TECHNICAL SPECIFICATION

ELECTRICAL VARIABLE SPEED DRIVE SYSTEMS

DEP 33.66.05.33-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP gives the minimum requirements for design and manufacturing of direct-coupled electrical variable speed drive systems (VSDSs). This DEP is a revision of and supersedes DDD 33.66.05.33-Gen., dated June 1987.

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, harmonic filters, and external heat-exchanger.

For purchasing, this DEP shall be used in conjunction with the requisition.

Individual components forming part of the VSDS shall comply with DEP 33.65.40.31-Gen., DEP 33.66.05.31-Gen., and IEC 146, with all modifications as specified in this DEP. Requirements deviating from or additional to those of this DEP will be given for each individual case in the requisition or order.

It should be noted that this DEP has been written to be applied to all VSDS irrespective of duty or size to provide the high standard of performance and reliability as is required for petrochemical installations. However, there is sufficient modularity in the small-product ranges to ensure that in the event of failure, fast component replacement is facilitated to avoid prolonged plant outage. Hence, to obtain the economic advantages offered through maximum standardisation, dispensations are given on VSDS's with low-voltage converters as shown in Appendix 11.

In the case of conflict between documents relating to the inquiry/order, the following priority of documents shall apply:

1. purchase order and variations thereof;
2. requisition and project specification;
3. this DEP;
4. the specifications for each individual component.

SI units shall be used throughout.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this document is confined to companies forming part of or managed by the Royal Dutch/Shell Group. It may be distributed to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

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

If national and/or local regulations exist in which some of the requirements may 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 as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

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

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

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

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Acceleration torque of a VSDS motor
The difference between the rated torque of the VSDS motor and the total load torque from zero to maximum speed available for accelerating the rotating parts.

Availability

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

Coastal installation
A land installation located within 1000 m from shore.

Crest value of the circuit voltage
U_{RWM} and U_{DWM} are the crest values of the circuit voltage applied across the converter element, see Appendix 7.

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

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

High voltage converter
A converter with an output voltage exceeding 1000 V.

Integer Harmonics on the machine-side
Harmonic quantities which are multiples of the invertor output frequency

Land installation
An installation located over 1000 m inland from the coast.

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

Low voltage converter
A converter with an output voltage not exceeding 1000 V.

Mean time between failure - MTBF*
Mean time between failure is defined as:

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

Mean time to repair - MTTR*
Mean time to repair is defined as:

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

NOTE: *The above MTBF and MTTR definitions are based on statistics and are valid only under the following conditions:
- at least one period of 4 years operating time of at least 4 pieces of similar equipment (but excluding the first 3 months of initial operation of the VSDS) shall have been experienced.
- MTTR shall only relate to VSDS repair.
- the MTTR time shall include a maintenance overhaul time of 80 hours over a 2 week period after 4 years of operation.
- operation of the VSDS shall have been in accordance with Manufacturer's instructions.
- assuming qualified men and materials to be available at the work site.

Maximum rated torque of a VSDS motor
The maximum motor torque at which a VSDS can be operated continuously within its operational speed range.

Non-integer Harmonics on the Machine-side
Harmonic quantities which are not multiples of the invertor output frequency. The most common source of these harmonics is supply ripple in the DC link.

Offshore installation
An installation located near open saliferous water, e.g. platforms, jetties.

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.

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 SDS can be operated during limited specified times outside its operational speed range.

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

The **requisition** is the information exchanged between the Principal and the Manufacturer prior to order placement, using requisition form DEP 33.66.05.95-Gen. and, if necessary, the blank requisition form DEP 30.10.00.94-Gen. Further details on the use of the requisition are given in Appendix 1.

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.

Site conditions
The external factors, e.g. altitude, air temperature, voltage changes, wind velocity, vibrations, earthquakes, black body temperature and relative humidity, which may influence the operation of a machine or apparatus.

Test report
Documents prepared by the Manufacturer indicating in detail the tests and verifications to which the electrical apparatus has been subjected and which includes their results.

Total running up time of a VSDS motor
The time for a VSDS motor 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 etc. and the running up time of the VSDS.

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

Vibration severity, ISO 2372
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 number is shown in brackets. Other documents referenced by this DEP are listed in (16.).

2. GENERAL

2.1 INFORMATION FOR THE PRINCIPAL

The interactions between the various components of an electrical Variable Speed Drive System VSDS make it imperative to purchase such a system from one technically acceptable (motor) manufacturer. The Manufacturer shall have ample experience in the design and application of those systems, power factor correction and harmonic filters. The Manufacturer shall also be capable of performing the necessary torsional vibration analyses and studies of the total train (drive system and driven equipment) to act as a suitable counterpart to the (gearbox and) driven equipment Manufacturer to ensure good overall coordination. The final result of these studies shall be acceptable to all parties involved.

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

2.2 SCOPE OF SUPPLY

The order for a VSDS shall include all responsibilities, design activities, materials, requirements, tests, documentations, instructions, as stated in this DEP.

The Principal shall decide if the Manufacturer is to provide the motor shaft and coupling from one forging as part of the VSDS order. In all other cases only the fitting and mounting of the motor coupling half and balancing the assembly is included in the order for the VSDS.

For a motor with pedestal bearings the motor baseplate is to be included in the order of the VSDS.

The order of a VSDS shall normally include start up assistance but not the site installation, installation materials, interconnecting cables.

At a later date the Principal may call upon these services from the Manufacturer.

The Manufacturer shall indicate in the quotation his capabilities in this respect.

2.3 RESPONSIBILITY

The order for a VSDS may be placed direct with a Manufacturer or through the Manufacturer of the driven equipment, both of whom shall be approved by the Principal.

In the latter case the Manufacturer of the driven equipment has the responsibility for the correct operation to specification of the combination of VSDS and driven equipment.

The Manufacturer 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 at the time of order.

The Manufacturer shall supply calculated rotor responses, lubrication requirements, ramp times, and the transient air gap torques with their duration in case of 2 and 3 phase short circuits on the motor terminals.

For running up and continuous operation, the Manufacturer shall supply data on all machine air gap torques including integer and non-integer harmonic torques in amplitude and frequency, stating his assumptions on ratings of dc-link components.

The Manufacturer shall quote a torsional vibration analysis as a separate item.

The Principal may request this study to be performed in addition to that performed by the driven equipment Manufacturer. In such event, the results shall be acceptable to all parties involved.

2.4 PRE-ORDERING MEETING

If deemed necessary by one of the parties involved, a preordering meeting shall be arranged to define clearly the scope, individual responsibilities and test methods.

If required by the Principal, the minutes of the pre-ordering meeting shall be made by the

Manufacturer of the VSDS and be sent for approval to the Principal and all other parties involved within 14 days.

The final minutes shall be issued within 30 days after the meeting.

3. STATEMENT OF COMPLIANCE

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

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

These values shall also be guaranteed by the Manufacturer of the VSDS under the most arduous conditions of this DEP.

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

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

4. BASIC REQUIREMENTS OF THE VSDS

This DEP gives technical requirements for the most common applications for VSDS. For certain applications it may be necessary to deviate from this DEP. The special requirements should be stated in the requisition.

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 operation for periods of up to 4 years. Within this four-year period, periods of running may alternate with idle periods of up to 6 months. Regreasing or replenishment of luboil, if required, shall be possible with the motor in operation.

The expected lifetime of the VSDS shall be 20 years. The VSDS including all individual components forming part of the system shall have an availability of minimum 0.997 and a minimum MTBF of 4 years.

The VSDS shall be capable of withstanding the thermal and dynamic stresses and the 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 given in the requisition, the following diagrams may be given to the Manufacturer:

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

4.1 SITE CONDITIONS

The VSDS shall be suitable for use in a saliferous, sulphurous and dusty atmosphere. Condensation and windloading shall be taken into account for equipment not installed in a building.

For equipment installed in the open air, and if not otherwise specified in the requisition, the conditions as specified in DEP 33.66.05.31-Gen. for motors shall apply.

For equipment installed in a building the following conditions shall apply:

maximum ambient air temperature	: 35 °C
average ambient air temperature over a period of 24 hours to be taken 3 °C below the maximum air temperature	
minimum air temperature	: 5 °C
relative humidity related to the temperature	: maximum 90%
altitude not exceeding	: 1000 m

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

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

Design data for coolers:

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

NOTE: The above data also apply to seawater.

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

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

The motor of the VSDS and its driven equipment will normally be mounted outdoors without shelter with a common base plate on the foundation.

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

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

The transformer of the VSDS will normally be mounted outside, close to a switch house.

The converter of the VSDS will normally be located inside a switch house or in a dedicated container.

4.2 DEGREE OF PROTECTION

The degree of protection for equipment located outside shall be at least :

- for land installations:
  - IP 54 for motor, transformer and auxiliaries
  - IP 55 for the terminal boxes and bearing housings
- for offshore and coastal installations:
  - IP 56 for the motor, transformer, the auxiliaries, the terminal boxes and bearing housing
- for dusty areas:
  - depending on the location the degree of protection of the motor, the transformer, terminal boxes and bearing house shall correspond to the above requirements.
- for submerged electric motors and electric drives of seal less pumps:
  - IP 68 to IEC 529 for the applicable parts

The degree of protection of equipment located inside the switch house shall be at least IP 31.

4.3 RATINGS

The required range of maximum continuous rated outputs within and outside its operational speed range shall be stated in the requisition, together with the torque/speed characteristic. This data to be used for quotation purposes only.

Some typical load characteristics:

$M \infty \frac{1}{n}$ or P = constant: e.g. winders, rotary cutting machines.

M = constant or $P \propto n$: e.g. hoisting gear, belt conveyors, rolling mills, extruders, mixers, reciprocating and screw pumps/compressors.

$M \propto n$ or $P \propto n^2$: e.g. calenders, eddy current brakes.

$M \propto n^2$ or $P \propto n^3$: e.g. centrifugal pumps, compressors, fans, centrifuges.

In which:
M = torque
P = shaft power
n = speed
$\propto$ = proportional

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

The current from the invertor to the motor should not exceed 1000 amps per phase up to ratings of 20 MW.

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

Where there is clear economic justification to exceed 1000 A, the Manufacturer may submit such alternatives. These shall include detailed proposals for cabling connections.

The Principal may state a preference for a 6-pulse or 12-pulse supply converter. In any case the Manufacturer shall ensure that such choice meets the requirements for lineside harmonics in (5.9).

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

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

4.4 ELECTRICAL SUPPLY SYSTEM

The nominal values of the line voltage, frequency, minimum and maximum short circuit capacity of the system from which the VSDS will be supplied, will be stated in the requisition.

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

- operation on an earthed system;
- operation on an unearthed system, which may have one phase earthed for a continuous period not exceeding 8 hours. The total operating time in this condition will not exceed 125 hours per year;
- The line voltage will under normal operation conditions deviate between 95% and 110% of the nominal values, further shall it be assumed to be sinusoidal in accordance with IEC 146-2.

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

The Principal shall indicate in the requisition the next higher/lower voltage level available to supply the VSDS in case the harmonic loading of the specified voltage level reaches unacceptable levels.

4.5 INFORMATION TO BE SUBMITTED WITH THE QUOTATION

The Manufacturer shall confirm in the quotation by completion of the requisition the compliance of the VSDS with this DEP.

Any deviations from this DEP concerning both the requirements and the recommendations shall be highlighted in the quotation, complete with the technical consequences.

All requirements stated in this DEP and the requisition which, according to the Manufacturer, require further discussion shall be listed by the Manufacturer, complete with his viewpoint and/or alternatives.

The Manufacturer of the VSDS shall state in the quotation the place of origin of the main parts of the VSDS.

For maintenance and overhaul at site the Manufacturer shall indicate the nearest service organisation for the location.

5. PERFORMANCE REQUIREMENTS OF THE VSDS

5.1 GENERAL

Unless otherwise stated in the requisition, the VSDS shall be suitable for 1 quadrant operation, operational speed range between 30% and 100% of the maximum speed, and should be capable of developing at least the following torques:

- for constant torque drives
  - during starting and restarting:
    - 150% maximum rated torque for 10 seconds
  - after starting and restarting and during reacceleration:
    - 120% maximum rated torque for 60 seconds
  - continuously:
    - the maximum torques according the maximum rated torque curve;
- for all other drives
  - during starting and restarting:
    - 120% maximum rated torque for 10 seconds
  - after starting and restarting and during reacceleration:
    - 110% maximum rated torque for 60 seconds
  - continuously:
    - the maximum torques according the maximum rated torque curve.

It is not expected that the above requirements will result in overrating of a standard drive. However, should this occur, the Manufacturer should separately quote an alternative option without overrating.

The VSDS shall meet the above torque requirements at any line voltage between 95% and 110% of the nominal line voltage. For line voltages between 90% and 95% of the nominal line voltage the same torque requirements apply. However, the maximum operating time under these conditions is limited to 3 minutes, and a lower speed than the corresponding required speed is allowed.

The rating of a converter of a VSDS which drives more than one motor shall be based on the sum of the full load currents of all connected motors. Starting of a motor will require the VSDS to stop, the motor to be connected to the common busbar and the VSDS to be restarted again. It is considered uneconomic to size the frequency converter for direct on-line starting of the motors.

During the continuous operation periods the VSDS shall be capable of developing sufficient torque under all load conditions to respond within the required times to alterations in the setpoint. If a required response time is not specified in the requisition, then the Manufacturer shall advise the longest envisaged response time for a 20% setpoint variation based on load and inertia data supplied by the driven equipment vendor.

The integrator action of the set point alteration shall be independently adjustable for both an upward and a downward alteration.

The minimum time interval between setpoint readjustments by the process control system will be 10 seconds.

5.2 SYSTEM CONTROL

5.2.1 General

The VSDS will be either speed, torque or power controlled in accordance with the requirement stated in the requisition.

A combination of the control functions is also possible. If required, this will be indicated separately in the requisition.

The VSDS will be controlled by the following signals which will be provided by the Principal:

- 0-4-20 mA reference signal.

  Input impedance of the VSDS shall be less than 600 ohm (and proportionately reduced

for group-controlled drives).

- Ready to start signal (interposing 'on' signal)

  This signal, represented by an external potential-free contact, shall be given if the VSDS is allowed to be started up.

- Stop signal (interposing 'off' signal)

  This signal, represented by an external potential-free contact, shall be given by an emergency condition of the driven equipment or the process. The function of this signal shall be identical to an internal VSDS trip signal.

- Remote stop signal

  The stop signal given from the stop button located near the motor shall trip the LV or HV contactor/circuit breaker directly. For a multi-motor VSDS this signal will trip the individual motor contactor.

If an early trip signal is required by the converter, all trip and stop signals of the VSDS shall trip the HV contactor/circuit breaker through a master trip relay located in Principal's HV switchboard.

For local control operation of the VSDS from the converter cubicle, the interposing 'on' and 'off' signals will be interrupted and a separate reference signal shall be created.

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 with the minimum operational speed, torque or power and a reference signal of 20 mA shall correspond with the maximum operational speed, torque or power of the VSDS.

Loss of the 4-20 mA reference signal shall normally result in alarm and no change in operational condition. For certain applications (for example, cooling fans) the Principal may decide that the VSDS is to run at maximum speed or power upon loss of the 4-20 mA reference signal. Alternatively, the Principal may specify reversion to minimum operational speed.

The starting, operating and stopping logic system of a HV-fed VSDS shall produce, via potential-free contacts, the closing and tripping commands for the HV contactor/circuit breaker located in the principal's HV switchboard.

Alternatively the Principal may choose to have the VSDS supply transformer energized permanently and control the operation of the converter through a contactor/circuit breaker installed in the converter cabinet.

The Principal shall state the preferred control in the requisition.

The Manufacturer shall indicate in the quotation the requirement of an early opening signal from this HV contactor/circuit breaker to provide for a controlled turn-down of the power semi-conductors.

The VSDS shall be self-supporting without the aid of auxiliary supplies other than auxiliary heaters.

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

The information shall be retained for a period of at least 4 days after interruption of the power supply to the VSDS (only applicable for HV-fed VSDS).

The VSDS shall be able to run through voltage dips less than 20%.

The VSDS shall be equipped with an automatic restart facility which will restart the system in case of voltage dips over 20% or power interruptions shorter than 4 sec. This includes all essential auxiliaries such as cooling-circuit drives.

Restart will only take place if the line voltage recovers to over 90% of its nominal value.

It shall also be possible to block the automatic restart.

Upon restart the converter shall be capable of synchronising onto a rotating motor, so-called 'flying restart', and develop full acceleration torque within 10 seconds.

If fast recovery of process flow is critical under transient conditions, the Manufacturer shall establish the minimum tolerable speed and acceleration to ensure successful ridethrough. On such occasion the Principal will confirm the requirement and provide the Manufacturer with the relevant process data. The Manufacturer shall obtain all other data from the driven equipment Manufacturer to calculate and ensure satisfactory speed excursions.

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

5.2.2 Output limitations

- The motor current limitation of the converter shall reduce the output frequency/voltage.
- The deviation between set point value and measured value shall normally be less than 2% of the set point value. When the measured value deviates more than 5% of the set point value, a 20-second time-delayed alarm will be raised.
- A power or torque controlled VSDS shall, if the speed exceeds 102% of the maximum operational speed, reduce its power or torque until the maximum operational speed is reached. All VSDS, shall trip if the speed exceeds 105% 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.

  A thermal overload of the motor shall trip the VSDS (see section 10.9 for ETD requirements).

  An electronic motor-overload detection instrument built into the converter may be used if technically approved by the Principal.

  For multi-motor VSDS, the overload detection device of a motor shall, upon activation, trip the individual motor contactor and raise an alarm signal.

5.3 NUMBER OF SEQUENTIAL STARTS

The VSDS shall be suitable for:

- two successive starts with the VSDS already at full load working temperature; with the motor coasting to rest between successive starts,
- after a 30 minutes cooling period at standstill another starting sequence of at least two successive starts shall be possible.

5.4 TRANSIENT TORQUES

If requested by the Principal, the Manufacturer shall state in the requisition the estimated maximum transient air gap torque and maximum transient torque (with their durations) at the coupling of the VSDS, accounting for inertias of the motor and the driven equipment, in case of a 2 and a 3 phase short circuit at the motor terminals.

5.5 RUNNING UP TIME (RT)

The estimated running up time at rated voltage at the line terminals of the VSDS shall be stated by the Manufacturer in the requisition. For the quotation, the inertia may be based on data given in IEC 34-12.

On final order and when the final values of inertia, tangential data and actual torque speed curves under process conditions of the driven equipment are known, the exact running up times shall, if requested by the Principal, be recalculated by the Manufacturer. The Manufacturer shall liaise with the driven equipment Manufacturer to obtain the necessary data.

5.6 TOTAL RUNNING UP TIME

The estimated total running up time at rated voltage at the line terminals of the VSDS shall be stated by the Manufacturer in the requisition. For the quotation, the inertia may be based on data given in IEC 34-12.

5.7 TEMPERATURE LIMITATIONS

The maximum allowable temperature rise of the VSDS is limited by:

- the maximum coolant temperature;
- the maximum allowable temperature of the insulation and other materials of the VSDS;
- the particular situation in which components of the VSDS are used, e.g. hazardous area, dusty atmosphere.

5.8 CRITICAL SPEEDS

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

The VSDS shall be designed to run through the critical speeds of the whole system in the shortest time possible.

Upon receipt of the final order the Manufacturer shall provide the final critical speeds of the VSDS.

For high speed motors different criteria regarding critical speeds shall apply. These criteria are specified in (10.13).

5.9 HARMONICS AT THE LINE SIDE

For 6- and 12-pulse line-commutated converters, individual current harmonics should be within the maximum levels specified in IEEE 519 with, where necessary, appropriate corrections for characteristic and non-characteristic harmonics (as defined in IEEE 519) according to pulse number.

Where these levels cannot be met, the Manufacturer shall calculate voltage distortions at the point of VSDS connection. Such calculation shall cater for the specified short-circuit impedance and harmonic contribution from other drives. The voltage harmonics so calculated shall be within the levels specified in DEP 33.64.10.10 Gen.

In the event that such voltage harmonics are unacceptably high, the Manufacturer shall propose corrective options, e.g. filters, and include such options in the quotation, taking into account interaction with other system components.

If, after such corrective actions, the levels of voltage distortion are still higher than specified, this may only be accepted when the total installation is specifically designed to cater for such effects; hence approval for such excessive levels shall first be obtained from the Principal.

Unless dispensation is granted by the Principal, the Manufacturer shall separately quote for site measurement of harmonic levels, detailing measuring equipment, procedure, and monitoring point. In the absence of more specific requirements, IEC 1000-4-7 should be followed; both quasi-stationary and fluctuating harmonics should be analysed in an observation time spanning the VSDS speed change within its operational range.

Unless dispensation is granted by the Principal, the Manufacturer shall demonstrate the absence of system resonance effects on other components, including capacitors, specified by the Principal.

For 24-pulse systems, whether pseudo or otherwise, the allowed levels shall be subject to specific agreement with the Principal.

5.10 ELECTROMAGNETIC COMPATIBILITY

5.10.1 Emissions

If EMC emission restriction is specified in the requisition, the Manufacturer shall quote specifically to meet the requirements of EN 50081-2 for generic emissions in an industrial environment, and highlight the costs incurred. The limits and test method shall be referenced from EN 55011 for Group 1 Class A equipment.

5.10.2 Immunity

The VSDS shall be immune to electromagnetic interference at severity level 2 in IEC 801-3.

5.11 PULSATING TORQUES

The Manufacturer shall calculate precisely all harmonic air-gap torques as per item 3.3 to the satisfaction of the Principal and make this information available to the driven-equipment Manufacturer before a mutually agreed date.

5.12 PULSATING CURRENTS

For VSDS driving equipment with a variable torque during each revolution, (e.g. reciprocating compressors, pumps) the maximum current variation shall be limited to 50% of the rated input current of the VSDS. This shall apply for all load conditions within the operational speed range and shall be based on a short circuit capacity of the supply system of 10 times the kVA rating of the VSDS.

If this value is exceeded during design calculations/simulations, the Manufacturer of the VSDS shall contact the driven equipment Manufacturer and the Principal to agree on action to be taken to meet above requirement.

The basis for verification of this variation shall be by oscillograph measurement and not by ammeter readings (refer to DEP 33.66.05.31-Gen.).

6. CONSTRUCTION REQUIREMENTS OF THE VSDS

6.1 GENERAL

Materials that are carcinogenic or release environmental toxicity shall not be used.

Hygroscopic materials shall not be used, e.g. for sound insulation. The materials shall be selected to prevent galvanic corrosion. All screws, bolts and nuts shall be corrosion-resistant.

All dielectrics and insulation shall be fire-retardant to IEC 332-3 category C.

Transport units heavier than 25 kg shall have eye bolts, lugs, extension pieces or mounted rails clearly marked for 'hoisting'. Tapped holes for eye bolts should be marked with thread form and diameter. When two or more eye bolts are mounted they should be of the collar type. The eye bolts shall not be part of the equipment protection.

For HV converters, the Manufacturer may separately quote a containerised system suitable for outdoor location and containing all converter components including DC-link, auxiliaries, interconnections, fire-protection, heat-exchangers, and container HVAC.

6.2 COMPONENT IDENTIFICATION

All major components of the VSDS, e.g. transformer, converter, reactor, motor, filters, shall have name plates and identification labels made of corrosion resistant material with indelible inscriptions in English or the language specified in the requisition.

The purchase order number, the year of manufacture, the name of the Manufacturer, the type and serial number of the equipment Manufacturer's and Principal's order number shall be clearly marked on the name plate on the outside of the component.

7. CONVERTER TRANSFORMER

7.1 GENERAL

The converter transformer shall meet the requirements of, and be tested in accordance with, DEP 33.65.40.31-Gen. and IEC 146-1-3. Dry type transformers may also be offered if fully complying with the requirements of this DEP and if approved by the Principal.

7.2 TEMPERATURE DETECTORS

The transformer shall be equipped with 2 embedded temperature detectors per phase.

For oil-filled transformers the embedded temperature detectors may be omitted. However, a Buchholz relay shall be installed on the transformer.

An overload of the transformer shall trip the VSDS and give an indicating alarm on the converter.

The trip temperature shall be set to 130 °C for dry-type transformers.

7.3 IMPEDANCE

The impedances of transformers with two secondary windings for 12 pulse systems shall be selected to ensure equal load/current sharing between the two secondary transformer windings, the converters and the motor windings under all operational conditions including starting and restarting.

7.4 HARMONICS

The converter transformer shall be suitable for operation with the non-sinusoidal current wave shapes and DC components under normal and abnormal (e.g. short circuits) conditions of the VSDS without exceeding its temperature or other limits under the conditions of this DEP.

7.5 CONSTRUCTION REQUIREMENTS

The secondary side of the transformer shall have isolation facilities if these are not provided at the converter.

7.6 NOISE

The converter transformer shall meet the sound pressure limits specified in DEP 33.65.40.31-Gen.

The noise limits shall be met at any load condition within the operational speed range of the VSDS.

7.7 MASS

The Manufacturer shall state in the quotation the mass of the active and non-active parts of the transformer. The final mass shall not be more than 10% greater than that stated in the quotation.

7.8 RATING PLATE

The rating plates shall be made of corrosion-resistant metal and be fixed to a non-removable part of the frame.

Rating plates shall in general give the following data, as far as possible actually measured. The values given shall be related to the maximum operating temperature and the most arduous site conditions.

Deviations from these data, if approved by the Principal, may be acceptable due to the

comparative size of the transformer.

7.8.1 Rating plate mounted on the transformer:

CONVERTER TRANSFORMER DATA:

- Manufacturer's name
- Manufacturer's serial number and year of manufacture
- Principal's purchase order number
- type of transformer and weight
- the degree of protection of the transformer in accordance with IEC 34-5
- rated transformer output and rated fire angle of line commutated converter
- rated no-load voltage
- rated currents
- rated frequency
- number of phases
- vector groups
- impedance and reference power
- type of cooling
- class of temperature for dry type transformer and temperature rise
- connection diagram
- insulation levels
- total mass
- transportation mass
- untanking mass
- mass of insulation oil
- insulation liquid
- details regarding tappings.

8. REACTOR(S)

8.1 GENERAL

The converter reactor(s) shall meet the requirements of, and be tested in accordance with, IEC 289.

8.2 HARMONICS

Converter reactor(s) shall be suitable for operation with the 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 DEP.

8.3 TEMPERATURE DETECTORS

The reactor(s) shall be equipped with 2 embedded temperature detectors.

For oil-filled reactors the embedded temperature detectors may be omitted. However, a Buchholz relay shall be installed on the reactor.

An overload of the reactor(s) shall trip the VSDS and give an indicating alarm on the converter.

The trip temperature shall be set to 130 °C for dry-type reactors.

8.4 NOISE

The reactor shall meet the sound pressure limits as specified in DEP 33.65.40.31-Gen.

The noise limits shall be met at any load condition within the operational speed range.

8.5 MASS

The Manufacturer shall state in the quotation the mass of the active and non-active parts of the reactor(s). The final mass shall not deviate by more than 10% from this value.

8.6 RATING PLATE

The rating plates shall be made of corrosion-resistant metal and be fixed to a non-removable part of the frame.

Rating plates shall in general give the following data, as far as possible actually measured. The values given shall be related to the maximum operating temperature and the most arduous site conditions.

Deviations from these data, if approved by the Principal, may be acceptable due to the comparative size of the reactor.

8.6.1 Rating plate mounted on the converter reactor(s):

CONVERTER REACTOR DATA:

- Manufacturer's name
- Manufacturer's serial number and year of manufacture
- Principal's purchase order number
- type of reactor and weight
- the degree of protection of the reactor in accordance with IEC 34-5
- rated output
- rated voltage
- rated current
- type of cooling
- class of temperature for dry type reactors, and temperature rise
- insulation level
- total mass
- transportable mass

- untanking mass
- mass of insulation oil
- insulation liquid.

8.7 LOCATION

The Manufacturer shall give the requirements regarding the location of the reactor(s) relative to the converter panels.

He shall also provide any technical preferred cable specification data.

This information will enable the Principal to lay out the building containing the converter and reactor(s). If air-cored reactors are offered, the extent of the iron-free zone around the reactor(s) shall be stated in the quotation for initial layout.

9. CONVERTER

9.1 CONVERTER ELEMENTS

9.1.1 In general, each converter should comprise:

- isolation switch (lockable in 'off' position)
- contactor/circuit breaker
- harmonic filter and power factor correction equipment if required to meet this DEP
- control and auxiliary equipment supply and distribution system
- control triggering and system control equipment
- protection, supervision and alarm equipment and measuring/ testing facilities
- rectifier
- DC link
- invertor
- earthing switches at both input and output of HV converters.
- cooling equipment

Details regarding application-related requirements shall be stated in the requisition.

For standard configurations refer to Appendices 1 to 6.

9.2 RATING OF THE CONVERTER ELEMENTS

9.2.1 The rating of all switchgear such as isolator-switches, contactors, busbars, shall comply:

- for LV switchgear, with DEP 33.67.01.31-Gen.,
- for HV switchgear, with DEP 33.67.51.31-Gen.

9.2.2 The Manufacturer shall advise the Principal on the selection criteria for power semiconductors.

In particular, he shall demonstrate the margins provided for envisaged voltage peaks and current maxima against component ratings.

Where series connection of power semiconductors is applicable, the Manufacturer shall provide n+1 redundancy.

9.2.3 The Manufacturer shall state in the quotation the maximum junction temperatures of the semi-conductors at 100% continuous load of the VSDS. The name of the Manufacturer of the semi-conductor elements shall be stated in the quotation and the type or the serial numbers of the semi-conductor which will be used.

9.2.4 Capacitors shall be selected for a minimum life of 20 years, taking into account the highest temperature inside the converter cubicle, the worst-case voltage stress, and the highest harmonic currents encountered. Records of such selection criteria shall be made freely available to the Principal.

9.3 TRANSIENTS INS THE OUTPUT VOLTAGE OF THE CONVERTER

The maximum voltage (crest voltage plus spike) supplied by the converter to the motor shall be < 2 times the crest value of the rated motor voltage. The voltage spikes of current source converters shall not exceed the crest value of the motor voltage and for voltage source converters the nominal RMS value of the motor voltage.

9.4 NOISE

The converter shall meet the sound pressure limit of 81 dB(A), with reference to 20 µPa, at any location 1 m distant from the converter under any load and/or frequency condition within the operation at speed range of the VSDS. If more stringent limits are required this will be indicated in the requisition. Data/requisition sheet DEP 31.10.00.94-Gen. shall be used to specify these requirements.

9.5 CABLING/SECONDARY WIRING

9.5.1 Terminations

Fixed internal wiring, e.g. between modules, shall be terminated by wire wrap, solder or equivalent.

Site installed wiring shall be terminated on terminals of the wedge type and such that it 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.

Where necessary, terminals shall be provided with test links or facilities to carry out diagnostic testing.

All terminals shall be clearly identified in accordance with the wiring diagram and be logically laid out by function.

9.5.2 Wiring

The wiring shall be able to withstand the most arduous operational conditions specified and be mould and vermin proof.

The wiring shall be readily identifiable and related to terminals and wiring diagram.

The general panel wiring shall be kept in place by means of insulating ducts, channels, and shall not be fixed directly to metal work.

The wiring shall be continuous and without joints between terminations.

The wiring shall have voltage withstand levels meeting the performance and routine test requirements.

Unnecessary lengths and loops shall be avoided for all wiring, including earthing conductors.

9.5.3 Cable termination

All cables should enter the converter from below. Cable entries, cable glands, cable clamping, earthing, supporting devices and terminals shall be provided. These shall be suitable to accept the type, size and number of cables specified in the requisition.

Where relevant, for all conductors individual terminals shall be provided unless terminals are specially made for more than one conductor. Terminals shall be of the non-loosening construction and of the wedge type, obviating the use of cable lugs and constructed in such a way that direct contact between screw, bolt or nut and conductor is avoided.

Cables terminated on terminals shall be identified at both ends by means of ferrules of insulating material, marked in accordance with the related wiring diagrams.

A free space of at least 200 mm height shall be available between the lowest cable terminal and the bottom plate of the floor mounted unit.

9.6 EARTHING

Converter cubicles shall be equipped with an earthing bar of high conductivity copper. The earthing bar shall be of sufficient cross-sectional area and mechanical strength to allow convenient connection of all cable earthing connectors and an external earthing cable of cross section 70 mm^2.

All major metal parts of the converter which may become energized during fault conditions shall be connected to the earthing bar.

9.7 MARKING OF THE CONVERTER COMPONENTS

Components, such as PC boards,thyristors, diodes, switching devices, protection relays, instruments, instrument transformers, fuses and fuse holders, shall be identified in accordance with the schematic diagrams by means of permanent labels.

In addition all components shall be marked according to Manufacturer's standard with their ratings and all other essential data as required, following IEC recommendations:

- Manufacturer's name or trade mark and type designation;
- rated main and auxiliary operational voltages, frequency and number of phases;
- rated currents or rated powers;
- accuracy class and accuracy limit factor, e.g. for instruments and instrument transformers.

On withdrawable-type units, identification labels shall be mounted on both the fixed and withdrawable parts.

9.8 CONVERTER CABINETS

9.8.1 Enclosure

The converter cabinet shall be self-supporting and suitable for floor/wall mounting. The maximum height of the cabinet shall not exceed 2350 mm (excluding fans, fan hoods or ducts) and the maximum door width shall be 800 mm. The floor shall not be considered as part of the enclosure.

Indoor converter assemblies shall have a degree of protection of at least IP 31, except heat-exchanger openings which may be IP 21.

Anti-condensation heaters shall have overcurrent and residual current protection and shall not be supplied from a UPS source.

9.8.2 Accessibility

Converter components should be accessible from the front. The design should make use of modular plug-in/draw-out assemblies for both the system control electronic equipment and power electronic equipment.

The converter elements shall be arranged in a logical segregated manner to allow easy recognition of components and safe maintenance work.

Exposed parts within the LV compartments of the converter which have to be accessible during normal operation of the VSDS for measuring, adjusting, resetting etc., shall, when the door is open, have an enclosure to a degree of protection of at least IP 20.

All components of LV converters should have a degree of protection of at least IP 20 with open compartment doors.

Measures shall be taken to ensure that HV compartments cannot be opened unless all components in the compartments are electrically dead and earthed.

9.8.3. Cooling of the converter

Cooling methods accepted for converter cooling are:

- Direct cooling, e.g.
  - natural ventilated air-cooled;
  - forced ventilated air-cooled.
- Indirect cooling, using a heat transfer agent, e.g.
  - air-to-air cooling;
  - air-to-liquid cooling;
  - liquid-to-water cooling;
  - oil-to-air cooling;
  - oil-to-liquid cooling.

For converters with maximum heat losses in excess of 10 kW, the indirect cooling method should be used. However, the Manufacturer may quote a direct-cooled option if this is his established standard and it offers a clear economic advantage. The preferred cooling method for the converter will be stated in the requisition.

The Manufacturer of the VSDS shall include in the quotation all equipment necessary for the preferred cooling method, e.g. air ducting and heat exchanger. An offer for an alternative method of cooling may be included in the quotation.

The Manufacturer shall provide in the quotation the data regarding the expected lifetime of components of the cooling system, e.g. ventilators, pumps, de-ionizers. If the expected life time of a component is less than 40 000 hours, a redundancy of the component according to the (n-1) principle should be incorporated in the design. Sealed bearings shall be filled with Shell Nerita HV grease and selected for an L10 life of 40 000 hours minimum.

For liquid-cooling circuits, arrangements shall be made to facilitate liquid-sampling, topping-up, and changing of deioniser and filter, all without unloading a running unit.

9.9 SYSTEM CONTROL, PROTECTION AND ALARM EQUIPMENT

9.9.1 General

The Manufacturer shall provide all the system control, protection and alarm equipment for the entire drive system and its auxiliary equipment.

Critical instrumentation including speed sensors and conductivity probes shall have redundancy unless their reliability has been proven to the Principal's satisfaction.

The Manufacturer shall provide in the quotation information with regard to the electronic control/protection and alarm functions of the VSDS including a description of the system built-up.

The system build-up shall be subject to agreement between the Principal and the Manufacturer prior to the order award.

Printed circuit boards should be installed in standardized electronic equipment frames with easily accessible front and rear sides.

Assembled cubicles shall be factory-wired to terminal strips and shall be functionally tested before dispatch.

9.9.2 System control equipment

Automatic sequence controls, such as
- start-up of cooling systems
- interlock checking
- automatic start and run-up of drive
- orderly shutdown
- emergency shutdown

should be executed to the largest possible extent by the use of microprocessor-based systems.

For microprocessor-based control systems and programmable logic controllers the following requirements apply:

- Depending on the flexibility required in operation, updating, modifying of logic functions, an interfacing to the VSDS system control equipment should be considered ranging from simple handheld programmers upto graphical display units. The Principal shall indicate the preferred interfacing in the requisition.
- System control equipment shall be provided with self check facilities including failure reporting/signalling.
- The program shall be protected against loss of supply voltage and faulty signals corrupting the information. Batteries or equivalent back-up shall be provided for memory supply and special measures shall be taken to protect the memory contents against e.g. RFI and other environmental effects.
- Restarting of the control system after power failure shall be incorporated
- If requested in the requisition, the system shall be able to communicate with remote control/fault diagnostic systems by means of a standard serial communication interface. Modbus RTU is the preferred protocol.
- All service adjustments that may be required in the field shall be possible from the front of the equipment. Measuring and test points shall also be front-accessible.

9.9.3 Protection and alarm equipment

A fully electronic protection system should be applied, obviating the need for special ultra-rapid semiconductor fuses.

For essential protection functions of the VSDS a separate backup protection shall be provided to accommodate for a failure of the electronic protection system.

For LV converters the backup protection can be e.g. a standard fuse protection. For other VSDS this should be an independent operating protection relay.

All earth potential connections should be connected to earth via one common connection to allow for checking the insulation resistance to earth. The main circuit earthfault protection shall be initiated at levels exceeding 3% of the rated motor current or 6A, whichever is lower, and with a maximum time delay of 1 second.

The protection and alarm system shall provide sufficient detailed information to enable maintenance personnel familiar with this type of equipment to troubleshoot the VSDS system down to printed circuit board or power semiconductor level.

Component failures which are covered by redundancy shall result in alarms and not unit trip. Watchdog failure shall result in alarm and not unit trip.

The following protection and alarm functions should be applied and be represented on an alarm indication system with FIRST-FAILURE INDICATION. If the Manufacturer wishes to add further trip functions, he shall first obtain approval from the Principal. It is not required to have all alarms represented on the outside of the converter.

KEY TO THE LETTER CODES:

S for synchronous motors
A alarm/pre-alarm
T alarm + immediate trip by means of de-energizing the VSDS followed by the tripping of the feeding contactor/circuit breaker

Motor

-	short circuit	(T)
-	loss of field	(S+T)
-	earth fault in the stator windings	(T)
-	overtemperature stator	(A+T)
-	bearing temperature, luboil flow, vibration	(A)

Pressurized motors may require additional protection and alarm functions.

Exciter

-	earthfault in stator winding	(T)
-	overtemperature stator	(A+T)
-	bearing temperature, luboil flow, vibration	(A)

Transformer

-	short circuit	(T)
-	earth fault	(T)
-	Buchholz	(A+T)
-	overtemperature	(A+T)

The short circuit and earth fault protection will be provided by the Principal in the HV contactor/circuit breaker cubicle. Buchholz and overtemperature protection shall raise an alarm in the Principal's HV cubicle and trip the HV contactor/circuit breaker.

Converter

(The applicable protection/alarm functions depend on the type of converter)

-	undervoltage incoming side	(A+T)
-	internal short circuit	(T)
-	d.c. link overvoltage	(T)
-	loss of control voltage	(T)
-	earthfault main circuit	(T)
-	earthfault secondary circuits	(T)
-	overtemperature power electronics enclosure	(A+T)

-	failures of auxiliaries together with identification of the failing unit (including coolant flow, level, temperature, conductivity)	(A) or (A+T)
-	one-phase interruption motor side	(T)
-	motor current protection	(A)
-	converter current protection	(T)
-	5% measured value deviation from the setpoint	(A)
-	105% overspeed	(T)
-	95% underspeed	(A+T)
-	motor stalled	(T)

The external alarm signal should be 10 seconds time-delayed. The external trip signal shall be direct-acting.

The following indications should be available as a minimum:

- Near the motor:
  speed indication on remote control station (if specifically requested by the Principal)
- On the converter:
- output frequency
- output current
- output voltage
- indication lights for the following signals:
  - ready for operation
  - running
  - alarm
  - trip
  - HV alarm (only for HV fed VSDS).

The use of filament lamps is not allowed.

9.10 MASS

The Manufacturer shall state in the quotation the estimated weights of the AC to DC converter and of the DC to AC converter. The weights after manufacture shall not deviate by more than 10% of the estimated weights.

9.11 RATING PLATES

The rating plates shall be made of corrosion-resistant metal and be fixed to a non-removable part of the frame. If additional rating plates are mounted on removable parts, the Manufacturer's serial number and reference shall be repeated on these rating plates.

Rating plates shall give the following data, as far as possible actually measured. The values given shall be related to the maximum operating temperature and the most arduous site conditions. Deviations from this data shall be approved by the Principal.

9.11.1 Rating plate mounted on the outside of the converter with data referring to the converter:

CONVERTER DATA:

- Manufacturer's name
- Manufacturer's serial number and year of manufacture
- Principal's purchase order number
- type of converter and mass
- the degree of protection of the converter
- maximum primary voltage
- maximum primary current
- maximum secondary voltage
- maximum secondary current
- pulse system primary side
- pulse system secondary side.

9.11.2 Rating plate mounted on the outside of the converter, with data referring to the total variable speed drive system:

VARIABLE SPEED DRIVE SYSTEM DATA:

supply system	:	V, 3 ph, 50/60 Hz		
	:	minimum short circuit capacity		MVA
	:	maximum short circuit capacity		MVA
speed	:	0 r/min	r/min	r/min
			(min. oper. speed)	(max. oper. speed)
output	:	0 kW	kW	kW
torque	:	Nm	Nm	Nm
power factor	:	-	-	-
torque characteristic	:	$c/f(n)/f(n^2)$		

9.11.3 Other information

A rating plate shall be mounted on the inside of the converter, with data of the motor based on sine wave currents and voltages. This will provide the Principal with repair and test data on sinusoidal supply.

If direction of rotation of converter supply is critical, a warning label shall be mounted near the cable termination point indicating the required direction of rotation.

10. MOTOR OF THE VSDS

10.1 GENERAL

The motor shall meet all the requirements of this DEP and DEP 33.66.05.31-Gen., under the electrical supply conditions dictated by the converter.

This section amends specific sections of DEP 33.66.05.31-Gen. (the amended section numbers are shown in brackets). In case of conflicting requirements, the requirements stated in this section overrule the requirements of DEP 33.66.05.31-Gen.

The maximum operational speed of the motor (defined as B below) shall be considered as the rated speed in DEP 33.66.05.31-Gen.

Motors shall be tested in accordance with DEP 33.66.05.31-Gen. on an electrical supply system similar in voltage to the incoming supply system for the VSDS and by the special tests mentioned in this DEP.

The table below shows a comparison between this DEP and the related driven equipment standards.

This DEP	DEP 31.29.40.30-Gen. (Centrifugal compressors)
	Normal speed
	Maximum speed (A)
Maximum operational speed (B)	Maximum continuous speed (1.05xA)
Trip speed (1.05xB = 1.1xA)	Trip speed gas turbine (1.1xA)
	Trip speed steam turbine (1.15xA)
Critical speed over 1.25xB	Critical speed over 1.2x1.05xA
Critical speed below 80% of min. operational speed	Critical speed below 85% of min. operational speed

10.2 VIBRATION (5.9)

For induction machines at or above 185 kW, the vibration limits specified in API 541 may be applied. For synchronous machines at or above 375 kW, the vibration limits specified in API 546 may be applied.

Where these limits are not applied, the following shall apply:

On the test bed the unfiltered vibration severity of the electric motor shall not exceed of 2 mm/s RMS over the whole operational speed range. The vibration severity should be measured with the motor soft-mounted or on a soft-mounted base plate. The measurements shall be taken in the direction of the three mutually perpendicular axes at the bearings and mounting points of the motor with the motor at no load, from zero to the maximum speed of the operational speed range.

The above measurements may also be taken with the motor mounted on a stiff foundation whereby the unfiltered vibration severity of the electric motor shall not exceed 3.0 mm/s RMS over the whole operational speed range.

If stated in the requisition, each bearing of an electric motor with sleeve bearings shall be provided with two noncontacting eddy current proximity probes in accordance with API 670. The probes shall be located at 90° to each other, mounted in such a way that they can be replaced whilst the motor is running. Rotors should be checked on run-out and the correct location of the probe elements shall be determined before installation in the machine housing.

For the assembled machine operating at maximum operational speed or at any other speed within the operational speed range, the overall unfiltered peak-to-peak amplitude of vibration, including run-out(*), in any plane measured on the shaft adjacent and relative to

each radial bearing shall not exceed the following values:

Speed below 3000 r/min : 50 µm peak-to-peak

Speed 3000 r/min and above : $10 \times \sqrt{\frac{75000}{n}}$ µm peak - to - peak

n = maximum operational speed in r/min.

At the trip speed of the VSDS, the vibration shall not exceed the above values plus 25%.

(*) Shaft run-out is the total indicator reading in the radial direction when the shaft is rotated in its bearings. If the vendor can demonstrate that 'electrical run-out' due to shaft anomalities is present, the combined total mechanical and electrical run-out shall not exceed 25% of the specified maximum test level or 6 µm minimum, whichever is greater.

Electrical run-out can be deduced by slow rolling the rotor in bearings while measuring run-out with a proximity probe and a dial indicator at the same shaft location.

10.3 NOISE LIMITS (5.10)

Noise limits shall be met at any location 1 m distance from the motor surface under full load conditions within the operational speed range.

For high power/high speed applications Manufacturer should quote the different options available to reduce the motor noise level.

10.4 PULSATING STATOR CURRENT (5.11)

Not applicable.

10.5 WINDINGS (6.3)

All HV motors shall have preformed stator coils.

LV motors with frame sizes exceeding IEC size 315 shall have preformed stator coils.

All motor windings shall be capable of withstanding the impulse voltage levels specified in IEC 34-15, with the following stipulations. LV windings shall meet 4Un and 2Un voltage impulses for main and interturn insulation respectively. The risetime for interturn wavefront shall be 0.1 microsecond unless the Manufacturer can confirm a longer front time on the converter output, in which case the actual wavefront shall determine test risetime.

The windings of motors with a motor voltage exceeding 2 kV shall have anticorona protection and stress grading.

10.6 STATOR CORE

The stator core of high speed motors should be built up out of coated laminated iron with each lamination not more than 0.5 mm thick. The reduced losses resulting from the use of 0.35 mm thick lamination shall be taken into consideration.

The complete assembled stator core of a 2 pole high speed motor over 1 MW shall be ring induction tested at full flux for 15 minutes. Directly thereafter the temperature difference between any two locations at the inside shall be less than 10 K.

10.7 TERMINAL BOX (6.4)

For motors which will be connected via multiple cables, the terminal box should have a separation between the cable connection chambers.

The preferred maximum cable size is 3-core, 185 mm^2, to allow reasonable bending radius and cable handling.

If applicable, the Manufacturer should provide his technically preferred cable specification data.

10.8 ROTOR AND FANS (6.6)

In case of a VSDS with a synchronous motor, the rotor of this motor shall be a solid steel forging with milled rotor bar slots for two-pole motors. The rotor shaft shall be made from one solid forging, unless specifically agreed otherwise by the Principal.

10.9 TEMPERATURE DETECTOR (6.7.1)

Every VSDS motor shall have 2 embedded temperature detectors per phase in its stator winding. For motors at and above 30 kW, the detectors shall be PT-100 platinum resistance elements to IEC 751. The elements shall be wired to a separate terminal box on the motor frame. The terminals and control amplifier shall be suitable for 3- or 4- wire systems.

For motors rated < 30 kW the temperature detectors may be of the thermistor type (PTC).

For motors rated < 7.5 kW the terminals of the motor and of the temperature detectors may be mounted in one terminal box.

10.10 AUXILIARY DEVICES FOR WATER-COOLED MOTORS (6.7.2)

Cooling air temperature detectors mounted at the inlet of the cooler(s) are not required for either alarm or trip.

10.11 BEARINGS (6.8)

The bearing arrangement shall meet all requirements of this DEP, e.g. maximum ambient temperature, lubrication intervals within the operational speed range.

The minimum relubrication interval of 4000 hours for horizontal and 2000 hours for vertical motors shall be considered to be based on continuous running at the maximum speed within the operational speed range.

The Manufacturer shall liaise with the driven equipment Manufacturer to obtain information on low-speed barring requirements of the whole train to adapt his bearing lubrication system to this extra requirement.

For test purposes the lubrication system should allow for the motor to run uncoupled at full speed for one hour. Bearing temperature at start of the test will be ambient temperature.

10.12 ADDITIONAL REQUIREMENTS FOR MOTORS IN ZONE 1 (8.0)

Motors for use in zone 1 areas with a type of protection 'e' shall be equipped with an extra 2 embedded temperature detectors per phase to meet the certification requirements.

10.13 ADDITIONAL REQUIREMENTS FOR HIGH SPEED MOTORS

High-speed electric motors used in VSDS applications shall meet the "Dynamics" requirements specified in API 617. The analysis and test-stand confirmation on critical speeds shall be made available to the Principal as part of the routine test results.

10.14 MASS

The Manufacturer shall state in the quotation the mass of the active and non-active parts of the motor. These first data shall not deviate more than 10% of the final data.

10.15 RATING PLATE (6.10)

Rating plates shall give the following values, as far as possible actually measured. The values given shall be related to the maximum operating temperature and the most arduous site conditions.

10.15.1 Rating plates located on the motor:

- Manufacturer's name
- Manufacturer's serial number and year of manufacture
- Shell purchase order number
- type of machine and weight
- the degree of protection of the motor in accordance with IEC 34-5
- the degree of protection of the terminal boxes and bearing houses in accordance with IEC 34-5

speed	:	0 r/min	r/min	r/min
			(min. oper. speed)	(max. oper. speed)
voltage	:	V	V	V
current	:	amp.	amp.	amp.
output	:	0 kW	kW	kW
torque	:	Nm	Nm	Nm
torque characteristic	:	c/f(n)/f(n^2)		
identification of compliance with this DEP				

For motors for use in classified areas following data to be included:
- type of protection of the motor in accordance with IEC 79
- type of protection of the terminal box and other relevant items in accordance with IEC 79
- area classification, gas group and temperature group.

For motors for use in Zone 1 following data to be included:
- certification number.

10.15.2 Rating plate located at the inside of the converter:

- all data as mentioned in DEP 33.66.05.31-Gen., Section 6.10, based on sine wave voltage.

Remainder of the section unchanged.

11. SPARE PARTS, INSTALLATION MATERIALS AND INSTRUCTIONS

Spare parts required or recommended by the Manufacturer for an initial four-year operation and based on the availability and reliability figures as given in this DEP shall be quoted separately, and this quote shall form an integral part of the bid. For guidance see DEP 70.10.90.11-Gen.

Recommended spare parts for subsequent operation shall be quoted by the Manufacturer after final order.

On final order Manufacturer shall supply detailed instructions for transport and installation of the VSDS.

12. ASSEMBLY AND SPECIAL TOOLS FOR THE VSDS

Transport units shall be clearly marked to facilitate assembly at site. Erection instructions and any special tools or instruments required for the erection and maintenance shall be packed with each order.

13. DOCUMENTS FOR THE VSDS

13.1 GENERAL

All documents shall be marked in the right-hand bottom corner with the Principal's order and item number together with the Manufacturer's references. All documents shall be the English language and shall be distributed as specified in the order.

13.2 TECHNICAL INFORMATION

The Manufacturer shall submit as a minimum the following information and data to a mutually agreed time schedule:

- Start-up and commissioning instructions and data.
- Fault diagnostic instructions and data.
- Operation and maintenance instructions.
- Manufacturer's proposed service and repair support after warranty.
- Certified outline and arrangement drawings of all equipment, including weights and floor cut out drawings.
- A lay-out showing the location of equipment, distances, cable routing.
- A block diagram showing the basic control and protection systems specifying the protection, control, trip and alarm functions at the different locations, the reference signals and commands and the auxiliary supplies, i.e. air, luboil, cooling water, electrical auxiliary supplies.
- An electric single line diagram showing the main and auxiliary circuitry, including main circuit breaker, unit transformer, DC link, system earthing and auxiliary supplies. It shall also show ct's, pt's, relays, meters, for the control, protection and operation of the variable speed drive with electrical data, i.e. voltage, current, time ratings, impedances, tolerances.
- A protection coordination diagram showing all protection curves of the variable speed drive relays.
- A torque/speed/current/power factor curve of the VSDS.

13.3 TEST REPORTS

The Manufacturer shall provide test reports with the results of :

- factory tests (including a 24-hour no-load soak-test on control cards and power electronics unless subsequent tests include a 6-hour full-load heat-run)
- performance tests
- routine and performance type test.

14. INSPECTION AND TESTS OF THE VSDS

14.1 PRODUCTION TESTS

The Manufacturer shall perform during the production of the VSDS all activities, functions and tests to prove that the requirements of this DEP are met.

14.2 FINAL TESTS

Before leaving the Manufacturer's works each VSDS shall be inspected, tested and the results recorded in test reports.

Measuring instruments and their accessories shall meet DEP 33.67.01.31-Gen., e.g. current transformers, voltage transformers, resistance, etc. shall at least be of the accuracy class 0.5 and have sufficient over current/overvoltage capacity. Ratio and scales of the selected instruments shall be accurate and allow for easy reading of the values.

Tests shall be carried out in accordance with this DEP unless otherwise agreed.

If the Manufacturer's test arrangements and test facilities are not adequate or he is not able to carry out the specified test, this shall be clearly stated in the quotation. Application of alternative tests shall be approved by the Principal before the order is placed, e.g. 60 Hz machines to be tested at 50 Hz or vice versa, tests under reduced load conditions, etc.

The Principal shall be notified at least two working weeks before the proposed inspection date for the VSDS.

The VSDS offered for final inspection shall be complete and ready to be prepared for shipment.

14.3 PERFORMANCE TESTS

The performance test shall be made on at least one VSDS of a group of identical systems to be supplied. The Manufacturer shall state in the quotation the availability of test data of identical VSDS, including auxiliaries, covering all performance test requirements, with protocol number and test date. This test protocol may be acceptable instead, if submitted well in advance of the delivery date of the VSDS and if approved by the Principal.

14.4 ROUTINE TESTS

A routine test shall be carried out on every VSDS not subjected to a performance test. Each routine test protocol shall refer to the original performance test protocol and the type and serial numbers of all components of that VSDS.

14.5 SPECIAL TESTS

VSDS for special duties or with special protection, etc. may require additional tests. These tests shall be described either in the requisition or the order or be required based on the certification of the type of protection.

14.6 STRING TEST WITH DRIVEN EQUIPMENT

This test, if required, shall be witnessed by the VSDS manufacturer.

If a string test with driven equipment is required this will be mentioned on the data sheet of the driven equipment.

15. TEST SPECIFICATION

15.1 PERFORMANCE TESTS

After the successful performance tests of individual items, e.g. motor in accordance with DEP 33.66.05.93-Gen., transformer and reactors in accordance with DEP 33.65.40.93-Gen., the VSDS shall be lined up for a complete test with all equipment included in the order, e.g. unit transformer, motor and auxiliaries, converter and excitation equipment.

Unless otherwise specified in the requisition, the performance test shall at least include the following tests:

Insulation tests

Insulation tests shall be in accordance with IEC 146-1-1.

Heat run

VSDS to run under the load and speed conditions whereby the maximum temperatures will be reached. The unit shall run until the temperatures of all components have stabilized, and continue for at least a further 2 hours.

It is not necessary to cover all operational conditions provided maximum-power and minimum motor-cooling conditions have been tested.

Measurements:

- current unbalance
- motor winding temperature rise (by resistance methods and by thermistors)
- converter temperature rises (Temperature readings shall be complemented by an infra-red survey or equivalent identifying all potential hotspots including all power connection points. All suspect hotspots shall be checked against allowable component temperatures.)
- bearing temperatures (at max. speed)
- shaft vibration (in case of proximity probes).

Load tests:

- overall efficiency determination at full and half load curve both at minimum operational speed and at max. operational speed of the total unit and of the transformer, converter and motor individually
- ditto for power factor
- ditto for harmonic distortion in the current on the line side
- ditto for harmonic distortion of the current on the motor side
- noise test (of all individual items)
- output voltage characteristics
- output current characteristics
- 110% nominal current test for at least 10 minutes
- linearity between setpoint signal and output.

No-load test (over the whole speed range)

- motor shaft voltage
- motor noise test
- vibration severity measured at bearing housing.

Functional tests at 100% supply voltage

- demonstrate rated torque capability (if this condition is not covered under heat-run)
- Test of speed protection
  at 102% of the maximum operational speed (for power or torque controlled VSDS)
  at 105% of the maximum operational speed at 95% of the minimum operational speed
- test the response times and the adjustability (ramp times) within the operational speed range
- test capability to ride through voltage dips less than 20%
- test capability to restart VSDS and resynchronize converter onto a running motor after a voltage interruption
- test of 0-4-20 mA reference signal

- test of remote control conditions
- test of output frequency/voltage reduction initiated by motor current limitation
- test of 5% 'set point measured point' deviation alarm
- component/auxiliary component failure
- test of all protection, alarm and trip functions
- autostart of standby auxiliaries.

Fault condition tests

Type test results on units from the same design range can be accepted instead.

NOTE: For any of the tests mentioned below, the protection devices of the VSDS may be activated. After resetting/ replacing these devices, the VSDS shall be fit for operation again.

- two phase short circuit at motor terminals at no-load condition up to maximum rating of 1 MW
- earth fault tests at the motor
- one phase interruption of the motor cable at full-load condition (simulation above 1 MW)
- one phase interruption in the VSDS supply cable at full-load condition (simulation above 1 MW)
- three phase interruption of the motor cable at full load condition (simulation above 1 MW)
- earth fault in the control supply system
- interruption in the 0-4-20 mA control signal
- short circuit in the 0-4-20 mA control signal

Visual inspection

Check drawings against the approved drawings and availability of instruction manuals.

Check degree of protection of cubicles.

Check simulation facility control signals for testing purposes.

Check memory function of fault diagnostic and indication logic.

Check availability of eye bolts for lifting heavy components.

Mains isolator to be lockable in the off-position.

Check voltage/current rating power semiconductor elements.

Terminals and wiring to be marked.

Check space available for cable termination, size and number of terminals, cable supporting devices.

Wiring shall not be fixed directly to metal parts.

Check earthing of cubicles and cubicle doors containing electrical equipment.

Check marking of components according to the relevant drawings.

Check dimensions of converter.

Check accessibility of components and IP 20 protection.

Check all external signals and indication/alarm signals on converter. Filament signal lamps shall not be used.

Check weight of converter.

Check all rating plates of VSDS main components according to specification.

15.2 ROUTINE TESTS

After the successful routine tests of the individual items (e.g. motor according to DEP 33.66.05.93-Gen. and transformer and reactors according to DEP 33.65.40.31-Gen.) following testing shall be performed on the total VSDS:

- No-load tests

- Insulation tests
- Functional tests, excluding those requiring loads and the locked rotor test
- Visual inspection

For an HV VSDS the Principal may decide to limit the routine tests to the routine tests of the individual items only. The routine test of the complete string shall than be waived. If not specifically agreed otherwise, the routine test of the complete string is included in the scope of supply.

15.3 PERFORMANCE VALUES

In addition to the requirements in this DEP, see the following DEPs when applicable.

Power transformers	DEP 33.65.40.31-Gen.
Electric motors three-phase, cage-induction type	DEP 33.66.05.31-Gen.
Low voltage AC switchgear	DEP 33.67.01.31-Gen.
High voltage switchgear and controlgear assemblies	DEP 33.67.51.31-Gen.

16. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Data/requisition - equipment noise limitation	DEP 31.10.00.94-Gen.
Centrifugal compressors (Amendments/Supplements to API 617)	DEP 31.29.40.30-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Power transformers	DEP 33.65.40.31-Gen.
Requisition for power transformers	DEP 33.65.40.93-Gen.
Electric motors three-phase, cage-induction type	DEP 33.66.05.31-Gen.
Requisition for electric motors	DEP 33.66.05.93-Gen.
Requisition for variable speed drive system	DEP 33.66.05.95-Gen.
Low voltage AC switchgear	DEP 33.67.01.31-Gen.
High voltage switchgear and controlgear assemblies	DEP 33.67.51.31-Gen.
Spare parts for initial and normal operation	DEP 70.10.90.11-Gen.

AMERICAN STANDARDS

Form-wound squirrel-cage induction motors - 250 horsepower and larger	API 541
Form-wound brushless synchronous motors - 500 horsepower and larger	API 546
Centrifugal compressors for general refinery services	API 617
Non-contacting vibration and axial position monitoring systems	API 670

Issued by:
American Petroleum Institute
Publications and Distribution Section
2101 L Street Northwest
Washington, DC 20037, USA.

Recommended practices and requirements for harmonic control in electrical power systems	IEEE 519

Issued by:
Institute of Electrical and Electronics Engineers (IEEE)
PO Box 1331
445 Hoes Lane
Piscataway NJ 08855 1331
USA.

EUROPEAN STANDARDS

Electromagnetic compatibility- generic emission standard Part 2: Industrial environment	EN 50081-2
Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical radio-frequency equipment	EN 55011M

Issued by:
CENELEX
rue de Starsart 35
B 1050 Brussels.

INTERNATIONAL STANDARDS

Rotating electrical machines	IEC 34
Part 5: Classification of degrees of protection provided by enclosures for rotating machines	IEC 34-5
Part 12: Starting performance of single-speed three phase cage induction motors for voltages up to and including 660 V	IEC 34-12
Part 15: Impulse voltage withstand levels of rotating ac machines with form-wound stator coils	IEC 34-15
Electrical apparatus for explosive gas atmospheres	IEC 79
Semi-conductor converters	IEC 146-1 (3 parts)
Semiconductor self-commutated converters	IEC 146-2
Reactors	IEC 289
Classification of degrees of protection provided by enclosures	IEC 529
Industrial platinum resistance thermometer sensors	IEC 751
Radiated electromagnetic field requirements	IEC 801-3
Tests on electronic labels under fire conditions Part 3: Tests on bunched wires or cables	IEC 332-3
Electromagnetic compatibility (EMC): Part 4: Testing and measurement techniques: Section 7: General guide on harmonics and inter-harmonics measurements and instrumentation, for power supply systems and equipment connected thereto	IEC 1000-4-7

Issued by:
Central Office of the IEC
1, rue de Varembé
1211 Geneva 20, Switzerland.

APPENDIX 1 DATA TO BE SUBMITTED

1. BY PRINCIPAL

The information to be provided by the Principal for a VSDS is given in the requisition for variable speed electric motors DEP 33.66.05.95-Gen. These data are for the overall system and its performance requirements.

In addition to requisition DEP 33.66.05.95-Gen., it is recommended that sub-component requisition sheets are submitted with the VSDS enquiry to establish the basic performance characteristics of the plant on fundamental sinewave frequency for the basis of the comparison of the quotations.

The sub-component requisition sheets that should be considered are:

- Power transformers, DEP 33.65.40.93-Gen.
- Electric motors, DEP 33.66.05.93-Gen.

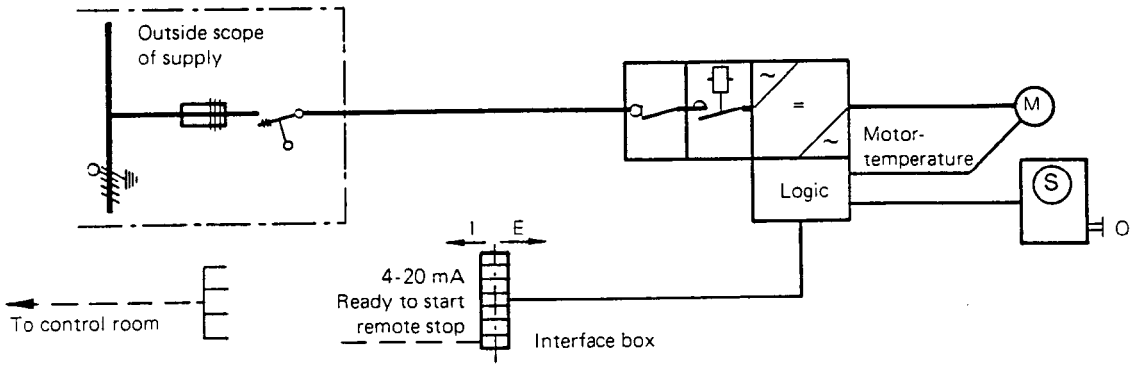
2. BY MANUFACTURER WITH QUOTATION

The data on the total VSDS overall system performance, construction, etc. shall be submitted in the requisition.

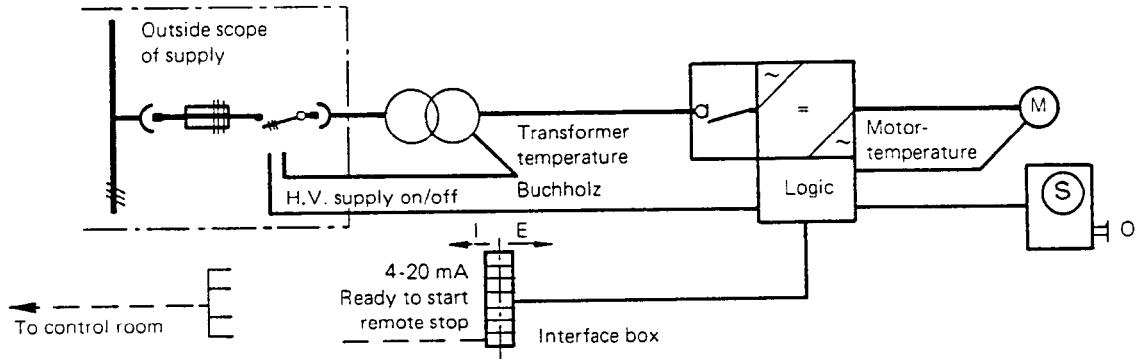
The subcomponent requisition sheets shall be completed giving basic data of the unit for fundamental sinewave frequency.

APPENDIX 2 TYPICAL BLOCK DIAGRAMS

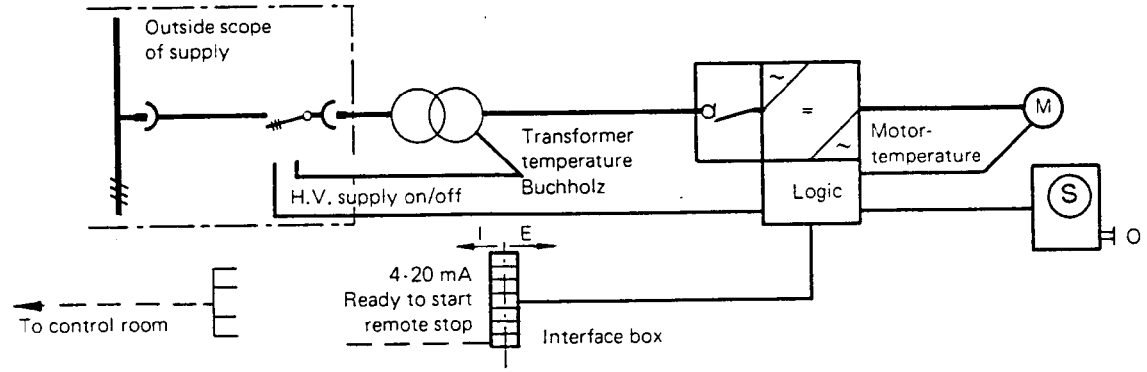
LOW VOLTAGE VSDS



VSDS WITH HV SUPPLY SWITCHED BY CONTACTOR



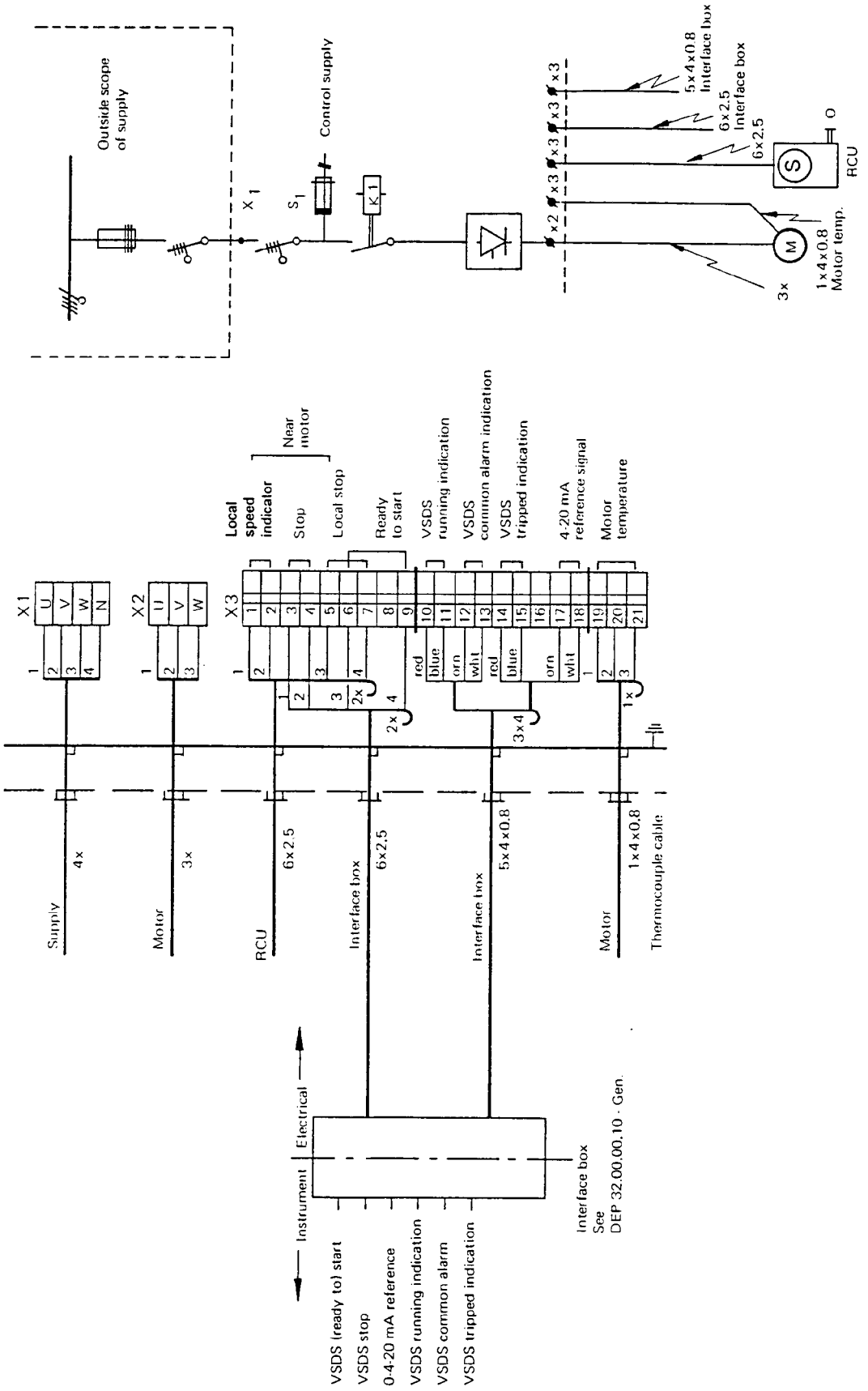
VSDS WITH HV SUPPLY SWITCHED BY CIRCUIT BREAKER



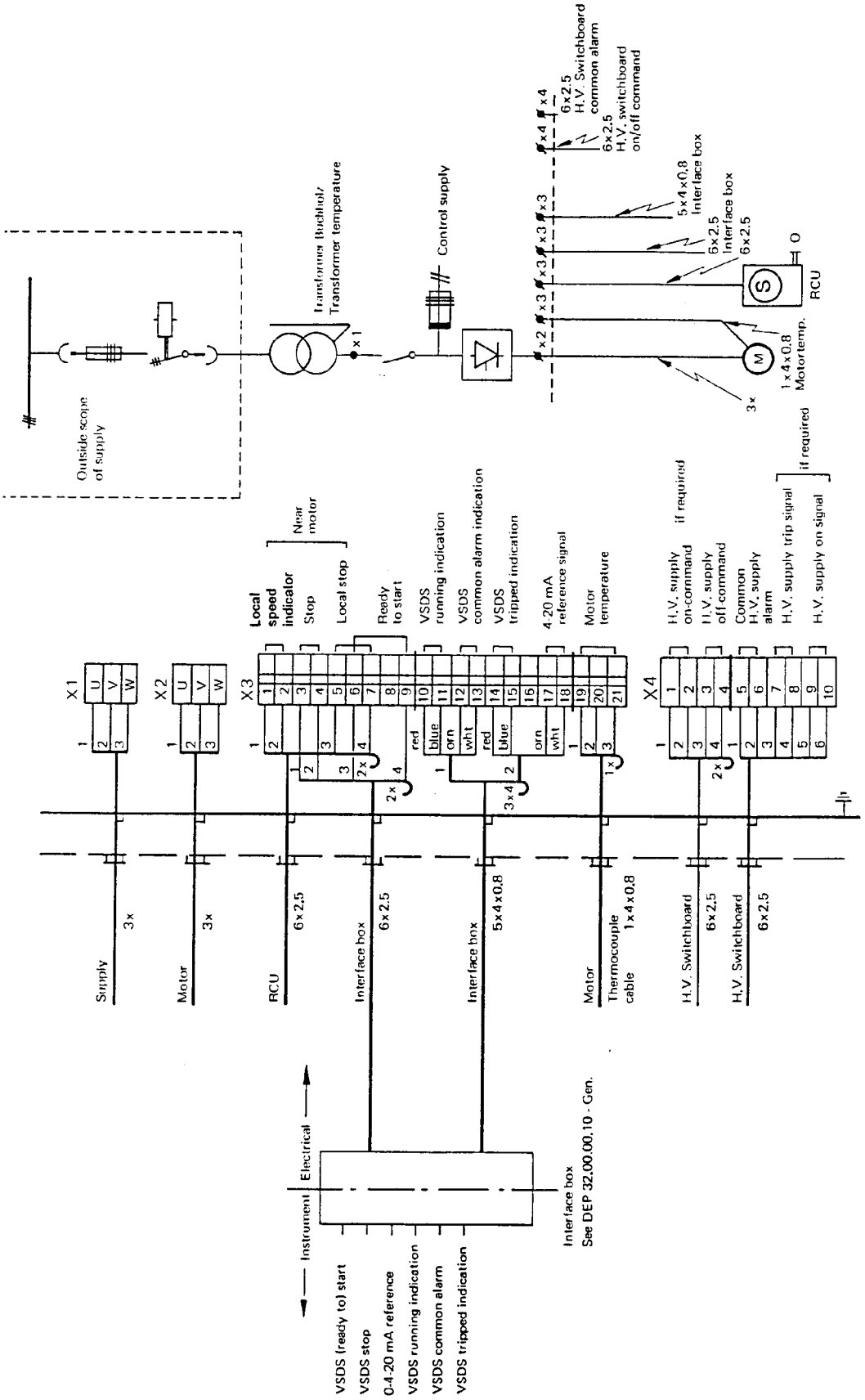
Electrical signal line

Instrument signal line

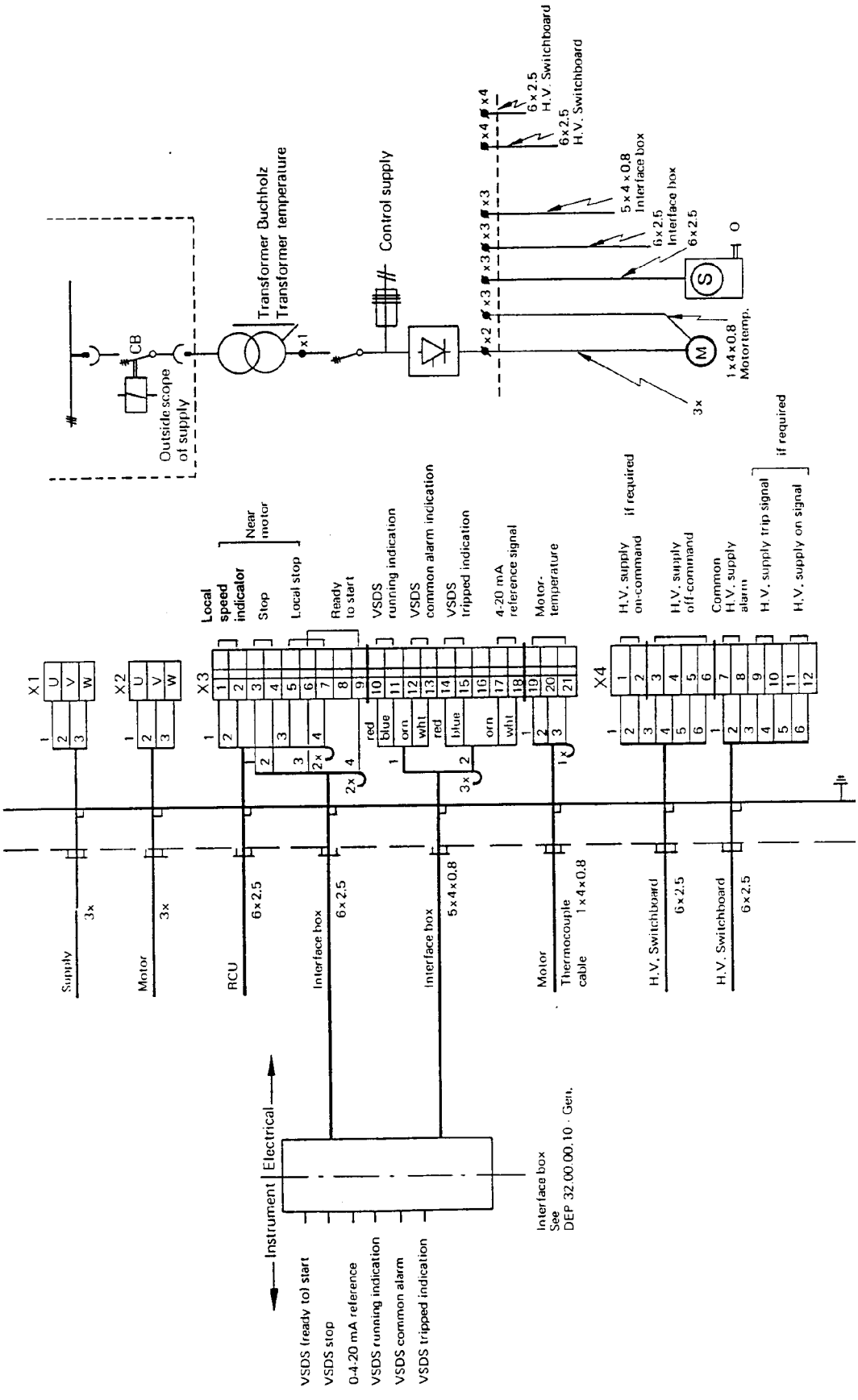
APPENDIX 3 TYPICAL LOW VOLTAGE VSDS



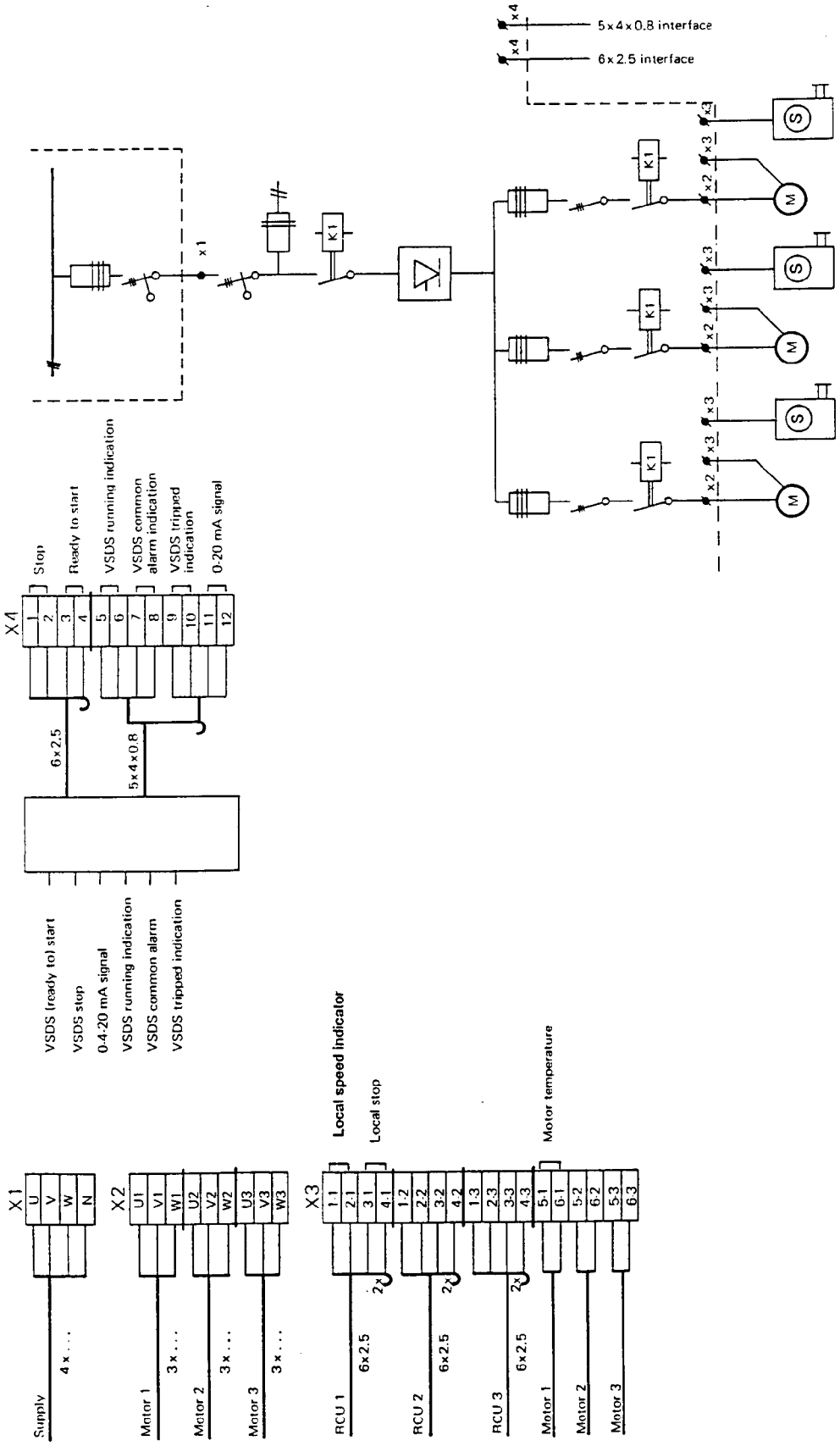
APPENDIX 4 TYPICAL VSDS WITH HV SUPPLY SWITCHED BY CONTACTOR



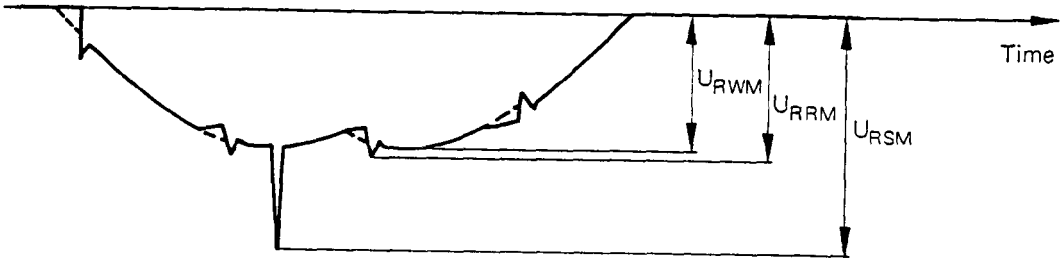
APPENDIX 5 TYPICAL VSDS WITH HV SUPPLY SWITCHED BY CIRCUIT BREAKER



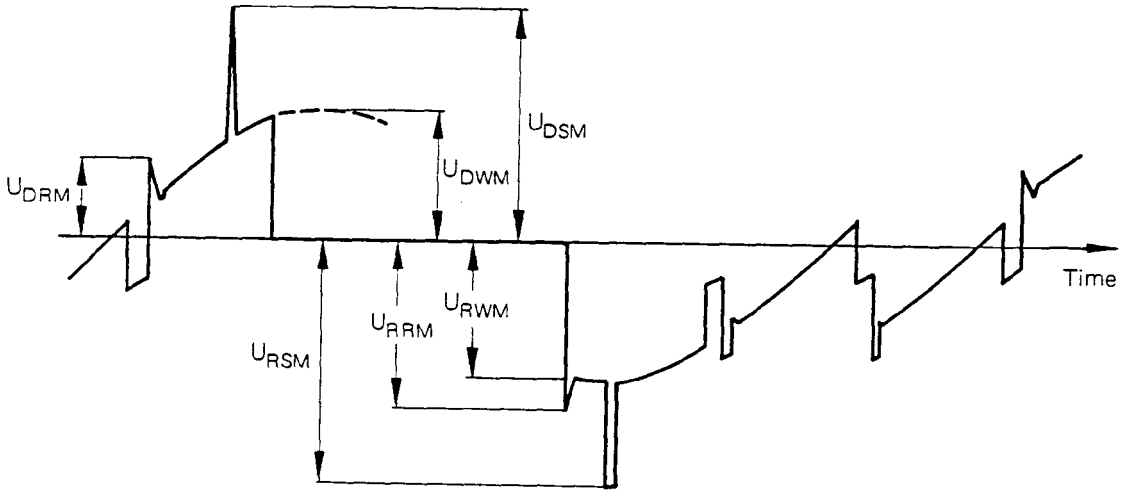
APPENDIX 6 TYPICAL LOW VOLTAGE VSDS FOR MULTI-MOTOR DRIVE



APPENDIX 7 TYPICAL VOLTAGE WAVE FORMS



UNCONTROLLED CONVERTER CIRCUIT ELEMENT



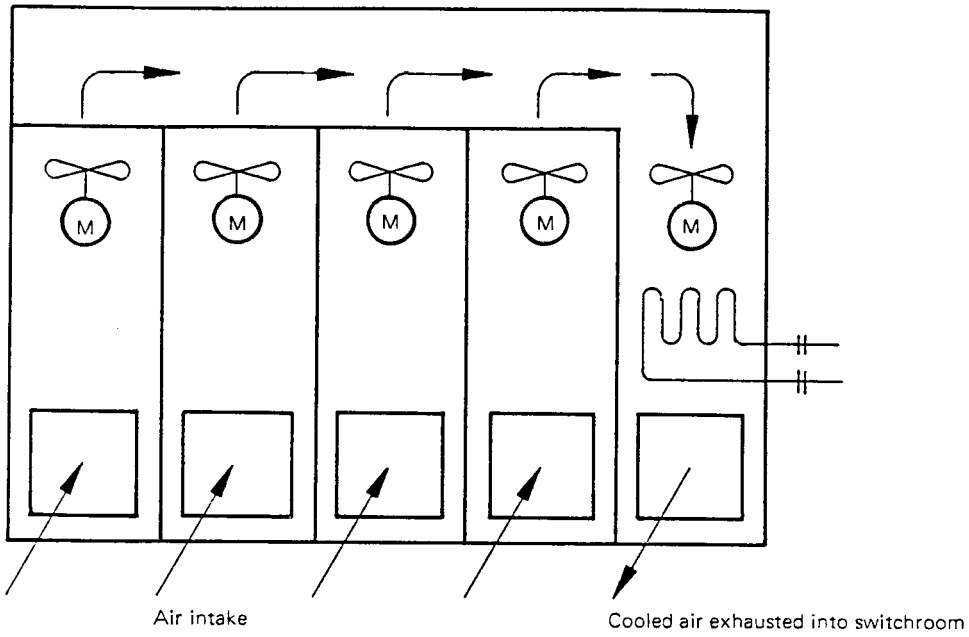
CONTROLLED CONVERTER CIRCUIT ELEMENT

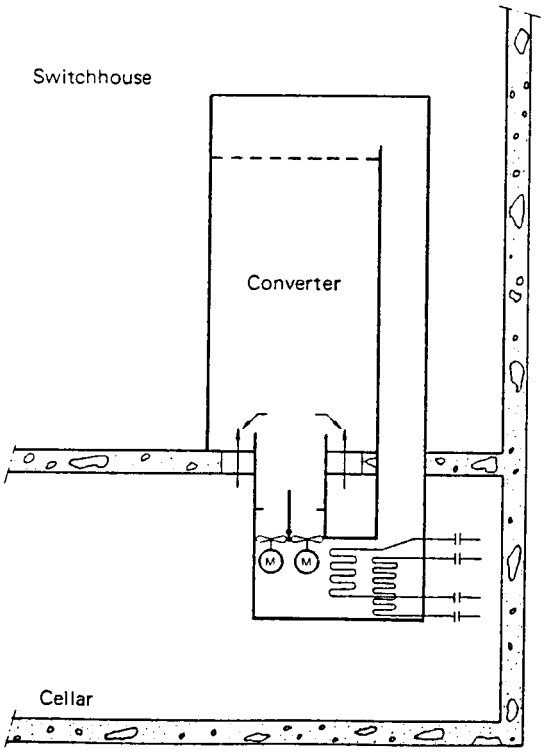
U_{RWM} and U_{DWM} : Crest value of circuit voltage

U_{RRM} and U_{DRM} : Repetitive voltage peaks

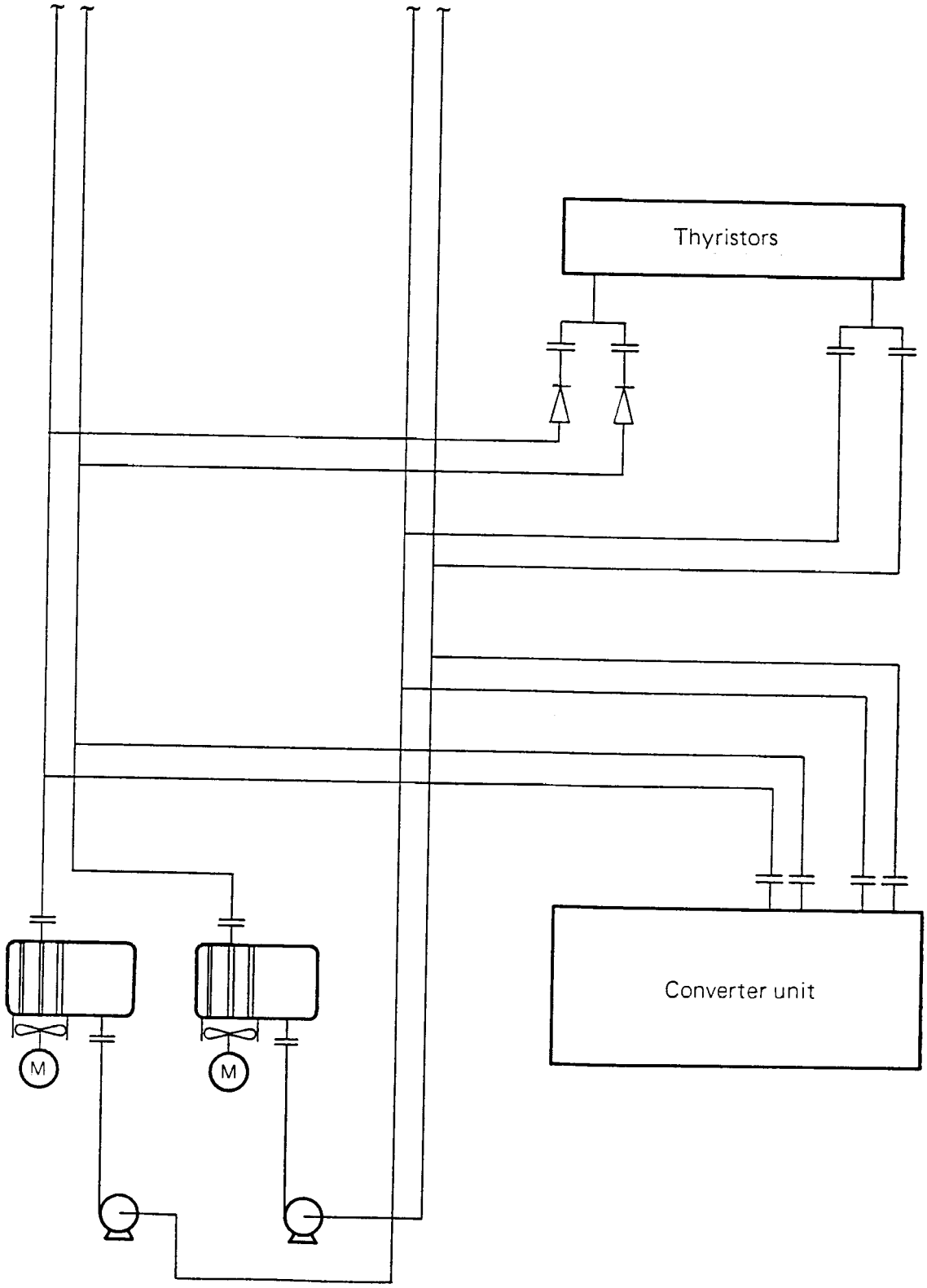
U_{RSM} and U_{DSM} : Non-repetitive voltage peaks

APPENDIX 8 TYPICAL CONVERTER INSTALLATION AIR TO LIQUID COOLED

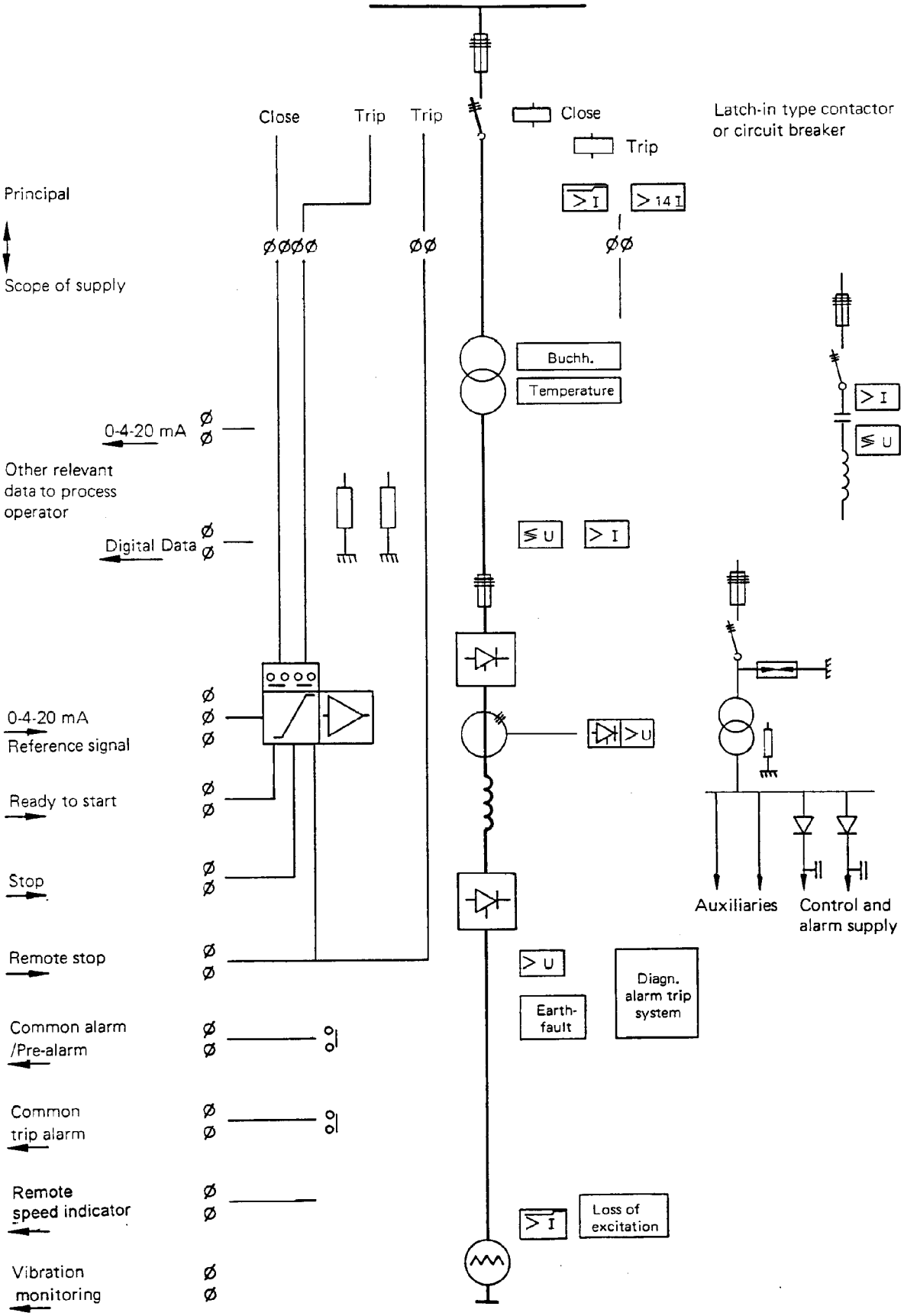




APPENDIX 9 TYPICAL ARRANGEMENT OF A LIQUID COOLING SYSTEM



APPENDIX 10 TYPICAL ARRANGEMENT



APPENDIX 11 DISPENSATIONS FOR VSDS WITH LV CONVERTER

Unless expressly disallowed by the Principal, the following dispensations may be given on drives with low-voltage converters:

- To satisfy (3.3 and 5.9), the Manufacturer may provide generic values of airgap harmonic torques typical of the drive type and rating to the driven equipment Manufacturer. The Manufacturer should not quote separately for a full torsional analysis.
- The Manufacturer need not introduce external fault-limiting components, e.g. reactors, to confine damage under (4).
- Standard options which preclude requirements in (5.2.1) for automatic restart and reacceleration may be offerred for non-critical applications.
- Supervision and alarm for deviation between setpoint and measured value as stated in (5.2.2) are not required.
- If the Manufacturer cannot meet the current harmonic levels specified in (5.9), he may advise the Principal on expected levels and leave voltage harmonic calculations on the system to the Principal. This does not absolve the Manufacturer of performance test requirements.
- The Manufacturer need not quote for site measurement of harmonic levels in (5.9).
- The contactor in (9.1.1) may be separately supplied by the Principal and located in his switchgear.
- Power semiconductor n+1 redundancy in (9.2.2) is not required.
- Individual component marking as specified in (9.7) is not required provided layout drawings are included which explicitly identify components.
- Redundancy on cooling fans as implied in (9.8.3) is not required.
- Redundancy on control instrumentation and field sensors as specified in (9.9.1) is not required.
- The protection and alarm requirements in (9.9.3) are further qualified as follows:
  - the requirements relating to synchronous motors, transformers, bearings, luboil, and motor vibration are not applicable;
  - the prealarms for overtemperature and underspeed are not required; immediate tripping is acceptable;
  - failure of non-redundant cooling auxiliaries shall result in VSDS tripping;
  - output torque and power indications are not required.
- The equipment layout and protection coordination diagram under (13.2) are not required.
- The no-load soak-test in (13.3) may be reduced to 6 hours.
- Type tests on similar units will be adequate to satisfy (14.3) on performance test requirements.