria are met. Certified test data of all tests conducted shall be provided with final documentation.

11.2.7 The VFD manufacturer shall offer an option for testing to be witnessed by customer’s representative(s). A projected test schedule and a copy of proposed test procedures shall be provided at least 1 month in advance of test date. Customer shall be given at least 1 week notice or confirmation of actual test date(s).

12.0 DOCUMENTATION

12.1 With Proposal

Proposal information shall include, but not be limited to:

12.1.1 Preliminary spare parts list

12.1.2 Certification of compliance with this specification

12.1.3 Warranty

12.1.4 Preliminary dimensions and weights

12.1.5 VFD system continuous current and voltage rating

12.1.6 VFD system one minute current rating

12.1.7 Efficiency and power factor at 100%, 75%, 50%, and 25% load

12.1.8 Input current at 100%, 75%, 50%, and 25% load

12.1.9 Current and voltage harmonic distortion calculation with the point of common coupling located at the input connection of each VFD

12.1.10 External interconnection one-line wiring diagram showing all power, control, and protection cabling required to complete the VFD system on-site

12.2 After Order Submittals

12.2.1 Submittals shall be custom prepared by the VFD system manufacturer for this specific application.

12.2.2 Submittal information shall include, but not be limited to:

12.2.2.1 General arrangement drawings
12.2.2.2 Overall outline dimensions and Maintenance Clearances
12.2.2.3 Weights and Lifting Drawings
12.2.2.4 VFD System Description & Customer Information (Including Input / Output Voltages, Current, Heat Loss, Control Voltages)
12.2.2.5 Anchor Bolt Details
12.2.2.6 Terminal Block Location and Connections
12.2.2.7 Input / Output Power Locations
12.2.2.8 Conduit Entrance Space and Locations
12.2.2.9 Three-Line diagrams
12.2.2.10 Electrical schematics and wiring diagrams
12.2.2.11 Cooling system drawings
12.2.2.12 Mechanical Interlock Scheme
12.2.2.13 Cable and piping locations
12.2.2.14 Location of ground pads
12.2.2.15 Grounding and Shielding requirements
12.2.2.16 Project schedule
12.2.2.17 Final O&M manuals

12.3 Final Documentation
12.3.1 Start-up and commissioning instructions and data
12.3.2 Certified as-built drawings of all equipment with information listed above
12.3.3 Operation and maintenance manual
12.3.4 Manufacturer’s service and repair support during and after warranty
12.3.5 Spare parts lists

13.0 DELIVERY
13.1 VFD system shall be delivered to the site pre-assembled and wired with all specified interconnecting wiring and cable. Cabling for connection across shipping splits shall be neatly coiled and identified. Exposed sections of equipment shall be fully protected from damage during shipment. All necessary hardware for reconnecting shipping splits shall be provided.

13.2 Setting equipment in place, aligning, and anchoring will be done by others. The VFD system manufacturer shall be responsible for all system interconnections across shipping splits at the site.

13.3 Complete instructions for handling and storage shall be provided prior to delivery of the equipment.
14.0 WARRANTY

14.1 All equipment furnished under this section shall be warranted by the contractor and the equipment manufacturer(s) for a minimum period of 24 months after shipment. Warranty shall include all parts, labor, and expenses to perform necessary work.

15.0 TRAINING

15.1 If required, the VFD system supplier shall offer a factory training school for customer’s operations, maintenance, and service personnel. The training school shall include classroom discussion on the theory of operation of the equipment, as well as, maintenance and service methods for the purchased equipment. Topics covered shall include safety, hardware layout and functions, power and control wiring, diagnostic indicators, keypad/display interface, software mapping, programming, setup, configuration, control loop tuning, operational indicators, faults, diagnostic tools, troubleshooting, and preventive maintenance. Hands-on training shall be provided on equipment of the same design as that provided. Documentation shall be provided, which shall include actual manuals for the equipment and drawings and schematics of equipment supplied for this project.

16.0 START-UP

16.1 VFD system manufacturer shall provide the field services of a technician, as necessary, to supervise/inspect installation, test, and start-up all equipment provided as part of the fixed price proposal. The firm price shall include all travel and living expenses, in addition to, the engineer’s time required to complete supervision of the installation, testing, and start-up. All equipment required for testing, start-up, and performance verification shall be provided by the start-up technician.

16.2 Verification of VFD input harmonic voltage and current distortion limits specified must be verified at rated speed and rated power as part of final startup and acceptance. A recording type Fluke, Multilin PQM, BMI, or equivalent harmonic analyzer displaying individual and total harmonic currents and voltages must be utilized.

17.0 SPARE PARTS

17.1 The following spare parts shall be furnished and replaced only by appropriate qualified personnel:

17.1.1 One field replaceable phase module (including but not limited to rectifier, inverter, and DC link power and control components)

17.1.2 One phase module input fuse

17.1.3 One of each control circuit board, including all diagnostic system printed circuit boards

17.1.4 One keypad and keypad adapter

17.1.5 One controller power supply

17.1.6 Door filters

17.2 In addition to the spare parts listed in 17.1, the following spare parts shall be furnished and replaced only by appropriate qualified personnel, if power module bypass feature is included:

17.2.1 One phase module bypass contactor assembly

17.2.2 One bypass power supply and power supply fuse

17.2.3 One bypass controller board
17.3 Those systems that do not allow for individual repair or replacement of parts at the site will not be accepted.

17.4 All parts supplied with the equipment shall be properly labeled for ease of identification and to permit the shortest possible time to repair. Manufacturer shall state closest point where spare parts are stocked and where service can be obtained. Minimum response time for trouble calls shall be 2 hours. A qualified service technician shall be on site within 24 hours of a qualified request. Manufacturer shall warrant that all parts shall be available for a minimum of 10 years.

******************************************************************************END OF SECTION******************************************************************************