

PETRONAS TECHNICAL STANDARDS

MANUAL

Electrical Variable Speed Drive System

PTS 33.66.05.33

FEBRUARY 2011



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PTS Circular 2011 – 1



PTS No:	33.66.05.33
PTS Title:	Electrical Variable Speed Drive System

This revision of PTS **33.66.05.33– Electrical Variable Speed Drive System (February 2011)** has been reviewed and updated to incorporate PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic font* (if any).

The previous version of this PTS **33.66.05.33– Electrical Variable Speed Drive System (February 2010)** will be removed from PTS binder / e-repository from herein onwards.

Document Approval

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Revision History

Rev No.	Reviewed by	Approved by	Date

PREFACE

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1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and gives recommendations for the design and manufacturing of direct-coupled AC electrical variable speed drive systems (VSDSs).

This PTS may also be applied to generation units with generators operating at variable speeds and feeding into an electrical system with a constant frequency.

A VSDS comprises the electric motor, the converter with its control and protection equipment, and, where specified in the requisition, also the supply transformer, and harmonic filters.

The requisition shall indicate whether a ventilation/cooling/climate conditioning facility for the converter has to be included in the supply. This shall generally be the case if the HVAC system of the room where the converter will be installed is not sufficient to cater for the heat dissipation of the converter equipment.

The VSDS shall be designed in accordance with the following IEC standards:

- IEC 61800-2
- IEC 61800-3
- IEC 61800-4
- IEC 61800-5-1
- IEC 60146

This PTS gives the additional information and requirements and where applicable selects options given in the above IECs.

Individual components forming part of the VSDS order shall comply with:

- PTS 33.65.40.31.
- PTS 33.65.11.31.
- PTS 33.66.05.31.

with all modifications as specified in this PTS.

This PTS shall be applicable to all VSDSs irrespective of duty or size to provide a high standard of safety, performance, reliability and maintainability. Data/requisition sheet PTS 33.66.05.95. shall be used to make order-specific requirements and shall be returned by the Manufacturer with the requested data and the quotation.

However, there is sufficient modularity in the lower rated segment of the VSDS product ranges to ensure that in the event of failure, components can be replaced quickly to avoid prolonged plant outage. Hence, to obtain the economic advantages offered through maximum standardisation, the Principal may decide to give dispensations on VSDSs rated 75 kW and lower. For such cases, reference shall be made to Appendix 10 and to data/requisition sheet PTS 33.66.05.96.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to PETRONAS companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, gas plants, chemical plants, exploration and production facilities and supply/marketing installations.

When PTSs are applied, a Management of Change (MOC) process should be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regard to the safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

The definitions as given in the IEC standards and PTSs referenced in this PTS are applicable. The following additional definitions apply:

Active front end converter

Converter with input circuitry designed to limit the lineside harmonics.

Availability

Availability is defined as :
$$\frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

Communication protocol

Application tool set to allow various systems to communicate with each other.

Condition monitoring system

Management tool to monitor system behaviour and to execute trending.

Expected lifetime of the VSDS

The expected lifetime of the VSDS is the time during which the VSDS remains suitable for the application for which it was designed, provided it is used, regularly inspected, examined and serviced in accordance with the Manufacturer's instructions and with the replacement of lubricant etc. and of parts subject to mechanical wear and electronic component ageing.

Electromagnetic compatibility (EMC)

The ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

High speed motor

A high speed motor is a motor with a speed of more than 3600 r/min within its operational speed range.

High voltage converter

A converter with an output voltage exceeding 1000 V (ref: IEC 61800-4).

Heating Ventilation and Air Conditioning system (HVAC)

A system that maintains within the defined limits the temperature relative humidity and air quality in a room, building or enclosure.

Integer harmonics on the machine-side

Harmonic quantities which are multiples of the inverter output frequency.

Locked rotor torque of a VSDS motor

The average measured torque that the motor of the VSDS will develop with the rotor locked at any angular position and with the control-command set at a setpoint within the operational speed range of the VSDS.

Low voltage converter

A converter with an output voltage not exceeding 1000 V (ref: IEC 61800-2).

Mean time between failure - MTBF

Mean time between failure is defined as:

$$\frac{\text{operating time}}{\text{number of faults that have resulted in outages}} \quad (\text{hours})$$

Mean time to repair - MTTR

Mean time to repair is defined as:

$$\frac{\text{time to repair and to come back in service}}{\text{number of faults that have resulted in outages}} \quad (\text{hours})$$

Non-integer harmonics on the machine-side

Harmonic quantities being no multiples of the inverter output frequency.

Offshore installation

An installation located near open salt water, e.g. platforms, jetties, floating production storage and offloading vessels (FPSO).

Operating time

Total running time elapsed after initial commissioning and start up of the VSDS at site but excluding the first 3 months of initial operation.

Operational speed range of the VSDS motor

The specified range of speeds at which the VSDS motor can operate continuously at specified ratings or torques.

Point of Coupling of the VSDS (PC)

The point in the electrical network at which the VSDS is connected to that network.

Rated current curve of a VSDS motor

The rated current curve is the range of the maximum measured root mean square current taken from the line with the VSDS motor at maximum rated output over the whole speed range.

Rated torque curve of a VSDS motor

The whole of numerical values of the motor torque curve at which a VSDS can be operated continuously within its operational speed range and those values at which a VSDS can be operated during limited specified times outside its operational speed range.

Reliability

Reliability is calculated as: $e^{-\left(\frac{8760}{\text{MTBF}}\right)}$

Requisition

Is PTS 33.66.05.95.

(Data/requisition for AC variable speed drive system)

or PTS 33.66.05.96.

(Data/requisition for AC variable speed drive system $\leq$ 75 kW)

NOTE: Requirements for additional equipment, e.g. power transformers, will be detailed on specific data/requisition sheets

Running up time of a VSDS motor

The time for the motor of a VSDS motor to complete, after being energized, one start up to the minimum operational speed at specified line voltage when coupled to the actual load under the most arduous process conditions.

Speed Window Control

Control of the speed of the motor of the VSDS within the permitted operational range.

Total running up time of a VSDS

The time for a VSDS to complete one start up to the minimum operational speed at specified line voltage when coupled to the actual load. The total running up time is the sum of the times for the logic to start up all auxiliaries and the running up time of the VSDS.

Variable Speed Drive System VSDS

A system consisting of a line-fed AC to AC conversion system, electric motor and all facilities required to operate the motor at variable speeds on a variable voltage or current and frequency.

Vibration severity

The vibration severity is the root-mean-square value of the vibration velocity.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced by this PTS are listed in (16.).

2. GENERAL

2.1 RESPONSIBILITY

The interactions between the various components of a VSDS make it imperative to make one technically acceptable Manufacturer ultimately responsible for the total system.

The order for a VSDS may be placed direct with a Manufacturer or through the Manufacturer of the driven equipment, both of whom shall be approved by the Principal. In the latter case the Manufacturer of the driven equipment has the responsibility for the correct operation to specification of the combination of VSDS and driven equipment.

NOTE: The Principal may include in his enquiry documents a list of acceptable VSDS and motor Manufacturers.

The Manufacturer of the VSDS shall be responsible for the performance of the VSDS as described in this PTS and for compliance with the requirements of the driven equipment as given to him by the driven equipment Manufacturer at the time of order. The Manufacturer of the VSDS shall have ample experience in the design and application of those systems, power factor correction and harmonic filters.

The following shall be provided by the Manufacturer:

- calculated rotor responses;
- ramp times;
- transient air gap torques with their duration in the event of 2 and 3 phase short circuits at the motor terminals;
- for running up and continuous operation, data on all machine air gap torques including integer and non-integer harmonic torques in amplitude and frequency, also stating the assumptions on ratings of dc-link components;
- lubrication requirements.

Furthermore the responsible Manufacturer shall be capable of:

- performing the necessary torsional and lateral vibration analyses;
- performing the required studies of the total train (drive system and driven equipment) and acting as a suitable counterpart to the Manufacturer of the driven equipment (and gearbox if included) to ensure good overall coordination;
- performing the necessary electrical system studies (4.5).

The final result of these studies shall be acceptable to all parties involved.

If specified in the requisition, the Manufacturer shall quote a torsional vibration analysis as a separate item. The Principal may request this study to be performed in addition to that performed by the driven equipment Manufacturer. In such event, the results shall be acceptable to all parties involved. The Principal may request a third party to investigate the analysis on his behalf.

For the technical evaluation of the quotations at least all data specified in the requisition shall be available. Quotations without all these data shall not be accepted.

2.2 SCOPE OF SUPPLY

The scope of supply of the VSDS shall include:

- detailed design
- studies as indicated in this PTS and the requisition
- supply of materials
- factory and site inspection and testing
- documentation including certification
- commissioning and start-up assistance

and where specified in the requisition or order:

- spare parts for 2 years' operation (11)
- site installation

The Manufacturer shall give detailed information in the quotation to prove his capabilities to deliver in accordance with the required scope of supply.

2.3 PRE-ORDERING MEETING

If deemed necessary by any of the parties involved, a pre-ordering meeting shall be arranged to define clearly the overall scope of supply, individual responsibilities and test methods.

3. STATEMENT OF COMPLIANCE

The Manufacturer of the VSDS shall confirm that the equipment fully complies with the quotation and the whole system is properly designed, constructed and suitable for the specified duty.

All performance values laid down in the pre-ordering meeting or quotation (whichever comes later) shall be regarded as maximum or minimum values as applicable.

These values shall also be guaranteed by the Manufacturer of the VSDS under the most arduous conditions specified in this PTS and the requisition.

Tolerances shall be in accordance with this PTS. All the components of the VSDS shall be tested individually and in combination at the Manufacturer's works to prove their capability and compliance with the specification and performance data.

If any one of the components or the whole system does not comply with the specification and any agreed amendments, the Manufacturer shall rectify and re-test the VSDS within a mutually agreed time.

4. BASIC REQUIREMENTS OF THE VSDS

This PTS gives technical requirements for the most common applications for VSDSs. For certain applications it may be necessary to deviate from this PTS. Any special requirements shall be stated in the requisition and other bid documentation.

The Manufacturer shall in principle offer equipment from his standard range, where applicable modified to achieve conformity with this PTS.

The VSDS shall be suitable for the load characteristics and the operational duty of the driven equipment.

The VSDS and auxiliaries shall be suitable for continuous uninterrupted operation for periods of at least 6 years. However, within this six-year period, periods of running may alternate with idle periods of up to 6 months. Re-greasing of bearings or replenishment of lube oil, if required, shall be possible with the motor in operation.

The VSDS shall be designed for an expected lifetime of at least 20 years.

For large VSDSs the expected lifetime of the electronic controls may be less than 20 years. The Manufacturer shall state in the quotation the expected lifetime of these components. This shall not be less than 10 years. The Manufacturer shall also confirm that replacement components will be available and indicate an expected duration of the replacement process. In the quotation the Manufacturer shall give documented evidence that replacement of the electronic controls shall not have an impact on the rest of the VSDS.

The Manufacturer shall also confirm that he shall provide software support for the VSDS during the lifetime of the applied control system.

The VSDS shall be capable of withstanding the thermal and dynamic stresses and transient mechanical torques such as those resulting from a short circuit. Any damage resulting from such a short circuit or internal fault shall be confined to the component concerned. The motor/driven equipment shall be able to withstand the transient torques developed during short circuit conditions.

The cooling system (exhaust fan) shall be designed following N+1 configuration and fan operation control is based on temperature fluctuation.

In addition to the requirements stated in the requisition, the following information shall be given to the Manufacturer:

- A layout diagram indicating the area classification, the ambient conditions of the different items related to their location, the location of the individual equipment items, distances and the cable routing.
- A block diagram indicating the basic control and protection systems specifying the protection, control, trip and alarm functions to be fulfilled at the different locations. The diagram shall also specify the reference signals and commands needed and all the auxiliary supplies required such as air, lube oil, cooling water, and electrical auxiliary supplies.
- A single line diagram indicating the main and auxiliary circuitry, unit transformer if any and information on fault level, system earthing and auxiliary supply systems.

Depending on the size and complexity of the VSDS, the driven equipment and the process, additional information may be required. The Manufacturer shall obtain this information from the Principal in the quotation stage (2).

The cooling system (exhaust fan) shall be designed following N+1 configuration and fan operation control is based on temperature fluctuation.

4.1 RELIABILITY AND AVAILABILITY

The VSDS including all individual components forming part of the system shall have an availability of minimum 0.997 and a Mean Time Between Failure (MTBF) of at least 6 years.

The Manufacturer shall provide documented evidence that the figures quoted for MTBF and Mean Time To Repair (MTTR) can be met.

For VSDSs that have a sufficient user base the MTBF and MTTR figures shall be based on statistics and the following criteria:

- at least one period of 6 years' operating time of at least 4 pieces of similar equipment shall have been experienced (the first 3 months of initial operation of the VSDS shall be excluded).
- MTTR shall only relate to converter repair.
- MTTR shall include a maintenance overhaul time of 80 h over a 2-week period after 6 years of operation.
- operation of the VSDS shall have been in accordance with the Manufacturer's instructions.
- qualified men and materials shall be assumed to be available at the work site.

For newly developed VSDSs the quoted MTBF and MTTR figures shall be based on calculations.

4.2 SITE CONDITIONS

All the VSDS components shall be suitable for use in a salty, sulphurous and dusty atmosphere. Condensation, solar radiation and wind shall be taken into account for equipment installed outdoors.

The motor of the VSDS and its driven equipment will normally be installed outdoors without shelter with a common base plate on the foundation. The area classification according to IEC 60079-10 shall be stated in the requisition or its appertaining documentation.

The Manufacturer shall assume a background vibration severity level of 0.4 mm/s at motor bearings.

Motors installed on mobile and fixed offshore installations shall also be capable of absorbing shocks of twice the acceleration of free fall ($2 \times g_n$) when running or standing idle. If indicated in the requisition, motors shall be earthquake-proof in accordance with local requirements.

Converter and where applicable unit transformers installed on mobile and fixed offshore installations shall not be affected by vibration and shock. The equipment for these applications shall be tested according to IEC 61892-3:1999, Item 9 of Table 9.

If a transformer forms part of the supply package then it shall normally be located outside the substation building in a non-hazardous area according to IEC 60079-10.

Reactors, harmonic filters, etc. may be installed outside the substation building in a non-hazardous area according to IEC 60079-10.

The converter of the VSDS is normally located inside a substation or in a dedicated container.

Unless otherwise specified in the requisition, the equipment to be installed indoors shall be located in a ventilated building or container in which the following conditions apply:

- maximum ambient air temperature : 40 °C;
- mean ambient temperature (over 24 h period) : 35 °C;
- average room air temperature (conditioned) : 20 °C to 25 °C;
- minimum ambient air temperature : 5 °C;
- maximum relative humidity : 90 %;
- maximum altitude : 1000 m
- pollution degree according to IEC 61800-5-1 : 2
- climate class according to IEC 60721-3-3 : 3K3
- Area Classification according to IEC 60079-10 : Non-hazardous

Note : Pollution degree 2 : Normally, only non-conductive pollution occurs. Occasionally, however, temporary conductivity by condensation is to be expected.

For equipment installed outdoors, and if not otherwise specified in the requisition, the following conditions apply:

- maximum ambient air temperature : 40 °C;
- mean ambient temperature (over 24 h period) : 35 °C;
- minimum ambient air temperature : -15 °C;
- maximum relative humidity : 100 %;
- maximum altitude : 1000 m

Note: The Principal may refer to IEC 60721-2-1 for site conditions deviating from those stated above.

If water is used for cooling purposes the cooler shall be calculated for the following water conditions:

- maximum inlet water temperature : 30 °C
- average inlet water temperature over a 24 h period does not exceed : 28 °C
- minimum inlet water temperature : 5 °C
- maximum static water pressure : 8 bar (ga)
- minimum static water pressure : 3 bar (ga)

Design data for coolers:

- minimum cooling water velocity : 1 m/s
- maximum outlet water temperature : 42 °C
- maximum tube surface temperature : 52 °C
- value of fouling resistance : $0.52 \times 10^{-3} \text{ m}^2.\text{K/W}$

NOTE: The above data also apply to seawater.

The test pressure of the coolers shall be at least 1.5 times the maximum static water pressure.

If the water pressure in the cooler is controlled by a valve or pressure reducing device connected to the water supply where the pressure is higher than the working pressure of the cooler, the cooler shall be designed for the higher pressure and tested at 1.5 times the higher pressure.

4.3 DEGREE OF PROTECTION

The degree of protection, in accordance with IEC 60529, of equipment located outdoors shall be at least:

- for land installations:
 - IP 54 for motor, transformer, reactor and auxiliaries
 - IP 55 for the terminal boxes and bearing housings
- for offshore installations
 - IP 56 for the motor, transformer, reactor, auxiliaries, terminal boxes and bearing housing
- for dusty areas:
 - The requisition shall specify whether special measures are required with respect to ingress of dust. Reference is also made to IEC 61241.
- for submerged electric motors and electric drives of sealless pumps:
 - IP 68 for the applicable parts

Dry type transformers and reactors shall have their live parts insulated. Dry type transformers and reactors that are not safe to touch shall be installed in an enclosure or in a lockable fenced area with a minimum degree of protection of IP 21.

The degree of protection of equipment located inside the substation or container shall be at least IP 31.

4.4 RATINGS

The Manufacturer of the VSDS shall obtain from the driven equipment Manufacturer all relevant data such as the exact torque speed characteristic of the driven equipment for the design of the VSDS and adapt his technical specification accordingly.

The current from the inverter to the motor shall not exceed 1000 A per phase up to ratings of 20 MW.

For motors with two-phase shifted three-phase stator windings, the current in each winding shall not exceed 1000 A.

Where there is clear economic justification to exceed this 1000 A limit, the Manufacturer may propose such alternatives to the Principal at the quotation stage. These shall include detailed proposals for cabling connections.

The Principal may state a preference for a 6-pulse or 12-pulse supply converter or alternatively for a converter operating on the Active Front End principle. The Manufacturer shall ensure in any case that such selection meets the requirements for line side harmonics in (5.8).

The rated motor voltage shall be derived from the above criteria.

Installations with motor voltages over 1000 V shall be considered as, and designed according to, rules and regulations applicable to HV installations.

4.5 ELECTRICAL SUPPLY SYSTEM

The VSDS shall be capable of operating according to the specification under the conditions described in this clause.

The nominal voltage and frequency shall be indicated in the requisition.

During normal system operation and under steady-state conditions, the voltage at the Point of Coupling (PC) shall not deviate from nominal voltage by more than 5 % and the system frequency shall not deviate from the nominal frequency by more than 2 %. Where these values differ from the above, e.g. at offshore facilities, this shall be stated in the requisition.

The AC power supply at the Point of Coupling (PC) of the VSDS will be symmetrical and sinusoidal, although the input voltage may be subject to transients resulting in short term voltage excursions between 80 % and 110 % of nominal, and to voltage interruptions during system short circuits. Transient high frequency voltages of up to 2 kV may also be superimposed on the input voltage as a consequence of system switching operations.

NOTE: The PC of a VSDS that includes a main transformer is at the primary terminals of the transformer.

A LV VSDS shall be connected to a TN-S supply system, unless otherwise specified in the requisition.

NOTE: TN-S is a system of earthing as described in IEC 60364-1.

A HV VSDS shall be suitable, as indicated in the requisition, for:

- operation on an earthed supply system;
- operation on an unearthed supply system, which may have one phase earthed for a continuous period not exceeding 8 h. The total operating time in this condition shall not exceed 125 h per year.

NOTE: The earthing of the supply system refers to the condition at the Point of Coupling. The output of the converter may either be earthed or unearthed.

For floating supply systems, e.g. 12 pulse, the likelihood of motor earthfault currents circulating in the filter-capacitors shall be reviewed with the Principal in the quotation stage.

The Manufacturer shall, if specified in the requisition, perform network system studies to assist in defining the characteristics of the VSDS. The Manufacturer shall at the time of final order state the information he requires from the Principal to perform these studies.

The requisition shall state the maximum and minimum prospective short circuit current at the Point of Coupling (PC) of the VSDS.

The design of the VSDS shall meet the immunity levels of IEC 61800-3.

Line disturbance data, if relevant, shall be given by the Principal to the Manufacturer.

If available, the Principal shall advise the Manufacturer of the Supply grid characteristics and impedances on his request.

If requested by the Manufacturer in the quotation stage (2), the Principal shall advise the next higher/lower voltage level available to supply the VSDS in case the harmonic loading of the specified voltage level reaches unacceptable levels.