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भारत सरकार
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**GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS**



**SPECIFICATION FOR THREE PHASE AC-AC
TRANSMISSION SYSTEM
&
ASSOCIATED CONTROL EQUIPMENT
FOR
1600 HP DIESEL ELECTRIC MULTIPLE UNIT**

**SPECIFICATION NO. MP. 0.24.00. 45 (Rev.- 03)
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SPECIFICATION FOR THREE PHASE AC-AC TRANSMISSION SYSTEM & ASSOCIATED CONTROL EQUIPMENT FOR 1600 HP DIESEL ELECTRIC MULTIPLE UNIT

0.0 Foreword

0.1 Diesel Electric Multiple Units are self-propelled units consisting of Driving Power Car and Trailer Cars. They have been developed to give faster service for sub-urban areas where traffic density is high. These have operational features of fast acceleration and fast braking enabling them to function as a stopping train while maintaining the average speeds of fast Mail/Express trains.

The main features of DEMU are as follows:

- Fast and frequent service.
- No need for reversals at the terminals as it can be driven from either end.
- High acceleration.
- Low capital and maintenance costs.
- Efficient use of rolling stock.
- Electro-pneumatic brakes

0.2 At present, Diesel Electric Multiple Units (DEMUs) are manufactured with AC-DC transmission system. Indian Railways has successfully introduced AC-AC technology on mainline 4000HP diesel-electric locomotives. A recent development has been introduction of 3-phase AC-AC technology on EMUs and a large number of AC-AC EMUs are in service in Mumbai suburban area. AC-AC transmission system provides improvement in reliability, haulage capability and maintenance. Considering the future trend and its advantages, it is proposed to manufacture 1600HP DEMUs based on 3-phase AC-AC technology.

0.3 This specification has been prepared for development of a proven and modern 3-phase AC-AC transmission system with microprocessor based controls for the Indian Railways 1600HP BG Diesel Electric Multiple Units.

0.4 AC-AC transmission system and allied microprocessor based controls shall be used with diesel engine and allied mechanical/electrical systems to manufacture 1600HP AC-AC BG DEMU.

0.5 The equipment shall incorporate features to ensure high availability of DEMU, low maintenance requirements, high reliability in operation and excellent transmission efficiency.

0.6 Easy access for inspection and maintenance requiring minimum attention shall be given special consideration in the design of the electrical equipment and the layout of DEMU.

- 0.7** The manufacturer is expected to provide all the items required for proper functioning of the equipment in accordance with the best current international practices, whether included in this specification or otherwise.
- 0.8** The specification has been prepared for general guidance of the manufacturer. Any deviation from specification intended to improve the performance, reliability and efficiency of the equipment as a whole or part thereof may be proposed for consideration. All such proposals shall, however, be accompanied with complete technical details and justification for proposed deviation.
- 0.9** Performance of 3-phase AC-AC DEMU shall largely depend upon design of traction inverter and microprocessor based control system. Therefore, it may be noted that irrespective of whatever has been stated in this specification, complete integration (electrical, mechanical as well as software controls) of the offered equipment with the other equipment fitted on the DEMU shall be sole responsibility of the successful tenderer. Successful tenderer shall provided required supervisory support for proper mounting, installation and shall be responsible for commissioning and satisfactory performance of DEMU in the field trials.
- 0.10** Offers from only those tenderers, who have developed and have experience in manufacture and integration of equipment for 3-phase AC/AC traction system shall be accepted. Therefore, tenderers must submit the evidence of successful track record of manufacture and integration of equipment for 3-phase AC/AC traction system along with the offer. Preferably, tenderer shall also submit detailed indigenization plan with the offer.
- 0.11** Tenderer shall have manufacturing, assembly and testing facilities for the equipment being offered for 3-phase AC/AC DEMU viz., Traction control converter, microprocessor based Vehicle Control System, traction machines, control equipment etc.
- 0.12** All the provisions contained in RDSO's ISO procedures laid down in Document No. QO-D-7.1-11 dated 19.07.2016 (titled "Vendor-Changes in approved status") and subsequent versions/amendments thereof, shall be binding and applicable on the successful vendor/vendors in the contracts floated by Railways to maintain quality of products supplied to Railways.

1.1 DEFINITIONS

- 1.1.1 'RDSO' means Research Designs and Standards Organization, Ministry of Railways, Manak Nagar, Lucknow-226 011.
- 1.1.2 'ICF' means Integral Coach Factory, Chennai-600038.
- 1.1.3 'BG' means 1676 mm gauge, referred to as Broad Gauge.
- 1.1.4 'IEC' means International Electro-technical Commission.
- 1.1.5 'IS' means Indian Standard.
- 1.1.6 'AAR' means Association of American Rail-roads.

- 1.1.7 'UIC' means Union International Des Chemins defer (International Union of Railways)
- 1.1.8 'IRS' means Indian Railway Standard.
- 1.1.9 'IR' means Indian Railways.
- 1.1.10 Throughout this specification the words:
- 1.1.11 Horse Power (HP) shall be taken as metric horse Power, i.e. 75 kg metre/sec.
- 1.1.12 Tonnes (T) shall be taken as metric ton i.e. 1000 kg.

2.0 SCOPE

2.1 Scope of supply of equipment for each unit shall be as under:

S.N.	Equipment Description	Qty. per DPC
1.	New generation diesel engine as per RDSO specification no. MP-0.08.00.102 (Rev. 01).	1 no.
2.	Traction Alternator to be directly coupled to diesel engine.	1 no.
3.	Base Rail arrangement with mounting brackets & bolts for mounting Engine and alternator.	1 set
4.	IGBT based traction converter system including power rectifier, DC link and associated controls (Hardware and software). The software for converter control system shall be compatible with that of Vehicle Control System	2 nos. or 4 nos. (as per configuration)
5.	Microprocessor based Vehicle Control System (Hardware and software) along with all control, protection and indication equipment required for proper functioning of the DEMU. This shall be compatible with other equipment on DEMU such as diesel engine, traction alternator, traction converter, etc.	1 no.
6.	Three-phase induction motors with gear wheel and gear case suitable for input supply from traction converter(s).	4 nos.
7.	Solid state Auxiliary Power Control (APC) for supplying auxiliary power for battery charging, controls, light, fan, electric driven compressor, ventilation fan, rectifier blower motor (if required) (please refer para 9.0) may be supplied. The APC shall draw power from Traction Alternator.	1 set
8.	Electrical motor driven compressor (Motor-compressor-air dryer module).The motor shall draw power from the APC (Auxiliary Power Control).The compressor shall be of a proven design and design shall be cleared by RDSO.	1 no.
9.	All the power contactors, MCB's, relays etc.	1 set
10.	Battery alongwith SS battery box: a. 24 V, 500/450 AH for engine starting b. 96V/110V supply of suitable 120AH capacity for controls	1 set 1 set
11.	Speed indicator gauge on the Driver Desk	1 set
12.	Driver Desk including all accessories and excluding EP Brake, parking brake, flasher light, head light, tail light and fire alerter.	1 set

13.	PC/Laptop based software tool for downloading the fault data packs, viewing and changing the user settable parameters along with user license.	1 no.
14.	Inter Vehicle Couplers alongwith end wall terminal panels for power, control & data communication with cable assembly. Inter Vehicle couplers required for DPC & TCs of one basic unit (1 DPC + 4 TC) are in the scope of tenderer. Inter Vehicle Coupler shall be user-friendly and generally confirm to ICF Spec. No. ICF/Elec/133 latest revision.	1 set
15	Driver cab FRP interior paneling.	1 set
16	Junction boxes, ducts and filters	1 set
17	Installation, testing and commissioning charges. Installation includes all the above items except item no – 9&10. Item no.9&10 will be installed by ICF.	(to be quoted)
	OPTIONAL:	
18	GPS based PAS/PIS system for one basic unit (1 DPC + 4 TC). (See details given in Para)	1 set
19	Close Circuit cameras (CCTV) in the Driver's cabin and Ladies compartment along with Digital Video Recorder. (One camera at Driver's cab & two in Ladies compartment)	1 set
20	All Power cables, control cables and special cables like Optic Fiber cables for one basic unit (1 DPC + 4 TC).	1 set
21	Fuel oil level sensor	1 set
22	Any other item not covered in the above breakup and scope of supply, but essentially required to buind up the rake	(to be quoted)

2.2 The Tenderer shall supply above items to ICF and fitment of these equipment along with testing and commissioning of the complete DEMU shall be done at ICF under the supervision of successful tenderer. Tenderer shall arrange for special instruments, tools etc. required for installation and commissioning of the DEMU which are not available at ICF.

OPTIONAL:

The contractor shall supply above items to ICF and fitment of the equipment and accessories along with testing and commissioning of the complete DEMU shall be done by the contractor. The contractor shall also supply hardware required for all the equipment, stainless steel air ducts required for traction motor, Traction inverter, auxiliary converter, vent fan and radiators, Fuel piping between fuel tank and engine, and any special instruments and tools required for installation and commissioning of the DEMU. Assistance for transport and loading of heavy equipments with electric/ pneumatic power connection will be arranged by ICF.

2.2.1 Requirement for PAS/ PIS System (S.No. 17 of Scope of Supply)

a) The Passenger Information System shall include a high resolution LCD display suitable for the remote displaying of moving messages in Hindi, Regional language & English on board the train, in the passenger area.

Hindi, Regional language and English messages shall be scrolled on the display simultaneously and in synchronism. The colour of Hindi, Regional language and English character shall be approved by ICF. Emergency announcements may be displayed in red. Two such display units per car shall be provided.

- b) The location of the display units shall be proposed by the Contractor taking into consideration the need for all-round good visibility by passengers within the saloon.
- c) The Contractor shall submit proposal, including diagrammatic representation of the angle of visibility of the display units.
- d) The passenger information system shall meet technical requirements of RDSO specification no. RDSO/PE/SPEC/EMU/0065(Rev03) in general.

2.2.2 Requirement for Cables (S. No. 19 of Scope of supply)

- a) All power and control cables shall be E-Beam type conforming to RDSO Spec. no. ELRS/SPEC/ELC/0019(latest). All data cables shall be confirming to CLW Spec. no. CLW/ES/3/0459(latest). RDSO approved sources for power and control cables and CLW approved sources for data cables shall only accepted. However, prior approval shall be obtained from ICF.
- b) All cables shall be supplied in pre-harnessed form as per harness chart issued by ICF which can be obtained after finalization of design with ICF. Pre-harnessed cables shall be supplied in proper packed condition before delivery to ICF. The packing condition shall be approved by ICF before commencement of supply.
- c) Terminal boards and MCBs required for termination of Train line cables on the end wall of all the coaches shall be supplied in pre-wired and assembled form. Terminal blocks and MCBs of ICF/RDSO approved makes shall only be accepted.

3.0 ENVIRONMENTAL CONDITIONS

- 3.1 The complete microprocessor based vehicle controls and inverter systems shall be required to work continuously at full load under following atmospheric conditions:

Maximum temperature (Atmospheric)	(i) 70 °C (under sun) (ii) 47 °C (in shade) (Temperature inside DEMU may reach 60 °C.)
Minimum temperature (Atmospheric)	-20 °C.
Humidity	90 % (Up to 100% during rainy season as per IEC 60721-3-5.
Altitude	Max. 1200 meter above mean sea level
Reference site conditions	(i) Ambient temp. 47 °C (ii) Temp. inside engine compartment 55 °C (iii) Altitude 160 m.

Annual rainfall	Between 1750 mm to 6250 mm. DEMU shall be designed to permit it's running at 5 Km/h in a flood water level of 102 mm above R.L.
Dust	Extremely dusty and desert terrain in certain areas. The dust content in air may reach as high a value as 1.6 mg / m ³ .
Atmospheric conditions in coastal areas in humidity salt laden and corrosive atmosphere	All the equipment shall be designed to work in coastal areas in humidity salt laden and corrosive atmosphere. (a) Maximum PH value : 8.5 (b) Sulphate: 7 mg / liter. (c) Max. concentration of chlorine: 6 mg/ litre (d)Max. conductivity: 130 micro siemens/cm

- 3.2** All the equipment shall be designed to withstand ambient conditions indicated above without any harmful effect even after sustained working at 100% load factor. Complete system shall be suitable for rugged service normally experienced for rolling stock where DEMUs are expected to run up to a maximum speed as indicated in para 4.0 in varying climatic conditions existing throughout India. All the equipment and their mounting arrangement shall be designed to withstand vibrations and shocks as specified in IEC-61287 and IEC-60571 for the inverters and electronic equipment respectively. Complete Vehicle control and inverter systems with their controls and gate drive electronics shall be protected from dusty environment by providing well-sealed enclosures. Necessary precaution should be taken against high degree of electromagnetic pollution anticipated in the DEMU. The cooling system shall be designed to take care of tilting and centrifugal forces which would normally be encountered in service.

4.0 OPERATING REQUIREMENTS (half worn wheels)

Maximum test speed	123 km/h	For unit: 1 DPC + 4 TC
Maximum operating speed	110 km/h	
Maximum Tractive effort at start	16 ton (from start till 20 kmph) or superior	
Installed power (standard)	1600 HP	
Power input to traction (at 47 °C site condition)	1450 HP (approx.)	
Speed Vs TE characteristic	Refer graph at annexure-I. The offered equipment should be capable of meeting this characteristic.	

The tractive effort Vs speed performance characteristic of the proposed 1600 HP DEMU is given at **annexure - I**.

- 4.1** The supplier shall state the value of maximum starting tractive effort, continuous tractive effort and continuous speed values that shall be developed under dry rail conditions and also under all weather conditions, which shall be demonstrated during testing. Supplier shall try to improve the performance beyond above stated values.

- 4.2 The tenderer shall clearly specify the minimum guaranteed reliability of the equipment in terms of km/failure.
- 4.3 The tenderer shall clearly specify the efficiency of various equipment and also the overall transmission efficiency.

4.1.0 ADHESION REQUIREMENTS

- 4.1.1 Microprocessor based control system shall be provided with state of the art adhesion improvement system. The system should be able to optimize the adhesion for all weather conditions - dry rail, wet rail conditions- and all track conditions - mainline, branch line and station yards- and operating conditions (starting, running, braking).
- 4.1.2 The torque pulsations of traction motors arising out of imperfections in waveform shall be controlled in such a manner that the coefficient of adhesion between wheel and rail is utilized fully in entire speed range of DEMU. The mechanical transmission shall be adequately designed to cater for loading imposed by torque fluctuations.
- 4.1.3 Tenderers are required to indicate the expected level of adhesion in various conditions. The proposed inverter and vehicle control system shall achieve far better adhesion performance compared to existing DEMUs which are based on AC/DC transmission system.

4.2.0 EMI REQUIREMENTS

- 4.2.1 The DEMU shall be working under 25 kV, 50 Hz, OHE system also. Electronic signals generated inside the traction inverters and vehicle control systems shall not be affected by this and DEMU shall work without any adverse performance.
- 4.2.2 The tracks over which the offered system shall work may be equipped with DC track circuits, 83-1/3 Hz track circuits as well as track circuits at higher frequencies. Harmonics generated by the inverter system should not affect signalling gears like audio frequency track circuits and axle counters which work in the range 0-5 kHz with a limit of 400 mA. On the communication network, control circuits, teleprinter circuits as well as VHF/UHF and microwave circuits are employed. The psophometric voltage induced on communication circuit running by the side of track should not exceed 1 mV.
- 4.2.3 The electric and electronic equipment used in the inverters and Vehicle Control System shall comply emission and immunity aspects of EMC to CENELEC standard EN-50121-3-2. The internal EMC shall cover a combination of earthing, shielding and isolation of interference sources so that conducted and radiated noises are properly segregated or suppressed and no other equipment is affected due to operation of inverter. The following interference current in the output current waveform shall not be exceeded at any point in the operating envelope of the DEMU:

Psophometric current \leq 5 A

100 Hz - 400 mA

1700 \pm 50 Hz - 300 mA

2000 \pm 50 Hz - 300 mA

2300 \pm 50 Hz - 300 mA

2600 \pm 50 Hz - 300 mA

5100 \pm 50 Hz - 100 mA

Emission from DEMU to outside world shall be limited to level specified under CENELEC standard 50121-2.

4.3.0 SPACE AND WEIGHT REQUIREMENTS

All the equipment offered shall fit within the space available in various sections of the DEMU. Layout drawings (RDSO drg. Nos. CG-K6004 and CG-K6014) of the proposed 1600 HP DEMU are enclosed at **annexures IV & V** respectively for guidance. The total weight of the AC-AC equipment offered shall preferably not exceed the weight of the existing AC-DC equipment. The break up of weight of various components/ equipment of the system shall be furnished by the tender.

5.0 ELECTRIC TRANSMISSION SYSTEM

- 5.1** The Power car shall be powered by fuel efficient diesel engine capable of producing approx 1600 HP at 1800 rpm under standard conditions. The engine shall be adjusted to deliver 1450 hp to the alternator under site conditions.
- 5.2** The rectified traction alternator output shall be fed to traction inverter(s) through a DC link. Traction inverter system shall be used to generate 3-phase variable voltage-variable frequency (VVVF) output to be fed to four 3-phase asynchronous traction motors connected in parallel. Inverter output voltage and frequency shall be matched to traction requirements over the entire speed range of the DEMU and shall be continuously regulated.
- 5.3** Solid state Auxiliary Power Control (APC) shall be provided to cater to battery charging, controls lighting, Electric motor driven Engine room ventilation fan and electric motor driven compressor requirements.
- 5.4** The 3-phase propulsion equipment should be offered such that alternator excitation and engine HP for idle and intermediate notches are so chosen that the engine is operated at the optimum SFC points.
- 5.5** All electrical equipment shall comply with relevant latest IEC/AAR/IEEE standards. Tropical humid weather conditions prevailing in India shall be kept in view in the design of all electrical components. The successful tenderer /supplier shall submit detailed information about traction machines and equipment used as per **annexure - II**.

6.0 TRACTION ALTERNATOR

- 6.1** A three phase synchronous alternator preferably with integrated brushless exciter and rotating diodes shall be offered. The traction alternator shall be of self-ventilated type.
- 6.2** The traction alternator shall be coupled with fuel efficient diesel engines capable of producing approx 1600 HP at 1800 rpm under standard conditions. The engine shall be adjusted to deliver 1450 hp to the alternator under site conditions.
- 6.3** The traction alternator offered shall be directly coupled with the engine. The mounting arrangement of the engine with alternator shall be decided mutually between engine manufacturer and tenderer. No any modification shall be carried out in the engine/engine block for the purpose of mounting the proposed traction alternator. If any modification is required for successful mounting of the proposed traction alternator, it should be carried out in traction alternator only. Any changes in the mounting design should be approved by RDSO.
- 6.4** The main terminal box shall be mounted at suitable location such that connection / disconnection can be made easily. The neutral connection shall preferably be available for ground fault detection, if required.
- 6.5** The alternator shall be designed for a high voltage low current operation such that the alternator voltage at rated engine output is sufficient for proper operation of the system.
- 6.6** The alternator efficiency with rated output shall not be less than 95%. The efficiency curve for the alternator over the entire speed range shall be furnished. The alternator shall be designed such that its output when rectified by a three-phase bridge rectifier does not result in a ripple factor more than 5%.
- 6.7** The weight of the Alternator should be approximately 3 tons.

7.0 TRACTION MOTOR

- 7.1** A suitable traction motor matching with the entire system shall be offered. The traction motor shall be of AC 3-phase squirrel cage asynchronous type. It should have a three phase stator winding suitable for voltage of wide frequency range from inverter.
- 7.2** The traction motor shall be self-ventilated type with axle hung nose suspension arrangement. The motor shall be fitted with roller suspension bearings.
- 7.3** Suitable arrangement for sensing of the motor temperature shall be provided to allow microprocessor based controls to sense and take required action to prevent motor failure.

- 7.4** The motor shall be designed so as to be capable of withstanding voltage fluctuations and other conditions caused by stalling and wheel slip under difficult operational conditions.
- 7.5** Extreme adverse environmental conditions as stated in clause 3.0 and vibrations due to average track conditions should be taken into consideration during the design of the motor.
- 7.6** The traction motor shall operate satisfactorily over the entire range of loading with ripple/harmonic currents imposed from the supply system (comprising of alternator, rectifier, inverter, etc.). The manufacturer shall conduct necessary tests on the traction motor to establish compliance with this requirement.
- 7.7** The traction motor shall be of a high voltage and low current design such that it is compact. The maximum voltage rating of the traction motor shall be commensurate with the alternator/inverter voltage rating.
- 7.8** The maximum working speed of traction motor corresponding to 110kmph with full worn wheel of 877mm diameter shall not exceed 3030 rpm. Traction motor speed should be as low as possible.
- 7.9** The motor efficiency at continuous rating shall not be less than 93%.
- 7.10** The weight of the traction motor should be approximately 2 tons.

7.11 Gear case

The gear case shall be of sturdy and lightweight construction and shall be adequately supported through the traction motor frame to prevent dropping down under the most severe vibration that may be generated due to adverse track conditions.

7.12 Traction Gears

Traction gears & pinion shall be of proven design and performance capability.

8.0 INSULATION SYSTEM FOR TRACTION MACHINES

- 8.1** The insulation scheme for Traction alternator and traction motor should be class 200 or above.
- 8.2** The machine shall be designed such that the 'hot spot' temperature under any condition of loading in stator winding does not exceed the average temperature of that winding (measured by resistance method) by more than 15 deg. C.
- 8.3** The manufacturer shall provide maximum possible margin in temperature rise for prolonged life of the traction machines after taking into consideration the system of insulation adopted and environmental conditions prevailing on Indian Railways.

9.0 AUXILIARY MACHINES DRIVE

Successful Tenderer shall offer auxiliary machine drive as follows:

- Solid state Auxiliary Power Control (APC) for supplying auxiliary power for battery charging, controls, light, fan, Electric driven Engine room ventilation fan , Electric Motor driven compressor and optionally rectifier blower motor, Radiator fan (if required) etc.
- The APC shall draw power from Traction Alternator.
- Adequate rating of APC shall be provided to supply DC auxiliary loads from other APC if one APC fails in a rake formation of 2 DPC's.

The vendor shall submit a suitable design of a proven electric compressor. The design shall be cleared by RDSO.

The Engine room radiator fan shall be hydrostatic drive/ electrically driven.

10.0 POWER RECTIFIER

10.1 The power rectifier shall be a 3-phase bridge using silicon diodes suitable for rectifying the 3-phase AC output of traction alternator throughout the range of operation of the alternator. More than one bridge units may be connected in parallel depending upon requirement.

10.2 Proposed rectifier shall have sufficient margin in continuous / short time ratings and surge withstanding capability. Also, it shall have adequate margin to withstand internal short circuits due to string failure condition and short circuit across DC link. Cooling air requirement for the rectifier shall be indicated by the tenderer in the offer.

10.3 The devices used in the rectifier assembly shall preferably be of a standard type of a reputed make such that, in case of urgency, the purchaser can interchange these devices with commercially available devices of another make.

10.4 The layout of components inside the rectifier assembly shall provide for easy accessibility and replacement of the failed components during maintenance without having to remove large number of other healthy components. Each component shall be clearly marked to indicate type, nomenclature and rating.

10.5 All the components such as diodes, heat sinks, fuses, micro switches, snubber capacitors/resistors etc. and their mounting arrangement shall be designed to withstand vibrations and shocks as specified in IEC-60571.

11.0 TRACTION INVERTER SYSTEM

11.0.1 Proposed traction inverter system may preferably have four inverters using one inverter individually for each motor. Alternatively, a configuration of two traction inverters may also be offered. In this case each traction inverter shall drive traction motors on one bogie. Input supply for all the traction inverters shall be the same DC link.

11.0.2 The basic control philosophy for the induction motor shall be such as to achieve best suited results for traction application like minimum device losses, high dynamic response, stable constant speed operation, fast acting slip/slide control etc. Direct Torque Control, Vector Control, Slip Frequency Control etc. are some of the popular control strategies used for traction drives. Vector control system is not used in the existing DEMUs. The tenderer shall furnish the details of control strategy duly describing its merits.

11.0.3 The software of the inverter control system shall be fully compatible with the Vehicle control software including closed loop propulsion control, slip slide control, exchange of temperature data, fault diagnosis etc. The inverter system should have its own protection and control logic, which it should also be able to communicate with the vehicle control software in the event of a fatal failure to initiate a protective shutdown of the DEMU. Damage to IGBT devices of the inverter shall be prevented in case of a short circuit at the load end.

11.0.4 Motor or bogie cut out facility shall be provided to isolate defective traction motor(s) in case of any fault. In case axle control philosophy is followed, each defective traction motor can be isolated individually. In the event of bogie control system and in case of inverter cut out, inverter control system shall be designed to automatically reduce DEMU power adequately so that remaining inverters and motors are not overloaded and the DEMU is able to reach up to destination with reduced power. DEMU power shall be reduced in proportion to the number of traction motors cut out at that time.

11.0.5 Inverter Protection System shall be used to protect the inverters from over voltage and over current conditions on supply as well as load side. Protection shall be achieved by turning OFF the traction alternator excitation by vehicle control system in case current or voltage exceeds a pre-set value. An alternative proven and reliable protection system may also be offered by the tenderers giving full justification of the offered scheme.

11.0.6 The proposed traction inverter system shall be capable of withstanding dielectric test voltages as per IEC-61287-1(for power circuit) and IEC-60571-1(for control circuit).

The traction inverter system shall be designed for following protection class:

- (a) For phase modules : IP20
- (b) For electronic compartments : IP54

The complete converter box shall be IP 65 complied (for the electronic portion).

11.0.7 The main power semiconductor device used for switching shall be Insulated Gate Bipolar Transistor (IGBT) with sufficient PIV rating. The IGBT module may contain external or internal protection circuits and gate drive circuits.

The complete system shall be designed as simple as possible with reduced number of components without compromising reliability and efficiency. The devices offered should be field proven. The detailed characteristics of the devices along with details of gate drive circuits and protection circuits used shall be furnished in the offer.

11.0.8 Suitable temperature sensors shall be provided so that temperature of phase modules / IGBT modules can be continuously monitored by the control system. In case of over temperature, traction motor torque should be gradually reduced to keep phase modules / IGBT modules at safe operating conditions. Additionally, IGBT modules should preferably be provided with a built-in self-protection function to avoid failure on over temperature, in case of failure of temperature sensor.

11.0.9 The proposed inverter system shall be modular in construction so as to facilitate ease of maintenance and replacement. In case of any fault, removal and replacement of phase modules should be easy. Tenderer shall confirm support for obsolescence of all semi conductor devices for a minimum period of 15 years.

11.0.10 Preferably forced air cooling shall be used for inverters. It is preferable that cooling requirement of complete inverter system be met by blowers that are located inside the inverter cabinet(s) itself. Alternative cooling method for the main inverter can be proposed by the tenderer and clearance shall be obtained from RDSO.

11.0.11 The weight of the Inverter & rectifier combined should be approx. 2 tons.

11.1 GENERAL POINTS FOR TRACTION INVERTER DESIGN

11.1.1 Inverter shall be of PWM type with high switching frequency to obtain near sinusoidal waveform and reduce current harmonics even in the lower speed region of traction motor. The harmonics of the output waveform of inverter shall be controlled to minimize the traction motor torque pulsations, traction motor heating and also to provide constant and high adhesion between wheel and rail throughout the operating speed range of the DEMU.

11.1.2 The components and technology used shall ensure very high efficiency of the inverter system. Typical efficiency of about 98% is preferred. Manufacturer shall furnish the expected efficiency with respect to DEMU load/speed.

11.1.3 For semi conductor devices a safety margin of 25% on the ratings for current and voltage under worst operating conditions shall be provided and established through calculations.

11.1.4 Inverter system shall be provided with following features to minimize possibility of trains being stalled on the section:

- (a) In case of axle unit system, one axle can be cut-out in the event of major faults with the inverter. Similarly in case of bogie control, traction motors of a bogie may be cut out in the event of an inverter fault. In either case, it must be ensured that journey is completed with defective equipment isolated.
- (b) Suitable margin shall be provided in the equipment rating such that under emergency conditions with isolation of single traction unit such as inverter, traction motor(s), etc., there is no necessity to reduce trailing load on level track and the journey can be completed at reduced speeds, if adhesion conditions are satisfactory. The one-hour ratings of the equipment shall not be exceeded under such operations. The successful tenderer/supplier shall submit short-time ratings of the major equipment.

11.1.5 Inverter electronics shall be TCN compatible. All communication interfaces should be TCN compatible as per IEC-61375-1 or alternatively Optical fiber CAN communication can be used. However, if it is not possible to design TCN compatible or optical fiber based CAN communication inverter control system having proper functional interface with vehicle control system, then the alternative communication interface offered shall be got approved. In this case, the tenderer shall submit details of the alternative protocol to RDSO for approval.

11.1.6 Features of data logging for monitoring fault conditions. Facility for interfacing PC / laptop for upload / download of data for fault diagnostics and further analysis shall be provided. A real time clock unit is to be provided along with the fault logs so that tripping time can be co-related with the operating conditions of the DEMU. The fault codes should be in text format which shall be comprehensible for the operating and maintenance personnel. Faults should be stored in permanent memory with a buffer battery. Minimum fault log size should be 50 faults with ring buffer. It should be possible to download the fault log using a lap top computer and interpret it through a separate common PC application such as MS EXCEL etc. Important parameters of the equipment at the time of occurrence of the fault should be recoverable for fault analysis and must include the following:

- a) Identification of the fault & its brief description in text and coded form.
- b) Identification of components and sub assemblies involved.
- c) Time and date of fault occurrence.

❖ The programme download must preferably be through an online connected PC platform without the need to remove the memory chips. A FLASH based program memory is preferred.

❖ Features to take corrective action in case of recognizable faults. The inverter system should have its own protection and control logic, which it should also be able to communicate with the loco control system in the event of a fatal failure to initiate a protective shutdown of the DEMU.

- ❖ The protective shutdown in case of defined fatal conditions shall be based on a predictable logic preferably implemented in the hardware of inverter electronics. Damage to IGBT devices of the inverter shall be prevented in case of a short circuit at the load end.

11.1.7 Proper shielding against electric and magnetic interference shall be provided. Cable length for gate drive timing signals transmitted from traction control system shall be kept minimum to minimize losses and prevent loss of data. Actual firing pulses shall be generated by gate drive units mounted in the phase modules. Proper electrical isolation for low voltage gate drive signals and high voltage gate drive power supplies shall be provided. Proper creepage distances between high and low voltage circuits as well as to the ground shall be maintained.

12.0 D.C. LINK

For smoothing the voltage ripple of the rectifier output and for supplying the reactive power for inverter switch-over and traction motor excitation, a capacitor bank of optimal value shall be provided keeping considerations of permissible ripple voltage in the intermediate circuit on one hand, and the space occupied and the current to be controlled in the event of a short circuit on the other.

13.0 VEHICLE CONTROL SYSTEM

13.0.1 All the digital input signals of Switches, Relay Contact Feedbacks, Contactor Feedback contacts, etc shall be electrically isolated before being given to the Vehicle Control Computer through a Digital Input Interface. All such Digital Input interfaces should be provided with reverse polarity and surge protection to prevent damage to the computer circuits against inadvertent wrong connection.

13.0.2 All driving output signals for the Relays, Contactors, Lamps, etc shall preferably be driven through a MOSFET based circuit of adequate rating. These outputs shall be electrically isolated from computer circuits and shall be provided with protection against short circuit and reverse polarity.

13.0.3 All the analog input signals that are received from the various Sensors e.g. Voltage, Current, Temperature, Pressure etc, shall be conditioned and electrically isolated with Isolation Amplifiers before being used by computer. Similarly all the analog outputs shall be electrically isolated from CPU and shall have short circuit protection.

13.0.4 An optical fiber based communication system to be provided between Vehicle Control Computer and Traction Inverter Control system. Dual redundant optical fiber communication link with adequate redundancy shall be provided to improve the reliability of the system.

13.0.5 The CPU shall consist of a 32 bit micro controller running at minimum 40MHz along with its programmed software, various peripheral and interface circuits e.g. Real Time Clock, Non Volatile Memory, etc. All other circuits that are meant for processing either input or output signals shall be controlled through commands from this card. The CPU shall continuously monitor all the inputs and control all the outputs of the system based on the software program. Provision shall be made to configure the control system through Laptop for using the system with different types of traction equipment/DEMUs, through user programmable parameters, loaded in Non Volatile Memory of CPU. The details shall be finalized in consultation with RDSO.

13.0.6 A removal type of non-volatile memory module shall be provided for storing the Event Data. This data shall be logged during running of the DEMU. This memory module shall be prevented from unauthorized access by a Lock and Key arrangement. The details of the data to be stored shall be finalized in consultation with RDSO.

13.1 GENERAL REQUIREMENTS OF CONTROL EQUIPMENT

- The system design shall be made modular in construction to the extent possible with provision of visual indications by means of LEDs for easy trouble shooting by maintenance staff.
- Various cards used in the design shall have polarized connections to prevent inadvertent insertion into wrong slot and possible damage resulting due to this.
- The system hardware design shall have provision to carry out self-diagnostics at Driver's Instruction and at Power ON.
- The Electronic components used shall be of Industrial Grade.
- It shall be preferable to have the entire control system hardware so optimized that, the component count is kept as low as possible, without sacrificing the overall system performance and reliability.
- Password protection shall be provided for configurable parameters.
- Voltage, Current, Temperature, Pressure, Speed, etc parameters shall be monitored through sensors of adequate rating. The sensors used in the system shall be provided, wherever necessary, with regulated power supplies.
- Sensors used in the system shall be based on the latest technology prevalent for the Rolling Stock application in the world.
- All electronic equipment shall be housed in dust proof enclosures either by providing the complete equipment in dust proof cabinets and/or pressuring the cabinets

13.2 FUNCTIONAL REQUIREMENTS

The major functions of the proposed Vehicle Control Computer shall be

- Propulsion Control,
- Excitation control of Main Alternator,

- Traction Control
- Wheel Slip Control,
- Control of Auxiliaries,
- On line Fault Diagnostics
- Speed recording
- Display of operating status, faults in the traction equipment/electronics.
- Communication with Traction Control computers

13.3 FAULT DIAGNOSTICS

The Vehicle Control System shall monitor the temperatures, pressures, currents, and voltages of various traction equipments and identify the faulty equipment. Whenever a fault is identified, the control system shall take appropriate action to restrict the operation of the DEMU depending upon the fault, and to save the other equipment from consequential damage. The system should preferably have a built-in feature to ensure that in case of failure of a component, DEMU operation, if feasible, is either not vitiated at all or downgraded only in such a manner that the DEMU is enabled to complete the trip safely. A set of data packs and an appropriate fault message shall be recorded in a nonvolatile memory. It shall be possible to download the faults through a Laptop PC by the maintenance shed staff. An application software shall be provided for use on Laptop PC. It shall be menu driven and easy to use by maintenance shed staff without any requirement for much computer literacy.

13.4 DISPLAY UNIT

All displays shall be on LCD TFT monitor not more than 10.4". There shall be two display screens on the control desk for use by the driver (one is for redundancy). Same displays can also be used as maintenance display which shall continuously display important data such as loco speed and tractive effort, MR pressure and BP pressure in analog gauge picture form whereas the other one (on the vehicle control microprocessor unit) also a digital display showing turbo, lube, fuel, load meter data etc. on recall through an alphanumeric keypad.

The display on the vehicle control microprocessor unit shall be MENU driven and shall be made user friendly. It shall display operational status of DEMU, fault messages and data packs, running totals etc. Any fault, Alarm condition, etc shall be shown on the display with suggested action, if any, and sounding of audio alarm for the benefit of the Driver. It shall be possible to conduct self tests on various equipments, by using a key pad to be provided on the display unit. It shall also be possible to conduct self load test on the engine and Traction Alternator through the keypad. The details of the various Display Screens, Text Messages, etc shall be finalized in consultation with RDSO.

13.5 USER SETTABLE PARAMETERS

For flexibility of operation and future upgrades in the traction equipment, it is desirable to provide user configurability for various control parameters like currents, voltages, horse powers, temperatures, pressures and speeds of the traction equipment. It shall be possible to configure these parameters through a laptop PC. A menu driven easy to use application software shall be provided for loading on the Laptop PC for this purpose. Password protection shall be provided to safeguard against misuse.

14.0 TORSIONAL VIBRATION ANALYSIS

14.1 After placement of order, the manufacturer shall furnish complete relevant data and dynamic system details pertaining to proposed traction alternator/auxiliary generator required for carrying out torsional vibration calculations. The manufacturer shall also furnish complete set of dimensional drawings required for the calculation of mass elastic data i.e. mass moment of inertia, stiffness of different shafting, etc. Material specification and the permissible vibratory stress values of different shaft sections of the proposed system shall also be indicated by the manufacturer. Dynamic system details of the diesel engine and other auxiliary attachment of DEMU shall be supplied by RDSO to the manufacturer to assist them in deciding the dynamic system details by some approximate analysis. The details indicated here shall be submitted by the manufacturer to RDSO, well in advance of the actual manufacture, for scrutiny and approval.

14.2 Verification of torsional matching of the equipment offered with other equipment shall be done by RDSO by carrying out detailed torsional vibration analysis.

14.3 The manufacturer shall be prepared to carry out modifications in the design of offered equipment if considered necessary from the torsional matching considerations.

15.0 DOCUMENTATION

15.1 Following documents shall be submitted by each tenderer along with the offer for evaluation:

- (a) Functional description of the complete system.
- (b) Clause by clause compliance with the specification.
- (c) Salient features and advantages of the offered system.
- (d) Details of technical support and training offered.

15.2 Following documents shall be submitted by the successful tenderer, before commissioning of the equipment on DEMU:

- (a) Technical documentation explaining complete system including characteristic curves, inverter output curves and efficiency, diagnostics, and protection circuits etc.
- (b) Vehicle Control System schematics.
- (c) Layout and mounting drawings of inverter controls, traction machines etc.
- (d) Drawings of each sub-system with interface details.
- (e) Technical data sheet of all the equipment offered (as per **annexure - II**)
- (f) Cooling system details.
- (g) Details of enclosures provided.
- (h) Details of lubricants.
- (i) Procedure for user settable parameter alteration, fault data downloading and analysis etc.
- (j) Maintenance and trouble shooting manual for all the equipment offered.
- (k) Recommended list of spares for 3 years.
- (l) List of special tools, jigs and fixtures needed for testing, commissioning, maintenance and repair.
- (m) Modifications needed in the existing DEMUs to adopt the offered system.

16.0 TESTING & INSPECTION

- 16.1** Type and routine tests of the individual equipment of AC traction system shall be conducted separately. Complete AC/AC system shall also be tested after its installation on DEMU.
- 16.2** In general, traction inverter shall be tested in accordance with IEC-61287 & control electronics of inverter and Vehicle Control System shall be tested as per IEC-60571 whereas traction alternator and traction motors shall be tested as per IEC-60349. Type and routine tests on other equipment shall generally be conducted in accordance with relevant IECs as mentioned at **annexure- III**. However, if the tenderer proposes a different test scheme, the same can be examined by RDSO on provision of alternative test procedures submitted by the tenderer.
- 16.3** The supplier shall submit detailed type and routine test programs to RDSO for approval. RDSO may also decide to carry out some tests on any one or all the equipment, which are not covered by relevant IEC specifications. Tests shall be carried out as per mutually agreed test program and the total cost shall be borne by the manufacturer.
- 16.4** The prototype of Alternator, Traction Motor, Inverter/Rectifier/TCC and vehicle control microprocessor shall be tested by RDSO representative(s) at the manufacturer's premises. All facilities for carrying out the prototype test should be made available by the firm. After successful type test and fitment on the DEMU, the equipment shall be kept for field trials for a period of three months.

- 16.5** All the modifications required due to defects noticed or design improvements found necessary as a result of the test / trial shall be carried out by the tenderer in the least possible time. Total cost of such modifications/design changes shall be borne by the manufacturer.
- 16.6** Type test shall be performed on one prototype unit of given design to verify that product meets the specified design requirements. However, routine tests shall be carried out on each equipment.
- 16.7** If mutually agreed between manufacturer and RDSO, witnessing of routine test may be waived for sets manufactured after the prototype. The routine test of equipment, for which witnessing has been waived, shall be accepted after successful scrutiny of test results submitted to RDSO.
- 16.8** Subject to agreement between RDSO and manufacturer, some or all the type tests shall be repeated on sample basis so as to confirm the quality of the product. This shall be part of revalidation of vendor approval. Type test may also be repeated in any of the following cases:
- Major modification of equipment, which is likely to affect its functionality or performance.
 - Failure or major performance variations established during type or routine testing.
 - Resumption of production after an interruption of more than two years.
- 16.9** To obtain additional information regarding performance and functionality of any equipment or sub-system, investigation tests may be specially requested by RDSO.

16.10 INSTRUMENTATION

- (a) All the instruments used for testing should be duly calibrated. The calibration certificates are to be shown to RDSO representative(s) on demand.
- (b) Value of the fundamental component and THD of traction inverter output shall be measured by power analyzer during the prototype test at various mutually decided pre-set points. True RMS value of output voltage is also to be measured for record.

17.0 WARRANTY

Complete system with controls shall be warranted for satisfactory and trouble free operation for a period of at least 24 months from the date of commissioning or 30 months from the date of supply whichever is earlier. All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement for rectification of failures reported under warranty.

Warranty period of any equipment of the system may be extended as per mutual agreement between RDSO and supplier if the equipment has undergone major design modifications during the warranty period.

18.0 FAILURES DURING WARRANTY PERIOD UNDER MAINTENANCE CONTRACT

- 18.1** In case of any failures, the details of failure and action taken to arrest re-occurrence of similar failure in future with failure analysis report etc. is to be submitted to RDSO.
- 18.2** In case of repeated failures, necessary changes in design on the units put in service or in production line are to be made by the manufacturer. Investigation tests, if considered necessary, are to be arranged/conducted by the manufacturer.

19.0 MARKING AND PACKING

- 19.1** Each equipment shall bear for identification ICF order number, batch/lot number, serial number, type, year of manufacture, manufacturer's name as well as important nominal and short time ratings.
- 19.2** All equipment of the complete system shall be suitably packed in strong water proof boxes to prevent any damage during transit and handling.

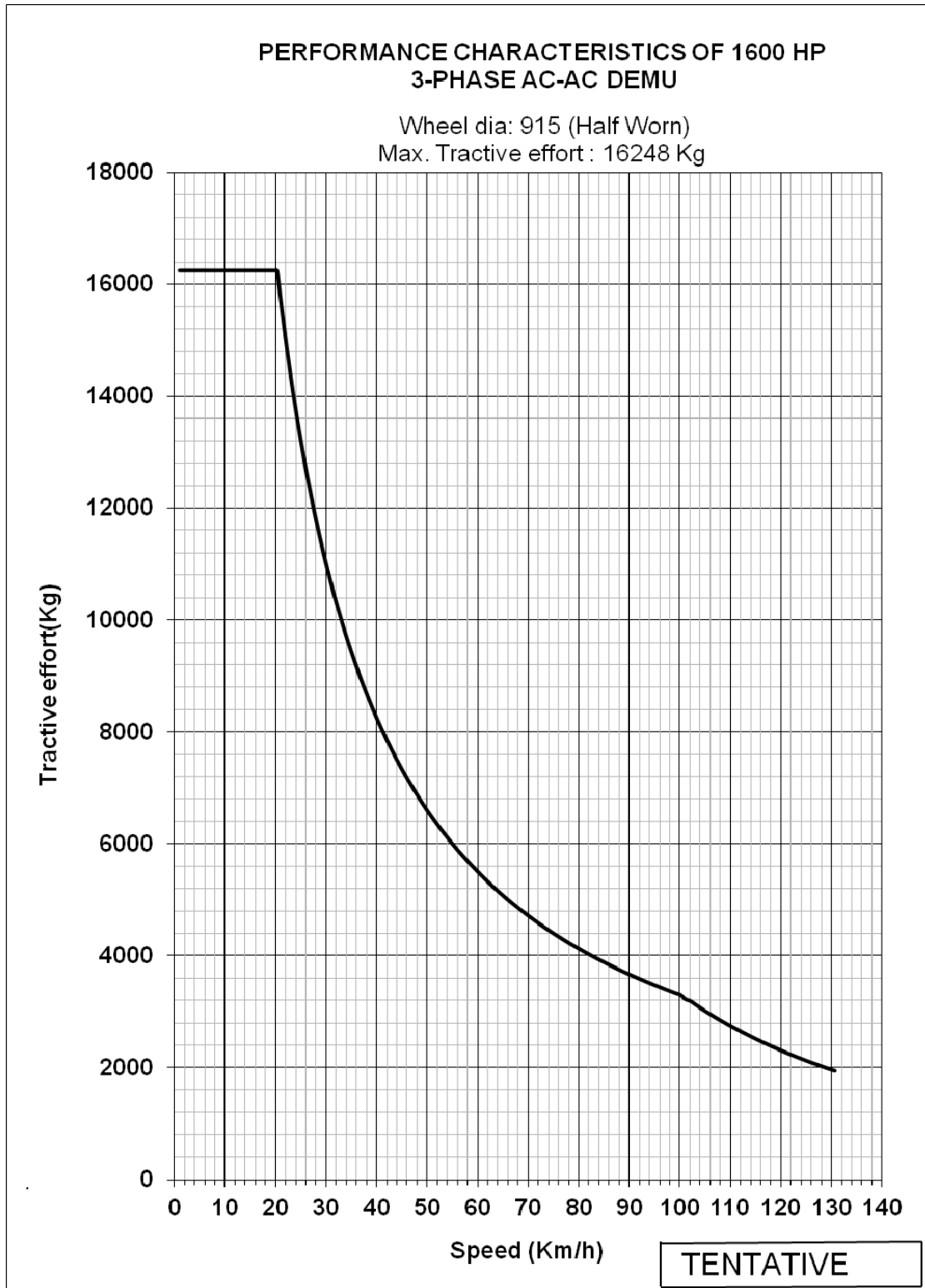
20.0 INFRINGEMENT OF PATENT RIGHTS

Indian Railway shall not be responsible for infringement of patent rights arising due to similarity in design, manufacturing process, components used in design, development and manufacturing of complete system and any other factor, which may cause such dispute. The responsibility to settle any issue lies with the manufacturer.

21.0 TRAINING

The successful tenderer shall arrange to train Indian Railways personnel at the premises of the manufacturer or premises of his sub-contractors in the field of design appreciation, quality control, inspection and maintenance of the equipment supplied for a cumulative period of around 40 man days against each order free of cost at the said premises. The to and fro fare and living expenses shall be borne by Indian Railways.

Annexure-I



Annexure - II

Following data/details pertaining to electrical equipment shall be submitted:

1. Alternator

Make and type, drive arrangement, one hour and continuous ratings, maximum design/test/service speeds, maximum output voltages at no load and full load, maximum output current, Characteristic curves, details and data of windings including method of impregnation and varnish used, estimated temperature rise, cooling arrangement, rating under natural cooling, details of insulation. Motorette test results, evaluation criteria and test programme, results of type and routine tests(if conducted), details of exciter and rectifier assembly, details of bearings including L10 life and lubrication scheme, mounting arrangement, fits and clearances adopted, overall dimensions and weight.

2. Traction Inverter

Make and type, number of inverter cubicles, nominal input voltage and current, continuous output rating, maximum phase to phase output voltage at nominal input voltage, nominal output current at nominal input current, maximum output frequency, arrangement and details of IGBT devices (Manufacturer's data sheet shall be furnished), declared duty cycle rating, thermal characteristics of devices and heat sinks, details of cooling requirements/arrangement, maximum operating junction temperature of devices under worst operating conditions, safety margin, evaluation criteria and type test programme, protection and indication scheme, overall dimensions and weight.

Technical details of DC link capacitors and any other filter/choke offered by the tenderer for fitment at the DC link .

3. Traction motor

Make and type, continuous rating, one hour rating and short time rating, design/test/service speeds, starting current and duration, current ratings for various operating voltages, gear ratio, traction motor characteristics under different voltage conditions, details and data of windings including method of impregnation and varnish used, estimated temperature rise in windings, bearings etc., cooling arrangement including ducting details, rating under natural cooling, details of insulation, design of the bearings including L10 life and lubrication scheme, details of data for motorette test, evaluation criteria and test programme, results of type and routine tests (if conducted), fits and clearances adopted, overall dimensions and weight of traction motor, detailed design features of suspension roller bearings(if provided).

4. Auxiliary Power Control (APC)

All relevant details as in case of main traction inverter. The auxiliary power requirement catered to by this inverter as well as the reserve available for use in future shall be clearly stated.

5. Auxiliary Drive for blowers

The technical details and controls/protection between AC supply to the terminals of the AC drive machines shall be submitted.

6. Master Controller

Make and type, rated current, making and braking current, position of reverser and throttle handle, details of cam and auxiliary interlocks, overall dimensions, weight, mechanical and electrical endurance test data.

7. Contactors

Make and type, rated voltage and current, making and braking capacity, number of auxiliary contacts with control circuit voltage, magnet valve and coil details, overall dimensions, weight, mechanical and electrical endurance test data.

8. Relays

Make and type, rated current and voltage, range of setting, rated control voltage, rating of contacts, details of material of the contacts, type of enclosure, temperature rise limit, indication system provided, overall dimensions, weight and mechanical and electrical endurance test data.

9. Microprocessor Controls

Make and type, details of traction alternator excitation controls, analog / binary inputs / outputs signals, vehicle bus, train bus interface, CPU details and power supplies for electronic systems. Details of interface with the traction inverter system and braking system. Details of protection and indication system. Details of adhesion control system. Overall dimension / weight and redundancy.

10. Traction Gears

Basic rack, number of teeth, module, pressure angle, helix angle (if any), profile displacement (x.m), center distance between mating gears, quality & accuracies of gear teeth and other related information.

Material specification, chemical composition and mechanical properties, forging ratio etc.

Heat treatment process adopted for hardening the gears i.e. case hardening / through hardening /induction hardening.

Hardness at tip, flank and root of the gear teeth. Case depth of case hardened gears and hardness distribution of cross section in case of induction hardened gears shall also be furnished.

Annexure - III

EQUIPMENT	TEST SPECIFICATION
1. Traction Motor	IEC - 60349 (Pt - 2)
2. Auxiliary machine	IEC - 34.1
3. Power inverter	IEC - 61287,
4. Power Rectifier	IEC - 60411,
5. Relays & Contactors	IEC - 60337, 60157, 60158, 77
6. Control cubicle	IEC - 68-2-14
7. Traction Alternator	IEC - 60349 (Pt - 1)
8. Control Electronics	IEC - 60571
9. Equipment Blowers	BS - 848
10. Electromagnetic Compatibility (Rolling Stock – Apparatus)	EN : 50121-3-2 (CENELEC)
11. Electromagnetic Compatibility (Emission of the whole railway system to the outside world)	EN : 50121-2 (CENELEC)
12. Train Communication Network	IEC-61375-1