

**WATER SUPPLIES DEPARTMENT**  
**STANDARD SPECIFICATION E-86-02**  
**L.V. VARIABLE SPEED DRIVES**

1. GENERAL

This Specification outlines the technical requirements of Variable Speed Drive (VSD) equipment for providing variable frequency and voltage supply from 380V 50Hz a.c. power supply. The VSD equipment shall include all sub-units and components to form a complete working system.

The VSD equipment shall comply with the requirements for efficient utilization of power and energy efficiency requirements for power quality as stipulated in the Code of Practice for Energy Efficiency of Electrical Installations issued by the Electrical and Mechanical Services Department (EMSD) and WSD Standard Specifications E-00-01 and E-80-01.

2. DESIGN

2.1 General Requirements

The VSD shall be of solid state and preferably based on the principle of pulse width modulation (PWM) capable of converting 380V $\pm$ 10%, 50Hz $\pm$ 2Hz and 3 phase mains supply to adjustable frequency and voltage output at its rated throughout power for variable speed control of squirrel cage induction motors designed for pumping system and process plant applications.

The VSD shall conform to BS EN 61000-6-3 [2001], BS EN 61000-6-4 [2001] and BS EN 61800-3 [2004] or other similar recognized international standards on Electromagnetic Compatibility (EMC) compliance for industrial or commercial applications and shall be manufactured to ISO 9001. Certificate of compliance shall be issued for each standard rating of VSD provided after being fully tested at the manufacturing facility.

The VSD shall be manufactured by a reputable manufacturer which has continuously manufactured VSD's for at least 5 years and their manufacturing facility shall have a local agent to provide full technical support which includes adequate spares holding and technical expertise in testing, commissioning and trouble-shooting. Training shall be provided by the manufacturer's representatives for client on operational and maintenance aspects including essential trouble-shooting techniques.

The output rating of the VSD shall be as specified in the Particular Specification and shall be suitable for motor load at power factor of 0.8 lagging and starting current of 7xFLC under direct-on-line starting condition at power factor of 0.2 lagging. The VSD shall be capable of continuously delivering the rated output voltage even when the mains supply voltage is down by 10% of its nominal value. It shall be able to control 3 phase squirrel cage induction motor over a speed range of 20% to 100% continuously and smoothly without the need to derate the motor kW rating, and to

provide the total power factor of not less than 0.9 lagging, without external chokes or power factor correction capacitors, at full loads within the speed range. The inrush current shall be zero and during starting, the current shall start from zero and rises as the load accelerates with no danger of exceeding full load current.

The Contractor shall submit design calculations to substantiate that the offered rating of the VSD will be adequate and suitable for the continuous and stable operation of the squirrel-cage induction motor taking into account the VSD enclosure IP rating, motor characteristics, operational conditions, ventilation requirements and harmonic filters etc.

Harmonic filters shall be provided with the VSD equipment to ensure that harmonics generated in the electricity supply system shall comply with the Statutory and local power companies' requirements on harmonic distortion and power quality.

## 2.2 Performance Requirements

The VSD shall meet the following performance requirements :-

### (a) Output Voltage

The output voltage shall be proportional to the output frequency with voltage/frequency (Volts/Hz) ratio fully adjustable up to rated voltage at 380V 3 phase and rated frequency at 50 Hz.

### (b) Output Frequency

The output frequency shall be from 0.5 Hz start-up frequency up to the rated frequency of 50 Hz with automatic control from a 4-20mA d.c. input current and manual control from potentiometer or push-button. The start-up frequency shall be adjustable between 0.5 Hz to 10 Hz. 10 programmable preset speeds (including at least 2 skip frequencies of adjustable bandwidth to overcome mechanical resonance) shall be provided.

### (c) Frequency Regulation

The VSD steady state output frequency shall not deviate by more than  $\pm 1\%$  due to temperature, load and input voltage variations.

### (d) Slip Compensation

The VSD shall have slip compensation function to facilitate the drive to automatically increase its output frequency with load to provide speed regulation to within  $\pm 1\%$ .

### (e) Overload Capability

The VSD shall be capable of withstanding overload at 150% rated output for not less than 60 seconds.

(f) Efficiency

Efficiency of VSD at rated output and power factor shall not be less than 95% and not less than 90% at any other operating loads.

(g) Electromagnetic Compatibility (EMC)

The VSD shall comply with BS EN 61000-6-3 [2001], BS EN 61000-6-4 [2001] and BS EN 61800-3 [2004] or other similar recognized international standards on Electromagnetic Compatibility (EMC).

(h) Audible Noise

Audible noise of the VSD shall not exceed 75 dB(A) sound pressure level at a distance of 1 meter from the VSD panel enclosure.

(i) Power Supply

The power supply to the VSD shall be 380V  $\pm 10\%$  3 phase 50Hz $\pm 2$ Hz with neutral solidly earthed. The input power supply circuits of the VSD shall be protected by HRC fuses to IEC 60269.

(j) Line Reactor

AC line reactor shall be provided at the incoming power supply side to protect against voltage spikes and suppression of the total harmonic distortion at the power supply terminals to comply with the Statutory and local power companies' requirements on harmonic distortion and power quality.

(k) Displacement Power Factor

Input displacement power factor shall be improved to a minimum of 0.9 lagging, without external chokes or power factor correction capacitors, at full loads within the speed range.

(l) Output Reactor

Output reactor shall be provided to limit the rate of rise of voltage generated at the motor terminal and reduce the electrical stress of motor insulation for long length of motor supply cable as specified in the Particular Specification.

## 2.3 Facilities

The following features shall be included in the VSD :-

(a) Standard Provisions

- (i) DC voltage boost for maximum motor output torque; and
- (ii) Adjustable Acceleration and Deceleration Rates.

(b) Protection

The VSD shall incorporate the following protective functions :-

- (i) Input undervoltage and overvoltage;
- (ii) DC bus undervoltage and overvoltage;
- (iii) Output overcurrent and overvoltage;
- (iv) Loss of mains and motor phase;
- (v) Motor short circuit;
- (vi) Input transients;
- (vii) Earth fault;
- (viii) Power unit over temperature; and
- (ix) Motor overload.

Input contact shall be provided in the VSD for connection to thermistor or RTD controller for motor thermal/overload protection. A volt-free changeover output contact for VSD tripped and fault alarm shall be provided for remote alarm initiation.

(c) Control and Monitoring

The VSD shall be microprocessor controlled with automatic and manual frequency control functions. The output frequency of the VSD shall be varied by a control input of 4-20mA d.c. under automatic operation and potentiometer or push-button control under manual operation.

A local display panel as the human machine interface (HMI) for operator's information shall be provided for control and programming functions of the VSD unit. Self-diagnostics and data memory functions shall be incorporated. The display panel shall include all the controls and indicators showing the operating status of the VSD and shall include but not limit to the following :-

- (i) Display and keypad for function / data programming;
- (ii) Output frequency, output voltage, output current, output power, speed, faults and alarms indications;
- (iii) VSD on/off switch;
- (iv) Automatic / Off / Manual selector switch;

- (v) Local / remote selector switch;
- (vi) Frequency setting potentiometer or push-button;
- (vii) Digital and analogue 4-20 mA control signal;
- (viii) Programmable pre-set speed control; and
- (ix) Built-in RS232/485 serial communication port for communication with computer. The communication protocol shall support MODBUS / PROFIBUS or other approved communication protocol.

The VSD shall provide analog outputs for the external connection of the output current ammeter and output frequency meter.

### 3. CONSTRUCTION

#### 3.1 Panel Enclosure

The VSD panel shall be individually floor-mounted, wall-mounted or accommodated in a motor starter panel as specified in the Particular Specification. The panel enclosure shall have degree of protection of IP32 to BS EN 60529 suitable for natural air ventilation for the VSD equipment.

The VSD shall be suitable for continual operation inside the IP 32 enclosure under ambient temperature of 40°C without de-rating. The VSD panel enclosure shall be fabricated with 2mm mild steel with front access doors in accordance with WSD Standard Specification E-11-03. Where the panel width exceeds 800mm, double-leaf doors shall be provided. For floor-mounted or wall-mounted VSD enclosure, a detachable cable gland plate shall be provided to facilitate bottom cable entry.

If forced ventilation is required for the VSD unit, suitable detection system shall be provided to monitor satisfactory operation of the forced ventilation fan units and initiate alarm on fan failure.

#### 3.2 VSD Functional Units

The VSD shall incorporate a 6-pulse full-wave uncontrolled diode bridge, fixed voltage-fed d.c. link with inductors and capacitors to form a filter, a mains filter for EMC compliance, a pulse width modulation (PWM) inverter bridge utilizing insulated gate bipolar transistors (IGBTs) and output inductors in the motor lines. The inverter bridge shall be controlled by a microprocessor to produce a pulse width modulation (PWM) waveform or similar technique which would result in full motor voltage and sinusoidal current mains supply in the motor circuit.

4. TESTING

4.1 Test Requirements

The VSD shall be tested at manufacturer's works according to WSD Standard Specification EM-00-01. The tests shall clearly demonstrate that the equipment fully complies with the specified performance and reliability criteria.

The minimum requirements for tests on VSD are listed below. The contractor shall also be responsible for performing any additional tests as may be required to clearly demonstrate that the equipment complies with the Specification. Any such additional tests shall be deemed to have been allowed for in the tender price.

- (a) Demonstrate the performance of the VSD under conditions of 0 to 100% full design load;
- (b) Demonstration of the operation of all protective devices;
- (c) Operational checks of all alarm and indication facilities; and
- (d) A test run of seven days prior to witness inspection and performance testing.