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*ABB Inc.*

*Effective September 1, 2021*

*ACQ580-PNPT02U-EN*

*Sample Specification for*

*Variable Frequency Drives*

*For Water & Wastewater Applications*

Example styles in this document per CSI Master/Section/Page specifications. Sub paragraphs levels 5 and 6 are added to compensate for all 9 multi-list level styles in Microsoft Word

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Master Specification Note: This guide specification is written according to the Construction Specifications Institute (CSI) Format. The section must be carefully reviewed and edited by the Architect or Engineer to meet the requirements of the project. Coordinate this section with VFD schedule, other specification sections and the drawings.

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water and wastewater

VARIABLE FREQUENCY DRIVES

1. *GENERAL*
	1. DESCRIPTION
		1. This specification is to cover a complete Variable Frequency Drive (VFD aka: VSD, AFD, ASD, Inverter, AC Drive, et al) consisting of a pulse width modulated (PWM) inverter designed for use with a standard AC induction motor, synchronous reluctance (SynRM) and permanent magnet (PM) motors in water and wastewater applications. The VFD must provide a V/Hz or sensor-less vector mode of operation.

The drive manufacturer shall supply the drive and all necessary options as specified. VFDs that are manufactured by a third party and “brand labeled” shall not be acceptable. All VFDs installed on this project shall be from the same manufacturer.

* 1. QUALITY ASSURANCE
		1. Referenced Standards and Guidelines:
			1. Institute of Electrical and Electronic Engineers (IEEE)
				1. IEEE 519, Guide for Harmonic Content and Control.
			2. Underwriters Laboratories (as appropriate)
				1. UL508C
				2. UL61800-5-1
			3. National Electrical Manufacturer’s Association (NEMA)
				1. ICS 7.0, AC Adjustable Speed Drives
			4. International Electro-technical Commission (IEC)
				1. EN/IEC 61800-3
				2. 2014/35/EU Low Voltage Directive
				3. 2014/30/EU Electromagnetic compatibility (EMC)
				4. 2006/42/EC Machinery Directive
			5. National Electric Code (NEC)
				1. NEC 430.120, Adjustable-Speed Drive Systems
			6. International Building Code (IBC)
				1. IBC 2012 Seismic – referencing ASC 7-05 and ICC AC-156
		2. Qualifications:
			1. The VFD shall comply with the technical requirements of UL according to UL61800-5-1. A UL listing document shall be available to confirm VFDs compliance with the requirements.
				1. In lieu of UL61800-5-1 compliance, the VFD shall comply with the technical requirements of UL according to UL508C. A UL listing document shall be available to confirm VFDs compliance with the requirements.
				2. Along with the declaration, there shall be the UL (Underwriters Laboratories) mark on the VFDs type label to identify the compliance.
				3. Pending UL approval is not accepted.
				4. The VFD shall be UL labeled 100 kA SCCR, RMS Symmetrical, 600V max.
			2. The VFD shall be compliant with the Ecodesign Directive (EC) 2009/125 and its implementation regulation (EU) 2019/1781.
				1. The VFDs type label shall have:

a unique identifier by QR code, according DIN SPEC 91406, which provides a serial number specific link to:

%loss data at operation points (0;25), (0;50), (0;100), (50;25), (50;50), (50;100), (90;50), (90;100), as well as standby losses

IE classification and information on the parameters used for loss determination and classification

Product data sheet

Other product documentation, such as user manuals

the IE class and %loss at (90,100) operation point to rated apparent power

* + - 1. Environmental Manufacturing
				1. The VFD shall comply with Restriction of Hazardous Substances in Electrical and Electronic Equipment directive 2011/65/EU requirements, so called RoHS II requirements.
				2. The VFD shall be easy to recycle. The manufacturer shall make recycling instructions publicly available. The recycling instructions shall provide recycling information in accordance to Waste Electrical and Electronic Equipment directive 2012/19/EU (WEEE).
				3. The VFD shall not contain toxic or hazardous substances or elements above the maximum concentration values as specified in the People’s Republic Electronic Industry Standard (SJ/T 11364-2014). The EIP (Electronic Information Products) mark shall be on the VFDs type label to identify EIP compliance.
			2. Functional Safety
				1. The VFDs shall support ‘Safe Torque Off’ (STO) function capable for safety related applications up to SIL 3, SILCL 3 and PL e.
				2. The VFD shall comply with the following standards

IEC 61508:2010; SIL

ISO 13849-1:2006; PL e

IEC 62061:2005; SILCL 3

IEC 61800-5-2:2007; SIL 3

* + - * 1. There shall be a 3rd party statement of compliance available to confirm the VFDs compliance. Manufacturer’s statements are not accepted to confirm compliance
	1. SUBMITTALS
		1. The Submittals shall include the following information:
			1. Product Overview
			2. Dimensional Drawings
			3. Control Circuit Drawings
			4. Engineering Data including rating tables and weight
			5. General Notes
1. *Variable Frequency Drives (VFD)*
	1. VARIABLE FREQUENCY DRIVES (VFD)
		1. The VFD shall be solid state, with a Pulse Width Modulated (PWM) output. The VFD shall be a Sensor-less Vector AC to AC converter utilizing the latest Insulated Gate Bipolar Transistor (IGBT) technology. The VFD shall employ a Sensor-less Vector inner loop torque control strategy that mathematically determines motor torque and flux. The VFD must also provide an optional operational mode for V/Hz Operation.
		2. Acceptable manufacture: ABB ACQ580 product family
		3. Ratings
			1. The VFD shall be rated to operate from 3-phase power at one of the following voltage ranges. (380-480), VAC +10%/-15%, 48Hz to 63Hz. 5-400 hp the VFD shall employ a full wave rectifier to prevent input line notching and operate at a fundamental (displacement) input power factor of 1.0. at all speeds and nominal load. The input power factor shall have programing capability to adjust power factor lagging to leading. The ULH standardVFD efficiency shall be 96.5% or better at full speed and load.
			2. The overvoltage trip level shall be a minimum of 30% over nominal, and the under-voltage trip level shall be a minimum 35% under the nominal voltage.
			3. Normal Duty / Variable Torque output voltage and current ratings shall match the adjustable frequency operating requirements of a standard AC induction, synchronous reluctance (SynRM) or permanent magnet (PM) motors in water and wastewater applications. The short-term normal duty overload current capacity shall be 110% of rated current for one (1) minute out of ten (10) minutes.
			4. Heavy Duty / Constant Torque output voltage and current ratings shall match the adjustable frequency operating requirements a standard AC induction, synchronous reluctance (SynRM) or permanent magnet (PM) motors in water and wastewater applications. The short term heavy duty overload current capacity shall be 150% of rated current for one (1) minute out of ten (10) minutes and peak overload capacity shall be 180% for two (2) seconds out of each minute with an instantaneous overcurrent trip at 350% or higher.
			5. Output frequency shall be adjustable between 0Hz and 500Hz forward or reversing. Operation above motor nameplate shall require programming changes to prevent inadvertent high-speed operation.
			6. The VFD shall be furnished in an Open Chassis (IP00) , UL Type 1 (NEMA 1) or UL Type 12 (NEMA 12) listed enclosure rated as specified for operation at ambient temperatures between -15oC and 40oC at an altitude not exceeding 3300 feet, with relative humidity less than 95% and no condensation allowed.
			7. The printed circuit boards (PCB) shall be conformal coated to protect from atmospheric contamination by H2S (Hydrogen Sulfide), SO2 (Sulfur Dioxide), NO2 (Nitrogen Dioxide), NH3 (Ammonia) and Cl2 (Chlorine) per IEC 60721-3-3 edition 3/ISO9223 at a concentration level of C4.
	2. Harmonics
		1. Wall mount designs from horsepower reference range of 5HP to 150HP in UL Type 1 (NEMA 1) or UL Type 12\* (NEMA 12\*) and a single point power connection per each electrical phase.

Horsepower range of 200HP to 400HP shall be in UL Type Open (NEMA Open) and a single point power connection per each electrical phase.

* + 1. The VFD construction shall maintain current distortion levels at the VFD’s input terminals to levels at or below those listed in “IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems, IEEE Std. 519.”
			1. Compliance to IEEE Std 519 shall not require the use of additional 12 or 18 Pulse Rectifier bridges, external active filters or passive harmonic filters
			2. Ultra Low Harmonic drives (ULH) are allowed 5 Hp to 400Hp, 480 vac. The ULH must contain, within the same enclosure a T- Configured, Series rated LCL filter specifically engineered by the drive manufacturer. The LCL line filter rated for the full current of the drive to remove high order components cleaning the AC waveform above switching frequency of the active supply unit.
			3. VFD’s without an LCL circuit are not allowed, as the LCL circuit adds extra impedance to the line reducing overall current, including harmonics, and lowering fault current potential.
			4. The LCL filter must contain a contactor system that will remove the capacitor within the LCL filter while in a powered but not running state.
		2. The PCC shall be the input lugs of the drive solution without exception. This requirement ensures compliance with IEEE519, alleviates concerns regarding harmonic loading on the transformer (utility provided power) and standby generator, ensuring reduce electrical stress placed on the standby generator.
			1. 6 pulse VFDs (a drive solution only using diodes in the rectifier section) along with ac line reactors or dc chokes are disallowed
			2. 6 pulse VFDs (a drive solution only using diodes in the rectifier section), along with ac line reactors or dc chokes with the addition of active filter or passive filter with or without shorting contactors are disallowed.
		3. The VFD shall have a total harmonic content of 5% or less of full rated current at the input terminals of the VFD.
		4. The VFD solution provided must maintain IEEE519 at the input lugs with up to and including 3% phase unbalance.
		5. All harmonic mitigating components must be internal to the VFD and supplied as a complete integrated solution.
		6. Regenerative front end VFDs used as harmonic solutions are not acceptable, due to possible regeneration on to power distribution network. The VFD shall not interfere with the Emergency Back-up Generator’s voltage regulator.
		7. Stand alone Active or Passive harmonic filters are not acceptable.
		8. The VFD drive solution provided must maintain Unity Power Factor (1.0 Power Factor) across the useable speed range
		9. Harmonic solutions that have a potential to produce leading power factor shall not be acceptable.
		10. VFD’s without DC Bus capacitors are not acceptable
		11. The VFD shall have a DC bus voltage controller to automatically maintain the DC bus levels in high or low line conditions, for the purpose of maintaining full motor voltage at all times, with a less than a 10% voltage drop.
		12. The VFD shall maintain rated output motor voltage. The VFD shall be capable of operating the motor at full output with a 10% drop on input voltage.
		13. The VFD shall employ an active supply unit design, implemented in multiple variants and generations of drives of similar technology, with over 20 years of use in industry.
		14. All models shall provide a complete, ready-to-install solution.
		15. Built in Power Quality values: There shall be built in Power quality values to provide connected grid information.
			1. Line Current
			2. Active Current
			3. Reactive Current
			4. Grid Voltage
			5. Grid Power
			6. Power Factor of the Drive
	1. MOTOR CONTROL
		1. The VFD shall be capable of controlling an induction motor, permanent magnet motor and synchronous reluctance motors as standard. Have a maximum allowed motor cable length 1000 feet (300 meters). The VFD shall commission an induction motor, permanent magnet motor and synchronous reluctance motor with the motor nameplate values only, without the need to get the motor values from other sources.
		2. Scalar and vector control modes shall be supported and there shall be independent control chains and parameters for both of the motor control modes.
		3. The overload rating of the VFD shall be 110 % of its rated normal duty current for 1 minute every 10 minutes and with a minimum of 130 % for 2 seconds every 1 minute. Overload ability shall be available at all times - not only at start.
		4. The VFD shall be capable of sensing the loss of load (broken belt / broken coupling / dry pump) and signal the loss of load condition. The drive shall be possible to be programmed to signal this condition via a control panel warning, relay output and/or over the serial communications.
		5. Relay outputs shall include programmable for on/off time delays that will allow for drive acceleration or deceleration to and from zero speed, without signaling a false underload condition.
		6. It shall be possible to disconnect a motor running full speed by opening an optional contactor between motor and VFD without causing any damage to the VFD.
		7. The VFD shall include a standard embedded functional safety feature Safe Torque Off, (STO), to make the motor mechanically safe.
		8. The VFD shall include an energy optimization circuit (flux optimization) that will automatically reduce applied motor voltage to the motor to reduce energy consumption by up to 10% and lower audible motor noise.
		9. The VFD shall be capable of starting into a spinning load (forward or reverse) up to full speed and accelerate or decelerate to a set-point (flying start) without tripping or component damage.
		10. The VFD shall restart after a power loss without the need to resend the start command. This feature shall be there regardless of the control source, control panel, I/O or fieldbus.
		11. Flux braking shall be available, where the VFD controls the motor to dissipate the extra rotary energy as heat whenever braking is required. It shall be possible to use this flux braking feature to decelerate the motor from one speed to another – not only for stopping the motor.
		12. Power-Loss-Ride-Through shall be programmable. If the incoming supply voltage is cut off, the VFD continues to operate using the kinetic energy of the rotating motor. The drive continues to be operational as long as the motor rotates and generates energy.
		13. The VFD shall include a switching frequency control function. This adjusts the switching or carrier frequency, based on actual VFD temperature, and allows the highest carrier frequency without de-rating the VFD or operating at high carrier frequency only at low speeds (temperature fold-back). It shall be possible to set a minimum and a reference switching frequency.
		14. The VFD shall include a noise smoothing function, which distributes the acoustic motor noise over a range of frequencies instead of a single tonal frequency resulting in lower peak noise intensity.
		15. The VFD shall have three (3) programmable critical frequency or critical speed lockout ranges to prevent the VFD from operating the load continuously on an undesirable speed range (skip frequencies)
	2. STANDARD CONTROL HARDWARE FEATURES - ADJUSTABLE BY THE USER
		1. General I/O
			1. All I/O terminals shall be color coded to simplify wiring and troubleshooting and shall have a special mode for testing I/O and the drive configuration without being connected to equipment.
			2. All I/O shall be accessible (monitor and control) for fieldbus protocols (pass-through I/O).
			3. It shall be possible to monitor status of the I/O from VFDs control panel

### ANALOG I/O

* + - 1. The VFD shall have at least two (2) programmable analog inputs. Both inputs shall accept current (0 to 20 mA or 4 to 20mA) or voltage (0 to 10 VDC) signals. The signal type selection, voltage or current, shall be made via VFD user interface. DIP-switches or jumpers are not allowed for input type programming. Analog Input shall have an inaccuracy of ≤1 % of full scale in both current and voltage modes
			2. The analog inputs shall be programmable to be used as: speed reference, frequency reference, pressure monitor, PID loop controller’s set-point reference or signal feedback, or other defined inputs.
			3. If the analog input reference (4 to 20 mA or 2 to10 VDC) is lost, the VFD shall give the user the option of: (1) stopping and displaying a fault; (2) running at a programmable preset speed and displaying an alarm; (3) hold the VFD speed based on the last good reference received and displaying an alarm. The drive shall be programmable to signal this condition via a control panel warning, relay output and/or over the serial communication bus.
			4. The VFD shall have at least two (2) programmable analog outputs (0 to 20 mA or 4 to 20 mA) out of which one shall be software configurable to be either voltage (0 to 10 VDC) or current output. Analog Output shall have an inaccuracy of ≤1 % of full scale in both current and voltage modes
			5. The analog outputs shall be programmable to give an output signal proportional to frequency, motor speed, output voltage, output current, motor torque, motor power, DC bus voltage, active reference, or other defined data.

### DIGITAL I/O

* + - 1. The VFD shall have at least six (6) programmable digital inputs (24 VAC and 12 to 24 VDC, PNP or 5 pcs NPN) to connect to external devices, as follows:
				1. All inputs can be configurable for PTC sensors.
				2. There shall be a programmable run permissive circuit.
				3. Up to four (4) programmable free text interlock inputs shall be available.
				4. The VFD shall have at least one digital input which can be configured to receive a pulse signal up to 16 kHz.
		1. Relay I/O
			1. The VFD shall have at least three (3) programmable digital Form-C relay (changeover) outputs. The relays shall include programmable on and off delay times and adjustable hysteresis.

### I/O Optional Extension Modules

* + - 1. The following I/O option modules shall be available:
				1. Relay Extension module with two relay outputs and one digital output, with an external input 24 volt to maintain power and control of module.
				2. PTC input module for up to 6 PTC sensors with an external input 24 volt to maintain power and control of module and is capable of triggering the STO circuitry of the VFD.
				3. Digital input option module to provide additional 6 digital inputs which can be operated with 115 VAC or 230 VAC voltage.

## SOFTWARE FEATURES

### Pump specific features:

* + - 1. The VFD shall have specific pump control functionality to control up to six pumps with one VFD to allow distribution of pump usage in a multiple pump system.
			2. The VFD shall have multi-pump functionality with an intelligent master/follower configuration for controlling up to eight parallel pumps equipped with own VFD without additional devices:
				1. The VFD shall have a parameter synchronization feature to broadcast PID, Multi-pump and Analog Input parameters to ensure system parametrization is equal in the parallel VFDs
				2. The VFD shall have specific functionality to start and stop the pumps based on the required pumping capacity. In order to balance the operating time of the pumps, the VFD shall have the capability to change the order in which the pumps are started and stopped.
				3. The VFD shall have the capability to give priorities for parallel pumps in the system to enable the most efficient pumps to be operated the most.
				4. The VFD shall have the capability to set a maximum stationary time to ensure all pumps get exercised regularly, regardless of their priorities.
				5. The VFD shall have the capability to control across-the-line pumps instead of parallel VFDs, in order to resolve the system demand.
			3. The VFD shall have a level control function with operation modes for optimal tank filling or emptying supporting up to eight parallel pumps.
				1. User–programmable start level shall indicate the point at which the pump will start.
				2. The pump(s) shall operate in user-programmable “efficient speed”.
				3. If the level keeps raising, more pumps will be started based on unique start levels.
				4. There shall be a possibility to connect high- and low- level limit switches, which will trigger either full speed pumping or pump stop, depending if the application is for filling or emptying a tank
			4. The VFD shall have the ability to calculate the flow based on the measured pressure difference (using pressure sensors) or the power curve of the pump (sensor-less).
				1. There shall be a multiplier parameter to enable correction for the calculation.
				2. There shall be a specific energy parameter to measure actual flow per input power ratio. The motor speed can be adjusted to locate the most economical pumping point.
			5. The VFD shall have two additional ramps for quick acceleration and two additional for deceleration in order to reduce wear of the mechanical parts in submersible pumps.
			6. The VFD shall have soft pipe filling function with flexible user parameter settings to protect the system. There shall be a configurable pipe fill time to ensure the setpoint is reached within a desired time.
			7. The VFD shall have a specific “Pump cleaning” functionality, based on a series of rapid reverse and forward rotation of the impeller, to prevent pump and pipe clogging.
				1. The VFD shall have the cleaning cycle counter and user-programmable cleaning count time to give a warning and indicate the need for manual inspection.
				2. The cleaning function shall consist of forced stopping, reverse and forward rotations to allow debris to be removed from the impeller.
				3. There shall be a cleaning cycle status visible on the control panel screen when the cleaning function is active for monitoring the cleaning progress.
				4. The VFD shall resume normal operation after the cleaning cycle is complete.
			8. The VFD shall have a programmable Sleep functionality for PID control in pumping systems to stop the pump during low demand.
				1. The VFD shall have a specific “Sleep Boost” functionality to minimize the amount of unnecessary pump starts and stops during periods of low demand. The sleep boost function is used to boost the pressure or water level up before the pump shuts down in order to extend the pumps sleeping time.
			9. The VFD shall support a torque boost function for applications where boosting of the torque is required for initial starting of the pump.

### PID control

* + - 1. The VFD shall have a minimum of two independent process PID controllers as standard, allowing pressure or flow signals to be connected to the VFD, using the microprocessor in the VFD for the closed loop control.
				1. The VFD shall have 250 mA of 24 VDC auxiliary power and be capable of loop powering a transmitter supplied by other suppliers.
				2. The loop controller setpoint shall be adjustable from the VFDs control panel, analog inputs, or over the serial communications bus.
				3. The VFD shall have a minimum of four constant setpoints available for each loop controller.
				4. The setpoint shall be possible to be set and displayed in engineering units. Using only percentage as setting and display unit is not acceptable.
				5. There shall be two parameter sets for the first PID loop controller. Switching between the sets shall be possible via digital inputs, timed function, and serial communications or from the control panel.
			2. All setpoints, process variables, etc. shall be accessible from the serial communication bus.
			3. The VFD shall have the ability to calculate air or water flow from pressure difference. There shall be the possibility to use a differential pressure transducer or two separate pressure transducers. The control panel shall be able to display the flow in engineering units.
			4. PID controller shall be standard in the VFD, allowing an analog input signals to be connected to the VFD for the closed loop control. The VFD shall have 250 mA of 24 VDC power to power an external transmitter supplied by others. The loop controller set-point shall be adjustable from the VFD control panel, analog inputs, or over field bus. The set-point shall be set and displayed in engineering units.

### Function block programming

* + - 1. The VFD shall provide a PLC-like programming capability as standard.
			2. It shall be possible to use different kinds of arithmetic, logical, selection, comparison, and operation function blocks to monitor and control the VFD, functions, inputs, outputs, and variables.
			3. There shall be a possibility to run different kinds of function block programs in different states and to set the criteria when to change the state

### Timed functions

* + - 1. A real-time clock and calendar shall be available as standard for giving true time and date information to fault event history. The real-time clock shall have a minimum of 10 years power-off back-up without optional components. Back-up battery shall be replaceable without opening the VFD enclosure
			2. A real-time clock shall be possible to use with timed functions, which shall allow controlling the VFD and its functions based on: time of the day, day of the week, seasons of the year, holiday periods and holiday dates and special working periods and working days
			3. Timed functions shall be possible to use for: starting and stopping the VFD, for selecting the speed reference, for selecting the PID loop controller’s set-point, for controlling the relay outputs, for selection the control location, for giving the run permissive or interlock signal to the VFD, etc.
			4. There shall be the ability to temporarily override the time-controlled start and start the and/or its functions regardless of the time of the day, day of the week, season of the year, holiday, or workday.
		1. Fault Logger: A fault logger shall accommodate seven diagnostic values together with a date and time stamp.
		2. Built in Energy Calculators: There shall be built-in counters for calculating energy savings achieved with the VFD.
			1. Used and saved energy
			2. CO2 reduction
			3. Saved money
			4. Programmable kW rate
		3. Pre-Set Speeds: There shall be a minimum of seven programmable pre-set speeds or frequencies.
		4. Operating Values: All applicable operating values shall be capable of being displayed in engineering (user) units. A minimum of three operating values from the list below shall be capable of being displayed at all times. Engineering units shall be freely configurable for the user to display.
			1. Output frequency
			2. Motor speed (RPM, %, or engineering units)
			3. Motor current
			4. Calculated motor torque
			5. Calculated motor power (kW)
			6. DC bus voltage
			7. Output voltage
			8. Energy Consumption
		5. Underload and overload curves shall be user definable.
		6. Independently adjustable acceleration and deceleration ramps with 1 to 1800 seconds adjustable time ramps. There shall be a possibility to use start delay before acceleration to ensure that all start conditions have been fulfilled.
		7. Changed parameters list shall be available in order to assist commissioning and troubleshooting.
		8. The VFD shall include pass code protection against unauthorized parameter changes. The pass code and the protection level shall possible to be defined by the user.
		9. The VFD shall have ability to use any internal parameter value as input for any other parameter
		10. The VFD shall have the capability to fault or to show warning when triggered from external sources.
	1. PROTECTIONS

### The following protection functions shall be available:

* + - 1. Dry pump Protection (prevents the pump from running dry, protecting the pumps bearings and shaft seal from damage when there is no water in the pump)
			2. Overvoltage and under-voltage controller
			3. Ground Fault (Earth-leakage) supervision
			4. Motor short-circuit protection
			5. Output and input switch supervision
			6. Overcurrent protection
			7. Phase-loss detection (both motor & line)
				1. The VFD shall have the capability to continue running at a reduced output current when an input phase-loss is detected.
				2. The VFD shall have the capability to detect an open circuit on the output of the VFD without the requirement to have the VFD modulating.
			8. Underload and overload supervision
			9. Freely configurable supervisions for any parameter or signal to trigger an action.
			10. Communication loss functionality to ensure uninterrupted operation.
				1. The VFD shall have the capability to change the control location from PLC to another external location identified by user, e.g. VFDs embedded PID/loop controller and change back when communication is recovered.
			11. The VFD shall have pump protection functions for flow and pressure to avoid damages of the pump and for leakage detection.
				1. Inlet protection for avoid dry run, cavitation, and blocked pipe.
				2. Outlet protection for avoid high pressure and leakages.
				3. Stall protection for avoid running locked pump.
			12. The VFD shall have the capability to detect cavitation within the pump without need for external devices
				1. There shall be a possibility to enunciate a warning only, fault the VFD, or control the output frequency of the VFD to try and eliminate the cavitation.
				2. There shall be user-programmable values for the cavitation control feature, to allow application specific response when controlling the output frequency.
	1. USER INTERFACES

### Detachable control panel

* + - 1. The control panel shall be detachable in all types of VFD protection classes and/or enclosures, without tools to allow easy commissioning and programming of multiple VFDs.
			2. The control panel shall include a backlit LCD.
			3. The control panel shall have a real-time clock with battery backup for adding time stamps to events, as well as for use with timer functions.
			4. The control panel shall provide a clear, interactive, context sensitive menu-based user interface to make it easy to adjust the settings of the VFD.
			5. The display shall be in complete words, in a language selectable by the user, for programming and fault diagnostics (alphanumeric fault codes are not acceptable).
			6. The control panel shall provide interactive assistants (wizards) to help to commission and use the VFD.
			7. A dedicated “Help” button shall be available on the control panel. The Help button shall provide context sensitive assistance for programming and troubleshooting.
			8. The control panel shall provide an easy to use I/O menu, where the user can see the status and function of all the analog and digital inputs and outputs.
			9. The control panel shall have a menu, which contains diagnostic data about the VFD operation. The data shall include data about active faults, warnings, and events. In addition, the data shall contain a summary of VFD active control sources.
			10. There shall be an editable home-view in the control panel to allow different customer specific configurations.
				1. A minimum of three operating values shall be capable of being displayed at all times.
		1. All applicable operating values shall be capable of being displayed in engineering (user) units.
		2. Engineering units shall be freely configurable for the user to display.
			1. The control panel shall include Hand-Off-Auto selections and manual speed control.
				1. The VFD shall incorporate “bump-less transfer” of speed reference when switching between “Auto” and “Hand” modes.
				2. It shall be possible to disable the Hand and Off buttons of the control panel.
				3. As a safety feature, the control panel’s Hand and Off buttons shall have clear symbols to allow non-English speaking people to understand the meaning of the buttons. English text only is not acceptable in the Hand and Off button marking.
			2. There shall be a possibility to reset the VFD from the control panel.
			3. The VFD shall have the capability to change the output phase rotation sequence by use of a parameter. This parameter must be independent from, and not affecting, any speed reference or direction input to the VFD.
			4. The VFD shall have the capability to run the motor in either direction, forward or reverse. Additionally, the VFD shall allow for forcing the direction in a given direction, regardless of the speed reference or direction input to the VFD.
			5. A listing of changed parameters shall be readily available in order to assist with commissioning and troubleshooting.
			6. The VFD shall have flexible selections within a parameter. Not only shall the parameter have a list for easy selection, when applicable, but also the ability to choose any other signal/parameter that may not be within the list.
			7. The VFD shall include pass code protection against unauthorized parameter changes. The pass code and the protection level shall be possible to be defined by the user.
			8. The control panel shall contain at least one back-up of the VFD settings. Back-up information shall be possible to be saved on the control panel both manually and automatically.
			9. The control panel shall have the capability to copy VFD settings from one VFD to another VFD, regardless of the VFD power, voltage, or enclosure rating.
			10. The control panel shall have an editable “Contact info” that shows up in case of a fault.
			11. The user shall be able to take a screen capture snapshot of the display with the control panel and be able to download the screen capture for user’s computer for further purposes.
			12. The user shall be able to connect a PC tool with a standard USB cable to the control panel in order to set up and control the VFD. It shall be possible to connect the USB cable without using any tools.
			13. The VFD shall provide a possibility for wireless communication to allow working outside the arc flash boundary area and/or when there is no easy or safe access to the VFD. Wi-Fi connection is not acceptable because of its cyber security limitations.
				1. For safety reasons, the VFD supplied with wireless communications shall have a local control panel with control buttons regardless of the wireless connection possibility.
			14. There shall be an optional blue Bluetoothᵀᴹ Control Panel available, which can be added at the time of order or as a separate item.
				1. The control panel shall have optional Bluetoothᵀᴹ capability and there shall be an available application for a portable hand held device (ie, cell phone, tablet, etc.) to control, monitor or troubleshoot the VFD.
				2. Control panel connectivity allowing connections via Bluetoothᵀᴹ device (customer provided) having free downloadable app (DriveTune) installed to backup, program, and troubleshoot drive.
				3. Support package download and share capability via optional Bluetoothᵀᴹ/Free App (DriveTune) and no change, PC software (DriveComposer) to communicate drive existing parameters, event logger, and data logs for troubleshooting purposes.
			15. The control panel shall be able to keep two (2) time and date stamped manual backups and one (1) automatic backup of parameters.
				1. Automatic backup is created two hours after the last parameter change. After completing the backup, the panel waits for 24 hours before checking if there are additional parameter changes. If there are, the control panel creates a new backup overwriting the previous backup.
		3. Serial communications
			1. The VFD shall have an EIA-485 (RS-485) port for serial communications as standard.
			2. The VFD shall be equipped with built-in fieldbus communication of type Modbus RTU
			3. There shall be following optional protocols available as plug-in and inbuilt options:
				1. Ethernet/IP, Modbus/TCP, CANopen, DeviceNet, PROFIBUS-DP, PROFINET.
				2. Protocols that have a governing authority shall be certified. Use of non-certified protocols is not allowed.
				3. The use of third-party gateways or multiplexers is not acceptable, and all communication modules shall fit inside the enclosure of the VFD.
				4. Serial communication capabilities shall include, but not be limited to: run-stop control, speed set adjustment, proportional/integral/derivative (PID) control adjustments, loop controllers’ set-point adjustment, current limit, acceleration/deceleration time adjustments and lock and unlock the control panel.
1. EXECUTION
	1. INSTALLATION
		1. Installation shall be the responsibility of the installation contractor. The contractor shall install the VFD in accordance with the recommendations of the VFD manufacturer as outlined in the VFD installation manual.
		2. Power wiring shall be completed by the electrical contractor, to NEC code 430.122 and adhering to local electrical codes, wiring requirements based on the VFD input current. The contractor shall complete all wiring in accordance with the recommendations of the VFD manufacturer as outlined in the installation manual.
	2. START-UP
		1. A factory-authorized service technician shall perform start-up on each drive.  "Start-up" shall not include installation or termination of either power or control wiring.  Start-up costs shall include time and travel for the estimated number of visits required.  Additional labor or return trips to the site shall be billed at ABB published or negotiated rates.  Upon completion, a startup service report shall be uploaded to ABB Service and can be provided upon request
	3. PRODUCT SUPPORT
		1. Factory trained application engineering and service personnel that are trained on the VFD products offered shall be locally available at both the specifying and installation locations.
		2. A toll free 24/365 technical support line connected to factory support personnel located in the US shall be available. Technical support offered only through the local sales office is not acceptable.
		3. Training shall include installation, programming, and operation of the VFD, and serial communication. Factory authorized start up and owner training to be provided locally upon request.
	4. WARRANTY

* + 1. The VFD Product Warranty shall be 30 months for start-up performed by an authorized factory-trained provider or 36 months (3 years) from the date of manufacture, whichever occurs first. Any warranty claim shall include all parts, labor, travel time and expenses.
		2. Product warranty can be extended to a maximum of 5 years from the data of manufacture for an additional, nominal fee.

End of Section