DEP SPECIFICATION

A.C. ELECTRICAL VARIABLE SPEED DRIVE SYSTEMS

DEP 33.66.05.33-Gen.

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DESIGN AND ENGINEERING PRACTICE

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the design and manufacturing of direct-coupled AC electrical variable speed drive systems (VSDSs), and is based on the following IEC standards:

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

This DEP 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 will indicate whether a ventilation/cooling/climate conditioning facility for the converter is to be included in the supply. This will 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.

This DEP gives additional information and requirements, and where applicable, selects options given in the relevant IECs.

This is a revision of the DEP of the same number dated September 2013; see (1.5) regarding the changes.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall 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 could be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable with regards 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 DEP 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 DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that 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.

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

The **Principal** is the party that initiates the project and ultimately pays for it. 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 DEPs referenced in this DEP are applicable. The following additional definitions apply:

Term	Definition
Active front end converter	Converter with input circuitry designed to limit the lineside harmonics.
Availability	Availability is defined as : $\frac{MTBF}{MTBF + MTTR}$
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/Supplier'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.
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.
High voltage converter	A converter with an output voltage exceeding 1000 V (ref: IEC 61800-4).
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 set-point 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).

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Term	Definition
Mean time between failures – MTBF	Mean time between failure is defined as: $\frac{\text{operating time}}{\text{number of faults that have resulted in outages}}$ (hours)
Mean time to repair – MTTR	Mean time to repair is defined as: $\frac{\text{time to repair and to come back in service}}{\text{number of faults that have resulted in outages}}$ (hours)
Non-integer harmonics on the machine-side	Harmonic quantities not being a multiple of the inverter input 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: $e^{-\left(\frac{8760}{MTBF}\right)}$
Requisition	Is DEP 33.66.05.95-Gen. (Data/requisition for AC variable speed drive system) Or DEP 33.66.05.96-Gen. (Data/requisition for AC variable speed drive system < 250 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 by 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.

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Term	Definition
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 DEP are made, the referenced section or clause number is shown in brackets ( ). Other documents referenced by this DEP are listed in (16).

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number dated February 2012. The following are the main, non-editorial changes.

Section/Clause	Change
2.1	• Reference to DEP 33.64.10.17-Gen. added. • Rating of VSDS modified to 250kW for applicability of dispensation
2.2	Requirement of transient air gap torque removed, as this requirement is mentioned in motor DEP
2.2	Requirement of losses and efficiency calculation added
4.1(b)	Statement on auxiliary supplies for air, lube oil, cooling water, and electrical auxiliary supplies removed.
16	Added feedback form - DEP 00.00.05.80-Gen.

NOTE: Clause numbers in this table refer to numbering in the current version of the DEP.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be submitted to the Administrator using one of the following options:

Shell DEPs Online (Users with access to Shell DEPs Online)	Enter the Shell DEPs Online system at https://www.shelldeps.com Select a DEP and then go to the details screen for that DEP. Click on the “Give feedback” link, fill in the online form and submit.
DEP Feedback System (Users with access to Shell Wide Web)	Enter comments directly in the DEP Feedback System which is accessible from the Technical Standards Portal http://sww.shell.com/standards. Select “Submit DEP Feedback”, fill in the online form and submit.
DEP Standard Form (Other users)	Use DEP Standard Form 00.00.05.80-Gen. to record feedback and email the form to the Administrator at standards@shell.com.

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Feedback that has been registered in the DEP Feedback System by using one of the above options will be reviewed by the DEP Custodian for potential improvements to the DEP.

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2. GENERAL REQUIREMENTS

2.1 GENERAL

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

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

This DEP gives 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 the following DEPs with all modifications as specified in this DEP:

- DEP 33.65.40.31-Gen.
- DEP 33.65.11.31-Gen.
- DEP 33.66.05.31-Gen.
- DEP 33.64.10.17-Gen.

This DEP 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 DEP 33.66.05.95-Gen. shall be used to make order-specific requirements and shall be returned by the Manufacturer/Supplier with the requested data and the quotation.

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 250 kW and lower. For such cases, reference shall be made to Appendix 2 and to data/requisition sheet DEP 33.66.05.96-Gen.

2.2 RESPONSIBILITY

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

The order for a VSDS may be placed direct with a Manufacturer/Supplier or through the Manufacturer/Supplier of the driven equipment, both of whom shall be approved by the Principal. In the latter case the Manufacturer/Supplier 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/Supplier of the VSDS shall be responsible for the performance of the VSDS as described in this DEP and for compliance with the requirements of the driven equipment as given to him by the driven equipment Manufacturer/Supplier at the time of order.

The following shall be provided by the Manufacturer/Supplier:

a) calculated rotor responses

b) ramp times

c) for running up and continuous operation, data on all machine air gap torques

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including integer and non-integer harmonic torques in amplitude and frequency, also stating the assumptions on ratings of dc-link components

d) lubrication requirements

e) Losses and efficiency calculation of complete system including inverter, transformer and output filter if provided.

Furthermore, the responsible Manufacturer/Supplier 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/Supplier of the driven equipment (and gearbox if included) to ensure good overall coordination;
- performing the necessary electrical system studies

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

If specified in the requisition, the Manufacturer/Supplier 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/Supplier. 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.

2.3 SCOPE OF SUPPLY

The scope of supply of the VSDS shall include:

a) detailed design

b) studies as indicated in this DEP and the requisition

c) supply of materials

d) factory and site inspection and testing

e) documentation including certification

f) commissioning and start-up assistance

and where specified in the requisition or order:

g) spare parts for 6 years operation (11)

h) site installation

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

2.4 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.

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3. STATEMENT OF COMPLIANCE

The Manufacturer/Supplier 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/Supplier of the VSDS under the most arduous conditions specified in this DEP and the requisition.

Tolerances shall be in accordance with this DEP. All the components of the VSDS shall be tested individually and in combination at the Manufacturer/Supplier'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/Supplier shall rectify and re-test the VSDS within a mutually agreed time.

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4. BASIC REQUIREMENTS OF THE VSDS

4.1 GENERAL

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

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

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

The Manufacturer/Supplier 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.

In addition to the requirements stated in the requisition, the following information will be given to the Manufacturer/Supplier:

a) 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.

b) 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.

c) A single line diagram indicating the main and auxiliary circuitry, and information on fault level, system earthing and auxiliary supply systems.

d) Specification of cooling water where applicable.

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

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

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

a) 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).

b) MTTR shall only relate to converter repair.

c) MTTR shall include a maintenance overhaul time of 80 h over a 2-week period after 6 years of operation.

d) Operation of the VSDS shall have been in accordance with the Manufacturer/Supplier's instructions.

e) 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.

4.3 SITE CONDITIONS

The atmospheric conditions inside the VSDS room shall normally be in accordance with IEC 62271-200. However, allowance shall be made for the entry of dust, salt and sulphur contaminated air when doors are open or cable entrances through the floor are uncovered during maintenance and construction periods. The Manufacturer/Supplier shall quantify that allowance in the quotation. Depending on the area where the VSDS will be installed condensation inside the VSDS may occur. Proper measures, e.g. by installing sufficiently rated panel heaters shall be provided.

For offshore applications the VSDS will be installed indoors and shall be suitable for operation in an environment where the relative humidity may reach 98 %. 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 IP Code Part 15 shall be stated in the requisition or its appertaining documentation.

The Manufacturer/Supplier 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.

VSDS cubicles to be installed offshore shall be suitable for mounting on a deck, which may be expected to flex with the general movement of the platform structure. Unless otherwise specified in the requisition, deflection between support points of the VSDS cubicle shall not exceed 5 mm of the free span.

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, 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 IP Code Part 15.

Reactors, harmonic filters, etc., may be installed outside the substation building in a non-hazardous area according to IP Code Part 15.

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:

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