

SCOPE

- I 1.1 This practice covers Engineered Variable Frequency Drive Systems (EVFD systems) for the speed control of a-c induction and synchronous three-phase machines. These EVFD's are not available as standard packaged designs from manufacturers. They are typically 500 kW and greater, and can be rated to operate on medium or low voltage. This practice shall be used for applying EVFDs to new or existing electrical machines and covers all including: control and protective switchgear, supply transformers, variable frequency drive converters, reactors, harmonic filters, cabling, and cooling systems for the drive or the rotating electrical machine.
- I 1.2 This practice may also be applied to frequency converters for electrical generators driven by expanders or by variable speed gas turbines, where the energy produced will be delivered to a constant frequency power system.
- I 1.3 **An asterisk (*)** indicates that a decision, or approval, by the Purchaser is required, or that additional information will be furnished by the Purchaser.

SUMMARY OF ADDITIONAL REQUIREMENTS

VENDOR QUALIFICATION

- I 2.1 **Proposals shall be accepted only from Vendors who have manufactured and tested**, at the proposed manufacturing location, at least **three EVFDs which have been in continuous operation for at least 2 years** driving loads having similar characteristics. The Vendor shall have also supplied systems which are similar in design, construction, voltage rating, power rating, speed range, torque range, and shall have successfully applied power factor correction, harmonic filtering and (if specified) automatic EVFD bypass. The Vendor shall be able to perform, and analyze, torsional vibration analysis of complete train systems, including the driven machinery.
- I 2.2 The following practices shall be used with this practice:

PRACTICES	
IP 15-6-3 Programmable Logic Controllers IP 15-7-2 Protective Systems IP 16-9-2 A-C Motors: Medium Voltage and Low Voltage Over 200 HP (150 kW)	IP 16-10-1 Power Transformers IP 16-12-1 Switchgear, Control Centers and Bus Duct

- I * 2.3 The following standards shall be used with this practice when specified by the Purchaser.

STANDARDS	
IEC Standards 34 - Rotating electrical machines - 60034-1 Part 1: Rating and performance -Section 14: Electromagnetic Compatibility (EMC) 34-5 Part 5: Classification of degrees of protection provided by enclosures of rotating electrical machines (IP Code) 34-12 Part 12: Starting performance of single-speed three-phase cage induction motors for voltages up to and including 660V 34-15 Part 15: Impulse voltage withstand levels of rotating AC machines with form-wound stator coils 34-17 Part 17: Guide for the application of cage induction motors when fed from converters 79 - Electrical apparatus for explosive gas atmospheres 79-0 Part 0: General requirements 79-2 Part 3: Electrical apparatus 79-7 Part 7: Increased safety "e" 79-14 Part 14: Electrical installations in hazardous areas 79-15 Part 15: Electrical apparatus with type of protection "n" 146-1 Semiconductor converters (3 Parts)	IEC Standards (cont.) 146-2 Semiconductor self-commutated converters 289 Reactors 529 Degrees of Protection Provided by Enclosures 1000-4 Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques 1000-4-3 Section 3: Radiated, radio frequency, electromagnetic field immunity test 1000-4-7 Section 7: General guide on harmonics and inter-harmonics measurements and instrumentation for power supply systems and equipment connected thereto 1800-3 Adjustable speed electrical power drive systems Part 3: EMC product standard including specific test methods IEEE Standards 519 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems API Standards 541 Form-Wound Squirrel-Cage Induction Motors - 250 Horsepower and Larger 546 Brushless Synchronous Machines - 500 kVA and Larger

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- I 2.4 The equipment and installation shall be in compliance with any code or standard specified by an authority having jurisdiction.

DEFINITIONS

- I 3.1 **Air-cooled** is the use of air as the cooling medium used to directly remove the heat from heat producing parts of the system. The air can be moved convectively or forced with fans or blowers.
- I 3.2 **Converter** is defined as the section of the EVFD which converts a-c power to d-c power.
- I 3.3 **EVFD System** is defined as the entire group of components and accessories needed to absorb power at a fixed voltage and frequency from the point of common coupling and to provide power with a selected voltage and frequency to an electric machine; or, in the case of a power recovery system to deliver power at a fixed frequency and voltage to the point of common coupling, having absorbed power at a variable frequency and voltage.
- I 3.4 **EVFD System Efficiency** is the efficiency as measured across the entire EVFD system, including all accessories, the cooling system, input and output filters, power factor correcting capacitors, and inductors.
- I 3.5 **Line filter** is a filter in the input power circuit used to prevent, or reduce, harmonic currents from being introduced into the power system at the point of common coupling.
- I 3.6 **Liquid-cooled** is a means of cooling the heat producing parts of the EVFD by circulating a liquid through the parts to remove the heat, and rejecting the heat via an air or water cooled exchanger.
- I 3.7 **Load filter** is a filter located between the converter output and the motor cable used to reduce the harmonic current or harmonic voltage being supplied to the motor.
- I 3.8 **Machine base frequency** is the frequency for which the machine (motor or generator) was designed to operate - usually 50 Hz or 60 Hz
- I 3.9 **Point of common coupling** is the first upstream bus which supplies other loads.
- I 3.10 **Super-synchronous operation** is the operation at a frequency above the machine base frequency.
- I 3.11 **UPS** is an uninterruptable power supply.

DOCUMENTATION

- I * 4.1 **The Vendor shall provide the following documentation with the proposal:**
- All data specified in the Table 2 (Data Sheets)** and any addenda. Quotations lacking data shall not be accepted.
 - A one-line electrical diagram** showing the power circuits, and auxiliary/control loops, of all major equipment from the supply busbars to the motor. The diagram shall include points of power isolation, and main power conductor maintenance grounding provisions.
 - Physical layouts and specifications** of all major equipment.
 - Physical requirements of the reactors or filters** relative to the converter panel, and the specification of any preferred type of interconnecting cable.
 - Data to **show the extent of any iron-free zone or nonmagnetic zone** required around air-cored reactors.
 - A flow diagram of any external cooling system** showing all components, control loops and type of cooling.
 - Documentation to **confirm compliance with local and national hazardous area classification regulations**. If these are not available, suitable tests shall be carried out and documented as required by the appropriate authority having jurisdiction.
 - Either a complete **manual covering a similar, previously supplied EVFD system**, or a 25% summary of the manual for the proposed EVFD system, that must cover the system description, operation and maintenance requirements in full.
 - Converter bypass arrangement**, when specified, with time to transfer to and from the bypass supply including any intentional time delays.
 - Specifications for any interconnecting cables**.
 - Ratings of any UPS (Uninterruptable Power Supply)** supplied by the Vendor.

CONSTRUCTION REQUIREMENTS

MECHANICAL

- R * 5.1 The **EVFD motor and transformer shall be suitable for outdoor installation**, unless otherwise specified. A transformer with multiple secondary windings may be used indoors if it is an integral part of the EVFD, i.e., close coupled to the rectifier or converter cells.
- I 5.2 It is preferred that the motor and driven machine be located on a common bedplate.
- R 5.3 The **EVFD shall be designed to withstand the mechanical and electrical stresses due to electrical short circuits** and sudden driven mechanical equipment failures. The EVFD electrical and mechanical systems shall be designed so that drive equipment failures are confined to the affected component, or subsystem, and not propagate to other drive components.

ELECTRICAL

- M 5.4 **The Vendor shall provide complete instructions for installing the semiconductor power devices**, including face mounting forces required to prevent high resistance, or arcing across these elements.
- M,O * 5.5 The principle modules of the EVFD, (harmonic filters, input switchgear, converter, reactors and converter cooling system, output filters) **shall be placed together in a common location to eliminate the need for long cables carrying low-level logic and control signals**. The modules shall be designed for indoors unless otherwise specified. The supplier shall provide the temperature limits and the heat load for the equipment over the full range of operation. When the Purchaser specifies, (or the Vendor recommends,) an outdoor self-contained enclosing structure to house the EVFD equipment, **the price of the outdoor structure and associated support equipment** (fire detection and protection, HVAC, etc.) **shall be cited separately from the price of the EVFD components**.
- M,O 5.6 Depending on size, the EVFD may require a separate control panel or desk, protection and alarm panel, and digital communication panel. **The segregated system shall include features for protecting maintenance and operating personnel from energized circuits; for minimizing the chance of losing electrical signals; for minimizing the number of equipment voltage levels** in an enclosure; for providing redundancy for cooling systems; and for providing sufficient air flow in and over the panels to prevent equipment damage during an orderly shutdown if a cooling system fails.
- O * 5.7 **The Vendor shall state specific requirements for power and control cable characteristics, reactor location, transformer location, main and auxiliary switchgear**, and any other facilities with which the Purchaser should comply, so as to ensure correct integration of the site layout and required EVFD external services.

CONTROL AND INDICATIONS

- I * 5.8 **The Vendor should specify the following in the proposal:**
- All local and remote indications offered for the EVFD and supporting systems; e.g., cooling system(s).
 - Hard-wired outputs for monitoring and control circuits.
 - All EVFD indications and controls which are available as digital signals and controls .
- O 5.9 **Control supply shall be configurable** for both 4-20 mA and 0V to +10V at the input reference terminals.
- O,M 5.10 All **analog and digital field I/O shall be electrically isolated** from EVFD logic-level circuits. Optical or transformer isolation is acceptable.
- O,M 5.11 The following minimum **indications shall be displayed** at the EVFD control panel:
- "Local" or "Remote" selected
 - Ready to start
 - Running
 - Alarms
 - Tripped
 - Output power
 - Output frequency and voltages
 - Input frequency and voltages
 - Input power
 - Output current (rms)

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- R 5.12 **All indication lamps shall be long life LED type**, and shall have a lamp test feature.
- I * 5.13 **Vendor shall provide control details** including:
- EVFD microprocessor scan time, and response times for analog, digital and serial communications signals.
 - Interface and protocol data for serial communications between the EVFD and any terminal, logic controller or other EVFD.

SOFTWARE BASED SYSTEMS

- I,O * 5.14 **When specified, the EVFD control system will be required to accept and confirm digital control input from, and transmit information** to, an external PLC or process computer supplied by others. The EVFD shall be capable of communicating at least the following functions:

RECEIVE AND VERIFY	TRANSMIT TO EXTERNAL SYSTEM
Speed set point	Trouble codes for EVFD diagnostics and alarms
Start sequence initiate	Speed
Shutdown sequence initiate	Power input and output
	Drive output voltage and current to motor

The proposal shall include the proposed transmission protocols, data rates, and available ports and channels. When data logging is specified, the Vendor shall separate the cost of providing the EVFD data logging from the cost of the EVFD drive power and control modules.

- O 5.15 **All EVFD malfunction and shutdown protection systems shall be internal to the drive system.** Control signals from external systems shall not interfere with, or override these systems.
- O,M 5.16 **The use of well-proven software modules is preferred.** These should be fully documented to the extent that anyone skilled in the art, but unfamiliar with the system, can understand their function. **Documentation should include the following as a minimum:** a written description of each module describing how it functions and its limitation(s); system data and logic flow diagrams and source-code listing, commented to provide full understanding; the description of the levels of security. All software and documentation shall be provided in electronic format so that field changes can be made when required. When the software modules are required to be compiled to run on the system, a copy of the compiler shall be supplied by the Vendor.
- O 5.17 **The variety of interfaces between sensors, system components, actuators and EVFD system devices shall be minimized.**
- O,R 5.18 **The security and protocol** for PLCs, microprocessors, and digital computers as used in the EVFD shall meet the requirements in **IP 15-6-3 Programmable Logic Controllers** for the programming, logical control and security of data.

CONVERTER COOLING SYSTEMS

- R * 5.19 **Air cooling of equipment is preferred. Fluid cooling systems may be used if specified or required.** The reliability of the cooling system(s) shall be included in the reliability and availability estimate for the entire EVFD. If the cooling systems require external support, (e.g., building air conditioning or cooling water), the Vendor shall provide Owner's Engineer with the availability required of these services to achieve the required EVFD reliability/availability cited in **Par. 6.1**.
- I * 5.20 **The Vendor shall provide the operating temperature range of the equipment in the proposal.** If external cooling water, or conditioned air is needed, the inlet temperature range and quantities of these shall be stated.
- R * 5.21 **Redundant cooling system components** (when specified) **shall be supplied from independent power supplies.** Any element in the system shall be capable of being easily and safely replaced, or maintained, with the EVFD system in operation.
- O 5.22 **Heat loss estimates** for the individual EVFD equipment modules shall be supplied by the Vendor.
- I,O 5.23 **If reacceleration of an EVFD system is required** following a power system disturbance, **operation of the cooling system (including supervisory alarms) shall be delayed for the time required to reaccelerate.** The Vendor shall provide an estimated time that the EVFD can operate with the cooling system off following a restart.