Vibration of the motor and driven equipment at least 25% above the motor operating speed range.

System Grounding

(a)	11 kV , 3.3 kV	:	Low Resistance Grounded to limit the earth fault current to 300 Amps
(b)	415 V	:	Solidly Grounded
(c)	220V DC	:	Ungrounded

Fault Level

(a)	11 kV , 3.3 kV	:	40 kA for 1 second
(b)	415 V	:	50 kA for 1 second
(c)	220V DC	:	15 kA for 1 second

Degree of Protection

(a)	Indoor Motors	:	IP 54
(b)	Outdoor Motors	:	IP 55
(c)	Cable Box located in Indoor Area	:	IP 54
(d)	Cable Box located in Outdoor Area	:	IP 55

Winding Insulation

(a)	For 11 kV/3.3 kV AC Motors	:	Class - F
(b)	For 415V AC Motors	:	Class - F
(c)	For 220V DC Motors	:	Class - F

Winding Conductor Material

(a)	For 11 kV/3.3 kV AC Motors	:	Copper
(b)	For 415V AC Motors	:	Copper
(c)	For 220V DC Motors	:	Copper

Bearing

(a)	For Drive End	:	Roller
(b)	For Non Drive End	:	Roller / Ball

Temperature Rise

(a)	For Air Cooled Motors	:	70 °C over ambient temperature
(b)	For Water Cooled Motors	:	80 °C over inlet cooling water temperature

Motor Earthing

(a)	Motors above 90 kW	:	50 x 6 mm GI Flat
(b)	Motors above 30 kW and up to 90 kW	:	25 x 6 mm GI Flat
(c)	Motors above 5 kW and up to 30 kW	:	25 x 3 mm GI Flat
(d)	Motors up to 5 kW	:	8 SWG GI Wire
(e)	Terminal Box	:	8 SWG GI Wire

Space Heater

(a)	For Motors 30 kW rating and above	:	Space heater suitable for 1Phase, 240V AC, 50 Hz supply
(b)	For Motors below 30 kW	:	No Space heater required

rating.

Painting

(a)	Paint Type	:	Epoxy based with approved class
(b)	Paint Thickness	:	Within 100 to 150 micron.

4 SPECIFIC REQUIREMENTS

4.1 Locked Rotor Withstand Time

HT Motor

- The locked rotor withstand time for HT motors under hot conditions at 110% rated voltage will be more than the starting time at minimum permissible voltage by at least three seconds or 15% of the accelerating time whichever is greater.
- Provision of speed switches will be avoided to the extent possible. In case speed switch is required to mount on the motor shaft, the same will remain closed for speeds lower than 20% and open for speeds above 20% of the rated speed. The speed switch will be capable of withstanding 120% over speed in either direction of rotation.

LT Motor

- The starting time of the motor will be at the minimum permissible voltage.
- For motors with starting time up to 20 seconds at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit will be at least 2.5 second more than starting time.
- For motors with starting time more than 20 second and up to 45 seconds at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit will be at least 5 second more than starting time.
- For motors with starting time more than 45 seconds at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit will be more than starting time by at least 10% of the starting time.
- Speed switches mounted on the motor shaft will be provided in cases where above requirements are not met.

4.2 Starting Voltage Requirement

(a)	85% up to 1500 kW
(b)	80% for above 1500 kW up to 4000 kW

(c) 75% > 4000 kW

Motor will be designed for direct on line starting at full voltage.

The motor will be capable of withstanding the stresses imposed if started at 110% rated voltage.

H.T Motor will start with rated load and accelerate to full speed with 80% rated voltage at motor terminals except for mill motors for which 90% RV will be the minimum starting voltage. L.T Motor will start with rated load and accelerate to full speed with 85% rated voltage at motor terminals.

Pump motor subject to reverse rotation will be designed to withstand the stresses encountered when starting with non-energized shaft rotating at 125% rated speed in reverse direction.

The motor may be subjected to sudden application of 150% rated voltage during bus transfer, due to the phase difference between the incoming voltage and motor residual voltage.

The motor will be designed to withstand any torsional and/or high current stresses, which may result, without experiencing any deterioration in the normal life and performance characteristics.

4.3 Winding and Insulation

(a)	Type	:	Non-hygroscopic, oil resistant, flame resistant
(b)	11 kV and 3.3 kV AC motors	:	Winding material shall be of copper. Insulation shall be of Class F with winding temperature rise limited to Class B. They shall withstand 1.2/50 microsecond switching surges of "4U+5 KV" (U=Line voltage in KV). The coil inter-turn insulation shall be suitable for 0.3/3 micro second surge of 32 / 12 KV followed by 1 min power frequency high voltage test of appropriate voltage on inter turn insulation.
(c)	415V AC & 220V DC	:	Winding material shall be of copper. Insulation shall be of Class F with temperature rise limited

	motors	to Class B.
(d)	Conveyor motors	Short circuit rings of conveyor motors shall be either joint less or welded type. Brazed joint is not acceptable.

4.4 **Motor Control**

(a) **For HT Motors**

- Motors of rating above 160 kW and up to 750 KW shall be suitable for 3.3 KV voltage
- Motors above 750 KW shall be suitable for 11 KV voltage.
- Frequent starting motors of rating above 160 kW to 750 kW shall be suitable to be controlled by vacuum contactors

(b) **For LT Motors**

Motors of rating 90 KW and up to 160 KW shall be operated by Air circuit breakers from PCC/ PMCCs and shall be provided with comprehensive numerical motor protection relays

Motors of rating less than 90 kW shall be operated by Contactor from respective intelligent MCCs as below:.

- Motors of rating up to 18.5 KW shall be provided with MPCBs, Electronic overload relays etc.
- Motors rated above 18.5 KW and below 45 KW shall be provided with MCCBs Electronic overload relays etc
- Motors of rating 45 KW and above but less than 90 KW shall be provided with MCCBs, CT operated Electronic over load relays etc

4.5 Starting duty

Motors will be suitable for 3 nos. consecutive Cold starts up and 2 nos. consecutive Hot starts up. Motors will be suitable for three equally spread starts per hour when the motor is under normal service condition. However in case of multiple start motors like conveyor motors three starts will be allowable from hot condition with maximum 20 starts per day and minimum 20,000 starts during life time of motor.

4.6 Bearings

- Anti-friction type radial and thrust bearings (ball, roller) and sleeve bearing will be rated for minimum standard life of 40,000 hours taking bearing and driven equipment loads (in case the drive is not having separate thrust bearing) into account. If bearings are lubricated, loss of grease will be scarce and it will not creep along shaft into motor housing. Facility of removal of excess grease will also be provided for grease lubricated bearings.
- Vertical shaft motors will be provided with thrust and guide bearings. Thrust bearing of tilting pad type is preferred. However, if Anti-friction bearings can take vertical thrust, thrust & guide bearings are not required.
- Bearing will be effectively sealed against dust ingress and will be pressure grease gun lubricated. The bearing and housing will be so designed that greasing will be possible while the motor is running, without removal of covers.
- Where bearing supports are attached to the motor casing, adequate bracing will be provided on these supports to reduce vibrations and ensure life of bearings.
- If the bearings are oil lubricated, a drain plug will be provided for draining residual oil and oil level gauge will be provided to show precisely oil level required under standstill and running conditions.
- Unless otherwise approved, bearing lubricating system will be such that no external forced oil or water is necessary to maintain required oil supply to keep bearing temperature within design limits.
- Lubricants will be selected for prolonged storage and normal use of motors in tropical climate and will contain corrosion and oxidation inhibitors. Greases will have suitable bleeding characteristics to minimize setting. The selected lubricants will be indigenously available.
- Motors rated above 1000 kW will have insulated bearings to prevent flow of shaft currents.

4.7 Temperature Rise

- For Air Cooled Motors, temperature rise of insulation should be limited to 70 Deg C over ambient temperature by resistance method.
- For Water Cooled Motors, temperature rise of insulation should be limited to 80 deg. C over inlet cooling water temperature mentioned elsewhere, by resistance method.

4.8 Cooling

All motors will be either Totally Enclosed Fan Cooled (TEFC) or Totally Enclosed Tube Ventilated (TETV) or Closed Air Circuit Air Cooled (CACA) type. However, motors rated 3000 kW or above can be Closed Air Circuit Water Cooled (CACW).

4.9 Enclosure

- All motor enclosures will conform to the degree of protection of IP54 for indoor and IP-55 for outdoor installation unless other wise specified. Motor for outdoor or semi outdoor service will be of weather proof construction. Motors of large output rating located indoor could have screen protected drip proof (SPDP) enclosure conforming to IP-23.
- For motors located in outdoor & corrosive locations, FRP canopy will be provided. In case steel canopy is provided, the same will be epoxy painted to meet the surrounding atmosphere. Motors located in hazardous areas will have flame proof enclosures conforming to IS: 2148 as detailed below:

  - Fuel oil area : Group – IIB

4.10 Noise Level and Vibration

- Noise level will be limited to 85 dB (A) at 1.5 meters from the motor. However the same will be as per IS: 12065 unless otherwise specified. The peak amplitude of vibration will be within the specified limits laid down in IS: 12075. Motors will withstand vibrations produced by driven equipment. HT motor bearing housings will have flats in both X and Y directions suitable for mounting 80mmX80mm vibration pads. Vibration pads with screwed holes for mounting vibration probes will be provided at both DE and NDE.

4.11 Temperature Monitoring

In HT motors, at least four numbers simplex/ two numbers duplex platinum resistance type temperature detectors will be provided for each phase of stator winding. Each bearing will be provided with dial type thermometer with adjustable alarm contact and two numbers duplex Platinum resistance type temperature detector (3 wire 100ohm at zero deg C). In case of CACA and CACW motors dial type temperature indicator will be provided (one each for hot and cold air temperature monitoring for CACA and CACW and one each for inlet and outlet water temperature monitoring for CACW). If alarm and trip are required for cooling air temperature, temperature switch will be provided. The contact rating will be minimum 0.5A at 220V DC and 5A at 240V AC. Flow switches will be provided for monitoring cooling water flow of CACW motor and oil flow of forced lubrication bearing. The contact rating will be minimum 0.5A at 220V DC and 5A at 240V AC.

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4.12 Earthing

Motor body will have two earthing points on opposite sides. Motor terminal boxes will also have separate grounding terminals.

4.13 Termination

- HT motors can be offered with either Elastimold termination or dust tight phase segregated double walled (metallic as well as with insulated barrier) cable boxes. In case Elastimold terminations are offered, then protective cover and trifurcating sleeves will also be provided. Removable gland plates of thickness 3 mm (hot/cold rolled sheet steel) or 4 mm (non magnetic material for single core cables) will be provided in case of cable boxes. The main cable box / terminal box shall withstand a fault current up to 40 kA for 0.25 seconds for MV motors and 50 kA for 0.25 seconds for LV motors. Separate terminal boxes will be provided for space heaters and RTDs.
- All the terminal boxes except phase segregated terminal of main terminal box will be capable of being turned through 360 degrees in steps of 90 degrees.
- For HT motors the distance between gland plate and the terminal studs will not be less than 500 mm.
- Minimum inter-phase and phase-earth air clearances for LT motors with lugs installed shall be as follows:

Table 4.1

Minimum inter-phase & Phase earth air Clearances

S.No	Motor MCR in kW	Clearance, in mm
1	Up to 110kW	10
2	Above 110 and Up to 150kW	12.5
3	Above 150kW	19

4.14 Differential Protection

- For motors rated 11kV, 1000 KW & above, neutral current transformers of PS class will be provided on each phase in a separate neutral terminal box for differential protection.

4.15 Tropical Protection

- All motors will have fungus protection involving special treatment of insulation and metal against fungus, insects and corrosion.

- All fittings and hardware will be corrosion resistant.
- Space Heater
- Suitable single phase space heaters operated at 240V, 50Hz, 1Phase AC supply will be provided on motors rated for 30KW and above to maintain windings in dry condition when motor is standstill. Separate terminal box for space heaters & RTDs will be provided.
- The space heater will be sized to maintain the motor internal temperature above dew point when the motor is in idle condition.

4.16 Rating Plate

Motor will have Stainless steel nameplate(s) showing diagram of connections, all particulars as per IS: 325 / NEMA-MG-1 and following additional information:

a) Type of bearing and recommended lubricants along with location of insulated bearing.
b) Temperature rise under normal/abnormal conditions.
c) In addition to above, an arrow block will be screwed on to the body of motor on the non-driving end to indicate normal direction of rotation of motor.
d) Year of Manufacture

4.17 Drain Plug

Motor will have drain plugs so located that they will drain the water, resulting from the condensation or other causes from all pockets of the motor casing.

4.18 Dowel Pins

Motor will be designed to permit easy access for drilling holes through motor feet or mounting flange for installation of dowel pins after assembling the motor and driven equipment.

4.19 Painting

The complete motor assembly including fan will be painted with corrosion proof paints of approved class.

4.20 Lifting provision

Motor weighing 25 Kg or more will be provided with eyebolt or other adequate provision of lifting.

5 TESTS

5.1 HT Motors

5.1.1 Routine Test

All equipment will be completely assembled, wired, adjusted and routine tested as per relevant IS / IEC Standards at manufacturer's works in the presence of consultant /purchaser or his representative.

5.1.2 Type Test

For each type & rating of HT motors the Contractor will submit for Owner's approval the reports of all the type tests as per relevant standards.. These reports should be for the tests conducted on the equipment similar to those proposed to be supplied under this contract and the test(s) should have been conducted at an independent laboratory.

In case the Contractor is not able to submit report of the type test(s) conducted,, or in case the type test report(s) are not found to be meeting the specification requirements, the Contractor will conduct all such tests under this contract free of cost to the Owner and submit the reports for approval.

5.2 LT Motors

5.2.1 Routine Test

All equipment will be completely assembled, wired, adjusted and routine tested as per relevant IS/IEC Standards at manufacturer's works in the presence of consultant /purchaser or his representative.

Type Test

LT motors shall be of type tested quality. For each type & rating of LT motors rated above 50 KW, the Contractor shall submit for Owner's approval the reports of all the type tests as per relevant standards These reports should be for the tests conducted on the equipment similar to those proposed to be supplied under this contract and the test(s) should have been conducted at an independent laboratory.

In case the Contractor is not able to submit report of the type test(s) conducted,, or in case the type test report(s) are not found to be meeting the specification requirements, the Contractor shall conduct all such tests free of cost in the presence of the Owner and submit the reports for approval.

5.3 Test Witness

The tests shall be carried out in presence of the Owner's representative, for which a minimum 7 days notice shall be given by the Contractor. The Contractor shall obtain the Owner's approval for the type test procedure before conducting the type test. The test procedure will clearly specify the test set-up, instruments to be used, procedure, acceptance norms, recording of different parameters, interval of recording, precautions to be taken etc. for the type test(s) to be carried out.

5.4 Test Certificates

- Certified copies of all tests carried out at works and at site shall be furnished in requisite no. of copies for approval of the Owner.
- The equipment shall be dispatched from works only after receipt of Owner's written approval of shop test reports.

6 DRAWINGS, DATA & MANUALS

Drawings, data & manuals for the motors will be submitted as indicated below:

Dimensional General Arrangement drawing

- Motor sizing calculation
- Foundation Plan & Loading
- Cable end box details
- Space requirement for rotor removal
- Thermal withstand curves hot & cold
- Starting and speed torque characteristics at 80% & 100% voltage
- Complete motor data
- Erection & Maintenance Manual
- Test reports
- QAP

VOLUME- IV
SECTION-3,
VARIABLE FREQUENCY DRIVE (VFD)

TABLE OF CONTENT

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1 GENERAL

This specification is intended to cover the design, engineering, manufacture, assembly, testing at manufacturer's works, supply & delivery, properly packed for transport to site of Variable Frequency Drive complete with all accessories for efficient and trouble-free operation of 2 x 500 MW New Thermal Power Plant at Neyveli, Tamilnadu for Neyveli Lignite Corporation Limited.

2 CODES AND STANDARDS

All equipment and materials will be designed, manufactured and tested in accordance with the latest applicable Indian Standards (IS) / IEC as given below except where modified and/or supplemented by this specification.

IEC-61800-3,4&5

IEC-60664-1

IEC/EN-60204-1

IEC/EN-60529

IEC/EN-61000-3-12

IS-13947

IEE 519

IEC 354 / IS6600

Equipment and material conforming to any other standard, which ensures equal or better quality, may be accepted. In such case, copies of the English version of the standard adopted will be submitted during detail engineering.

The electrical installation will meet the requirements of Indian Electricity Rules as amended upto date and relevant IS Code of Practice. In addition, other rules and regulations applicable to the work will be followed.

3 TECHNICAL SPECIFICATION FOR VFD

The VFD system will be complete with Squirrel Cage Induction Motor/ synchronous motor. Converter, Converter input transformer, drive output transformer (if required), DC link reactor with associated auxiliaries and harmonic filters (if required)

The Contractor will be responsible for engineering and functioning of the complete system, meeting the intent and requirement of this specification and data sheets. This will include but not be limited to inverter sizing, input and output transformer sizing, selection of transformer impedance & vector group, input and output harmonic filter design and sizing, output dv/dt filter sizing, motor cable selection and motor sizing/selection.

This specification applies to drive systems having converter input voltage above 1000 V AC and up to and including 11000V AC.

In case of imported equipment, standards of the country of origin will be applicable, if these standards are equivalent or stringent than the applicable Indian standards.

4 TECHNICAL REQUIREMENT

A) Performance Requirement

The system will be energy efficient, designed as standard product and will provide very high reliability, high power factor, low harmonic distortion and low vibration / wear / noise. It will be easy to install in minimum time and expense and no special tools will be required for routine maintenance.

The system will be designed to deliver the motor input current and torque for the complete speed torque characteristics of the driven equipment , with input supply variation of ±10 and frequency variation of ±5 % . The system will be suitable for the load characteristics and the operational duty of the driven equipment. It will be capable of withstanding the thermal and dynamic stresses and the transient mechanical torque, resulting from short circuit.

The drive system will be designed to operate in one or more of the following operating modes as to suit characteristics of the driven equipment or specified in the data sheet:

a. Variable torque changing as a function of speed i.e. Speed squared

b. Constant torque over a specific speed range

c. Constant power over a specific speed range where the torque decreases when speed increases

The drive controller will be equipped with microprocessor based digital regulator with programmable functions. The power control regulator logic will provide for an acceleration/deceleration current limit curve and will be capable of field adjustments without shutting the system down. Linear acceleration and deceleration shall be separately programmable from 0.1 to 20 seconds.

The total harmonic distortion (THD) of the voltage and current at inverter output shall be as per IEC 61800-4 and it will be considered in the design of the motor.

Harmonics at the supply side of the drive system at primary of the main input transformer will be restricted within the maximum allowable levels of current and voltage distortion as per recommendations in the latest edition of IEEE-519. The Contractor will perform design calculation for harmonic filter system considering VFD connected to the power system and including the supply of harmonic filters along with all accessories which will be installed at owner's power system unless otherwise specified. These harmonic studies will be conducted with maximum and minimum system fault level, cable capacitance, system equipment reactance etc. The studies will highlight but not be limited to maximum load current, expected resonant frequencies, need of harmonic filters, sequence of switching of filters, voltage wave form etc.

Unless otherwise specified, the overload capacity of the controller will be 150% of rated current of motor for one minute for constant torque applications, and 115% of rated current for one minute for variable torque applications at rated voltage. If the motor load exceeds the limit, the drive will automatically reduce the frequency and voltage to the motor to guard against overload. If a load demand exceeds the current limit for more than one minute,

the drive will shut down to prevent over heating of the motor and damage to the drive.

During operation, the system shall be capable of developing sufficient torque under all load conditions to respond to a 20% alteration in speed set point within a time limit up to 60 seconds.

The integrator action of the speed set point alteration will be independently adjustable for both an upward and a downward alteration. The minimum time interval between set point adjustments by the distributed control system will be considered as 10 seconds.

The drive shall trip in case the speed exceeds 105% of the maximum operational speed or reduces to 95 % of the minimum operational speed for more than 10 seconds.

Maximum noise level measured at a distance of 1.5 meter from the outer surface of the motor in all horizontal directions and at a height of 1-meter from the floor level, under rated load with all normal cooling fans operating shall not exceed 85 dbA.

Variable frequency drive will be arranged so that it can be operated in an open circuit mode, disconnected from the motor for start up adjustments and troubleshooting/ maintenance.

Voltage at motor neutral will be maintained at ground potential for the total operating condition.

B) Control Requirement

The system will operate on constant V/f supply with required voltage boost capability in low frequency mode of operation.

Short time voltage dips up to 20% of nominal voltage (e.g. in case of a large motor start up connected to the same bus as VFD) shall not cause the control system to stop functioning and will not trip the drive system.

The system will also be equipped with a facility which will restart the system in case of voltage dip over 20% or power interruptions for less than 2 seconds, with recovery of the voltage to its nominal value. The drive will have the facility to block this feature, if required by the operator. Upon restart the converter shall be capable of synchronizing on to a rotating motor and develop full acceleration torque within 10 seconds.

The system will be suitable for number of starts as per technical specification for High Voltage Motors.

The power controller will be controlled to always start the motor in the forward direction. Logic will be provided to prevent the motor from being started in the reverse direction.

The drive motor shall be speed controlled corresponding to 4-20 mA or 0-10 V reference input signal unless other wise specified Upon complete loss of the user's speed reference signal, the drive will automatically run at constant speed at the last speed reference available prior to the loss of signal. It will be possible to vary the speed of the drive in either manual or auto mode. Auto/manual selection will be from VFD panel unless otherwise specified.

a. With the selector switch in "manual" mode, the operator will be able to set the speed through keypad, mounted on front of the drive panel or from

speed increase/decrease push buttons on the panel. Motor operated potentiometer will be provided as a speed set point device.

b. With the selector switch in "auto" mode, speed of the motor will be controlled from a 4-20 mA signal, from owner's DCS (Process Control) system. Necessary equipment required for interfacing with DCS will also be provided in the drive panel.

The required provision for the interface with remote I/O will be through hardwired connection (with potential free contacts and transducers)

Drive system will have provision for interface with upper level automation such as Substation monitoring system or electrical control system.

The closed loop control feedback for the drive system having output transformer will be tapped from the secondary side of the output transformer.

C) Panel Construction

The panel will include suitable semi conducting power devices (Diodes / IGBT) modules with protective devices, reactors (if required) , filters (if required), control circuit, control accessories, indication and annunciation etc. The construction of the panel will provide effective protection against electromagnetic emissions and will meet the design requirement of integrated standards.

Safety Interlock will be provided so that power cabinet can not be opened unless the upstream breaker is disconnected, safety-grounding switch is closed and DC link capacitor is discharged. Power source breaker can only be closed once the earthing switch is open and panel door is closed with lock defeat facility.

The drive will be suitably housed in sheet steel panels fabricated with 2 mm thick cold rolled sheet steel. The panel will be suitable for indoor installation, if not otherwise specified. The panel will be free standing with degree of enclosure protection as IP-31. The maximum and minimum operating height shall be 1800 mm and 400 mm respectively.

Bolted un-drilled gland plate shall be provided at bottom. Clamp type terminals shall be used for connection of all wires up to 10 mm2 and terminal for higher sizes shall be bolted type suitable for cable lugs. Minimum space for power cable termination shall be 600 mm clear from bottom of the cable gland plate.

Bus bars will be of electrolytic copper, color coded separately for AC and DC system. All the live parts will be sleeved / shrouded to ensure complete safety to personnel intending to carry out routine inspection by opening the panel doors. All the equipment inside the panel and on the doors will be provided with suitable nameplate.

All the switches component and accessories which are essential for normal and emergency operation will be mounted on the door and will be operable externally. Digital meters shall be preferred. Analogue instruments, where provided, shall be switchboard type, back connected, 72x72mm. Scale will have red mark indicating maximum permissible operating rating.

Each panel will be provided with illuminating lamp (preferably CFL) with switch and fuse. 5/15A, 240V power socket with switch and fuse will be provided.

Each panel will have space heater with switch fuse and variable setting thermostat.

Copper earth bus of min. 50X6 mm size will be provided in the panel with provision for connection to plant earth grid. All the non-metallic components/parts will be connected to the main earth bus bar. Separate earth bus bar and stud for electronic control system as required will be provided.

All the metal parts will be treated so as to ensure efficient anti-corrosive protection. Hardwares will be zinc-passivated or electrogalvanised. Panel enclosure and structure supports will be thoroughly cleaned and degreased to remove mill scale and rust etc. External surface will be prepared for final paint shade 631 and 632 as per IS-5 for indoor and outdoor area respectively.

All panels will be of same height so as to form a uniform line-up, to give good aesthetic appearance.

All the control wiring will be enclosed in plastic/ metal channel. Each wire will be identified at both ends by self-sticking wire marker tapes or PVC ferrules. Power and control wiring inside the panel shall be done with BIS approved, PVC insulated, fire retardant, copper conductor wire. 1.5 mm2 size wire shall be used for control circuits, 2.5 sq.mm for CT/PT circuits and 0.75 mm2 for electronic circuits. All wires shall be ferruled and terminals shall be properly numbered. Minimum 20% spare terminals shall be provided.

All electronic modules and components will be accessible from front of panel only. Modular assemblies for both the system control electronic equipment and power electronic equipments will be used.

All low voltage compartment and cabling will be electrically and physically separated from the high voltage compartment.

DC link capacitor and pre charging and discharging circuit will be preferably mounted in the rear of the panel. Suitable removable type hooks will be provided for lifting the panel.

Perspex type transparent insulating material will be used for covering live components.

Drive keypad, operator control panel required for control, monitoring and measurements will be supplied and installed outside the panel on the front door. It will be accessible for operation without opening the front door and will be non-removable type.

All equipment will be complete with double compression glands, lugs etc.

D) Cooling

The drive panel will be naturally cooled or water cooled type as per manufacturer's standards. However it is preferred to have natural air cooled system. If unavoidable, forced type-cooling system will be provided. Cooling system will include well-dimensioned panel, adequate cooling airflow path, module cooling fan and if necessary, panel cooling fan or water-cooling system will be considered. Contractor will ensure that the panel dimensions and flow paths have been designed for continuous running at the specified ambient without overheating. For fan cooled drives, redundant ventilating fans (N + 1) will be provided.

For water-cooled drives, entire cooling system including but not limited to heat exchanger, flow and pressure meters and pumps will be included. The system will be provided with closed circuit water cooling system requiring only make up water required for topping up. The cooling water pumps in case provided shall have 100% redundancy. Water quality/characteristics will be as defined in the data sheet and selected cooling water system components/material will be suitable for the same.

Necessary starters will be provided with in the VFD panels for the Ventilation fans CW circulation pumps, any other auxiliary motor etc. The system provided will be interfaced with drive starting and shut down such that safety interlocks such as start permit from cooling system to drive and trip signal from cooling system to drive in case of cooling system failure etc., will be incorporated in the overall sequence logic.

MCB for motor space heater, auxiliary power supply if required for local panel, drive panel space heater etc. will be included and mounted in easily accessible location.

5 EQUIPMENT/ COMPONENT SPECIFICATION

A) Motor

The motor will be designed, constructed and tested in accordance with the Specification for high Voltage Induction / Synchronous Motor, in addition to the following requirements:

i. The motor will be suitable for VVVF control.

ii. The motor will be suitable for the current waveforms produced by the power supply including the harmonics generated by the drive.

iii. The motor will be designed to operate continuously at any speed in the operating range for the driven equipment (ie; ID fan / Coal feeder).

iv. The permitted voltage variation will take into account the voltage drop across the AC drive and all other system components upstream the motor.

v. Motors required to be transferred to DOL by-pass mode will be rated for specified variations in system line voltage and frequency. Starting current of motor in DOL bypass mode will be limited to value specified in motor specifications.

vi. The motor will be constructed to withstand torque pulsations resulting from harmonics generated by the solid-state power supply.

vii. The motor insulation will be designed to accept the applied voltage waveform, within the Vpeak and dv/dt limits as per IEC-61800-4.

viii. The drive manufacturer will be solely responsible for proper selection of the motor for the given load application and the output characteristics of the drive.

B) Converter Transformer/ Output transformer

The converter transformer will be dry type or oil filled type. In case of the dry type transformer it will preferably be mounted near the drive system panel and will be as per specification covered in Section-05. The impedances of converter input transformers with more than one secondary windings for 12/18/24 pulse systems will be selected to ensure equal load/current sharing between the secondary windings, the converters and the motor windings under all operational conditions including starting and restarting.

C) **The specification for the Oil filled transformer will be as follows.**

1) Type: Outdoor type, Mineral oil filled, ONAN, Three phase unit, suitable rectifier duty.

2) Rating

a. The Transformers will be sized so as to have 10% margin at ambient conditions after considering final load requirements at peak conditions. The vector group will be suitably designed for the variable drive system

b. The voltage rating of primary winding shall be 11 KV, +/- 10%. The secondary voltage rating shall be decided by the Contractor to suit his system.

3) Max. Temperature Rise

Winding : 55 deg C above ambient of 50 deg C

Top oil : 50 deg C above ambient of 50 deg C

Operational Requirements

Tap Changer: Off-circuit, +/-5% in steps of 2.5% shall be provided. It will be hand operated by an external handle with position markings, pad locking facility in each position and mechanical stops to prevent over cranking beyond extreme positions.

Loading Capability

Continuous operation at rated KVA on any tap with voltage variation of +/- 10% corresponding to the voltage of the tap as well as in accordance with IEC 354/IS: 6600.

Flux Density

Not to exceed 1.9 Wb/sq.m. at any tap position with +/-10% voltage variation from voltage corresponding to the tap. Transformer will also withstand following overfluxing conditions due to combined voltage and frequency fluctuations:

110% continuous

125% for at least one minute.

140% for at least five seconds.

Noise Level: Not to exceed values specified in NEMA TR-1.

Features

All transformers will be suitable for cable termination. A dust proof cable box will be provided. Also, a sheet steel, vermin and dust proof marshalling box will be furnished with each transformer to accommodate temperature indicators, terminal blocks for control cables, aux. relays, signal lamps etc. All protection relays, instruments, CTs etc. will be wired to marshalling box. The transformer will be provided with all fittings and accessories to be complete in all respects for satisfactory operation.

Tank

Tank will be fabricated from tested quality steel and designed to withstand continuous internal pressure of 35KN per sq.m. over normal pressure as well as short circuit forces. The main tank body including tap changer compartment, radiators and coolers will be capable of with standing full vacuum. All steel surfaces in contact with insulating oil will be painted with two coats of heat resistant oil insoluble insulating varnish. Tank shields, if provided, will not resonate at natural frequency of equipment.

Tank mounting

Transformer tank will be mounted on bi-directional rollers for rail gauge of 1676 mm. Suitable locking arrangement will be provided to prevent accidental movement of transformer. Tank will also be provided with lifting lugs and minimum four jacking pads.

a At least two adequately sized inspection openings, one at each end of the tank for easy access to bushings and earth connections will be provided.

b Core will be High grade non-aging cold rolled grain oriented silicon steel laminations.

c Winding conductor will be Electrolytic grade copper. Windings will be uniformly Insulated.

d Conservator tank of adequate capacity for expansion of oil from min. ambient to 100 deg.C, oil temperature will be provided. The transformers rated 8MVA and above will be provided with air bag breathing through silica gel breather. For lower rating transformers, conventional single compartment conservator with dry air filling the space above oil and connected to silica gel breather with inspection window and oil seal will be provided. Drain valve will drain the conservator oil completely.

e Bushings will be Porcelain.

f Bushing CTs Will be provided on the LV neutral side of adequate rating for WTI.

g Radiators will be Tank mounted with shut off valves.

h Insulating oil will conform to IS: 335. No external inhibitors are permitted.

i Marshalling box will be provided with thermostatically controlled space heaters and will be suitable for IP-55 degree of protection.

j Additional L.V. neutral bushing will be brought out for earthing at equipment end.

k Fittings

Transformer will be provided with the following fittings:

- Double float type Buchholz relay with alarm and trip contacts and valves on both sides. Gas sampling device at an accessible height and an air release cock for Buchholz relay will be provided.
- A spring operated pressure relief device with extension pipe to bring oil to plinth level along with electrically insulated contact for alarm and tripping will be provided for transformer rating 2MVA and above. The device will operate at a static pressure less than the hydraulic test pressure for the transformer tank.
- Diaphragm type explosion vent will be provided for transformers of rating less than 2MVA.
- Winding temperature indicator (WTI) and Oil temperature indicator (OTI), Dial type (150mm) with alarm and trip contacts and max. reading pointer along with resetting device will be provided. WTI will have temperature sensing element and image coil.
- Magnetic oil level gauge with alarm contact will be provided with minimum and maximum level marked. Oil level gauge will be Prismatic/toughened glass type.

D) **Power Converter**

a The static power converter will consist of a line side power converter for operation as a rectifier and a load side power converter for operation as a fully controlled inverter. Power converter will be fast switching, most efficient and low loss type.

b Adequate short circuit and over voltage protection will be provided for the converter and inverter system.

c All power converter devices will include protective devices, snubber networks and dv/dt networks as required.

d The current rating of the converter's semi-conductor components will not be less than 120% of the nominal current flowing through the elements at full load of the VFD through the whole speed range.

e All power diodes will be of silicon type with minimum VBo rating as 2.5 times the rated operating voltage.

f The power converter circuit will be designed so that motor can be powered at its full nameplate rating continuously without exceeding its rated temperature rise due to harmonic currents generated by the inverter operation.

g The conversion devices and associated heat sinks will be assembled such that individual devices can be replaced without requiring the use of any special precautions/tools.

h The cooling system of the electronic components, if provided, will be monitored and necessary alarms will be provided to prevent any consequential damage to the power control devices.

i Offered system will also take in account the distance between Drive panel and motor and system will include all material and accessories to make system suitable for a distance of 350m unless otherwise specified in the data sheet.

E) DC Link Reactor

a Smoothing reactors for the DC link will be designed to sufficiently decouple the rectifier and inverter portion of the converter and to limit fault currents in this circuit.

b Unless otherwise specified, the reactor will be air-cooled or fan cooled type located within the panel.

c Reactor will be suitable for operation with the non-sinusoidal current wave shapes and DC components under all operational conditions of the system without exceeding its temperature limits.

F) Output filter

VFD output current waveform should be inherently sinusoidal at all speeds, with harmonic limits as specified in this specification. Output filter will be provided if required. Output filter capacitors will be provided with discharge circuits to ensure that all residual stored charge is reduced to less than 50 V DC within 300 seconds after a loss of AC voltage. All capacitor will be maintenance free and self-healing type.

The VFD system will inherently protect motor from high voltage dv/dt stress, independent of cable length to motor. Output filter will be an integral part of the VFD system and included within the VFD enclosure.

G) Bypass Feature

a Bypass feature for VFD will be provided as per technological requirement.

b Bypass breaker / contactor-HRC fuse complete with protection, annunciation and metering will be provided.

c All Variable frequency drives (VFD) having bypass feature will have motor protection relay along with necessary control and metering etc. Switching scheme will be such that in case of drive mal-operation, the motor could be taken on bypass control manually, while the drive could be attended by opening its isolation devices.

d Safety interlock between inverter and bypass breaker/contactor will be provided such that closing of healthy device is inhibited in case of external fault.

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Note: In case of ID fan, VFDs of dual channel feeding from separate breakers with separate transformers, Converter Bridge, motor circuit breaker, reactor, control and excitation panel etc. for each of the channels will be provided if bypass arrangement is not provided.

H) Local motor control Station

a The local motor control station will be installed near the motor . Components and accessories that are required in the local motor control station may be mounted on the local field mounted panel envisaged for the driven equipment.

b Meters in the local control station will be suitable for 4-20mA transducer outputs and will be calibrated for the actual motor current. Further, for drives with bypass facility, the meters will be capable of reading bypass full load and starting currents, as well as the drive current.

c Requirement of controls and indications required in the Local Control Station will be as specified in the data sheet.

I) Breaker/Contactor

a Type will be Vacuum type, restrike free, stored energy operated and with electrical anti-pumping features.

These will be electrically operated, mechanically latched type & will have protection against over load, all AC/DC transients and voltage surges etc.

Electronic control module will be electrically isolated from these power switching devices

a Temperature Rise

b Temperature rise of busbars will not exceed 55 deg. C for silver plated joints and 40 deg. C for other joints, over an ambient temperature of 50 deg. C under any condition.

c CT/PT/Meters

As required for the system offered & will be suitable for variable frequency operation.

J) Protection, Control, Metering, Indication and Annunciation

The Contractor will provide all the necessary system control, protection, alarm equipment and metering for the entire drive system and its auxiliary equipment.

Automatic sequence control will include start-up of cooling system, auxiliary system of the motor, interlock checking, automatic start and run-up of drive, planned and emergency shutdown. The same will be processed through microprocessor-based system.

K) Operator Control Panel

a Each drive will be equipped with a front mounted operator control panel consisting of a backlit alphanumeric display and a keypad with keys for parameterization and adjusting parameter which will not be limited to start/Stop, Local/Remote, auto/manual, Increase/Decrease, menu navigation and protection and measurement parameter selection, etc.

b All parameter names, fault messages, warnings and other information will be displayed in complete English words or standard English abbreviations to allow the user to understand what is being displayed without the use of a manual or cross-reference table. This will also be used for the modification of all electrical values, configuration parameters, drive menu parameters, application and activity function access, faults, local control, adjustment storage, self test and diagnostics. Keypad will be operable with password for changing the protection setting, safety interlock etc. However the parameters such as measurements, setting, mode of drive etc. will be allowed to be viewed without any password.

c Operator console will have facility /port to connect external hardware such as Lap-Top etc. Console will have facility for upload and download of all parameter settings from one drive to another identical drive for start up and operation.

d Drive system control will also have facility to receive tripping signal from up stream breaker for tripping and also provision for closing up stream breaker after all required process parameters are achieved.

e User-friendly software for operation and fault diagnostic will be loaded in the drive system panel before commissioning.

Suitable interface with DCS to be provided for control and status signals of VFD.

6 PROTECTIVE FEATURES

The system offered will incorporate adequate protective features, properly coordinated for the drive control and for motor but not limited to the following:

i. Incoming line surge protection
ii. Under / Over voltage protection
iii. Phase loss, phase reversal protection.
iv. Programmable Over current protection and under load protection.
v. Motor differential protection for motor rated above 1000 kW
vi. Inverter Fault.
vii. Over frequency operation.
viii. Ventilation loss,
ix. Over temperature of equipment.
x. Over speed of motor.
xi. Specific motor protection, including motor winding, bearing temperatures, over-current, overload, negative phase sequence, locked rotor and earth fault protections etc.

xii. System Earth fault protection.

xiii. Excitation system protection for synchronous motor

xiv. Over and under frequency, rotor earth fault, field failure protection for synchronous motor

xv. Additional protection for drive system

7 CONTROL

The following controls will be provided as a part of the Operator Control Panel or through separate switches.

i. Start/Stop

ii. Speed control (Raise/lower)

iii. Forward/Reverse(if Specified)

iv. Auto/Manual /test mode

v. Local/remote

vi. Emergency stop

vii. Start/stop for by pass starter (where specified)

viii. Trip-Remote Breaker

ix. Excitation control system for synchronous motors

x. Sequential switching of filters

8 INDICATIONS

Contractor will provide indications as required for normal operation and for easy maintenance, which shall not be limited to the following indications both at local and at plant DCS.

1. Motor running
2. Motor stopped
3. VFD System Fault
4. System ready to start
5. AC mains ON
6. Motor over speed
7. Rectifier output 'ON'
8. Motor zero speed
9. Remote breaker trip
10. Excitation system healthy for synchronous motors

Above indications may be provided as a part of the operator control panel, i.e., door mounted keypad or through hardwired indicating lamps/LEDS.

Potential free contacts of items i- iv will be wired separately for remote indications in DCS system.

9 METERING

Digital display of the following parameters shall be as a part of the Operator Control Panel, selectable by the operator.

a. Input AC voltage
b. Input AC frequency
c. Input AC Current
d. Output voltage
e. Output current VFD / Bypass
f. Output frequency
g. Motor thermal state
h. Drive thermal state
i. Motor speed
j. Motor energy meter
k. DC Link voltage
l. Hour Run
m. Voltage and current meter for excitation system for synchronous motor.
n. KVAR, power factor meter for synchronous motors
o. Necessary transducer shall be provided with 4-20mA output for indicating motor speed and motor current in DCS unless otherwise specified for other parameters.

10 AUDIO-VISUAL ANNUNCIATIONS

a. The system will incorporate audio-visual annunciations for protection, for various fault conditions, for the Drive motor, Supply cables, DC Reactor and the Converter, output transformer etc.

b. Alarms will also be included for the failure of various auxiliaries together with identification of the failing unit, loss of cooling system, various protection devices provided for converter transformer etc.

c. Audio-visual window annunciations will be provided on the front of the panel All annunciations as required for normal and satisfactorily operation of the drive system will be included as per Contractor standards. These annunciations can be part of operator console panel or separately mounted type.

d. Contractor will include audio-visual alarm as required for normal operation and maintenance of the system but not be limited to the following,

   i. Rectifier fuse failure
   ii. Main AC failure
   iii. Inverter fuse failure
   iv. Inverter overload
   v. Inverter high temperature
   vi. Cooling system failure

vii. Motor failed to start
viii. Transformer failure
ix. Excitation system failure for synchronous motor
x. Battery monitoring healthiness
xi. Communication and measurement system un healthy
xii. Motor temperature high
xiii. Harmonic filters monitoring

Common potential free contacts will be provided for above annunciations and these will be wired up to terminals of DCS I/O panels for remote alarm and monitoring.

11 FAULT DIAGNOSTIC

Fault diagnostic will be built into the system to supervise the operation and failure of the system. The information regarding failure of any of the system including shut down of the system will be available for a period of minimum 4 days (96 hours) after a shut down even though no supply would be available to the system. The system may be totally deenergized for maintenance or otherwise. It will be possible to retrieve the record of events prior to tripping of the system or de-energisation. Auxiliary supply to the system components or to the electronics (firmware) for the diagnostics / display will be taken care by the manufacturer for this purpose.

12 EXTERNAL POWER SUPPLY FOR AUXILIARY AND CONTROL CIRCUIT

Auxiliary power supply for devices external to VFD module, space heater supply for Motor, VFD panel space heater, auxiliary power supply for transformers, cubicle lamps (CFL) etc. will operate on 240 volts single phase AC.

All control circuit will operate at voltage of 110V AC or 220V DC.

Contractor will include supply of all control transformers, protective devices, required accessories etc. and any other control supply voltage as required for the system.

13 MAINTENANCE FEATURES

The controller design will incorporate the following maintenance features:

- Modular construction
- All components will be easily accessible.
- Standard diagnostics to aid maintenance personnel. These will include LED or alphanumeric displays, test or measurement points.

14 PAINTING

All metal surfaces will be thoroughly cleaned and de-greased to remove mill scale, rust, grease and dirt. Fabricated structures will be pickled and then

rinsed to remove any trace of acid. The under-surface will be prepared by applying a coat of phosphate paint and a coat of yellow zinc chromate primer. The under-surface will be made free from all imperfections before undertaking the finishing coat.

After preparation of the under surface, the panel will be provided with epoxy based powder coating. The color shade of the final paint will be as per manufacturer's standard, unless otherwise specified. Panel finish will be free from imperfections like pinholes, orange peels, runoff paint, etc.

All unpainted steel parts will be zinc passivated, cadmium plated or suitably treated to prevent rust and corrosion. If these parts are moving elements, then these will be greased.

Final paint shade will be light gray and dove gray 631 and 632 as per IS-5 for indoor and outdoor equipment respectively unless otherwise specified.

15 INSPECTION, TESTING AND ACCEPTANCE

During fabrication, the drive will be subject to inspection by Purchaser or his representative, to assess the progress of work, as well as to ascertain that only quality raw material is used.

All tests will be carried out at the manufacturer's works under his care and expense.

The routine test shall be conducted on all the drive system in presence of the purchaser or his representative. For the purpose of testing, drive system shall include input/output transformer

(where applicable), switchgears, converter, filters etc. The type test certificates for similar system and rating shall be furnished.

16 TESTS

The Routine and Type Tests to be performed on the drive system in the presence of the purchaser of consultant shall be as follows:

Routine tests

a) Visual Inspection

It involves checking of the various equipments/components fault diagnostic unit, Wiring, Terminals, earthing ratings etc. in line with the approved drawings and visual inspection shall not be limited to the following:

b) Insulation Test
c) Light Load and Functional Test
d) Load characteristics test
e) Load duty test
f) Checking of Auxiliary Devices
g) Checking the properties of the control equipment
h) Checking the Protective Devices
i) Checking of control and functional requirements
j) High voltage test

k) Leakage and pressure test for cooling water system where provided
l) Shaft current/bearing insulation
m) Automatic restart/re-acceleration

Type Tests

Test Certificates of similar panel conducted shall be furnished.

a) Allowable full load current versus speed
b) Efficiency
c) Temperature rise
d) EM Immunity
e) EM Emission
f) Current sharing
g) Voltage division
h) Line side current distortion content
i) Power factor
j) Audible noise
k) Torque pulsation
l) Motor vibration
m) Dynamic performance
n) Current limit and current loop test
o) Speed loop test capability to ride through voltage less than 80%
p) Test capability to restart the system and resynchronize converter onto running motor after a voltage interruption

Additional tests on switchgears and dry type transformers shall be carried out based on the requirement defined in the technical specification.

For Oil filled transformers, the routine tests will be conducted in presence of the purchaser or his representative. Type test certificates shall be furnished for similar type and rating of transformers. If certificates are not available, they have to be type tested, free of charge, to prove the design.

However, following type tests shall be performed on one of each rating of transformer, even if type test certificates are submitted by the Contractor for Purchaser's approval:

a) Impulse withstand test
b) Temperature rise test