

GENERAL SPECIFICATION

ELECTRICAL

GS EP ELE 121

HV Variable Speed Drive Systems
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1. Scope

This specification defines the minimum requirements for design, manufacture, inspection and testing of HV variable speed drive systems. It is to be read in conjunction with the corresponding Project specification and/or data sheets.

The Supplier shall clearly identify in his technical offer any deviation to these specifications.

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

Design and engineering shall conform as a minimum requirement to the current edition of the following in order of preference:

- Applicable laws and regulations of the country in which the system will be operated. In cases where no "local" regulations exist, the French laws and regulations shall be used
- Company Particular Specifications and data sheet (if any)
- Company General Specifications
- Applicable International Electro-technical Commission (IEC) Standards
- Applicable CENELEC Standards
- Applicable recognised standards and codes (e.g. UTE-NFC, BSI, VDE, etc.) where IEC publications have not yet been issued.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the effective date of this document.

Reference	Title
IEC 60034-1	Rotating electrical machines - Part 1: Rating and performance
IEC 60071 (All parts)	Insulation co-ordination - All parts
IEC 60076 (Parts 3; 6)	Power transformers - Parts 3; 6
IEC 60146-1-2	Semiconductor convertors - General requirements and line commutated convertors. Part 1-2: Application guide
IEC 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
IEC 60529	Classification of degrees of protection provided by enclosures
IEC 60871-1	Shunt capacitors for a.c. power systems having a rated voltage above 1000 V - Part 1: General
IEC 61000	Electromagnetic compatibility (EMC)
IEC 61071	Capacitors for power electronics

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Reference	Title
IEC 61378 (Parts 1; 3)	Converter transformers - Parts 1; 3
IEC 61800 (Parts 3; 4; 5-1)	Adjustable speed electrical power drive systems - Parts 3; 4; 5-1
IEC 62271-200	High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
IEEE Std 519	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
ISO 12944-2	Paints and varnishes. Corrosion protection of steel structures by protective paint systems - Part 2: classification of environments

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published in the applicable yearly collection.

Reference	Title
GS EP COR 350	External protection of offshore and coastal structures and equipment by painting
GS EP COR 354	External protection of onshore structures and equipment by painting
GS EP ELE 011	Electrical requirements for packaged units
GS EP ELE 079	Electrical apparatus for potentially explosive gas atmospheres
GS EP ELE 111	Induction motors
GS EP ELE 114	HV Synchronous Motors
GS EP ELE 141	Power transformers
GS EP ELE 221	Electrical Control System (ECS)
GS EP INS 135	Cyber Security requirements for design and supply of ICSS and Package Systems
GS EP PVV 145	Flanges
GS EP SAF 221	Safety rules for buildings
GS EP TEC 007	Obsolescence and Lifetime Cycle Management

3. Abbreviations

VSDS	Variable Speed Drive Systems
VSI	Voltage Source Inverter

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LCI	Load Commutated Inverter
ESD	Emergency Shutdown
MTTF	Mean Time To Failure
VPI	Vacuum Pressure Impregnated
ECS	Electrical Control System
ICSS	Integrated Control and Safety System
SSTI	Sub Synchronous Torsional Interaction

Note: Variable Speed Drive Systems consists of power equipment (possible harmonic filters, input transformer, converter section, possible output transformer or filter, motor), control, protection and auxiliaries.

4. Design Requirements

4.1 General

VSDS shall be suitable for continuous full load service and for the operational duty of the driven equipment within the rated conditions and specified ambient conditions without exceeding the temperature rises specified in the standards and without deleterious effects of any kind.

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 to avoid damage to other parts of the VSDS. The motor/driven equipment shall be able to withstand the transient torques developed during short circuit conditions (this shall be jointly managed with Supplier of motor driven equipment).

The Supplier shall provide, at the bid stage, the heat generated by all indoor equipment across the full operating range of the VSDS.

4.2 Environmental Conditions

The VSDS converter will be installed within a separate non-hazardous, pressurised, air conditioned, clean and dry building or container with an average ambient air temperature of 25°C but it shall be able to operate as long as room temperature does not exceed 40°C.

VSDS and all associated equipment shall be suitable for the specified place of installation with typical dusty and corrosive atmosphere.

4.3 Power Supply Conditions

Equipment shall be suitable for continuous operation with voltage and frequency variations as defined in [GS EP ELE 011](#).

Voltages for auxiliary equipment shall be compliant to [GS EP ELE 011](#).

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4.4 Operational Safety, Availability, Reliability, Maintainability

Safe conditions shall be ensured under all operating conditions, including those associated with start-up and shut-down of plant and equipment and throughout the intervening shut-down periods.

For all operational and maintenance purposes, modules which need to be changed or maintained shall be removable and replaceable without dismantling other components.

The design of the VSDS shall ensure periods of continuous operation of at least 5 years.

The VSDS including all individual components forming part of the system shall have an availability of at least 0.997 and a minimum MTTF of 5 years.

The VSDS shall be designed for 20 years operation under the specified operating conditions and adapted inspection, maintenance and repair program.

All hardware and software that may be developed by the Supplier, further to the VSDS delivery, shall ensure full ascending compatibility to allow for easy replacement of equipment that would become obsolete.

The Supplier shall guarantee hardware and software support during the expected lifetime of the VSDS.

The VSDS converter cubicle shall have a front door emergency stop button which shall be guarded with plastic cover to protect them from accidentals shutdown.

4.5 Degree of Protection

Minimum degree of protection of equipment, as defined in [IEC 60529](#), shall be:

- Outdoor equipment: IP55
- Indoor equipment: IP21.

4.6 Internal Arc Classification

The cabinet shall be Internal Arc Classified (IAC) type AFLR (or AFL depending of the room layout) for internal arc up to the supply system rated short-circuit current with duration of 500 ms. AFLR and AFL definition is as per [IEC 62271-200](#).

The cabinet shall be type-tested under conditions of arcing due to internal fault in accordance with [IEC 62271-200](#) or [IEC 61800-5-1](#). For [IEC 61800-5-1](#) the test condition chosen for the breakdown of components shall induce an internal arc fault.

Type test certificate shall be provided.

4.7 Mode of Operation

The VSDS shall have the capability to deliver sequential starting and load operating point duties without restriction. Where the VSDS, motor and driven equipment form one contract, the mode of operation will be specified in the project specification and will include start, run-up and stop requirements.

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4.8 Emergency Shutdown

For process ESD purpose, VSDS shall be fitted with a stop function category 0 as per [IEC 60204-1](#).

4.9 Acceptable Technologies

4.9.1 Motor

Motor type shall be:

- Induction motor for ratings lower than 15 MW
- Synchronous motor for ratings above and including 15 MW
- Defined case by case when specific design conditions have to be considered, in which case prior approval from the Contractor and the Company on the design is required.

4.9.2 Converter

Converters shall be:

- Based on VSI technology for ratings up to 20 MW, or based on LCI technology
- Designed such that the current in the motor stator winding (s) does not exceed 2000 A
- For LCI, the topology of the converter shall minimize inter harmonics, especially regarding the $6*(F_m - F_n)$ component frequency which shall be cancelled.

Note: F_m means Motor frequency in Hertz and F_n means Network frequency in Hertz.

Converters rectifier topology shall be:

- 12-pulse maximum for LCI
- Governed by [IEEE Std 519](#) harmonics requirements at network line side with the lowest possible design complexity (12 pulse as a minimum for VSI).

In case of Active Front End rectifier topology, a sine filter shall be installed on the rectifier side. If the Active Front End rectifier is used in a transformer less configuration, a study made by the VSDS's Supplier shall verify that this configuration does not modify the network fault current in case of earth fault. Mitigation measures (e.g. filter) shall be implemented by VSDS's Supplier if the earth fault current is modified.

4.10 VSDS Rating

VSDS shall comply with the driven equipment characteristics as described in the datasheets.

The Supplier of the VSDS shall obtain from the driven equipment Supplier all relevant data including the exact torque speed characteristic of the driven equipment and shall design the VSDS accordingly.

VSDS shall meet the torque requirements at any line voltage between 90% and 110% of nominal.

Supplier shall state within the offer the maximum cable length allowed from transformer to converter and from converter to motor without converter's output filter.

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As a general principle to be validated by the VSDS Supplier, earth fault current shall be limited to less than 10 A.

4.11 Rating of Converter Electronic Components

The ratings of the power semi-conductors including diodes, transistors and thyristors, shall be based on data given by the Supplier within his catalogue or in official data sheets. Voltage/Current margin and junction temperature on power semi-conductors shall be clearly indicated within the offer.

Sub components of identical power cells shall be from the same supplier with identical technical performances.

LCI shall use identical semi-conductors components for rectifier and inverter bridges.

Current rating of the converter semi-conductor component shall not be less than 120% of the maximum current flowing through the elements at full load throughout the whole operation speed range. Parallel-connected semi-conductors shall have current ratings not less than 140%.

All the converter components shall be suitable for permanent operation of the converter at 110% of the rated output power. Supplier shall provide all data allowing the over-sizing of the converter elements to be verified.

Power semi-conductors of the rectifier and inverter shall be designed to withstand the current of a short circuit on the DC side.

4.12 Converter Output Voltage Stress

In case of use of VSI, converter output voltage dV/dt shall be minimized to less than 1 kV/ μ sec.

4.13 Electromagnetic Compatibility

The VSDS shall meet EMC requirements of [IEC 61000](#).

4.14 Harmonics and Inter Harmonics at the Line Side

The VSDS shall meet the immunity levels of [IEC 61800-3](#).

The emission levels of harmonics shall meet the requirements of [IEEE Std 519](#).

Calculations at the Point of Coupling (PC) of the VSDS to demonstrate compliance with above including size and effect of harmonics and inter harmonics shall be provided by the Supplier. Such calculation shall cater for the specified short-circuit impedance and harmonic contribution from other drives. The details of the electrical network are provided by the Contractor.

Where [IEEE Std 519](#) levels requirements cannot be met, the Supplier shall propose corrective options, e.g. filters, and include such options in the quotation, taking into account any interaction with other system components. The design of filters shall consider the existing background harmonics of the network.

VSDS's Supplier shall make available harmonics rejection information to Contractor for an overall harmonic study of the electrical network by Contractor. If there are already existing harmonic filters connected to the electrical network, Contractor shall ensure that existing

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harmonic filters will not be overloaded by the VSDS, otherwise mitigations measures shall be implemented.

In case of use of large VSDS (>15 MW) with an islanded power plant, Sub Synchronous Torsional Interaction (SSTI) study of the power plant shall be done by a third party in cooperation with the VSDS's supplier under the supervision of the Contractor.

4.15 Pulsating Torques

Supplier shall advise special precautions to be followed to avoid unacceptable pulsating torques at the driven equipment. This advice shall be based on the expected driven equipment characteristics and Supplier's experience. The Supplier shall liaise with the driven equipment Supplier to ensure that the level of pulsation is acceptable.

Supplier pulsating torques calculation capability shall be demonstrated within the offer.

Supplier shall provide a detailed study to demonstrate effects of harmonics and inter harmonics on pulsating torque.

4.16 VSDS Efficiency

VSDS efficiency guarantees shall be provided within the offer for driven equipment guaranteed operating point(s).

4.17 Transformer

Transformer shall be designed, manufactured and tested in accordance with [IEC 61378-1](#) and [IEC 61378-3](#).

Transformer shall be compliant to [GS EP ELE 141](#).

In offshore application water forced cooling is accepted and all related auxiliaries shall be redundant.

Transformer shall be oil immersed type.

Converter transformer shall be suitable for operation with the non-sinusoidal current wave shapes and DC components under normal and abnormal conditions of the VSDS without exceeding its temperature or other limits under the operating conditions defined within this specification.

Maximum transformer induction shall be 1.6 Tesla.

Transformer temperature rise shall be limited to 60°K for the windings and to 55°K for the top oil with an ambient temperature below 40°C.

Transformer shall have reduced losses. No-load losses and copper losses shall be clearly indicated within the offer. Losses shall include harmonics losses.

Rated lightning impulse withstand voltage shall be in accordance with [IEC 60076-3](#) table 2 taking into account the highest value.

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4.18 Reactor

The converter reactor(s) shall be suitable for operation with non-sinusoidal current wave shapes and DC components under all operational conditions of the VSDS without exceeding its temperature or other limits under the conditions of this specification.

4.19 Capacitor

Capacitor(s) with a lifetime of at least 10 years shall be selected taking into account 40°C of ambient temperature.

4.19.1 Harmonics filter capacitors

Capacitor(s) shall be suitable for VSDS utilization with design, manufacture and test in accordance with [IEC 60871-1](#).

Capacitor(s) shall be suitable for continuous operation at 110% of the network rated voltage.

4.19.2 Capacitors for power electronics

Capacitor(s) shall be suitable for VSDS utilization with design, manufacture and test in accordance with [IEC 61071](#).

4.20 Output sine filter

If an output sine filter is installed, the VSDS's supplier shall detail the calculations and criteria used to sized it. The calculation note shall verify in the whole speed range that the resonances cannot be excited by the harmonics created by the inverter and the slots of the motor.

The calculation note shall in particular assess the followings points:

- Voltage and current THD of the motor in its speed range
- Self excitation phenomenon when the motor is stopped or tripped at full speed/power
- Peak voltage and dV/dt seen by the motor in its speed range.

Network voltage variation, cables parameters and motor parameters shall be taken into account in the calculation note.

Mitigations measures (eg: damping resistor, contactor...) shall be implemented, by the VSDS's supplier, in case of resonances or self excitation phenomenon issues.

4.21 Motor

4.21.1 General

Motor shall be compliant to [GS EP ELE 111](#) (Induction motors) or [GS EP ELE 114](#) (HV Synchronous motors).

Motor insulation level shall be compliant as a minimum to [IEC 61800-4](#) requirements.

For VSI, motor shall be 3 phase.

For LCI, number of motor windings shall be selected to reduce pulsating torque.

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The Supplier shall liaise with the motor Supplier to take into account in the motor design:

- The effects of harmonics and inter harmonics of the VSDS converter
- The VSDS converter voltage stress as a result of transient peak voltage values, peak rise time and repetition rate.

The motor of a VSDS should have a rigid, under-critical rotor bearing system with the first critical speed over 125% of the maximum operational speed of the VSDS.

The motor of a VSDS with a flexible, over-critical rotor bearing system shall have the first critical speed below 80% of the minimum operational speed of the VSDS and the second critical speed over 125% of the maximum operational speed of the VSDS.

High-speed electric motor used for VSDS applications shall comply with the same requirements with respect to critical speeds as the mechanical equipment being driven.

Full torsional analysis (including frequency resonance analysis) shall be carried out over the complete operating speed range. This shall be a joint responsibility between the motor Supplier and the driven machine Supplier.

Motor duty type shall be S9 as defined in [IEC 60034-1](#).

4.21.2 Variable Speed Motors in Hazardous Areas

GS EP ELE 079 shall be applied to motors installed in hazardous areas.

Motors and accessories shall bear their own marking, according to the mode of protection used.

4.22 Noise Levels

Unless otherwise specified, noise levels shall meet limit of **GS EP SAF 221** under any load and/or frequency condition within the operational speed range of the VSDS.

5. Construction Requirements

5.1 Converter

5.1.1 Converter Elements

Each converter shall consist as a minimum of the following minimum elements:

- Control and auxiliary equipment power supply and distribution system
- Control, triggering and control system equipment
- Protection, supervision and alarm equipment and measuring/testing facilities
- Combination as applicable of rectifier, DC link and inverter
- Cooling equipment
- Harmonic filter power factor correction equipment if needed to comply to network harmonics requirements.

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Supplier shall explain within the offer the means used to connect to earth both input and output power section of the HV cubicles when doors are opened. Without information given at bidding stage by Supplier, earthing switches shall be provided.

5.1.2 Cabling/Wiring

5.1.2.1 Power cable

The Supplier shall provide detailed cable specification and calculation for all interconnecting power cable taking into account current and voltage stress of the VSIDS.

Cable specification and calculation shall include cables connecting the transformer to the converter and the converter to the motor (i.e. insulation of the main conductors, quantity and physical arrangement of the main conductors, screening of the main conductors, etc.).

Conditions and detailed arrangement of the power conductor screen earthing shall also be provided.

For applications where there are several power cables bundled together (e.g. 2 subsea pumps fed from the same umbilical), when one of the cable is off, the voltage induced by the live cable on the cable off shall be assessed. In case of induced voltage >50 V, disconnector switch shall be installed to be able to disconnect the electrical cables off (power and control) from their power supply.

5.1.2.2 Terminations

Fixed internal wiring, e.g. between modules, shall be terminated by wire wrap, solder or equivalent and connected plugs to allow rapid module exchange.

Site installed wiring and connections between panels shall be terminated on terminals that will not loosen in service through the effects of heat or vibration, e.g. between transport units, cubicles and from the field. Individual terminals shall be provided for all wires.

Terminals shall be provided with test links or facilities to carry out diagnostic testing.

Space provision shall be made between HV connections and cable glands taking into account voltage level and number of cables to be installed.

5.1.2.3 Wiring

Wiring shall be able to withstand the most stringent operational conditions specified.

The wiring shall be readily identifiable and related to terminals.

For detail refer to [GS EP ELE 011](#).

5.1.2.4 Cable termination

Unless otherwise specified, cables shall enter the converter from below. Cable clamping, earthing, supporting devices and terminals shall be provided.

5.1.3 Earthing

Converter cubicles shall be equipped with an earthing bar of high conductivity copper. The earthing bar shall be of adequate cross-sectional area and mechanical strength to allow

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convenient connection of all cable earthing connectors and two external earthing cables sized 70 sqmm.

All metal parts, which may become energised during fault conditions, shall be connected to the earthing bar.

The doors of each panel shall be connected to earth through a bonding strip.

The Supplier shall advise the Contractor of the need for any special earthing requirements for any item of the drive system where normal substation earthing practice would not be suitable.

5.1.4 Converter Cabinets

Converter cabinets shall be self-supporting and suitable for floor mounting with access arrangements to suit the cabin. All cabinets shall be immuned to vertically dripping water.

When required in the datasheet:

- Converter cabinets shall be designed to allow infrared measurements on the power circuits
- Converter cabinets shall allow the compartments to be monitored by and connected to a VESDA system (very early smoke detection system).

5.1.5 Accessibility

All converter components shall be fully accessible.

Converter elements shall be arranged in a logical segregated manner to allow easy removal of components and safe maintenance work.

Exposed parts within LV compartments of the converter accessible during normal operation for measuring, adjusting, resetting, etc., shall have an enclosure to a degree of protection of at least IP20 when the door is open.

Measures shall be taken to ensure HV compartments cannot be opened unless all components in the compartments are electrically dead and earthed. Mechanical key interlocks shall be provided on all doors. Interlocking shall be fully coordinated to prevent access when live power is applied to all high voltage compartments, including transformer, filters or any component that is part of the VSDS.

5.1.6 Converter cooling

Supplier shall include in the quotation all necessary equipment for cooling.

For converters with heat losses in excess of 15 kW and unless otherwise specified in the data sheets, cooling methods shall be indirect using a heat transfer agent, e.g.:

- Air-to-water cooling
- Water-to-water cooling.

Cooling systems shall be designed to permit safe cool down without damage of the VSDS following total electrical blackout after sustained full load operation at maximum ambient.

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Forced cooling systems shall at least have redundant fans and pumps (i.e. duty and standby fans/pumps or 2 fans/pumps each having 100% of the required capacity), and replacement of fans/pumps shall be possible without shutdown of the VSDS.

In case of use of water cooling system:

- Replacement of filter, deioniser resin bottle shall be possible without stopping and unloading a running unit
- Replacement of power semi-conductor shall be possible without unloading the cooling system
- Conductivity probe shall be redundant
- Indoor heat dissipation in air due to water cooled pipe shall be stated for air conditioned design
- Piping interface shall be compliant to **GS EP PVV 145** paragraphs 3 and 5
- Converter cooling system shall maintain system coolant temperature within a safe minimum and maximum temperature to avoid dew point.

Note: **GS EP PVV 145** is not applicable for flange inside the converter cubicle, it must be considered only for piping interface.

5.2 Transformer

For ONAN mode of operation, rating shall correspond to full capacity. Transformer shall nevertheless be pre-equipped to allow easy additional installation of cooling fans at a later stage.

5.3 Reactor

Reactor(s) shall be suitable for VSDS utilization with design, manufacture and test in accordance with **IEC 60076-6**.

5.4 Motor

Motor of the VSDS with more than one system of 3-phase windings shall be equipped with separate terminal boxes for the phase and neutral of each system.

Motor shall be equipped with 2 PT100s in each winding (3 or 4 wire connection).

When specified in the motor datasheet, partial discharge motor monitoring sensor shall use Rogowski type current sensor. Partial discharge capacitive sensors are forbidden.

In case of use of synchronous motor:

- Exciter system winding shall be VPI
- Exciter winding voltage insulation level shall be in accordance with **IEC 60146-1-2**, and voltage insulation level shall be stated in the datasheet
- Exciter stator system winding shall be equipped with 2 PT100s in each phase
- Rotating diodes shall be removable without dismantling other components.

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5.5 Painting

For indoor equipments, unless otherwise specified, painting and colour system shall be Supplier standard.

For outdoor equipments, painting system shall be suitable for the site environmental conditions. The coating shall comply with Company General Specification **GS EP COR 350** (Offshore) or **GS EP COR 354** (Onshore). The Supplier may submit his coating system for protection against external corrosion for Company approval. Proposed coating must be suitable for the category of corrosion defined for the site of installation as per **ISO 12944-2**, and shall provide a warranty of 5 years - with a rusting degree $R_i = 2$. Colour shall be of Supplier's standard, unless otherwise specified in the project specification.

6. Control System, Protection and Alarm Equipment

6.1 General

The VSDS control system equipment shall ensure the utmost reliability and shall be based on a well proven technology. Any new or unproven technology will not be accepted by Company.

All control system, protection and alarm equipment for the entire drive system and its auxiliary equipment shall be provided.

Printed circuit boards shall be installed in standardized electronic equipment frames.

Assembled cabinets shall be factory-wired and shall be functionally tested as a complete system before dispatch.

The VSDS control system equipment shall use microprocessor-based systems and programmable logic controllers.

The VSDS control system equipment shall be provided with self-check facilities, including watch dog signalling features.

The VSDS control system shall have a memory function to retain program, software parameters and alarm/fault in case of power supply failure.

Restarting of the control system after power failure (either main line or auxiliary line) shall be clearly defined.

All service adjustments required in the field shall be possible from the front of the equipment. Measuring and test points shall be front-accessible as well.

When specified in the datasheet, the VSDS control system shall have a dual redundant CPU and shall switch over to the standby CPU without stopping the VSDS when the running CPU is in failure.

The VSDS control system equipment shall include programming facilities to run rapidly through and prevent permanent operation at any of the critical speeds identified for the complete rotating equipment train (i.e. motor and driven load).

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In case of use of water cooling system, the VSDS software shall allow to select:

- A mode where the cooling unit is switch off when HV power section is switch off
- A mode which keeps the water conductivity within running value even when HV power section is switch off in order to minimize the starting time of the VSDS.

During the first year of VSDS operation, for a monthly period, pump redundancy philosophy shall run 70% of the time one pump and the other one 30% of the remaining time. After the first year of operation each pump shall run 50% of the monthly period.

6.2 Control System Performances

VSDS shall be either speed or torque or power controlled or a combination of these control functions in accordance with the data sheets.

VSDS shall be able to run through voltage dips down to 80% of rated voltage.

The VSDS shall be suitable for automatic re-acceleration following very short voltage dips, i.e. the converter shall be capable of synchronising onto a spinning rotor to ensure a flying restart.

The control system shall be immune from spikes and voltage distortions due to operational and/or fault conditions within the VSDS.

Auxiliary drives shall continue normal operation after interruptions lower than 800 ms in the auxiliary power supplies and such interruptions shall not trip the VSDS.

Control system speed regulation accuracy shall be less than 0.5% of rated speed without encoder or tachometer feedback.

6.3 Interface and External Signals

The control system shall interface directly with driven equipment control system to transmit and receive operation commands according to the required mode of operation.

Provision shall be made for a serial link to interface the VSDS control system with ECS or ICSS, in this case as a minimum here under information shall be exchanged:

- VSDS Output speed
- VSDS Speed reference
- VSDS Output active power
- VSDS Ready for operation
- VSDS Running
- VSDS Alarm
- VSDS Fault
- VSDS Output current
- VSDS Output voltage.

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The VSDS control system shall be able to be synchronized with ECS in order to stamp VSDS electrical alarms and faults. Time synchro accuracy and time discrimination between two critical events shall be in accordance with **GS EP ELE 221** § 9.1.

The VSDS control system shall encompass a disturbance and fault recorder able to store at least 2.5 seconds of data triggered on status change and/or fault conditions with an adjustable time frame (typically [-500;+2000] ms).

The VSDS control system equipment shall follow cyber security requirements of **GS EP INS 135**.

VSDS shall be possibly controlled (refer to the related data sheets) by the following external signals:

- 4-20 mA reference for speed, torque or power control
- Load shedding signals
- Remote start and stop signals
- Emergency stop signals.

Note: Acceleration and deceleration slopes shall be adjustable in normal and load shedding mode.

The relationship between the speed, torque or power and the reference signal within the operational speed shall be linear.

A reference signal of 4 mA shall correspond to the minimum operational speed or torque or power and a reference signal of 20 mA to the maximum speed or torque or power of the VSDS, as indicated in the data sheets. The speed range shall be adjustable.

VSDS shall be capable of operating at 105% of the maximum operational speed as designed by the Process. Such speed shall correspond to the 20 mA reference as indicated above.

Loss of the 4-20 mA reference signal shall normally result in operation of the VSDS at the last set point before loss, and an alarm shall be raised.

6.4 Output Limitations

The motor current limitation of the converter shall reduce the output frequency and voltage.

Deviation of output between set point value and measured value shall normally be less than 2% of set point value. When the measured value deviates by more than 5% of the set point value, a 10 seconds time delayed alarm will be raised.

A power or torque controlled VSDS shall, if the speed exceeds 102% of the maximum operational speed, automatically reduce its power or torque such as the maximum operational speed is recovered.

VSDS shall trip if the speed exceeds 106% of the maximum operational speed.

If the speed is reduced to less than 95% of the minimum operational speed for longer than 10 seconds, the VSDS shall trip.

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6.5 Protection and Alarm Equipment

A fully electronic protection system is preferred obviating the need for specific ultra-rapid semiconductor fuses.

Fault diagnostic and indication logic shall be equipped with a memory function to retain information regarding the cause of tripping of the VSDS.

All earth potential connections shall be connected to earth via one common connection to allow checking of insulation resistance to earth.

2nd stage thermal overload of the motor, transformer or converter shall trip the VSDS.

In case of synchronous motor, VSDS control system shall include a rotor thermal protection computed by using excitation power supply current measurements.

In case of synchronous motor, VSDS control system shall cancel the excitation current as soon as a trip is triggered by the VSDS.

Protection and alarm functions shall follow [IEC 61800-4](#) Table 8.

In [IEC 61800-4](#) Table 8, all protection functions marked (X) shall trip the VSDS except for "loss of communication to process control" function which shall be treated as an alarm.

In addition to [IEC 61800-4](#) Table 8 the following protection and alarm functions shall be added and be represented on an alphanumeric display system with first-failure indication.

1. Motor

- Earth fault in the stator windings (T)

In addition for synchronous motors

- Loss of field (T)
- Excitation current short circuit (T)
- Excitation earth fault (T)
- Rotor current thermal protection (A + T)

2. Converter

(The applicable protection/alarm functions shall suit the type of converter and shall be confirmed in the data sheets).

- Undervoltage incoming side (A + T)
- 5% deviation from the set point (A)
- U/F ratio incorrect (A)
- 106% overspeed (T)
- 95% underspeed (T)
- Motor stalled (T)
- Emergency stop (T)
- Watch dog (T)

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Note:

- A Alarm/pre-alarm
- T Alarm + immediate trip by means of de-energizing the VSDS and by tripping the VSDS circuit breaker(s).

Transformer short-circuit and earth fault protections at primary side will be ensured by the transformer feeder circuit breaker.

If the harmonic filter is directly connected on a dedicated winding of the VSDS transformer, a circuit breaker with its associated protection relay shall be installed between the transformer and the filter.

The details concerning such protection will require the prior review and approval from the Contractor and Company.

6.6 Alphanumeric Display

The following indications shall be available on the converter as a minimum (with alphanumeric display).

- Output frequency
- Output current
- Output voltage
- Speed reference
- Output speed
- Output active power
- Elapsed time running meter
- Indication lights using LED for the following signals:
 - Ready for operation
 - Running
 - VSDS alarm
 - VSDS fault.

7. Inspections and Tests

7.1 Fabrication and Quality Control Plan and Inspections

Inspection and testing activities shall be defined by the Supplier on the fabrication and quality control plan based on the minimum requirements established within the inspection and test plan.

During the manufacturing period, VSDS and associated equipment could be subject to inspection by Contractor and Company inspectors or by others appointed by Contractor and by the Company. Accessory material could be subject to inspection too.

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The Supplier shall allow the free access of inspectors to the workshop, shall give all information required and shall make available all copies of internal orders to other sub-Suppliers.

Factory tests and performances tests of the converter shall be made with the final version of the control system software and settings.

7.2 Factory Tests

Routine tests shall be carried out on all equipments.

The tests shall be carried out in Supplier workshop at his care and expense.

Even in case Contractor and Company waives to witness the tests, the Supplier shall draw up the certificate of the tests carried out containing a full report and all the results and the measures of the tests.

The tests shall be carried out in accordance with the requirements of IEC codes and of the Inspection and Test Plan. Refer also to the project specification requirements for the individual tests relating to the electric motor and to the transformer.

The Supplier shall state in his proposal the methodology that will apply and the availability/ adequacy of the necessary equipment and testing infrastructure for performing satisfactorily the different tests listed below.

7.3 Performance Tests

The performance tests shall be performed on at least one VSDS of a group of identical systems to be supplied, and for all VSDS rated 4 MW and above.

Performance tests shall at least include the following tests:

- Insulation resistance tests
- Heat run tests at rated load, recording the following:
 - Transformer temperature rise
 - Motor temperature rise
 - Converter temperature rise
 - Bearing temperatures
 - Shaft vibrations
 - Current unbalance
 - Noise level
 - Linearity between setpoint and output.
- Functional tests (controls, alarms, trips, etc.)
- Test of the converter emergency stop at full load
- Test of flying restart capability following a trip at full speed
- Test of the earth fault protection
- Replacement of filter and deioniser resin bottle in operation

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- Recording of the motor voltage, current, speed and power during start-up, ramp-up and trip at full speed
- Visual inspection (dimensions, protection degree, individual marking, accessibility, etc.).

Thermo-sensitive strips installed on the power semi-conductors heat sinks shall allow monitoring and identifying the maximum temperature reached by the heat sinks in order to correlate this temperature with the junction temperature reached by power semi-conductors.

8. Special studies for motor fed through a long cable or transformer

Special studies, described here under, shall be carried out when a motor is fed by a VSD through a long cable (length >200 m) or through transformer(s).

8.1 VSDS control strategy document

This document shall define the choice for the control algorithm (vector control or direct torque Control). Any particular combinations of control strategy shall be described (eg start up at fixed frequency with U/F and then a switching to vector control or direct torque control).

8.2 VSDS start-up and ramp up simulation

This study shall simulate the start-up, ramp up and stop mode of the VSDS in order to verify the electrical design and the control strategy chosen are suitable to operate the motor within its speed range. The simulation shall use the cable data of the project. The simulation shall also use the torque of the load (e.g. Reciprocating compressor, Multi Phase Pump, etc.).

The simulation shall verify the absence of self excitation phenomenon when the motor is stopped or tripped at full speed.

If the VSDS has an output sine filter, the simulation shall model it in order to identify any electrical resonance during the ramp up and normal operation.

If the VSDS has an output transformer(s), the simulation shall display the flux seen by the transformer(s) during start up in order to verify the magnetic sizing of the transformer(s). In case of use of synchronous motor without rotor position sensor, the simulation shall consider the worst rotor position case which maximizes the flux seen by the transformer during start up.

8.3 Output transformer(s) sizing report (if applicable)

The document shall detail the calculation made to size the transformer(s) located between the converter and the motor. The sizing of the transformer(s) shall be based on the load flow and the flux seen by the transformer(s) during start-up; in order ensure that the transformer(s) will not experience magnetic saturation during the start-up.

The calculation note shall take into account the cable data and the type of motor to start (induction or synchronous). In case of use of synchronous motor without rotor position sensor, the calculation note shall consider the worst rotor position case which maximizes the flux seen by the transformer during start up, in order to ensure the motor start up in any rotor position.

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8.4 System impedance study

In order to identify the resonances of the system, the study shall calculate and display on the motor side the system impedance seen by the converter versus frequency.

8.5 Insulation coordination study

The purpose of this study is to verify the electrical insulation voltage level consistency between all the electrical equipment of the VSDS including the HV power cables.

In accordance with the earthing strategy of the VSDS, this study shall detail the selection of the rated withstand voltages for the phase-to-earth and phase-to-phase insulation of the equipment of the system. The insulation levels shall be chosen among the standard insulation levels listed in [IEC 60071](#).

The study shall calculate the permanent and transient voltage seen by the electrical equipments of the VSDS.

9. Design Life & Obsolescence

Facilities are typically designed with an expected design life in the order of 25 years.

The VSDS design shall therefore take into account the requirement that the equipment will most probably require to be upgraded during the design life of the facilities in particular for all the electronic based components (Control system, electronic protection relays, etc.). These requirements shall be incorporated from Basic Engineering stage.

The design will include provisions to allow an upgrade of the VSDS to be performed with minimal disturbance.

All hardware and software that may be developed by the Supplier further to the VSDS delivery shall ensure full ascending compatibility to allow for easy replacement of equipment that became obsolete with limited reconfiguration.

At the Bid stage, the VSDS Supplier shall detail his lifecycle management strategy focusing on product obsolescence, support options and further migration alternatives. The lifecycle/obsolescence management plan and associated cost shall be part of the Bid process evaluation.

The VSDS Supplier shall complete an inventory of all provided equipment (hardware and software) matching to different lifecycles phases, including all Sub-Vendors equipment (e.g. CPU, protection relays).

VSDS Supplier shall guarantee that:

- VSDS components (including software and hardware) shall remain in the “active products” range (i.e. supporting developments and releases) over a period of at least 15 years after the SAT
- An announcement to Customer is provided 5 years prior the end of the commercial phase
- VSDS components (including software and hardware) shall be fully supported and available over a period of at least 25 years after the SAT

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- Maintenance services including availability of engineering services shall be available to support the VSDS during the plant life time.

Obsolescence and life time cycle management shall be in accordance with **GS EP TEC 007**.

10. Documentation

As a minimum and unless defined in a project particular specification, the following drawings and documentation shall be supplied in a timely manner according to the specified schedule.

10.1 Within the Offer

- Deviation list to project specifications
- Completed data sheets including power cable sizing
- Preliminary VSDS overall arrangements, sizes and weights
- Description of Supplier inter harmonics and pulsating torques calculation capability
- Preliminary harmonics and inter harmonics study at line side
- Voltage/Current margin and junction temperature on power semi-conductors
- Description and guarantee of control hardware and software support during the expected lifetime of the VSDS
- VSDS torque-speed curve in all speed range surimposed to load starting curve and operating points. Curves at settle out of pressure must also be considered when VSDS drives a compressor load
- VSDS efficiency guarantees and listing of losses and heat dissipation for power equipment(possible harmonic filters, input transformer, converter, possible output transformer, motor) and auxiliaries
- Maximum cable length allowed from transformer to converter and from converter to motor.
- Preliminary list of AC consumers
- Description of converter earthing means
- Available type test certificate
- Performance test execution plan
- Component/equipment obsolescence plan.

10.2 Within Project Execution:

- Final completed Data sheets
- Final VSDS overall arrangements, sizes and weights
- Layout of connection cubicle
- Foundation guide details
- Arrangement details of auxiliary equipment

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- Cable specification and calculation for power and control cables
- Schematics, wiring and termination diagrams
- Network harmonics and inter harmonics study report
- Full motor torsional analysis including pulsating torques
- Description of protections and settings of the VSDS
- VSDS short circuit calculation note to assess the motor short circuit torque and VSDS short circuit currents. The calculation note shall consider a bolted 2 and 3 phase short circuit at the rectifier, inverter and motor terminals. The calculation note shall also consider a short circuit on the DC side of the converter
- For large VSDS (>15 MW) with islanded power plant, Sub Synchronous Torsional Interaction (SSTI) study
- Output sine filter calculation note (if installed)
- Special studies for motor fed through a long cable or transformer (if applicable)
- Alarm and fault list
- Final list of AC consumers
- Detailed component/equipment obsolescence plan
- Operation and maintenance manuals
- Type test certificate
- FAT report
- As built documents.



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Appendix 1

Appendix 1 Data Sheet

High Voltage Variable Speed Drive System

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Appendix 1**Exploration & Production****DATA SHEET****ELECTRICAL****DS EP ELE 121****High Voltage Variable Speed Drive System**

01	01/2012	Update
00	01/2011	First issue
Revision	Date	Notes

Owner: EP/DEV/TEC

Managing entity: EP/DEV/TEC/ELE

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 TOTAL Exploration & Production	COMPANY PROJECT NAME DATA SHEET High Voltage Variable Speed Drive System			
Doc. number:		Contractor document N°:		Page 1 / 4
Equipment location:				
Tag No:		Model:		
System No:		Serial No:		
Sub-system No:				
Supplier:				
Manufacturer:				
	Reason for issue	Rev.	Stat.	Date
1	GENERAL DATA			
2	Items:	Quantity:		
3	Material Requisition N°:	Service:		
4	Project Specifications:	Standards, Codes (see note 1):		
5	Supplier:	Manufacturer:		
6	ENVIRONMENTAL CONDITIONS			
7	Installation (Indoor / Outdoor):	Ambient Type:		
8	Altitude:	Hazardous area classification:		
9	Min. Operating Temperature:	°C	Relative Humidity @Min operating temperature: %	
10	Max. Operating Temperature:	°C	Relative Humidity @Max operating temperature: %	
11	Minimum Temperature For Transport / Storage:	°C	Seismic activity:	
12				
13	POWER SYSTEM			
14	Supply Network Voltage (see note 2):	kV ±	%	Supply Network Frequency (see note 2): Hz ± %
15	Supply Network Neutral system (see note 2):	Supply Network existing THDU (see note 2): %		
16	Maximum THDU required at Min. Fault Level:	Supply Network Earth Fault Current:		
17	Supply Network 3 Phases Max. Fault Level:	Supply Network 3 Phases Min. Fault Level:		
18				
19	Auxiliary Voltages:	V	V	V
20	AC UPS Voltage:	V	DC UPS Voltage: V	
21	Minimum PF required at VSD system connection		@ all operating points	
22	Minimum efficiency required		@ all operating points	
23	Note 1: General specification GS EP ELE 121 standards as a minimum			
24	Note 2: Upstream of VSDS Transformer if any			

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Equipment location:		Page 2 / 4	
Tag No: Refer to page 1		Model:	
System No:		Serial No:	
Sub-system No:			
Supplier:			
Manufacturer:			
	Reason for issue	Rev.	Stat.
1	CONVERTER DATA		
2	Converter Type:		
3	No. of Quadrants:	Braking chopper: Yes/No	
4	Input Side Isolating Device: Yes/No	Input Side Isolating Device Rating:	
5	Output Side Isolating Device: Yes/No	Output Side Isolating Device Rating:	
6	Earthing Switch:	Earthing Switch Location:	
7	Speed Range:	Power Range:	
8	Flying restart:	Restarting with breakaway torque (note5): Yes/No	
9	Operating Speed if Loss of Speed Signal:		
10	REMOTE CONTROL AND MONITORING		
11	Link type for ECS connection As per IEC 61850	Link type for ICSS connection	
12	Type of Control (Speed, Frequency, Torque, Power, ...):	Type of Signal (4-20mA, serial, ...):	
13	Remote Normal Start Signal:		
14	Remote Normal Stop Signal:		
15	Load Shed Signal:		
16	CONVERTER CUBICLE CONTROL AND MONITORING (as minimum)		
17	Infra red cubicle monitoring capability	VESDA monitoring capability	
18	Control redundancy requirement		
19	CONVERTER FABRICATION DATA		
20	Protection Degree: IP	Connection type: Cable Bus duct	
21	Semiconductor redundancy: Yes/No	Busduct/cable Type:	
22	Connection Entry:	Busduct/cable Type:	
23	Access:	Back to Back Test Possibility: Yes/No	
24	Painting (Manufacturer Standard, ...):	Painting Color: RAL	
25	Noise Level At Full Load (at One Meter): dB(A)		
26	Cooling Method:	Raw water inlet temperature:	
27	Cooling media characteristics:	Interface characteristics (flange, etc):	

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Equipment location:		Model:			
Tag No: Refer to page 1		Serial No:			
System No:					
Sub-system No:					
Supplier:					
Manufacturer:					
Reason for Issue	Rev.	Stat.	Date	By:	Checked by:
1 CONVERTER MANUFACTURER DATA					
2	Converter Type:			Protection Degree:	
3	Rectifier Semiconductor type with rating:			Inverter Semiconductor type with rating:	
4	Rectifier Semi conductor number per arm:			Inverter Semi conductor number per arm:	
5	Rectifier Number of Pulses:			Switching frequency: Hz	
6	Nominal Output Frequency: Hz			Maximum Connection capability: mm²	
7	Nominal Output Voltage: V			Nominal Output Current: A	
8	Nominal Output Power: kVA			BIL rating:	
9	Rectifier operating semiconductor junction temperature: °C			Inverter operating semiconductor junction temperature: °C	
10	Cooling Method:			Number of Fans or Pumps: No.	
11	Raw water inlet flow: °C			Water to Glycol percentage: %	
11	Heat Losses for dedicated cooling system: kW			Heat Losses inside building for HVAC sizing: kW	
12	Global Efficiency of VSDS (see note 4)			with Motor at Full Load: %	
13	with Motor at 75% Load: %			with Motor at 50% Load: %	
14	Global PF of VSDS:			Maximum input THDU at nominal speed: %	
15	with Motor at Full Load and with Harmonic Filter on: p.u.			with Motor at 75% Load and with Harmonic Filter on: p.u.	
16	with Motor at 50% Load and with Harmonic Filter on: p.u.			with Motor at 50% Load and without Harmonic Filter: p.u.	
17	with Motor at Full Load and without Harmonic Filter: p.u.			with Motor at 75% Load and without Harmonic Filter: p.u.	
18	Earth fault current limitation: A			Protection scheme in accordance to GS EP ELE 121: Yes/No	
19	VSDS capacitance seen by the supply network: nF			Noise Level At Full Load (at One Meter): dB(A)	
20	Length: mm			Width: mm	
21	Height: mm			Weight: kg	
22	Max. Distance between Transformer and Converter: m			Max. Distance between Converter and Motor: m	
23	Comments				
24	NOTES				
25	Note 1: As indicated in general specification GS EP ELE 121			Note 4: The global efficiency shall include at nominal speed: 1) motor losses with auxiliary fans 2) transformer and harmonic filter losses 3) converter losses with auxiliaries including cooling system	
26	Note 2: Upstream of VSDS Transformer if any			Note 5: Restart of compressor shall be able from the settle out pressure	
27	Note 3: Data sheet DS EP ELE 141 for converter transformer shall be attached to this data sheet if a transformer is required.			Note 6: A detailed study shall be performed with compressor/pump manufacturer. It shall be clearly referred to in this data sheet.	

