Note to Engineer:
Delete this and all other "Note to Engineer" highlighted boxes after completing edits to Specifications.

## PART 1 – GENERAL

This Section includes requirements for design, fabrication, supply and delivery of all variable frequency drives associated with all Mechanical equipment specified under divisions 20, 21, 22, and 23, such as pumps and fans.

### 1.01 RELATED DOCUMENTS

The provisions and intent of the Contract, the General and Supplementary Conditions, and Division 1 Specification Sections, apply to the Work as if specified in this Section.

### 1.02 REFERENCES

A. IEEE 519.

B. NEMA ICS 2 (National Electrical Manufacturers Association) - Industrial Control and Systems: Drives, Contactors, and Overload Relays, Rated Not More Than 2000 Volts AC or 750 Volts DC.

C. NEMA 12 (National Electrical Manufacturers Association) – Enclosures.

D. NEMA ICS 3.1 (National Electrical Manufacturers Association) - Safety Standards for Construction and Guide for Selection, Installation and Operation of Adjustable-Speed Drive Systems.

E. NEMA ICS 7 (National Electrical Manufacturers Association) - Industrial Control and Systems: Adjustable Speed Drives.

F. NEMA 250 (National Electrical Manufacturers Association) - Enclosures for Electrical Equipment (1000 Volts Maximum).

G. NFPA 70 (National Fire Protection Association) – National Electrical Code.

### 1.03 QUALITY ASSURANCE

A. Manufacturer Qualifications: Maintain, within 100 miles of Project site, a service center capable of providing training, parts, and emergency maintenance and repairs.

B. Listing and Labeling: VFDs shall be UL Listed and Labeled as a complete unit, and shall conform to NEMA ICS 2, IEEE 519 and ANSI standards.

C. Comply with NFPA 70, as adopted and administered by the Authority Having Jurisdiction.

D. Manufacturer Limitations:

1. All VFDs shall be supplied by one manufacturer.
2. To ensure quality, the complete VFD shall be tested by the manufacturer. The VFD shall drive a motor connected to a dynamometer at full load and speed and shall be cycled during the automated test procedure.
3. All optional features shall be functionally tested at the factory for proper operation.

E. Retain below if equipment mounting space is limited or weight is a concern.

F. Product Selection for Restricted Space: Drawings indicate maximum dimensions for VFDs, minimum clearances between VFDs, and adjacent surfaces and other items. Comply with indicated dimensions and clearances. VFD schedules to include weight limitations or basis of design in areas of concern due to seismic on existing buildings.

## 1.04 SUBMITTALS

A. Product Data: For each type of VFD, provide dimensions; mounting arrangements; location for conduit entries; shipping and operating weights; and manufacturer's technical data on features, performance, electrical ratings, characteristics, and finishes.

B. Shop Drawings: For each VFD:

1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings. Include the following:
   a. Each installed unit's type and details.
   b. Nameplate legends.
   c. Short-circuit current ratings of integrated unit.
   d. Delete subparagraph below if series rating of overcurrent protective devices is not used or if VFDs are used without front-end overcurrent protective devices.
   e. UL listing for series rating of overcurrent protective devices in combination with drives.
   f. Delete subparagraph below if combination controllers are not used.

g. Features, characteristics, ratings, and factory settings of each motor-control center unit.

2. Wiring Diagrams: Power, signal, and control wiring for each type of VFD.

C. Manufacturer Seismic Qualification Certification: Submit certification that VFDs, accessories, and components will withstand seismic forces as listed in the applicable International Building Code for Sea Tac airport locale. Include the following:

1. Basis of Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Delete paragraph below if independent testing agency is not used.

E. Field Test Reports: Written reports specified in Part 3.

F. Manufacturer's field service report.

G. Operations and Maintenance Data: For VFDs, all installed devices, and components to include in emergency, operation, and maintenance manuals. In addition to items specified in Division 1, Section "Operations and Maintenance Data," include the following:

1. Routine maintenance requirements for VFDs and all installed components.
2. Delete subparagraph below if circuit breakers are not used in VFDs.
3. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.

H. Load-Current and Overload-Relay Heater List: Compile after motors have been installed and arrange to demonstrate that selection of heaters suits actual motor nameplate full-load currents.

Select paragraph above or below if motor running overload protection is specified as part of bypass controller in Part 2 of the specification.

I. Load-Current and List of Settings of Adjustable Overload Relays: Compile after motors have been installed and arrange to demonstrate that dip-switch settings for motor running overload protection suit actual motor to be protected.

## 1.05 DEFINITIONS

A. IGBT: Insulated gate bipolar transistor.

B. LAN: Local area network.

C. PID: Control action, proportional plus integral plus derivative.

D. PWM: Pulse-width modulated.

E. VFD: Variable frequency drive.

## 1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver VFDs in shipping splits of lengths that can be moved past obstructions in delivery path as indicated.

B. Store VFDs indoors in clean, dry space with uniform temperature to prevent condensation. Protect VFDs from exposure to dirt, fumes, water, corrosive substances, and physical damage.

C. If stored in areas subject to weather, cover (shrink wrap) VFDs to protect them from weather, dirt, dust, corrosive substances, and physical damage. Remove loose packing and flammable materials from inside drives; install electric heating of sufficient wattage to prevent condensation.

## 1.07 COORDINATION

A. Coordinate layout and installation of VFDs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate equipment supports, roof penetrations, and installation of roof curbs.

C. Coordinate features of VFDs, installed units, and accessory devices with pilot devices and control circuits to which they connect.

D. Coordinate features, accessories, and functions of each VFD and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

## 1.08 EXTRA MATERIALS

Furnish manufacturer's recommended list of spare part numbers and sources.

## PART 2 - PRODUCTS

### 2.01 MANUFACTURERS

Subject to compliance with requirements, provide products by one of the following:

A. Yaskawa (18 Pulse, 6 Pulse or Matrix)

B. Allen Bradley.

C. Or Equal – Note that any manufacturer's product that is submitted for consideration as a substitution MUST be accompanied with a complete point by point, paragraph by paragraph description showing exactly how the proposed equipment meets every part of this standard.

### 2.02 VARIABLE FREQUENCY DRIVES

A. Arc Flash Protection Labeling: Variable Frequency Drives shall be marked to warn personnel of potential arc flash hazards. The marking shall be located to be clearly visible to qualified personnel before examination, adjustment, servicing or maintenance of the equipment.

B. Description: NEMA ICS2, IGBT, PWM, VFD; listed and labeled as a complete unit and arranged to provide variable speed of a NEMAMG1, Design B, 1.15 service factor, 3-phase, premium-efficiency induction motor by converting input voltage and frequency to a variable output voltage and frequency via a two-step operation.

C. Compliance: Meet all requirements of the latest edition of IEEE 519 for current and voltage harmonic standards.

1. Point of Common Coupling (PCC): Motor Control Center or supply panelboard shall be used as the Point of Common Coupling for all harmonic calculations and field measurements for voltage and current distortion.
2. IEEE 519, Table 10.2 Requirements: Individual or simultaneous operation of VFDs at full load and speed shall not add more than 3% total harmonic voltage distortion during operation from the utility source, or 5% during operation from a standby generator.
3. IEEE 519, Table 10.3 Requirements: Total harmonic current distortion during individual or simultaneous operation of VFDs at any point of the operating

range (speed and/or horsepower and/or torque) shall meet table 10.3 IEEE 519 as calculated and measured at the Point of Common Coupling.

4. VFD Requirements by Size and Total HP on PCC
    a. VFDs 40HP and above shall be 18 Pulse or Matrix.
    b. VFDs 30HP or less shall be 6 pulse or higher or Matrix and meet IEEE 519 2014 table 10.2 and have 12% maximum TDD.
    c. VFDs under 7.5HP shall comply to IEEE 519 1992 table 10.2 only.
    d. If the total HP for a group of VFDs under 30HP on a common PCC as documented in the project electrical drawings and defined in 2.02.C.1 exceeds 75HP the drives shall each have 5% line impedance and calculation(s) will be performed to determine if a common active harmonic filter shall be provided to meet IEEE 519 1992 table 10.3.
5. All needed filtering to meet PCC harmonic requirements must be within the VFD enclosure and be integrally listed and labelled with the VFD manufacturer.

D. Drive System Design: Space vector sine-coded pulse-width modulated (PWM).
1. Match load type such as fans, blowers, and pumps; and type of connection used between motor and load such as direct or through a power-transmission connection.
    a. VFD shall maintain a 0.95 minimum true power factor throughout the entire speed range.
    b. Drive system shall be 96 % efficient at full load and full speed, and 95 % efficient at 50 % load and 80 % speed.
    c. Design motors to operate no faster than 60-hertz under normal conditions.
2. Rated Input Power: 460 Volts, 60 Hertz.
    a. AC Line Frequency Variation: Plus or minus 3-hertz.
    b. Power Unit Rating Basis: 100 % rated current continuous, 110 % rated current for one minute, at rated temperature.
    c. Voltage Dip Ride-Through: Capable of sustaining continued operation with a 40 % dip in nominal line voltage.
    d. Power Loss Ride-Through: Capable of a minimum 3-cycle power loss without fault activation.

e. When power is restored after a complete power outage, the VFD shall be capable of 'catching' the motor while it is still spinning, and restoring it to proper operating speed without use of an encoder.

3. Ambient Temperature: 0°C to 40°C.
4. Atmosphere: Non-condensing relative humidity to 95 %.
5. Starting Torque: 100 % of rated torque or as indicated.
6. Speed Regulation: Plus or minus 1 %.

E. Drive System Components: Integral to unit, factory-wired and tested as a complete system, including:

1. Input rectifier-grade phase-shifting transformer.
2. Matrix or 18-pulse converter without harmonic filter; or

   6-pulse converter(s) with active or passive harmonic filter as required to meet 2.02C.

   a. VFD Supplier shall be responsible for the proper selection and implementation of the harmonic filter, including field labor and materials if the filter is external to the VFD.
   b. Minimum 5th, 7th, and 11th harmonic filtering, meeting IEEE 519 requirements.
   c. Passive harmonic filters shall include capacitor leg contactors and control transformers. The capacitor leg contactor shall be controlled by a relay contact in the VFD that closes at approximately 80% load (adjustable).
3. Output inverter.

F. Isolated Control Interface shall allow drive to follow a 4 to 20mA electrical signal at 24V, over a 10:1 speed range.

G. Self-Protection and Reliability Features: Integral to unit, factory-wired and tested as a complete system, including:

1. Under- and over-voltage trips; inverter overtemperature, overload, and overcurrent trips.
2. Electronic motor overload protection.
3. Instantaneous line-to-line and line-to-ground overcurrent trips.
4. Loss-of-phase protection.
5. Reverse-phase protection.
6. Three-phase short-circuit protection on VFD output terminal.

7. Power unit over-temperature alarm and trip.
8. Motor winding temperature detectors or thermostatic switches. Include normally closed dry contact input to the VFD for alarm and shutdown.

Delete below if surge suppression is not required

9. Input transient protection by means of surge suppressors, IEEE C62.41, selected for exposure category.

H. Status Lights: Door-mounted LED indicators or keypad message display shall indicate the following conditions:
   1. Power on.
   2. Running.
   3. Overvoltage.
   4. Line fault.
   5. Overcurrent.
   6. External fault.

I. Automatic Reset and Restart: To attempt three restarts after drive fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Bi-directional auto speed search shall be capable of starting into rotating loads spinning in either direction and returning motor to set speed in proper direction, without damage to drive, motor, or load.

J. Panel-Mounted Operator Station: Door-mounted keypad with integral digital display, capable of controlling the VFD and setting drive parameters.
   1. Include mode selector switch labeled “Hand/Off/Remote”, and manual speed control device.
   2. Digital display shall present all diagnostic messages and parameter values in English engineering units.
   3. Keypad shall allow operator to enter exact numerical settings in English engineering units.
   4. Keypad shall selectively display the following:
      a. Speed demand in %.
      b. Output current in Amperes.
      c. Output frequency in Hertz.
      d. DC Bus Voltage.
      e. Output Voltage.

f. Total 3-phase kW.
g. Kilowatt-hour meter.
h. Motor speed (RPM).

K. Control Signal Interface: Provide VFD with the following:
1. Electric Input Signal Interface: A minimum of 2 analog inputs (0 to 10V DC or 4-20 mA) (switchable) and 6 programmable digital inputs.
2. Remote Signal Inputs: Capability to accept any of the following speed-setting input signals:
a. 0 to 10V DC.
b. 4-20 mA.
c. Potentiometer using up/down digital inputs.
d. Fixed frequencies using digital inputs.
e. RS 485.
f. Keypad display for local "Hand" operation.
3. Output Signal Interface: A minimum of 1 analog output signal (4-20 mA), which can be programmed to any of the following:
a. Output frequency (Hz).
b. Output current (Load).
c. DC-link voltage (VDC).
d. Motor torque (%).
e. Motor speed (RPM).
f. Set-point frequency (Hz).
4. Remote Indication Interface: A minimum of 2 dry circuit relay outputs (120V AC, 1A) for remote indication of the following:
a. Motor running.
b. Set-point speed reached.
c. Fault and warning indication (over temperature or overcurrent).
d. PID high or low speed limits reached.
5. Power (Kw) Monitoring Interface. Provide analog or digital output interface to collect and record Kw and KwH from each VFD.

L. Communications: Provide RS 232, RS 422 or RS 485 communications port and integral Siemens Apogee and BacNet communications capability for interface to DDC system.

1. Additional communication modules or separate devices to meet this requirement are not allowed.
2. Integral to unit, factory-wired and tested as a complete system.
3. Both Siemens Apogee and BacNet are required, via a VFD parameter setting
4. Interface shall allow all VFD parameter settings, fault log and diagnostic log to be externally downloaded.
5. Provide capability for VFD to retain settings within nonvolatile memory.

Select options suitable for Project. Contact AV/F&I before making these selections.

M. Integral Disconnecting Means: NEMA [AB 1, instantaneous-trip circuit breaker] [AB 1, molded-case switch] [KS 1, nonfusible switch] [KS 1, fusible switch] with lockable handle or a 100KAIC circuit breaker if the VFD package can be labeled and rated 100KAIC without fuses.

N. Output Line Reactor: Provide output line reactor if cable lengths exceed three hundred feet between VFD and motor.

O. Fire Alarm Interface: Provide an override input so that opening dry contacts will absolutely stop the motor under any operating condition. This interface may occur though Smoke Control programming and not directly from fire alarm panel.

## 2.03 ENCLOSURES

NEMA 12, air filter, grounded enclosure with factory mounted and wired components and with adequate filtered ventilation openings for air circulation.

## 2.04 ACCESSORIES *ONLY ON LARGE CRUCIAL APPLICATIONS SUCH AS FIRE PUMPS ETC.*

A. Include current transformers as required to interface with incoming power, and control power transformers as required for drive circuitry.

Delete below if not required.

B. Microprocessor Based Multifunction Motor Protection Relay: Cutler-Hammer IQ-1000-II, GE Multilin 339 (Medium Voltage, 369 Low Voltage), or Engineer approved equal.

C. Elapsed time meter.

D. Push-Button Stations, Pilot Lights, and Selector Switches: NEMA ICS 2, heavy-duty type.

E. Stop and Lockout Push-Button Station: Momentary-break, push-button station with a factory-applied hasp arranged so padlock can be used to lock push button in depressed position with control circuit open.

Delete first paragraph below if not required. Many brands now have phase loss, phase rotation, low voltage built in with their microprocessor control, Such as Motortonics or Telemechanique.

F. Control Relays: Auxiliary and adjustable time-delay relays with phase fail sensitivity.

Use below with three external current transformers.

G. Current-Sensing, Phase-Failure Relays for Bypass Drive: Solid-state sensing circuit with isolated output contacts for hard-wired connection; arranged to operate on phase failure, phase reversal, current unbalance of from 30 to 40 %, or loss of supply voltage; with adjustable response delay.

## 2.05 FACTORY FINISHES

Finish: Manufacturer's standard color paint applied to factory-assembled and -tested VFDs before shipping.

## 2.06 FIRE ALARM INTERFACE

A. Provide an override input so that opening dry contacts will absolutely stop the motor under any operating condition.

# PART 3 - EXECUTION

## 3.01 INSTALLATION

Anchor each VFD assembly according to manufacturer's written instructions and anchoring requirements specified in Division 26, Section "Seismic Controls for Electrical Work."

## 3.02 CONNECTIONS

A. Ground equipment.

B. Power connection between Drive and Motor shall be isolated and separate from any other loads and shall include full sized stranded grounded conductor between Drive and Motor.

C. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

1. Mark lugs after torquing with red paint such that paint will be visibly disturbed if lugs are disturbed.

## 3.03 FIELD QUALITY CONTROL

A. Prepare for acceptance tests as follows:

1. Test insulation resistance of connecting supply, feeder, and control circuit for each VFD.
2. Test continuity of each circuit.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including pretesting and adjusting VFDs.

1. Utilize Fluke 41 or equivalent harmonic analyzer to display individual and total harmonic currents and voltages. Verify that specified input harmonic voltage and current distortion limits are not exceeded and record results.
2. VFD supplier shall take corrective action, at no additional expense to the Port, until compliance with requirements has been achieved.

C. Test Reports: Prepare a written report to record the following:

1. Test procedures used.
2. Identify all VFD's in reports using Port of Seattle mechanical ID numbers. Verify and record Drive model number, serial number and rating. Record Motor nameplate ratings, line voltage of each and ground. Record amperage running under load.
3. Test results that do not comply with requirements and corrective action.

## 3.04 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Complete installation and startup checks according to manufacturer's written instructions.

C. Complete a startup report to include all VFD operating parameters. Include all parameters changed from factory standard.

## 3.05 IDENTIFICATION

A. Identify VFD, components, wiring and controls according to the Mechanical Design Standards "MECHANICAL EQUIPMENT ID SYSTEM" and for wiring only Division 26 Electrical Identification.

B. VFD's are identified by the Mechanical equipment connected to the VFD with that equipment ID and add a VFD extension.

## 3.06 WARANTY

Provide three year written warranty with authorized start up.

## 3.07 DEMONSTRATION AND TRAINING

A. Engage a factory-authorized service representative to train Port maintenance personnel to adjust, operate, and maintain VFDs for a minimum of two hours.
   1. Train Port maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.
   2. Review data in maintenance manuals. Refer to Division 1, Section "Operations and Maintenance Data."

END OF SECTION