

NORSOK STANDARD

ADJUSTABLE SPEED AC MOTOR DRIVES

E -002

Rev. 2, December 1997

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FOREWORD

NORSOK (The competitive standing of the Norwegian offshore sector) is the industry initiative to add value, reduce cost and lead time and eliminate unnecessary activities in offshore field developments and operations.

The NORSOK standards are developed by the Norwegian petroleum industry as a part of the NORSOK initiative and supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Engineering Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Standards Institution).

The purpose of NORSOK standards is to contribute to meet the NORSOK goals, e.g. by replacing individual oil company specifications and other industry guidelines and documents for use in existing and future petroleum industry developments.

The NORSOK standards make extensive references to international standards. Where relevant, the contents of a NORSOK standard will be used to provide input to the international standardisation process. Subject to implementation into international standards, the NORSOK standard will be withdrawn.

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INTRODUCTION

This issue of NORSOK standard E-002 replaces E-CR-002, rev. 1, January 1996.

1 SCOPE

This standard contains provisions for electrical installations at all voltages and is intended to enable safety in the design of electrical systems, selection, and use of electrical equipment for generation, storage, distribution and utilisation of electrical energy for all purposes in offshore units which are being used for the purpose of exploration or exploitation of petroleum resources.

This standard is based on equipment and practices which are in current use but it is not intended in any way to hamper development of new or improved techniques.

2 NORMATIVE REFERENCES

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

EU 89/336	Electromagnetic compatibility (EMC) of 1989-05-23.
IEC 34	Rotating electrical machines. Parts 1 through 18 as relevant.
IEC 76	Power transformers, Part 1 through 5 as relevant.
IEC 146	Semiconductor converters, Part 1 through 4 as relevant.
IEC 551	Determination of transformer and reactor sound levels.
IEC 726	Dry type power transformers.
IEC 1136-1	Semiconductor power converters, Part 1: Adjustable speed electric drive systems, general requirements.
IEC 1800-2	Adjustable speed electrical power drive systems, Part 2: Rating specifications for low voltage adjustable frequency AC power drive systems.
IEC 1800-3	Adjustable speed electrical power drive systems, Part 3: EMC product standard including specific test methods
ISO 1680	Test code for the measurement of airborne noise emitted by rotating electrical machinery, Part 1: Engineering method for free field conditions over a reflecting plane.
NORSOK E-001	Electrical systems.

3 DEFINITIONS AND ABBREVIATIONS

3.1 Definitions

Can	Can-requirements are conditional and indicates a possibility open to the user of the standard.
Informative references	Shall mean informative in the application of NORSOK standards.
May	May indicates a course of action that is permissible within the limits of the standard (a permission).
Normative references	Shall mean normative in the application of NORSOK standards.
Shall	Shall is an absolute requirement which shall be followed strictly in order to conform with the standard.
Should	Should is a recommendation. Alternative solutions having the same functionality and quality are acceptable.

3.2 Abbreviations

ASDS	Adjustable Speed Drive System
BDM	Basic Drive Module. Converter and control section.
CDM	Complete Drive Module. Consists of BDM and FS.
CENELEC	European Committee for Electrotechnical Standardisation.
CSI	Current Source Inverter.
ET	Elektrisitetstilsynet (new name: Produkt- og Elektrisitetstilsynet)
FS	Feeding Section. Input transformer or input reactor as relevant, circuit breaker or ac switch and all auxiliaries and other equipment required.
h	Harmonic order.
IEC	International Electrotechnical Commission.
IFEA	Industriens Forening for Elektroteknikk og Automatisering.
In	BDM input current [A].
LCI	Load Commutated Inverter.
PAM	Pulse Amplitude Modulated.
PC	Personal Computer.
PCC	Point of Common Connection.
PDS	Power Drive System. Complete drive system CDM plus the motor.
Process	PDS plus driven equipment.
PWM	Pulse Width Modulated.
SAS	Safety and Automation System.
SL	Total apparent load in PCC [kVA].
Sn	BDM input apparent power [kVA].
SSC	Short circuit power (in PCC) [kVA].
Uh	Harmonic voltage component [%].
Un	BDM input line voltage [V].
UN	Motor line voltage [V].
UPS	Uninterruptible Power Supply.
VSI	Voltage Source Inverter.

4 DESIGN CRITERIA

Normally squirrel cage motor drives are used in the low voltage range ($UN < 1\text{kV}$). In the high voltage range ($UN > 1\text{kV}$) and higher power range the choice between synchronous and asynchronous motor drives shall be subject to agreement between customer and supplier.

4.1 System compatibility

Generally the PDS shall be designed, manufactured and tested by the same supplier.

If the PDS consists of equipment from different manufacturers, the BDM supplier shall be responsible for the integrity of the system.

The different parts of the PDS might be installed in locations separated from each other. The supplier shall indicate the maximum acceptable cable lengths between the different parts. The customer shall give information about actual distances when available and requested by supplier.

4.2 Operational conditions

The electrical supply system is defined in the data sheets in accordance with the standard E-001, Electrical systems.

The classification of the areas where the different parts of the PDS will be located is indicated on the respective data sheets.

The supplier is free to choose motor voltage and pole pairs unless otherwise stated in the data sheet. The required speed range is stated in the data sheet.

Unless otherwise stated in the data sheet the motor neutral shall be isolated.

The motor shall be designed for operation with the applicable BDM and take into account all additional losses and the actual load.

The PDS shall be capable of operating with specified torque within the given operational speed range with stationary line voltage variations between -5% and +10% of U_n unless otherwise specified in the data sheet. In the voltage range from -5% to -10% and from +10% to +15% the PDS shall operate normally, but reduced output power/torque is acceptable. A transient voltage dip down to 85% of U_n for 500ms shall not cause tripping.

The converter shall be designed in such a way that if a failure occurs in one part of the unit (such as semiconductor block, printed circuit board etc.) this failure shall cause no damage to other parts of the converter. This includes internal short circuits which if not protected by fuses shall be limited to the devices involved.

In cubicles which can be accessible during normal operation (open front door) all components with potentials above 50V shall have a degree of protection of at least IP20.

4.3 System control

The control system shall be able to control the drive by speed ramp, torque or power. The normal control mode is indicated on the data sheet.

4.4 EMC

The PDS shall fulfil the requirements of the EU Directive 89/336/EEC and IEC 1800-3, EMC product standard including specific test methods.

4.4.1 Transients and notches

The PDS shall be insensitive to all voltage spikes and dips produced by the PDS itself.

PDS connected to high voltage busbars shall be protected against externally generated voltage spikes. Spikes with amplitudes up to 3.0 per unit and duration less than 2ms (triangular shape) shall cause no harm to function or components. (Spike considered to be an ideal voltage source.)

For PDS connected to low voltage busbars the spike immunity level shall be 3.0 per unit amplitudes and maximum duration 0.750ms (triangular shape).

The PDS shall be insensitive to externally generated voltage dips of 20% with duration less than 3ms (rectangular shape, negative voltage source).

4.4.2 Harmonic distortion

Generally a harmonic distortion analysis is required when installing a PDS.

The total harmonic voltage distortion (THD) should not exceed 10% and no single harmonic should exceed 8% according to IEC 1800-3, applicable for low voltage (< 1000V) system only.

For high voltage PDS, the THD should not exceed 8% and no single harmonic should exceed 6%. At the time of issue of this document, no corresponding IEC standard is available for high voltage PDS. If required a harmonic filter shall be installed.

Other distortion levels can be accepted on local busbars if no sensitive equipment is installed on that busbar. It might be more reasonable to feed low power consuming loads from a UPS than to install a filter.

Table 1 has been developed on basis of IEEE standard 519-1992. In case of inductive grid systems it indicates the maximum permissible converter installation related to the short circuit power SSC (kVA) in the point of common connection, PCC. SL is the total apparent load (kVA) connected to the PCC and the table gives the percentage of this load which can be converter load.

Table 1 - Permissible relative converter load.

	Relative converter load [%]	
S_{SC} / S_L	6-pulse	12-pulse
20.00	17.00	36.00
$20 < 50$	27.00	57.00
$50 < 100$	40.00	86.00
$100 < 1000$	50.00	100.00
> 1000	67.00	100.00

Normally the table 1 will give voltage distortions not exceeding the limits of this clause. In case of significant capacitors in the grid a detailed study is mandatory.

5 SYSTEM REQUIREMENTS

5.1 General requirements

The PDS unit should be self supported without any need for auxiliary supplies. If external auxiliaries are required, the BDM supplier shall identify these.

After the commissioning period, the drive shall have the capability to run continuously for a period of at least 24 months for LV motors, 36 months for HV motors, under the specified site conditions without any scheduled shutdown. No component of the drive system shall require any routine or preventive maintenance that needs a shutdown of the system over any consecutive 24- respectively 36-month period following initial operation.

5.2 Process requirements

5.2.1 Critical speeds

The PDS/BDM supplier shall advice the critical speeds in his bid and if any inside the operating range he shall document how to avoid these critical speeds.

5.2.2 Pulsating torque

The PDS/BDM supplier shall give information about any pulsating torque in the low speed range as well as in the operating speed range.

5.2.3 System control

The reference signal shall be 4-20mA if not otherwise stated in the data sheet. 4mA shall refer to either minimum operational speed or standstill, i.e. zero speed, as stated in the data sheet.

If the reference signal is lost the drive shall either decelerate to minimum speed/torque/power or down to standstill as stated in the data sheet.

As a minimum the following potential-free output signals shall be provided:

- Ready to start.
- Running.
- Stop - when stopped by process system or PDS protection devices.
- Stop - when stopped by emergency push-button.

During normal operation after decelerating the motor to standstill it shall be possible to de-energise the motor by blocking gate/base signals to the power semiconductors, leaving line transformer and converter input circuit energised.

When automatic restart is specified in the data sheet this shall also be possible with a rotating motor, called "flying restart".

Serial link for communication to platform control system (SAS) shall be included as indicated in the data sheet.

6 EQUIPMENT REQUIREMENTS

6.1 General

6.1.1 Motor

The motor shall as far as possible comply with the requirements in E-001, clause 6.5.

The insulation shall be class F. The temperature rise at rated load and speed and at specified load in the entire speed range shall be limited to class B. Higher insulation classes may be agreed upon.

The rotor shall be dynamically balanced according to the limits in IEC 34-14.

6.1.2 BDM

The BDM shall be short circuit proof. If converter valves are not protected by fuses, power semiconductor devices are considered to be fuses. No damage shall occur on any equipment or components but the fuses or power semiconductors in the short circuit path.

The BDM shall include an alphanumeric panel display showing drive parameters and operating status and a fault detection/protection list (alarms).

The BDM fault diagnostic and analysing system and the indication logic shall have a memory function to retain information about the cause of tripping. This information should be retained for at least 72 hours even if the entire system is de-energised.

The BDM shall meet the requirements in IEC 1136-1 and IEC 1800-2 as relevant.

6.1.3 Feeding section

Converter transformers (if any) shall normally be of the dry resin cast type. These transformers shall meet the requirements in IEC 146-1-3 and IEC 726.

Note : Indoor transformers shall be designed for a yearly average ambient temperature of at least 25° C if not otherwise stated in the data sheet.

6.2 Low voltage squirrel cage motor drives ($U_N < 1\text{kV}$)

6.2.1 General

The overload capability shall as a minimum be 130% of rated torque for 10 seconds and 110% of rated torque for 60 seconds. The supplier shall inform about the actual overload capability of the PDS.

6.2.2 Motor

Random wound windings are acceptable.

Delta connected windings are acceptable if the BDM have supervision of asymmetric output current with alarm and tripping functions or if the system shall be equipped with an appropriate relay to detect asymmetry.

6.2.3 Basic Drive Module

The BDM shall provide protection of the PDS against overload, overvoltage, undervoltage and short circuit.

When by-pass is specified it shall be located in a separate by-pass cubicle if not otherwise specified. The by-pass shall be manually operated and provided with mechanical interlocks to prevent paralleling of the PDS and the by-pass power supply.

6.2.4 Feeding

If no converter transformer is to be used the BDM supplier shall evaluate whether an input reactor is necessary or advisable in order to fulfil proper function and to obtain the requirements given in clause 4. If so, this reactor shall be part of the BDM supplier's scope of supply.

Low voltage/low voltage transformer windings are accepted as dry type without cast resin insulation. The transformer shall meet the requirements in IEC 76.

6.3 High voltage squirrel cage motor drives (UN > 1kV)

6.3.1 General

Overload requirements, if any, will be stated in the data sheet.

All necessary cooling equipment shall be included.

The PDS supplier shall provide all required data to the process supplier for system torsional analysis, harmonic torque pulsations included.

6.3.2 Motor

The motor shall have preformed windings.

The winding shall be star connected. Unless otherwise agreed upon the star point shall be isolated.

6.3.3 Basic drive module

Measures shall be taken that HV cubicles/compartments can be completely de-energised, isolated and earthed. Earth bolts, accessible from the front, for portable earthing apparatus shall be provided.

The BDM shall provide proper protection for the PDS against overload, overvoltage, undervoltage and short circuit, asymmetric currents as well as inability to start and overspeed.

The BDM shall include a fault diagnostic system which indicates location of fault. The indication shall be given in plain text on the alphanumeric display and/or on the platform supervisory system and/or on connected PC.

The internal arrangement shall allow easy access to replaceable parts. If special tools are required it shall be specified and part of the bid.

Earth fault shall give alarm and controlled run-down.

6.3.4 Feeding

The converter transformer reactance shall be adequate for proper function and short circuit protection of the BDM, and meet the requirements in IEC 76.

The necessary protection devices such as temperature sensors and gas detectors (if applicable) and protection against unbalanced load shall be installed.

6.4 High voltage synchronous motor drives

6.4.1 General

Overload requirements, if any, will be stated in the data sheet.

All necessary cooling equipment shall be included.

The PDS supplier shall provide all required data to the process supplier for system torsional analysis, harmonic torque pulsations included.

6.4.2 Motor

The motor shall have preformed windings.

Unless otherwise agreed upon the motor windings shall consist of two three-phase systems with 30° electrical phase shift in order to minimise torque pulsations. The windings shall be star connected and isolated.

The exciter shall be of the brushless type. The rotor winding and the diodes shall withstand any symmetrical or asymmetrical fault occurring in the stator windings.

6.4.3 Basic drive module

Unless otherwise agreed upon the line side of the converter (the rectifier) shall be 12-pulse in order to minimise the harmonic current feedback. The load side of the converter (the inverter) shall have phases in accordance with the motor.

Measures shall be taken that HV cubicles/compartments can be completely de-energised, isolated and earthed. Earth bolts, accessible from the front, for portable earthing apparatus shall be provided.

The BDM shall be of short circuit proof design and shall also provide protection of the PDS against overload, overvoltage, undervoltage and asymmetric currents as well as inability to start and overspeed.

The BDM shall include a fault diagnostic system which indicates location of fault. The indication shall be given in plain text on the alphanumeric display and/or on the platform supervisory system and/or on connected PC.

The internal arrangement shall allow easy access to replaceable parts. If special tools are required it shall be specified and part of the bid.

Earth fault shall give alarm and controlled run-down.

6.4.4 Feeding

The converter transformer shall normally be of the three winding type. The reactance shall be adequate for proper function and short circuit protection of the BDM and meet the requirements in IEC 76.

The necessary protection devices such as temperature sensors and gas detectors (if applicable) and protection against unbalanced load shall be installed.

7 TESTING

7.1 General

The results of all tests shall be documented in a report which shall confirm agreed performance and ratings.

The sound levels shall be tested according to the description in IEC 551 and ISO 1680.

All external components and fittings that are likely to affect the performance of the specific equipment during the test shall be in place.

7.2 Equipment test

If type tests of the specific equipment already are available, new tests are not required.

Supplier shall in his bid identify his type and routine tests and advice which additional tests are recommended for the specific equipment. Annex B shows a relevant check list of equipment tests to be considered.

7.3 System test

A functional test of the PDS including all sub-systems shall be performed to prove thermal limits are not exceeded and functional performance is demonstrated throughout the operational speed range.

7.3.1 Temperature rise tests

The purpose of the tests are to determine the equipment temperature rises at realistic electrical conditions, including all harmonic components. These tests are regarded as type tests, hence only required once for identical PDSs.

The tests shall either be performed by help of a load machine or as back-to-back tests according to available facilities and test equipment or as part of string tests, which shall be agreed upon.

The tests shall be performed at rated speed, maximum speed and minimum speed and with load torque as specified.

If for the transformer the above mentioned tests are not applicable a temperature rise test at sinusoidal voltage and maximum/rated current will be accepted under the following conditions:

- The supplier shall in due time before the tests submit a report to the client comprising calculated losses and temperature rises at rated/maximum load with sinusoidal voltage and current and at maximum/rated load with all the harmonic currents included.
- The difference of the two calculated temperature rises described above plus 10% shall be added to the temperature rise measured. This sum shall be the basis of acceptance evaluation.

For high power drives where string tests including driven equipment have to be performed and where available power or load at test site represents limitations, all tests have to be discussed, agreed upon and documented. In such cases, calculated values at lower power shall demonstrate reasonable compliance with measured values at same power level.

7.3.2 Performance test

Performance tests may be done at low load or at no load as applicable for the verification of the specific function. These tests are regarded as routine tests. As a minimum the tests shall comprise the following:

- Test of current/torque limiting function.
- Test of stable operation at operating points within the specified speed range.
- Test/simulation of alarm and tripping function.

8 INFORMATIVE REFERENCES

ET Elektrisitetsstyret; Retningslinjer for jording i maritime anlegg
IEC 50 International electrotechnical vocabulary, Chapters 151, 441 and 601.
IEC 721 Classification of environmental conditions, Part 1 through 6 as relevant.
IFEA Guidelines for the documentation of selectivity (discrimination) in a.c. systems.

ANNEX A TEST CHECKLIST (INFORMATIVE)

The following table serves as a check list, and may be used as a basis for determining necessary testing to confirm agreed performance and rating. The actual markings have to be agreed upon prior to order placement.

The following abbreviations are used:

R: Routine test
T: Type test
O: Optional test
LV: Low voltage (≤ 1000 V)
HV: High voltage (> 1000 V)
I.A.: If applicable
N.A.: Not applicable
H: Hold point
W: Witness point

Table A.1

Equipment type	Type of test offered		Client requirements	
	LV	HV	LV	HV
Motor				H
DC resistance of stator winding			R	R
Insulation resistance of stator winding			R	R
No load test				R
Short circuit test			T	T
Phase sequence/direction of rotation				R
Stator winding voltage test			T	R
Vibration test				R
Functional check of auxiliaries				R
Temperature rise test			T	T
Measure shaft voltage				T
No load charact./iron & friction losses			T	T
Efficiency			T	T
For EEx e: Measure tE time			I.A.	I.A.
For EEx p: Measure pressure distribution				I.A.
Sound pressure levels				T
Moment of inertia			T	T
Overspeed				T

Table A.2

Equipment type	Type of test offered		Client requirements	
	LV	HV	LV	HV
Converter				
Converter circuit breaker				I.A.
Insulation level			R	R
Functional check of auxiliaries			R	R
Temperature rise test (Note 1)			T	T, H
Efficiency (Note 1)			T	T, H
Sound pressure levels				T
Alarms and tripping functions			R	R, H
Transformer				H
Winding resistance			R	R
Voltage ratio/phase displacement			R	R
Insulation resistance			R	R
Short circuit impedance and load losses			T	T, H
No load losses and current			T	T, H
Dielectric DLA and tan d test				R
Dielectric special tests (PDA, etc.)				
Temperature rise tests (Note 1)			T	T, H
Short circuit withstand				T
Sound levels				T
Power to auxiliary equipment				I.A.

Note 1: May be part of system tests. (See Table A.3)

Table A.3

Equipment type	Type of test offered		Client requirements	
	LV	HV	LV	HV
System			H	W
Temperature rise motor			T	T
Temperature rise transformer (Note 2)			T	T
Temperature rise converter			T	T
Acceleration requirements			I.A.	I.A.
Current and torque vs speed			T	R
Current / torque limit			R	R
Operation stability			R	R
Alarms and tripping			R	R
Sound levels			T	T
Vibration				R
Harmonic current feed-back at PCC				T

Note 2: May be part of component test, ref. clause 7.3.2

ANNEX B Equipment Data Sheets (Normative)

EDS-006	ER, CONVERTER FOR ASDS	Rev. 2, Jan 1996
EDS-008	EM, MOTOR FOR ASDS	Rev. 2, Dec 1997
EDS-009	ET, POWER TRANSFORMER FOR ASDS	Rev. 2, Dec 1997