

- 7.6.2 The construction of the door shall be such that it is able to resist without deformation or damage a load equivalent to that which could occur on a crush loaded train. The door shall be as light and rigid as possible.
- 7.6.3 The door leaf edges shall be such that when the doors are closed they form a weather tight seal extending the full height of the door.
- 7.6.4 Any seal shall not require regular cleaning. Seals and sensitive edges (if used) shall be effective under all operating conditions from tare to crush loading and particularly shall be resistant to atmospheric and chemical deterioration and to vandalism.
- 7.6.5 It shall be ensured that water does not enter/get trapped inside the door panels due to condensation or otherwise. The adhesives, if used, shall be type tested and certified for their performance under temperature cycles with 90% humidity & condensate.
- 7.7 **Platform Screen Door (PSD):**

It is intended to provide Platform Screen Doors (PSD) at all stations of line 2 & 7. These doors shall not be of full height and shall have provision to allow free flow of air for platform ventilation.

The train shall be fully compatible for PSDs functionality and shall be complete with any equipment/software (as per appendix TD), if required to be provided on rolling stock except for those which are necessarily required from PSD contractor. Any other issue shall be resolved during interface coordination meeting with the respective contractor(s) for trouble free commissioning and operation of the PSD(s).

7.8 **Passageway Sliding Door for 'First Class' Car:**

A suitably designed Passageway Sliding Door for 'First Class' Car shall be provided at one end of the 'First Class' Car to distinct it from other cars of the train. The clear door opening shall be approximately 1100mm wide.

The appearance, material and finish of the surface of the sliding door shall be same as the passenger saloon doors. The upper part of the sliding door shall be glazed with a single pane tinted safety glass.

It shall always be possible to open this sliding door from either side of the door. Under no condition this door shall be locked from either side of the door. However, suitable provision shall be made to lock this sliding door in fully open condition to ensure smooth passage of passengers in case of emergency condition. Details of design shall be discussed during design stage.

7.9 **Deliverables**

- 7.9.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	7.2.1 (xii)	Special tools for cleaning of the door guides.	At least four no. of special tools in each depot.
2.	7.2.1 (xvii)	DCU hardware/software operation & maintenance tool.	Two sets for each depot.
3.	7.2.7	Complete sets of maintenance devices and diagnostic tools (software/hardware) as per clause 7.2.7	Two sets for each depot.

Note:

- The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
- The cost of these deliverables is deemed to be included in the quoted price of contract.



8. HV AND PROPULSION EQUIPMENT

8.1 High Voltage and Propulsion Configuration

- 8.1.1 The High Voltage and Propulsion System shall be suitable for operation at 25kV AC single phase for the frequency variation from 48 to 52 Hz. The high voltage and propulsion system shall be configured such that it performs equally reliably for all consists, for all normal and abnormal duties defined herein.
- 8.1.2 All live parts on the roof including Bus bars, Joints, Terminals etc. shall be suitably insulated for 25kV AC Arrangements for insulation shall be finalized after approval from Engineer.
- 8.1.3 The Straight line distance from any live part on the roof, roof edge and platform shall be more than 3.5 meters and the clearances shall be in accordance with EN 50122-1.
- 8.1.4 All propulsion equipment shall be rated to ensure for operation of normally operating train for a further period of 2 hours or a round trip whichever is more with single unit in operation.
- 8.1.5 Complete map of spectrum of harmonics generated by the unit/train in traction and regeneration mode shall be submitted during design. The same shall be verified during system test and validated during line test. Harmonics emitted by the train and complete fleet operating in the system, including feed extended zone shall be compatible with the voltage distortion limits specified in IEC 61000-3-6 & IEEE 519-1992, 2014 and shall be validated as type test. All traction units shall be suitably interlaced to minimize the effect of harmonics in the power system. The overall harmonic voltage distortion levels viewed at pantograph shall not exceed 2% of the fundamental component under all modes of operation including regeneration with multiple number of trains in operation.
- 8.1.6 Contractor shall submit complete roof layout along with the clearance between roof equipment. This shall also include water drainage arrangement and insulation of exposed charged items.
- 8.1.7 It shall be possible to operate standalone single unit of 3 cars within depot.
- 8.1.8 Separate push button shall be provided on driver's desk to open line circuit breaker(s) in the event of extreme emergency by Train Operator.
- 8.1.9 It shall be possible to operate already working train for 2 hours or round trip, whichever is more, with one unit isolated in high tractive effort mode without exceeding the specified temperature limits.
- 8.1.10 Only one cut-out mode, low speed cut-out mode (25 kmph) shall be provided.
- 8.1.11 In the event of momentary jump in the line voltage due to unforeseen reasons, the line circuit breaker shall remain closed up to line voltage of 35kV for 2 second.
- 8.1.12 The stipulations of EN 50388 and IEC 62313 shall be complied. Further, the control system shall ensure that the train as an electrical system shall always behave as an inductive load with power factor near to unity (not leading) under all operating conditions of powering mode, braking mode and coasting mode at all loads. The Contractor shall include validation of same as a part of combined test bed and on mainline test.
- 8.1.12.1 Two trains on each line shall be instrumented with separate Power Quality measuring instruments, data acquisition systems and power analyser (with provision for permanent installation and necessary software/analysis tool) to measure, record and analyse the power quality. The measurement with these instruments shall include but not limited to Time, kW, kVAR, kVA, THD, TDD, Total pf and Displacement pf. The instruments supplied shall have the adequate capability of measuring and data acquisition to analyse higher order harmonics (up to 50th) and measure power quality parameters mentioned above with minimum accuracy of 0.1% and sampling rate of 100 kHz. Details of instruments shall be finalized during design stage.
- 8.1.12.2 Other trains shall also have necessary provisions (suitable space, wiring etc.) for installation and recording power quality parameters as per para 8.1.12.1 above.
- 8.1.12.3 If Contractor proposes to measure the power quality parameters as mentioned in para 8.1.12.1 above, through TCMS. In such case, TCMS shall have the adequate capability of measuring and data acquisition to analyse higher order harmonics (up to 50th) and measure power quality parameters mentioned above with minimum accuracy of 0.1% and sampling rate of 100 kHz. Also, a suitable power analyser, software/analysis tool shall be built in. However, this proposal shall be subjected to approval of the Engineer.
- 8.1.13 Design shall be suitable for 90 second headway.

- 8.1.14 The staggered closing of VCBs of trains shall be suitably ensured under both normal and extended feeding scenarios arising after power supply restoration to avoid tripping of VCB of substation due to high inrush current. Necessary command required for closing of VCB(s) from OCC shall be ensured as a part of interface design. Design shall be suitable for 90 sec headway.
- 8.1.15 Staggered acceleration of the trains within the same power supply feeding zone shall be suitably ensured under UTO operation for both normal and extended feeding scenarios arising due to power supply disruption or bunching of trains within the same feeding zone as a part of interface design for avoiding tripping of VCB of substation. Design shall be suitable for 90 sec headway.
- 8.1.16 In case of addition of one (T+M) unit (if required) the ratings of Propulsion equipment like Main Transformer, CI etc. shall be same as that of existing 6 car train.

8.2 HV Power Collection

- 8.2.1 Power shall be drawn from the OCS by pantographs.
- 8.2.2 The pantograph for the 25kV AC system shall be suitable for flexible auto-tensioned OCS consisting of catenary and contact wire as well as rigid catenary system provided in the tunnel section and shall be equipped with Auto-Dropping Device (ADD).
- 8.2.3 The pantograph shall be capable of sustained operation and satisfactory current collection from 150mm above the lockdown pantograph level up to the full range of contact wire height, and at all operating speeds as specified. The locked down height of the pantograph shall be limited to 4048 mm from the rail level.
- 8.2.4 A pantograph auto-drop function, which shall drop the pantograph automatically when excessive height is detected, shall be provided. An indication shall be provided to the Train Operator when this function has operated.
- 8.2.5 Pantograph controls shall be configured in the cab such that any one pantograph or all pantographs can be raised or lowered. Control of pantographs shall be available through hardwire and from TCMS.
- 8.2.6 Panto horns as well as panto strips shall be secured with Nord lock or equivalent suitable arrangement. The carbon strip shall be single piece carbon strip tested against EN 50405, glued with Epoxy phenol resin and arrangement for prevention of water ingress in support beam of carbon strip. V-type base support shall be provided as to ensure that strip remains fixed even if gluing ages.
- 8.2.7 The pan-head shall be designed with pure carbon strips with a view to achieve minimum dynamic mass. The Contractor shall furnish the expected frequency for replacement of strip in terms of kilometres earned by the car.
- 8.2.8 The width and profile of the pantograph shall be such that the Kinematic Envelope of the car is within specified limit in accordance with Appendix TE. Same panto shall be suitable for all sections i.e., tunnel, viaduct & ground. The contact wire, under the worst conditions of the sway on the Car and stagger shall be within the carbon strip portion of the pantograph. The Contractor to submit supporting calculations and wind tunnel test results during design review. The electrical clearance between the live portion of the pantograph and the roof shall not be less than 290mm. The minimum mechanical clearance from fixed structures at any time should not be less than 100mm. The straight line distance from panto horn live edge, roof and platform shall be more than 3.5 meters.
- 8.2.9 The pantograph shall be a single arm, direct air operated type with two strip pan-head arrangement and compliant to IEC 60494-2. The pantograph shall be of a proven design for both flexible and rigid catenary system. In case, the pantograph has not been used on both types of catenary, the supplier shall establish the suitability of the offered design on theoretical basis, which shall be validated by service trials. The pantograph shall be complete with air control equipment including air filter and pressure regulator. In case air is supplied to pantograph via an air-feed insulator. The creepage length of the insulators shall not be less than 900mm and shall be suitable for PD4 category and for unfavourable operating conditions of pollution (Ref EN50124).
- 8.2.10 Pneumatic pipe, other fittings and equipment provided on the pantograph frame shall be insulated from the frame to avoid any damage to pipes due to flow of fault current on account of earthing of the frame from any stray wire accidentally thrown by birds etc. on the roof. The insulation shall be suitable for 25kV AC system.
- 8.2.11 Incidences of stray wire being accidentally thrown by birds etc are quite frequent. With a view to



provide definite design solution, the Contractor shall examine various possible solutions and implement the chosen one on the trains, with due consultations with the Engineer. Base frame and roof bus bars/ equipment charged at 25 kV and exposed shall be suitably insulated for 25KV to ensure that direct earth fault does not occur between the base frame and car roof. Arrangement for insulation shall be got approved from the Engineer.

- 8.2.12 One set of on board Set up for monitoring, recording & analysing pantograph current collection performance shall be provided for each Depot. The cost of these setup shall be deemed to be included in the quoted price of the contract. Necessary training shall be provided to the Engineer.
- 8.2.13 The pneumatic connection for roof to the pantograph shall be through insulated air pipe suitable for the OHE voltages specified.
- 8.2.14 In case of entanglement of any pantograph with OHE, other pantographs of the same train shall be protected by Auto Dropping Device (ADD) feature in train. The system shall react immediately to lock down the other pantographs to avoid any physical damage to the system. It shall be demonstrated through the tests.
- 8.2.15 Deleted.
- 8.2.16 Contractor shall provide component manifold type control panel for pantograph.
- 8.2.17 Contractor shall provide at least one wayside measurement device in each depot for measurement of carbon strip width of pantograph and complete roof body inspection for any external agents (if any) during entry /exit point in the depot and details of equipment shall be finalized during design stage. The cost of these devices shall be deemed to be included in the quoted price of the contract.

8.3 25 kV Vacuum Circuit Breaker and Earthing Switch

- 8.3.1 A roof-mounted vacuum circuit breaker (VCB) of proven design shall be provided for the 25kV AC system vehicles, located close to the pantograph. The VCB shall be of the single bottle type having a short circuit rating of 400MVA, and conforming to IEC 60056, in conjunction with C3 category, type tested with 300,000 operations & IEC 60077-4. Protection class for the external portion and internal portion shall be IP 67 and IP 20 respectively. The creepage distance of the insulator shall not be less than 900mm for the highly polluted environment in accordance with IEC 815. The auxiliary contacts and control equipment shall be located beneath the base plate so as to be accessible from within the vehicle. The control cable shall be compliant to the requirements of EN 45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable to similar type of Metro operation in respect of fire, smoke, & toxicity characteristics. A 110 V DC connector of proven design shall be provided. The VCB base plate along with bottom cover shall be suitably protected to prevent corrosion in adverse environment of Mumbai the mounting plate of VCB shall be provided with a proper sealing to avoid ingress of water from roof. The past three year's record of proposed VCB shall establish NIL failure of vacuum tube and not more than two component failures in last three years. The VCB shall be suitable for repeated switching within short time comparable with the short (6m) neutral sections. Type test reports shall be submitted. Adequate Spare auxiliary interlocks duly cabled up to terminal block in the electrical cubicle shall be provided.
- 8.3.2 An Earthing Switch shall be provided, operable from inside the car, enabling each high voltage (HV) circuit to be earthed during maintenance. This switch shall be interlocked with the pantograph to prevent the pantograph being raised while the HV circuit is earthed and to prevent the HV circuit from being earthed while the pantograph is raised.
- 8.3.3 The Earthing Switch shall also be provided with a sturdy key lock proven for EMU metro applications. The key can only be removed after the Earthing Switch is in earth position and pantograph air supply is isolated. The Earthing Switch shall be hand operated from inside the vehicle. The exposed portion of switch shall be painted similar to VCB. This key shall be used to release multiple keys to open / close the covers of boxes of propulsion equipment for maintenance in accordance with the existing procedure. The Contractor shall submit for review and approval of the Engineer if any other alternative procedure is proposed, with due justifications.
- 8.3.4 Circuit breaker operation shall be recorded with time stamp and train location.
- 8.3.5 Design life of all the auxiliary switches of VCB shall be minimum 15 years. In case the Contractor propose the design life less than 15 years or the life obtained due to failures is less than 15 years, the Contractor shall supply/handover the quantities required for replacement before 15 years as free of cost to DMRC.

8.4 Lightning Arrestor

- 8.4.1 Gapless type lightning arrestors of proven design in accordance with specification IEC 60099-4 shall be provided on the roof. One LA shall be provided on incoming side after the pantograph and another LA shall be provided before the HT Transformer Bushing after the VCB, for protection against line voltage transients caused by lightning or system switching. The LA shall be rated for not less than 42kV with compatible rupture capacity. The failure of arrestor shall not be explosive in any case. No splintering etc. shall be permissible. This shall be included in the type test plan. The arrestor shall be exposed to line harmonics and line voltage/frequency fluctuations. Contractor is advised to take actual measurements before design. Frequency fluctuation of the order 47Hz to 54Hz may be considered as datum.

8.5 25 kV Potential Transformer (Explosion proof)

- 8.5.1 A 25 kV Explosion Proof Potential Transformer, duly type tested, to be mounted, on the roof, meeting the requirements of IEC 60044-2, for protection / measurement shall be supplied. Adequate protection shall be ensured to avoid secondary short circuit at PT output and effect of harmonics on the performance.
- 8.5.2 Deleted.
- 8.5.3 Accuracy class for measurement as per IEC 60044-2 shall be 0.5 or better.

8.6 AC Current Transformer

- 8.6.1 An AC Current Transformer, to be mounted along with 25 kV cable for protection and measurement, meeting the requirements of IEC-60044-1, shall be supplied.
- 8.6.2 Deleted.
- 8.6.3 Accuracy class for measurement as per IEC 60044-1 shall be 1 or better.

8.7 Main Transformer

- 8.7.1 The main transformer shall have a service life of at least 40 years, demonstrable through design calculations to the satisfaction of the Engineer.
- 8.7.2 The transformer shall be designed to conform to IEC 60310 and the temperature rise limits of windings and oil shall correspond to IEC 60310 limits minus 20°C.
- 8.7.3 The transformer shall be modular in construction, complete with oil pump, oil pump motor, radiator with blower, conservator and protection equipment all assembled as a single module. The Tank and conservator design shall be such that there is no possibility of any trapped air bubble in the tank.
- 8.7.4 The transformer shall be ester oil immersed to ensure the minimum acceptable standard for fire load. Force air cooling may be adopted, if required. The fire load of the transformer shall be furnished and ensure compliance with the specified fire load vide ERTS 2.19.3
- 8.7.5 The transformer shall be under-slung and the resilient mounting arrangement shall be described in detail by the Tenderer.
- 8.7.6 Measures shall be included to monitor for, and protect against, main transformer failure and leakage. The design shall minimize the fire load of the transformer.
- 8.7.7 The kVA rating of the transformer shall be designed to deliver the power to the continuous load as calculated with specified run cycle at ERTS 8.10.5. The overloading of transformer for typical run shall be specified and type tested. Short time Ratings (say 15 sec & 110 sec as the case may be) shall be submitted along with the justification.
- 8.7.8 Following protecting devices shall be necessarily provided:
- I. Thermometers with thermo-sensitive device to activate alarm contact, when oil temperature exceeds a pre-set value and trip command for temperature exceeding the max set value.
 - II. Oil flow relay to detect stopping of oil flow due to pump failure to trip the VCB.
 - III. Pressure relief valve to discharge abnormal pressure generated by gassing of oil with tripping of VCB and locking of transformer.
 - IV. Oil level gauge to monitor the oil level. Prismatic glass shall be used for oil level gauge. The gauge shall be mounted such that it can be easily seen from the side of the car. Alarm and trip command



- based on oil level, detected with Oil Level Detectors (OLD) shall be provided. Redundancy of OLD shall be provided if applicable.
- V. All sensors shall be so located that they are easily accessible for maintenance /replacements.
 - VI. All oil level sensors and relays shall be duplicated if applicable.
 - VII. Transformer bushings shall be provided with heat-detectors/LHD unit as per ERTS clause 2.20.
 - VIII. Heat detectors/LHD on low voltage/high voltage terminal boxes linked to TCMS/fire detection & control unit (refer ERTS clause 2.20) so that their status is monitored.
The above information shall also be logged in TCMS.
- 8.7.9 IP level of blower motor, pump motor and complete transformer including terminal box shall be IP65. Contractor shall declare the Vendors for Transformer's sub assemblies and shall submit an undertaking & commitment from Vendors to deal directly with Engineer in case of future procurement.
- 8.7.10 The provision shall be made to switch off and on the radiator blower fan with respect to temperature rise of the transformer.
- 8.7.11 All motors shall be dynamically balanced and shall have resilient four point mounting arrangement.
- 8.7.12 All gauges and sensors shall have easy access for monitoring and replacement.
- 8.7.13 Radiator filters shall be easily replaceable. Condition of the filters should be monitorable. Cleaning frequency of radiator filters shall not be less than a year.
- 8.7.14 Gaskets and sealants used shall be suitable and compatible for use with the transformer oil and high temperature. Test report and design life of gasket and sealants to be submitted.
- 8.7.15 Suitable oil filling equipment, complete with centrifuging, oil testing and other accessories shall be provided in each depot and cost of these accessories is deemed to be included in quoted cost.
- 8.7.16 Transformer cooling arrangement shall be designed to ensure completion of round trip (without loss of time) of already working train with only one radiator fan working.
- 8.7.17 In case of already working train, the non-working of radiator fans/ oil pump for at least 1 minute shall not affect transformer functionality and train performance in any way.
- 8.7.18 Maximum Transformer efficiency shall be achieved at AW2 load and Normal Mode as per IEC60310 and shall not be less than 97% at 22.5kV. The transformer efficiency shall also be validated in system test bed and line tests.
- 8.8 25kV Cable with HV Bushing and T-connector**
- 8.8.1 Copper cable of adequate voltage rating and diameter shall connect the vacuum circuit breaker to the main transformer. The cable shall be laid in a stainless steel pipe. The cable insulation and sheathing shall be halogen free, flame retardant, and having low smoke emission in compliance with EN 45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable to similar type of Metro operation. The details for roof end and the transformer end terminations shall be provided for the Engineer's review. The cable shall not have any straight through joint/ connector between HT bushing on the roof and transformer bushing in the transformer.
- 8.9 Power Converter – Inverter**
- 8.9.1 There shall be Two Converter and One Inverter in each motor Car feeding all the traction motors. However separate CI for each Bogie will also be acceptable. The power converter - inverter shall be a proven for metro application, four quadrant IGBT based unit, with VVVF control. The equipment shall conform to IEC 61287-1. Natural or forced air/water cooling shall be adopted. However, if forced air/water cooling is offered complete details of the arrangement including the method of dust filtration shall be furnished.
- During design of cooling system, it shall be noted that Mumbai's ambient conditions are heavily dusty with abrasive dust, high humidity and environment pollutants. The cooling system, natural/forced air shall ensure that the devices/components/electronics is completely sealed against intrusion of dust/water. IP65 level of protection shall be ensured. The sealing arrangement shall be such that this protection level is ensured after normal maintenance and replacements of components. Gasket shall have minimum life of 12 years.

- 8.9.2 The system shall be designed to minimize switching losses, switching noise, and weight, and improve heat dissipation.
- 8.9.3 The current rating of the semiconductor shall be such that the junction temperature has the minimum thermal margin of 10°C in the worst loading conditions taking into account the extreme ambient conditions in Mumbai and surrounding. Contractor shall consider the temperature rise of the air in vicinity of the equipment on account of different factors including proximity impact in the underframe, difference in wheel diameter of the bogie(s) and rescue operation etc.
- 8.9.4 The converter/inverter (CI) system and transformer shall be capable of withstanding the maximum short circuit under fault conditions. Short circuit protection of IGBTs shall be implemented.
- 8.9.5 The continuous rating (not thermal rating) of the converter shall be based on the continuous rating of the traction motor and inverters after accounting for the efficiency and power factor of the traction motor.
- 8.9.6 The converters in a train shall be controlled such that the harmonic currents in the track in the CBTC/ATP frequency range shall be below the specified level by Signalling Contractor under the worst conditions. The Contractor shall interface with signalling and train control contractors for limiting values of the return current in track in CBTC/ATP frequency range. The frequency details shall be as specified by the Signalling contractor (Appendix TD).
- 8.9.7 The power converter - inverter shall be designed to cater the pantograph-bouncing phenomenon. Adequate compensation using suitable rating of DC link Capacitor shall be provided for the pantograph bounce time or short time line interruption cases. Contractor shall submit the design calculations.
- 8.9.8 The box for the power converter - inverter shall be of stainless steel/Anodized Aluminium so as to avoid any corrosion in service on any account and the box shall last for the lifetime of the converter / inverter unit without needing any attention. The IP protection level of Converter box and that of aux. converter shall not be less than IP65. The connectors shall have IP67 protection. The cooling arrangement shall ensure no dust deposition on the component and associated electronics. The box cover which may have to be removed for maintenance shall be suitable secured against falling. Hinged opening cover arrangement shall be preferred.
- 8.9.9 Following special modes of operation shall be provided using VDU interface of TCMS:
- I. Low speed control to operate the train during train washing.
 - II. Low speed & low acceleration (settable parameters) during shunting operations
 - III. High Tractive Effort mode which may be used during MC isolation or rescue operation.
- 8.9.10 Slip/slide control during powering and electrical braking may be provided using speed sensor less vector control subject to its provenness in Mass Transits. Uncontrolled slip/slide should be clearly recorded in TCMS as critical fault.
- In case of excessive slip of wheels during acceleration, suitable speed regulation/restriction of 40 kmph shall be imposed up to the next station and it shall also pop-up as a fault in TCMS.
- 8.9.11 The Contractor shall submit quality specification of the regenerated energy including its harmonic analysis. The same shall be commensurate with the latest trends in metro transit systems and shall be in compliance with an accepted international standard as per ERTS 8.1.5. Interlacing of traction units within the train and the fleet shall be implemented to minimize the overall effect on the power system. Contractor shall submit detail document on the interlacing strategy and harmonic reduction measures during design stage.
- 8.9.12 Protection and diagnostics:
- I. Control circuit logic shall permit testing/monitoring, operation and fault simulation of the power converter-inverter. Appropriate test equipment shall be supplied.
 - II. The power converter-inverter shall carry out self-tests to ensure the integrity of the equipment. Sufficiently detailed status, fault and diagnostic information shall be transmitted to TCMS, to enable protective or corrective action to be taken immediately, when necessary.
 - III. The power converter-inverter shall use a control scheme that contains extensive self-diagnostic logic, which shall be fully integrated with TCMS. At a minimum, the diagnostics system shall identify a range of credible faults, identify whether a Least Replaceable Unit (LRU) is responsible for the fault, and whether the LRUs (or non-LRUs) must be replaced or the system merely reset. The diagnostics system memory shall be retained when the train is powered down.
 - IV. The train operator from the cab shall be able to isolate any power converter / inverter.



- V. Current drawn by each motor shall be measured and recorded.
- VI. Redundant Temperature/Heat sensor/LHD location shall be in proximity of IGBTs and shall be linked to TCMS/Fire Detection & Control Unit (refer ERTS clause 2.20) so that their status is monitored.
- VII. The auxiliary contacts of the contactors used in the converter-inverter and aux/. Converter shall be paralleled and shall be 100% redundant.
- VIII. Protection scheme for propulsion system shall include but not limited to:
- 1) Primary Circuit
 - Over Current of Primary Circuit
 - Interphase short in secondary circuit
 - Interruption of catenary circuit
 - 2) Main Transformer
 - Oil Flow Stop
 - Over Temperature of Main Transformer
 - Pressure Relief Valve
 - 3) Converter/Inverter
 - Over Voltage of Primary Circuit
 - Low Voltage of Primary Circuit
 - Frequency Irregular
 - Waveform Irregular
 - Over Temperature of Power Unit
 - Over current of Secondary Circuit
 - Ground Fault
 - Low Voltage of DC Circuit
 - Over Voltage of DC Circuit
 - OVT Failure
 - Wheel Slip / slide
 - Tractive Effort Failure
 - Regenerative Effort Failure
 - PWM Failure
 - Rotation Backward Detection
 - CPU Fault
 - Low Voltage of Control Power Source
 - Low Voltage of Gate Power Source
 - Low Voltage of DC 110 V Power Source
 - Calculated Speed Fault
 - Over current of Main Motor
 - Phase unbalance of motor current
 - Over Temperature of Main Motor
 - Traction Motor Current Unbalance in 4 motors
 - Fan Fault
 - Fault of Charging Circuit

The settings and calculations of above mentioned protections shall be discussed during Pre – Final Design Stage.

- 8.9.13 Not Used.
- 8.9.14 Facility shall be available to monitor the events on-line on a maintenance terminal. It should be possible to select the events, required to be monitored. All faults must have environmental data of pre and post initiation of the fault At least Two Maintenance terminals shall be provided as free supply item for each depot.
- 8.9.15 Separate CTs shall be provided for each inverter for measurement and protection functions.
- 8.9.16 Employer intends to maintain (both preventive and breakdown) the CI and other equipment in-house. All necessary tools, jigs/fixtures/hardware& software/test bench etc shall be provided by the Contractor.
- 8.9.17 The propulsion equipment shall ensure the guaranteed performance for wheel diameter differences

for at least up to 4 mm within any bogie without any adverse effect on any equipment. If the wheel diameter tolerances exceed the above limit, there shall be no damage to any equipment.

- 8.9.18 Power system fluctuations within the specified voltage range or feed extensions shall not cause propulsion system shutdown leading to jerks in the train. Adequate capacity shall be built in the DC link and control parameters shall be selected and fine tuned suitably so that in no case, system stability is adversely affected. The design shall permit to operate trains at 90 seconds headway with normal feeding zone of 15km and extended feeding zone of not less than 30km without any restriction. Contractor shall hire a reputed Power system analysis Design Consultant with the approval of Engineer and provision shall be made for arranging minimum three presentations by Consultant to Engineer.

Based on the operational requirements as above, Contractor shall furnish detail report on the minimum sub-station capacity required for adequate harmony with the all out mode operation of trains within the feeding zone, low frequency control stability to ensure no operational or reliability issue even if the specified headway and large number of trains in the same feeding zone, number of trains parked on the end depot with extended feed and resonance stability of the complete system.

- 8.9.19 The component cooling system shall be designed to ensure the control electronics temperature inside Converter-inverter/ auxiliary converter-inverter never exceeds 70°C under specified conditions after due consideration of proximity effect. The Contractor shall note that the air intake temperature for cooling can be appreciably higher than outside ambient temperature. The type measurements shall be normalized for maximum specified temperature.
- 8.9.20 For maintenance purpose, there shall be additional by pass ground switch in CI box duly interlocked with safety locks. Contractor shall submit the detail document for Engineer's review during design stage.
- 8.9.21 LED based lighting arrangement shall be provided in the CI box for maintenance purpose. Its fail safe interlocking with the box cover shall be ensured. Contractor shall submit the detail document for Engineer's review during design stage.

8.10 AC Traction Motor

- 8.10.1 Three phase asynchronous traction motors, suitable for the proposed converter/inverter operation shall be offered. The motor shall have adequate built in margin to cater to the environmental conditions given in the specification. The motor shall be designed to suit ripples and harmonics from the inverter and shall have a high degree of reliability in service during motoring as well as regeneration.
- 8.10.2 The traction motor shall be self ventilated and shall comply with the requirements of IEC60349-2- 'Electronic converter – fed alternating current motors'. An effective and efficient filtration system shall be provided to remove dirt and water from the self-ventilated traction motor cooling air. The air inlet openings shall include a protective screen designed in such a way as to preclude the accumulation of leaves and debris. If installed, filters shall require cleaning no more frequent than once every two weeks. Any sensor(s) if used shall be easily accessible for replacement and shall not necessitate removal of motor / its dis-assembly. Speed sensors if used shall not generally be placed on the gear case.
- 8.10.3 Evaluation of the insulation system for sealing against moisture shall be made in accordance with IEEE 429. The insulation system shall be evaluated for thermal endurance in accordance with the requirements of IEC 60505 (1975), its draft supplement and IEEE 304.
- 8.10.4 Various ageing parameters viz., thermal and electrical stresses, ambient temperature, humidity, dust and mechanical stresses, vibration etc., should be used in the evaluation and the temperature index of the insulation system corresponding to an extrapolated life of 20000 hours shall be established.
- 8.10.5 Traction motor design shall be based on following premises:

The RMS current of Traction Motor shall be calculated for all out run in the specified sections without stoppage (dwell) time.

The temperature rise limit for the stator winding shall be the maximum temperature index of the insulation minus 70°C and as indicated in clause 8.10.4 above under all operational conditions defined in Chapter 3.

The temperature rise shall be verified in system type test bed and the lines (as available) with 25% ventilation blocked. Contractor shall consider the temperature rise on account of different factors



- including proximity impact (not less than 10°C) in the underframe and specified wheel diameter difference in the bogie(s) as indicated in clause 8.9.17 above. The type test procedure and validation of temperature rise is described in Chapter 15.
- 8.10.6 The traction motor shall be suitably rated to meet the most severe service requirements as specified in design parameter Clauses 3.22.7 and 3.22.8.
- 8.10.7 The motor bearing maintenance inspection interval (excluding lubrication if required) shall exceed 1.2 million kilometres and the insulated bearing shall have a design life of minimum 2.1 million kilometres. Lubrication of motor and gearbox bearings shall be accessible without the need of equipment removal. Calculations supporting the choice of bearings shall be submitted for review. Minimum four traction motors shall be fully wired on four different trains (one Traction Motor on each train) fully equipped with data logger for data recording and sensors/thermocouples. The data loggers shall be able to record temperatures and vibrations at various points of traction motor at different speeds. The detailed locations of sensors in traction motors shall be as per the test bed scheme which shall be finalised during design stage.
- 8.10.8 The motor shall be mounted on the bogie frame via flexible coupling and gear unit, which shall be totally enclosed and free from lubricant leakage.
- 8.10.9 The grease used for the traction motor bearings shall be selected so as to ensure the expected maintenance interval considering the maximum temperature estimated to be reached in the bearings, under the worst conditions. It should be possible to replenish the grease periodically in situ and overflow arrangement should be provided to avoid the possibility of the over greasing.
- 8.10.10 The traction motors shall be designed for a life of thirty five years with no need for major overhaul before 1,000,000 kms.
- 8.10.11 The traction motor shall be connected to the single stage/double stage gear unit through a flexible coupling. The coupling design and the motor to gear unit mounting arrangement shall minimize coupling dynamic angular displacement. The motor shall be dynamic balanced. The gaskets shall be of suitable material, compatible for use with gear case oil and service life shall be more than 1,000,000 kms.
- 8.10.12 Each traction motor shall be provided with redundant thermistor for determination of temperature of stator winding. It should be possible to replace the thermistors in the depot without lifting the car. Traction motor terminal boxes shall be provided with heat-detectors/LHD linked to TCMS/fire detection & control unit (refer ERTS clause 2.20) so that their status is monitored.
- 8.10.13 Filters shall be of adequate size and cleaning interval of the motor shall be more than 6 months of train service. Cleaning of the filters shall be simple and Contractor shall suggest necessary equipment required for cleaning of filters and sanitization against fungal growth etc. Contractor shall provide minimum two sets of filter's cleaning equipment in each depot. Contractor shall also provide at least two no. of suitable equipment in each depot with provision of camera to determine the blockage in air cooling path for cleaning of filters. The cost of these equipment shall be deemed to be included in the quoted price of the contract.
- 8.10.14 Special attachment required for cleaning of air duct holes in the core shall be supplied for each depot. Cleaning frequency shall be more than one year and it shall be possible to undertake cleaning in-situ.
- 8.10.15 Motors shall be provided with noise mufflers or take alternative measures for minimising noise emission from motor.
- 8.10.16 In-situ traction motor cleaning arrangement/fixture capable of sucking dust from rotor and stator shall be provided to each depot. Additionally, cleaning arrangement for disassembled traction motor during major overhaul shall also be provided to each Depot.
- 8.10.17 In the event of train getting immobilised on line due to mechanical problems like bearing seizure, gearbox or axle defect etc., suitable arrangement shall be provided like wheel skate or similar device to quickly and safely transfer the train to the Depot. Suitable jacking points shall be provided beneath the axle boxes for enabling the placement of wheel skate. At least one such equipment shall be provided in each Depot.
- 8.10.18 AC traction motors shall comply with the requirements of Relevant standards i.e. IEC 60349-1, 60349-2, IEC 60349-3. Information on all the characteristics of the AC traction motor as stated in IEC 60349-2 shall be provided.
- 8.10.19 Any inspection covers provided shall be robust and designed for quick and easy removal /replacement and have secondary retention to prevent dropping. Inspection openings shall be as large as possible to facilitate inspection and maintenance.

- 8.10.20 The gearbox design shall give due consideration to minimizing weight.
- 8.10.21 The coupling of the gearbox shall accommodate all relative movements between the motor and the gearbox, including that caused by a free standing bogie, without damage to coupling.
- 8.10.22 The design of the motor installation shall permit the motor to be removed from, and refitted to, the bogie from above, without any need to disturb the axle and any bogie mounted equipment.
- 8.10.23 Where cables pass through holes in the traction motor frame, oil resistant resilient bushes suitably clamped shall be provided to prevent chafing of cables and to seal against the ingress of oil and water. The cables shall have sufficient freedom of movement to prevent stressing or fouling of other equipment during the full envelope movement of the bogie
- 8.10.24 There shall not be any permanent flying lead attached to the motor. All connections to the motor shall be bolted, torque tightened and marked.
- 8.10.25 Traction motors shall be fully interchangeable. All components requiring periodic replacement, whether mechanical or electrical, shall be fully interchangeable unless approved by the Engineer

8.11 Neutral Section Detection

- 8.11.1 A suitable arrangement shall be made to switch off the VCB automatically before a neutral section, resulting in the traction control equipment switching OFF without train operator's intervention. The VCB shall automatically re-close after the neutral section within bare minimum time, causing traction control equipment to switch ON again in the same operating mode, as before the switching OFF operation, without Train Operator's intervention. The sequence of VCB closure shall be such that not more than one unit is affected. Sequential opening and closing of VCB shall be ensured to minimize the power loss. Back up operation (both open and close) of VCBs of each unit shall be affected based on distance from the previous station.
- 8.11.2 The control logic for the neutral section detection shall ensure that the power demand smoothly reduces on approach to overhead line neutral sections and smoothly increases the power demand immediately after the neutral section under both normal and backup operation. Power ramping characteristics shall be submitted for review by the Engineer, and shall be validated by test.
- 8.11.3 Adequate redundancy shall be built in so that no single point failure can cause disruption. The status as well as failures of vital components shall be logged by TCMS.
- 8.11.4 There shall be complete TCMS backup arrangement for opening and closing of VCB before and after the neutral section meeting this functionality as stipulated in 8.11. Location of neutral section shall be made as an adjustable parameter in the TCMS Neutral section logic which could be edited by maintenance personnel. Contractor shall provide training to maintenance personnel in this regard.
- 8.11.5 Deleted.
- 8.11.6 In order to ensure VCB opening, distance based system for its operation during entry and exit of Neutral section shall be provided.
- 8.11.7 Signalling system shall provide a signal for operation on neutral section. Scope of provision would fall under the purview of Interface document Appendix TD.



8.12 Deliverables

8.12.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S. No.	Clause No.	Tools/Equipment/Software	Quantity
1.	8.2.12	On board setup for monitoring, recording & analysing pantograph current collection performance.	One set for each depot.
2.	8.2.17	Wayside measurement device for measurement of carbon strip width of pantograph and complete roof body inspection for any external agents (if any) during entry /exit point in the depot.	One set at nominated depot.
3.	8.7.15	Suitable oil filling equipment, complete with centrifuging, oil testing and other accessories for main transformer.	In each depot.
4.	8.9.12(i)	Test equipment as per clause 8.9.12(i).	One set at each depot.
5.	8.9.14	Facility to monitor the events of propulsion system on-line on a maintenance terminal.	At least Two maintenance terminal for each depot.
6.	8.9.16	All necessary tools, jigs/fixtures/hardware & software/test bench required for in-house maintenance (both preventive and breakdown) of the CI and other equipment.	One set at each depot.
7.	8.10.13	Filter cleaning equipment for traction motor. Suitable equipment with provision of camera to determine the blockage in air cooling path for cleaning of filters.	Minimum two sets of in each depot.
8.	8.10.14	Special attachment required for cleaning of air duct holes in the core.	In each depot.
9.	8.10.16	In-situ Traction motor cleaning arrangement/fixture as per clause 8.10.16	In each depot.
10.	8.10.17	Suitable arrangement like wheel skate or similar device to quickly and safely transfer the train to the Depot.	At least one such equipment in each depot.

Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

9. AUXILIARY SUPPLY EQUIPMENT

9.1 Auxiliary Supply System

- 9.1.1 Auxiliary power supply shall be provided on a three-car unit basis. This shall consist of a static converter-inverter(s) together with back-up batteries and battery charger. Auxiliary Converter-Inverter shall be suitable for operation at 25kV AC single phase for the frequency variation from 47 to 53 Hz. The failure of auxiliary power supply equipment shall be annunciate to the train operator in TCMS VDU/OCC. Failure/isolation of main converter shall not cause any reduction in performance of auxiliary converter-inverter.
- 9.1.2 The auxiliary power supply system shall be configured such that it performs reliably for all operating train consists. Full auxiliary power shall be available from 19kV to 31kV.
- 9.1.3 The auxiliary power distribution scheme shall be such configured that each 3-car unit (1DM +1T + 1M) has at least one auxiliary power supply equipment. When any Train Operator's cab is activated, all the auxiliary power supply equipment in the train shall operate. In the event of failure of an auxiliary power supply equipment on one 3 car unit in 6 car train, the remaining 3 car unit auxiliary power supply equipment must be capable of supplying all auxiliary power to complete 6-car train except for HVAC load which shall work at 50% of the rated capacity.
- In case of addition of one (T+M) unit (if required), provision of auxiliary supply during different emergency conditions to and fro between 'T+M' unit and existing 3-car units shall be finalized during design stage.
- 9.1.4 While traversing the neutral section or in the event of momentary non-availability of OHE during service the lights shall work normally. Contactor shall finalize the design during Pre-Final Design Stage.
- 9.1.5 In case of addition of one (T+M) unit (if required), the ratings of Auxiliary equipment like Auxiliary Converter- Inverter, Battery, Battery charger etc. shall be same as that of existing 6 car train.

9.2 Auxiliary Converter-Inverter

- 9.2.1 The static type auxiliary converter-inverter shall be of latest metro transit-proven energy efficient technology (IGBT/SiC or latest) with microprocessor based, pulse width modulation control. The auxiliary converter-inverter shall receive its power from a separate winding in the Traction Transformer. The three-output voltage shall be as follows:
- (i) Output 1: 415V 50Hz 3 ϕ 3 wire
 - (ii) Output 2: 230V 50Hz 1 ϕ
 - (iii) Output 3: 110V DC
- None of the above shall be accessible by passengers.
- 9.2.2 The auxiliary converter-inverter shall be capable of maintaining full output over the traction voltage supplied range specified and also for the frequency variation from 47 to 53 Hz.
- 9.2.3 Power semiconductors shall be mounted on grounded heat sinks. Under all normal and emergency operating conditions, the peak junction temperatures shall not exceed 90% of their declared peak ratings. Natural or forced cooling can be offered but natural cooling is preferred. However, if forced cooling is offered complete details of the arrangement including the method of dust filtration shall be furnished.
- 9.2.4 The output circuits are galvanically isolated from the input and each other. The auxiliary converter-inverter shall provide power supply to all auxiliaries including ventilation blower motor, air-conditioning units, air compressor, doors, light equipment, control units and low voltage loads.
- 9.2.5 The supply shall be regulated within $\pm 5\%$ of the nominal voltage and total harmonic disturbance shall be limited to 8% under all operating conditions. Phase-to-phase voltage imbalance shall not exceed 1% between phases. The converter-inverter shall otherwise comply with the provisions of IEC 61287-1.
- 9.2.6 The auxiliary converter-inverter shall be continuously rated to provide full auxiliary load on one 3 car unit (DM+T+M) plus other loads specified in clause 9.1.



- 9.2.7 Staggered starting shall be provided between auxiliary power supplies on the train to minimize start up loads.
- 9.2.8 Protection and diagnostics:
- (i) Control circuit logic shall permit testing and monitoring of the operation of the auxiliary power supply system when running.
 - (ii) Protection against single phasing and short-circuiting shall be incorporated into the auxiliary converter-inverter feeding 415V, 50Hz auxiliary drives.
 - (iii) The auxiliary power control system shall carry out self-tests to ensure the integrity of the equipment. Sufficiently detailed status, fault and diagnostic information shall be transmitted to the train integration management system (TCMS), to enable protective or corrective action to be taken immediately, when necessary.
 - (iv) The auxiliary converter-inverter shall use a control scheme that contains extensive self-diagnostic logic, which shall be fully integrated with TCMS. At a minimum, the diagnostics system shall identify a range of credible faults, identify whether a Least Replaceable Unit (LRU) is responsible for the fault, and whether the LRUs (or non-LRUs) must be replaced or the system merely reset. The diagnostics system memory shall be retained for at least 400 events.
 - (v) On the condition that the auxiliary converter-inverter has been started previously, in the event of an interruption of the primary power supply including loss of contact of pantograph with catenary, the auxiliary converter-inverter shall automatically re-start once the input power has been re-established.
 - (vi) The Train Operator from the cab shall be able to isolate any defective auxiliary power supply equipment.
 - (vii) All auxiliary power equipment shall be easily accessible for inspection, testing and maintenance.
 - (viii) Contactors shall be rated for maximum current capacity and overload interruption capability.
 - (ix) Protection scheme for Static Converter (auxiliary converter-inverter shall include but not limited to:
 - Over current detector
 - Over voltage detector
 - Converter fault output
 - Over temperature of semiconductor
 - Single phase detector
 - Inverter fault output
 - AC over voltage detector
 - AC low voltage detector
 - AC over load current detector
 - AC output short circuit current detector
 - Control power supply failure
 - Over voltage of inverter circuit
 - Over current of inverter circuit
 - Synchronous fault detector
 - Starting failure
 - Ground fault detector
 - DC over voltage detector
 - DC over current detector

The settings and calculations of above mentioned protections shall be discussed during Pre-Final Design Stage.

- 9.2.9 The box for auxiliary converter-inverter shall be such that to avoid any corrosion throughout the

service life on any account and the box shall last for the lifetime of the auxiliary converter-inverter unit without needing any attention. The box shall be of stainless steel/anodized aluminium. The box cover which may have to be removed for maintenance shall be suitable secured against falling. Hinged opening cover arrangement shall be preferred.

- 9.2.10 Industrial 415V 50Hz 3 ϕ socket outlets with spring loaded covers, capable of accepting a shore supply shall be provided on each unit at sole-bar level, on both sides. Each shall be accompanied by a red lamp, to warn of live sockets, when a shore supply is plugged in. The control logic shall ensure that train power up is not possible when shore supply is applied to the train. The design and type of the interface connector shall be submitted to the Engineer for review. Minimum 50 numbers of the mating connectors shall be supplied for installation in each Depot.
- 9.2.11 The shore supply shall have sufficient capacity, rating and provision to enable Employer's maintenance personnel to test all electrical auxiliary equipment in three-car unit. The shore supply connector of adequate capacity shall be provided at diametrically opposite convenient locations on either side of each unit.
- 9.2.12 Additionally, internal 230V 50Hz 1 ϕ socket outlets for vacuum cleaners, and others loads (minimum two per car and one in driving console) shall be provided in each car. Separate 230V sockets shall be provided (on both ends near the last row of seats) for Mobile/PC charging.
- 9.2.13 For maintenance purpose, there shall be additional by pass ground switch in SIV box duly interlocked with safety locks. Contractor shall submit the detail document for Engineer's review during design stage.
- 9.2.14 Heat detectors/LHD in SIV and battery charger shall be provided and status shall be linked to TCMS/Fire detection & Control unit (refer ERTS clause 2.20) so that their status is monitored.
- 9.2.15 LED based lighting arrangement shall be provided in the SIV box for maintenance purpose. Its failsafe interlocking with the box cover shall be ensured. Contractor shall submit the detail document for Engineer's review during design stage.
- 9.2.16 All auxiliary converter-inverters shall be identical, interchangeable and under frame mounted. All internal items of the equipment shall be easily accessible and detachable, with the converter-inverter "in situ", to facilitate maintenance.
- 9.2.17 Input power factor of auxiliary converter-inverter shall be near unity under all load conditions. Under no condition it shall behave as capacitive and export reactive kVAR into the system.

9.3 Battery Charger

- 9.3.1 The battery shall be charged from the local (three-car unit) static battery charger. The battery charger with automatic control shall be capable of providing a temperature compensated high rate boost charge or float charge compatible with the characteristic of the Ni-Cd batteries.
- 9.3.2 The battery charger shall be capable of charging a discharged battery to 80% full charge within 4 hours. Once the battery is fully charged, float charge should stop after 10 minutes.
- 9.3.3 Batteries shall be connected to a common Battery Bus throughout the train.

9.4 Back-up Batteries

- 9.4.1 Each three-car unit shall be equipped with a battery set consisting of nickel cadmium cells having a nominal voltage of 110V with PP cell casings. The battery shall be rated and tested in accordance with the requirements of IEC 60623 and shall also meet the requirements of IEC 60993 and EN 50547.
- 9.4.2 The backup battery shall utilise a sufficient number of cells to ensure that it is capable of:
 - i. Maintaining full DC loads when the train runs over neutral sections of the overhead line in case of 25 kV AC system.
 - ii. Supply emergency load for at least 60 minutes (with doors open and close every two minutes) in case of failure of battery charger or its supply with the battery charged to a level as expected during service but not better than 80% of its full capacity. Contractor shall also demonstrate that at any time of service, stage of charge shall not be less than 80%, before the voltage level at any device



falls below 77V DC Non-essential load shall be shed after 30 seconds of failure of battery charge supply. This feature shall be demonstrated during testing.

9.4.3 Emergency loads shall include, but need not be limited to:

- i. Emergency lighting.
- ii. All exterior lights.
- iii. Ventilation fans but not air conditioning.
- iv. Communication systems including public address, passenger emergency alarm, surveillance system and train radio.
- v. Propulsion and brake controls.
- vi. Door controls.
- vii. TCMS.
- viii. Electric horn.
- ix. Driving console indicators, lighting and interlocking.
- x. ATP train borne equipment.

9.4.4 The design and control of the battery shall ensure that there is sufficient capacity left under all conditions to raise all the pantographs simultaneously. Adequate circuit protection shall be provided to ensure the battery load shall be disconnected when the battery voltage has dropped below 70% of the nominal voltage and when the auxiliary load is re-connected, the initial battery load shall not cause the battery output to oscillate.

9.4.5 Battery electrolyte capacity shall be such that the batteries will not require topping up more than once in a year. Complete calculation of loss of water and float/boost charging shall be submitted. Batteries shall be designed with integrated topping up provisions. Suitable interconnection shall be provided so that topping up of all the cells can be carried out using from a single point on battery box. The design shall be submitted for review of the Engineer.

For the calculation of sizing of battery at high and low temperature, ageing de-rating factor and charging de-rating factor shall be considered and calculations shall be submitted to Engineer during detailed design stage.

9.4.6 The battery terminal voltage shall float on the 110V DC output of the auxiliary power supply of which the output voltage shall have fine adjustments and good stability to avoid over or undercharging of the battery.

9.4.7 The control elements taking power from the battery shall be capable of operating between 77V and 138V DC. The instantaneous battery voltage shall be monitored and recorded through TCMS.

9.4.8 Deleted.

9.4.9 One set of battery electrolyte automatic topping up devices shall be provided for each Depot. These devices shall be portable and easily operated by one person. They shall incorporate a feature to cut-off the electrolyte automatically when it has reached the correct level.

9.4.10 Two trains (one on each line) shall be fitted with Battery Control and Monitoring Unit (BCMU) to monitor the charging, discharging current, voltage etc. It shall be possible to install the BCMUs in any of the trainsets at later stage.

9.4.11 Battery Protection and Isolation:

- (i) Battery fuses of suitable rating shall be fitted in a separate box located adjacent to one of the battery boxes and shall enable easy access from track level.
- (ii) Back connected fuse holders shall be provided and the battery fuse enclosure shall be sealed to IP65 in accordance with IEC 60529.
- (iii) A battery contactor operable from inside the cab shall be provided to disconnect the battery from the car wiring electrically, when required.
- (iv) A low voltage earth bar shall be provided and located close to the negative fuse.
- (v) The status of fuse and circuit breakers shall be monitored by TCMS.

9.4.12 Battery temperature shall be displayed in TCMS.

9.5 Battery Box

- 9.5.1 The box for battery shall be such that to avoid any corrosion throughout the service life on any account and the box shall last for the lifetime of the cars. Within the battery box, the battery shall be mounted in roll out trays to allow for easy maintenance.
- 9.5.2 The roll out system shall be corrosion resistant, and shall be provided with the necessary stops and locks to limit the travel of the battery box and retain it in both extreme positions. When rolled out, the entire top of the battery shall be exposed. All the battery terminals, including battery positive and negative main connections shall be easily accessible for maintenance work.
- 9.5.3 The box interior / the roll out trays shall be lined with a non-flammable, electrolyte proof, insulating material of suitable thickness. The box shall be ventilated to preclude the possibility of built-up of any gas. Vibration proof automatic lock shall be provided to ensure absolutely no relative movement of the batteries inside the tray.
- 9.5.4 The battery box shall be sized to have at least 10% extra space to accommodate augmented capacity battery. Extra space shall be suitably packed.
- 9.5.5 Battery box shall not deshape/sag during lifetime of the car. Adequate strength shall be built in the battery box by providing suitable ribs etc. FEM & fatigue report of the battery box shall be submitted to establish the same.

9.6 Inverter for HVAC Ventilation

- 9.6.1 Adequately sized DC inverter shall be provided in the underframe/inside HVAC unit to feed the ventilation fans of both the HVACs of each car.

9.7 Deliverables

- 9.7.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	9.2.10	Mating connectors for shore supply installation.	Minimum 50 numbers in each depot.
2.	9.4.8	Battery electrolyte automatic topping up devices.	One set for each depot.

Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



10. TRAIN CONTROL MANAGEMENT SYSTEM**10.1 General****10.1.1 Features**

All the trains shall be equipped with microprocessor based Train Control Management System (TCMS) providing real-time distributed control and modular processing of all sub-systems in fully redundant manner with high reliability and availability required in adverse operating environment experienced in MRTS system.

TCMS shall be a completely integrated system equipped with

- i) data acquisition,
- ii) monitoring,
- iii) control,
- iv) record,
- v) display,
- vi) self-diagnostic,
- vii) fault diagnostic,
- viii) remote diagnostic,
- ix) configuration editing,
- x) troubleshooting-guidance

features/functions for the train, its systems and subsystems. Contractor shall submit a comprehensive list of capabilities for each of the above listed features.

10.1.2 Proven Design

Basic architecture and hardware of TCMS proposed to be implemented/used by the Contractor should already be functioning in Metros since last more than two years and shall be compliant with international norms. The Contractor shall submit basic system architecture with hardware for approval at the concept design approval stage and establish 'proven design' as specified.

10.1.3 Maximise Controls & Monitoring via TCMS

It is desirable that the control and monitoring functions are implemented by software, to the extent possible, so as to reduce hardware and cables. All functionalities that can be implemented by software shall be provided via TCMS unless specifically desired otherwise by the Engineer.

10.1.4 Deputation of Employer's Engineers

During the development of TCMS for the project, the Engineer shall depute a team of Persons to fully associate with the TCMS/controls design work so as to make them competent to implement software changes as required within the scope of this contract. Contractor shall ensure full association and support of Contractor/Sub-Contractor's design team with the Engineer's team throughout the project or as the case may be.

10.1.5 SIL Compliance

TCMS shall be SIL2 compliant for all vital and safety related control and monitoring functions including but not limited to the following hardware, software and control functions-

- VATC (Vehicle Automatic Train Control) operation mode (ATP, ATO and UTO etc.),
- Door Proving loop cut-out,
- PWM transmission (communication),
- PWM signal (Hardware) failure,
- Door Open Push Button,
- Direction control of train operation,
- Holding brake release,
- Speed transmission,
- Fire alarm transmission via VATC,

- ED (Electro Dynamic) brake cut-out signal transmission,
- Actual ED brake effort signal transmission,
- Sliding signal transmission,
- ED brake effective signal transmission,
- Holding Brake demand signal transmission,
- Holding Brake applied status transmission;

at all levels including but not limited to hardware, software and control functionality etc. Any change in SIL level shall be subject to the hazard analysis and acceptance or otherwise of the same by the Engineer, whose decision shall be final and binding.

10.1.6 UTO Compatibility

The TCMS architecture, functionality and redundancy level shall be compatible with the UTO mode of operation. Contractor shall submit details of all UTO specific design functionalities for Engineer's review.

10.1.7 Signalling Interface

TCMS shall have adequate facility and interfaces to communicate with wayside signalling for both UTO and non-UTO modes. It shall be possible to simultaneously operate different trains in a section in GoA2/GoA3/GoA4 without any safety/reliability issue as per IEC 62290-1:2006.

10.1.8 TCMS Configuration Details

The Contractor shall submit the complete TCMS configuration details including but not limited to Application Software Logic, Data Acquisition Routines, Control logic, Fault Detection Algorithms, Data Storage Logic etc. Graphical interface for editing and configuring the same shall be provided and submitted for Engineer's approval during design stage.

10.1.9 Applicable Norms and Standards

All communication protocols, architecture and data acquisition concepts shall be of the latest state of the art technology and compliant to international and railway industry standards. The Tenderer shall advise the proposed applicable standards for review.

10.1.10 Conceptual Approval Only

Design approval of proposed TCMS shall imply only conceptual approval. Further changes as required by Engineer based on operational, maintenance and functionality considerations shall be discussed during the contract and solution be implemented to the satisfaction of Engineer without additional cost. This will include finalization of event list, fault priorities, diagnostics and others.

10.1.11 The cables which are intended to be used in emergency circuit for alarms and communication shall have intrinsic fire resistant property in compliance with EN 50200.

10.2 TCMS Architecture

10.2.1 Data Communication Link

i) Ethernet based

The network communication technology to be adopted for all TCMS data communication links and subsystem communication interfaces shall be based on Ethernet (100 Base TX or better).

ii) EMI Immune

Proven train data communication links that are immune to EMI and harmonics generated by traction equipment shall be provided between the cars. Suitable physical bus interfaces, to ensure error-free and high speed data transmission shall be provided.

10.2.2 Ethernet Train Backbone (ETB)

Ethernet-based Train Backbone with redundant Train Backbone Nodes (TBNs) (at least two in each consist network) shall be provided to achieve interoperability between consists when coupled in the train as per IEC 61375-2-5.

The data transmission medium in Ethernet-based Train Backbone shall be doubled to support redundancy.



It shall be possible that number and type of connected consist networks in existing 6-car train can vary during operation by insertion of one "T+M" unit in the middle of the train to form a 8-car train in future as per Para 5.3: Train Compositions of IEC 61375-1.

10.2.3 Ethernet Consist Network (ECN)

Ethernet Consist Network with dual-homing ladder-type topology/dual-homing ring-type topology (compliant with IEC 61375-3-4) shall be adopted. The ECN shall maintain redundant communication links to the ETB.

10.2.4 Dual-Homing End Devices (ED)

All the End Devices shall support dual-homing type Ethernet connections to ECN via physically independent ports to increase system reliability and availability.

All digital and analog IOs interfacing with TCMS (directly or via an interface unit) shall also be fully redundant.

10.2.5 Redundant Processors

The processors running the TCMS application software for control, monitoring etc. shall be duplicated with a hot standby redundancy provision. Details for the switchover and recovery times shall be submitted by the Contractor for Engineer's review.

10.2.6 Single Point Failure Tolerant

The TCMS shall be of fault tolerant distributed control system architecture. A single point failure of any individual equipment/component/board/communication link etc. shall not affect data acquisition & processing or cause any adverse performance impact on train performance or loss of data.

Contractor shall submit the failure redundancy matrix for entire TCMS indicating the various failure modes, available redundancies and the effect on train performance.

10.2.7 Spares Provision

The TCMS components shall be modular in design at all levels (i.e. hardware, functional, communication etc.) with at least 10% spare capacity in each car for expansion at the end of DLP. The spare provision shall exist for all different equipment's pins, terminals, connectors, ports, train lines, communication packets bits, digital/analog IOs etc. and the same shall be available for after DLP. The hardware spares shall be duly wired to the nearest terminal box.

Considering that some changes/modifications would be required during DLP, at least 12.5% spares capacity shall be initially ensured by Contractor.

Contractor shall submit a detailed proposal for Engineers review and approval during design stage.

10.2.8 Expandability Provision

The Contractor shall also provide 10% expandability provision (i.e. expansion of capacity by adding of additional hardware) for pins, connectors, network ports, PCB cards, train lines etc. over and above the spares available at the end of DLP. Contractor shall demonstrate to the Engineer that adequate space has been reserved to exercise this option.

10.2.9 IEC 60571 Compliant

The hardware system shall conform to IEC 60571.

10.2.10 IP Rating

Minimum IP level of all TCMS cubicles/equipment or the panel in which it is installed shall be IP53 or higher and the same shall be declared by the Tenderer.

10.2.11 Labelling

The type, location and identification of all hardware, software interconnections, cabling and terminals shall be determined on a coherent hierarchical system basis. Labelling or identification shall use appropriate English language based mnemonics or abbreviations. The Contractor shall submit proposal for review.

10.2.12 Maximum CPU Loading

Contractor shall demonstrate to the Engineer's satisfaction that none of the TCMS CPUs/processors are loaded to more than 50% of their processing capacity. The Contractor shall

keep adequate margins in the design to allow for addition of functionalities to TCMS during DLP period. A verification report for the same shall be submitted.

10.3 Data Acquisition

10.3.1 Network Interfaced Systems

TCMS shall schedule, initiate and control data acquisition, processing and analysis by interfacing with all microprocessor/ microcontroller based on-board systems. These systems shall include, as a minimum:

- i) ATP/ATO,
- ii) HVAC System,
- iii) Auxiliary Power Supply System,
- iv) Brake System,
- v) On-Board Communication System,
- vi) Doors,
- vii) Propulsion System,
- viii) Train Radio,
- ix) PSSS (Passenger Saloon Surveillance System),
- x) Lighting System,
- xi) Wayside Wireless Communication,
- xii) Fire Detection Unit.

All interface signals with ATP/ATO and selected interface signals with other on-board systems shall be monitored and recorded with time stamp. The Contractor shall submit the details for Engineer's review.

10.3.2 Hardwire Inputs

In addition to above, TCMS will also acquire status data via hardwire from the various identified vehicle control circuit nodes, train lines, ATP/ATO, or any other subsystems. This data acquisition shall be fully redundant, bus monitored and duly recorded in TCMS. The interface units provided for this purpose shall be dual homing compliant.

10.3.3 Communication Protocol Details

The software and communication protocols used throughout the TCMS and the interfaces to subsystems shall be compliant to a common standard or standards. Contractor shall submit details of the communication protocols used in their design (at all different levels of the OSI model) clearly indicating how the requirements of monitoring and control are complied with. The Contractor shall also define the dual-homing compliant communication protocols for all EDs. Further details along with any hardware/software tools required shall be submitted during design stage.

10.3.4 Signal List Modification

It shall be possible for authorized maintenance personnel to update and modify the list of data acquisition signals and its associated parameters like periodicity, task cycle, data acquisition routine etc. Suitable graphical configuration editors shall be provided for this purpose.

10.3.5 Clock Synchronisation

TCMS shall synchronize its clock with the system master clock through the ATP/ATO interface. All the microprocessor/microcontroller based on-board systems shall synchronize respective clocks with TCMS clock. Detailed clock synchronisation proposal shall be submitted for Engineer's approval.

10.4 Control Features

10.4.1 Non-Vital Controls

TCMS shall be used to execute all non-vital commands and controls of the train.

10.4.2 Vital Controls



TCMS shall be designed to provide back-up controls of certain identified vital commands. Unless otherwise indicated specifically in these specifications, hardware back up shall be provided for each safety related control functions.

10.4.3 Control Strategy

The Contractor shall submit technical details of the TCMS control system with full explanation of control methods and strategy adopted in the design. The proposal shall also clearly discriminate between the implementation of vital & non-vital controls as well as manually triggered/operator-based & automatically executed controls.

10.4.4 OCC Remote Controls

TCMS shall have provision for receiving and implementing remote control commands from OCC/DCC. Necessary interface with S&T Contractors shall be ensured.

10.4.5 List of Operator Control Functions

Control features available for the Train Operator's control via on-board HMI or for the OCC/DCC's control via remote HMI shall include, but not be limited to, the following:

- i) Train start up.
- ii) Control of various saloon and cab air conditioner parameters such as selective and/or collective starting and switching off, car temperature control, provide override control of operating mode etc.
- iii) Isolation of any particular passenger side door that has been detected as closed and locked.
- iv) Override control over automatic selection of the saloon light circuit(s).
- v) Resetting of minor faults in sub-systems.
- vi) Provide a VCB control logic during Neutral section traversal as fully functional back up in all driving modes and directions.
- vii) Any other item as desired by the Engineer.

The Contractor shall submit detailed list of functions /features proposed to be controlled through TCMS for Engineer's review and approval.

10.4.6 Protective Controls

TCMS shall appropriately shut down or reset equipment in response to self-diagnostic test results or occurrence of specified faults. Detailed scheme for protective controls shall be submitted for Engineer's review and approval.

10.4.7 Speed Calibration Control

Automatic speed calibration through Doppler radar or better means shall be ensured specifically whenever wheel is turned and train is moving out of Depot for revenue service.

10.4.8 Speed Sensor Redundancy

Adequate redundancy shall be built in for correct train speed measurements in case of failure of any of the speed sensor. System shall also counter check the speed recorded by the ATP/ATO. For this purpose, the Contractor shall suitably interface with Signalling Contractor.

10.4.9 ATC Interfaced Controls

i) Remote Initialisation

TCMS shall interface with ATC for remote initialization of train at siding, stabling lines or in Depot for revenue operation. The "wake-up" command from OCC shall be implemented by TCMS after performing self-tests of different train borne systems. TCMS shall send train ok signal to train ATC else a corresponding fault code shall be sent.

ii) Sleep Control

ATC may initiate automatic train sleep function when trains are not required. Whenever sleep command is initiated by Train Operator, TCMS shall shutdown the relevant equipment except for control supply to necessary equipment.

iii) Standby Control

Train Standby function may be actuated by ATC system when train is in stabling siding. TCMS on



receipt of such command shall switch off auxiliary equipment except compressor, battery charger etc. and shall maintain train in a "Ready" state.

iv) Shunting Control

The shunting operation of train in depot shall be under GoA3/4 as initiated by ATC.

10.4.10 UTO/ATO Interface

TCMS shall be fully compatible and interface with signalling system to ensure safe UTO/ATO operation.

For UTO/ATO operation, the necessary train command digital inputs signals shall be provided by the Signalling Contractor. The ATP/ATO/UTO initiated signal demands shall be redundant. The redundancy shall also be provided on TCMS side by RS Contractor. The form of these inputs shall be coordinated between RS and Signalling Contractors.

The Contractor shall also liaise with the Signalling Contractor to harmonise his system with the energy saving modes under ATO/UTO.

10.5 Driving Console Interface

10.5.1 Visual Display Unit (VDU)

Each Driving Console shall be provided with a VDU to display real time information to the train operator. The VDU shall support both text and graphical presentation of information. Commands shall be entered by the train operator via touch screen. Suitable protection features for the safety of the VDU shall be provided.

10.5.2 VDU Display Information

The VDU shall display information related to, but not limited to, the following:

- i) Equipment operating status.
- ii) Faults and failure of both auxiliary and control functions.
- iii) Recommended remedial actions in the event of alarms or faults occurring on the train.
- iv) Time

All the screens shall display the time (24-hour format), date (dd/mm/yy), the train configuration and approximate number of passengers.

v) Odometer

A six-digit odometer to display recorded cumulative distance run by the unit, irrespective of direction.

vi) Energy Consumption Data

TCMS shall interface with the relevant sub-systems and shall provide the facility to display energy consumption for one sided/round trip as well as cumulative for each consist and for the train.

vii) Crew ID and Train ID

Facility shall be available to key in the Train Operator and Train Identification Number (in case same is not available through ATC interface).

viii) Train Speed

TCMS shall interface with the relevant sub-systems to reliably display and record the train speed.

ix) Push Button record

All operations of Train operator including pressing of push buttons etc. shall be recorded with time stamp and be made available on VDU.

x) Safety Switch Status

Status of safety switches shall be displayed on VDU and shall be acknowledged by the incoming train operator. The status shall be relayed to the Control centre through train radio.

10.5.3 VDU Screens Design

The VDU shall provide distinct screens for different functionality or subsystems. The information shall be divided among screens and presented in a logical and orderly manner. The screen layout



including the selection of default screen, abbreviations etc. shall be reviewed and approved by the Engineer.

10.5.4 Editing VDU Screens

The format/no./ contents of VDU screens shall be proposed by the Contractor during design and may have to be changed during the contract based on operational/maintenance requirements. The Contractor shall make such changes as and when required by the Engineer during the contract and shall also train Employer's engineers to design, review and execute the changes in VDU screens in post contract period. Necessary hardware and software tools shall be provided for each Depot.

10.5.5 VDU Access Control Levels

The level of access to distinct screens shall be controlled for the train operator and maintenance personnel. At least three levels shall be defined which shall be user name and password protected. The details shall be reviewed by the Engineer.

10.5.6 Test Mode Extension of VDU

The TCMS VDU shall be connected to the Ethernet Train Bus and it shall be possible to simultaneously plug-in multiple laptops at any point on the train bus and replicate the TCMS VDU display. Suitable application software shall be developed to enable replication of TCMS VDU along with touch and/or mouse-based interaction. Such additional VDUs shall login as "Test Mode" that shall be provided in addition to the "Operator and "Maintainer" modes of the TCMS.

10.5.7 VDU Hardware

Capacitive-touch screen based VDU or better shall be provided as approved by the Engineer. The display screen shall be of coloured Light Emitting Diode (LED) type, suitable for use in rugged railcar environment. VDU shall be equipped with brightness, sharpness, intensity and contrast controls etc.

10.5.8 CCTV Display Redundancy

Full redundancy shall be available between VDU of TCMS and CCTV. In case of failure of TCMS VDU, full functionality of TCMS VDU shall be available in CCTV VDU and vice-versa. CCTV images can be displayed on the TCMS VDU on demand or event generated. The TCMS VDU shall have provision of displaying multiple screens as per the requirements.

10.5.9 VDU Response Time

The response time for most complex VDU screen change from one TCMS screen to other TCMS screen, TCMS to CCTV screens, maneuvering from one camera image to other under full VDU loading including the conditions stipulated under 10.1.2 shall be approximately 0.5 seconds. Contactor shall submit compliance details during design stage which shall be got validated during line test.

10.6 Self-Diagnostic Features

10.6.1 TCMS Self- Diagnostic Tests

The TCMS unit shall incorporate built-in self-test diagnostic functions. The results of these self-diagnoses shall be accessible on VDU and any failures shall trigger appropriate faults/alarms/protective action. Details of the same shall be submitted during design stage for Engineer's review.

10.6.2 Subsystem Self-Diagnostic Tests

All the on-board microprocessor/microcontroller based subsystems shall also perform self-diagnostic tests and report the detailed health status to TCMS, both automatically and on specific request (using VDU) by maintenance personnel.

10.6.3 Self-Diagnostic Tests

The self-diagnostic tests shall assess and report the health of boards, sensors, memory, watchdog timers, inputs, outputs, bus connectivity, PCB level components status, software, firmware etc. Hardware and software shall be provided for self-diagnostic test of the critical system functions. Detection of a failure shall cause an indication to be displayed on the VDU.

10.6.4 Software Versioning



Time stamping of date of software(s) as well as version of software(s) used in different sub-systems of the train and their compatibility shall be ensured by TCMS. The details of version of software(s) used in different sub-systems with time of uploading shall be displayed at the TCMS at the time of Power Up (wake up). The system shall not permit loading of incompatible software(s). Manual override in certain cases can be permitted by the Engineer, details to be finalized during design stage.

10.7 Fault Diagnostic Features

10.7.1 Fault Diagnostic Function

TCMS shall perform the task of fault diagnostics, in addition to performing the control/monitoring tasks. The design shall consider the train as a complete system and diagnostic capability incorporated in the system shall detect any node or line section failure rapidly to ensure no impairment of normal control and monitoring functions. The Contractor shall submit proposed scheme and fault detection logic for Engineer's review and approval.

The fault diagnostic functionality of TCMS shall include, but not be limited to, the following features:

- i) continuously monitor the status and determine health of all connected equipment and subsystems,
- ii) detect and log events and fault occurrences,
- iii) perform fault analyses and perform failure management actions by,
- iv) causing appropriate action to be taken, and wherever necessary shut down affected equipment,
- v) present alarms & conditions/guidance to the train operator.

10.7.2 Fault Detection

Degraded performance condition monitoring shall be provided as an integral part of TCMS wherein on-board CPU shall process the inputs from on-board subsystems and be able to determine car level, unit level or train level faults based upon the defined fault parameters/detection logic.

The various important parameters/signals of the equipment/subsystems (i.e. associated trace/environment data) shall also be recorded for pre-determined period before and after of occurrence of associated events/faults with a view to enable proper fault analysis.

The key indicators of degraded performance, fault parameters/detection logic and trace data signals for all principal car systems shall be defined by the Contractor and reviewed by the Engineer.

10.7.3 Fault Analysis and Management

Appropriate corrective actions shall be taken to reset critical faults and guidance shall also be provided to operator in the form of Troubleshooting Directory (as defined in Section 10.8). Details of failure management actions shall be submitted during design stage for Engineer's review and approval.

10.7.4 Fault Info Display

Real-time diagnostic information shall be made accessible on the train VDU and the OCC GUI to assist the operator to operate the train safely, quickly, efficiently, and to rectify resettable faults or failures.

10.7.5 Fault Levels

The scheme proposed shall differentiate between faults which are not potentially life threatening (e.g. air conditioning failure) and other system faults which could be life threatening (e.g. failure of the brake system).

The faults/events shall be at three or more levels with 'Level 1' events displayed on HMI with buzzer, 'Level 2' events displayed on HMI without buzzer and 'Level 3' being events recorded in the memory.

10.7.6 Auto-upgradation of Frequent Faults

Provision shall exist to temporarily upgrade the level of the fault/event automatically in case of its being experienced for predetermined number of times (settable by the authorized maintenance



personnel) in pre-determined time period (settable by the authorized maintenance personnel). Detailed proposal for the same shall be submitted for Engineer's review and approval.

10.7.7 Editing Fault Configuration Logic

Fault analysis and fault management algorithms, data acquisition routines and data storage logic shall be programmed and presented using Windows or equivalent user interface software and shall be fully editable by the Engineer.

Authorised maintenance personnel shall have facility to select and edit:

- i) event details (e.g. displayed fault text, fault level etc.),
- ii) list of associated parameters/trace data,
- iii) periodicity of the parameters/trace data,
- iv) time interval for pre and post event capture of parameters /trace data,
- v) fault detection algorithms and fault management logic.

Complete facilities to implement the same shall be supplied.

10.7.8 Specific Fault Provisions

The following are some faults that shall necessarily be included in fault detection logic:

- i) Popping up and acknowledgement of the status of each safety switches not in normal state at the time of taking traction and cab activation.
- ii) Loss of redundancy of equipment and subsystems.

10.8 Troubleshooting Directory

10.8.1 General

For quick guidance of Train operator and Maintenance staff, a summarised menu driven, user friendly Trouble Shooting Directory (TSD) shall be made available in the HMI. The TSD shall have separate login modes for operators and maintainers. Extensive use of graphics shall be made in TSD for better understanding of the T.O.'s. Details shall be decided during design & revenue service period.

10.8.2 Maintainer Mode

- i) Highlighted FBD

The maintainer mode of TSD shall display detailed Functional Block Diagram (FBD) (as per IEC 61131) for the fault detection software logic wherein the relevant pathways of the logic diagram tree that triggered the fault shall be highlighted.

- ii) Input Output Signal State

The TSD shall also display the real-time states of the various input and output signals related to fault detection logic in tabular form.

- iii) Action Items

Detailed action item text containing description of fault logic, possible failed device(s) info, troubleshooting instructions and corrective action as collapsible blocks of text shall be included on TSD screen. This text shall be colour coded so as to indicate the most pertinent points for any particular failure.

- iv) Mode Switch

It shall be possible to switch from maintainer mode to operator mode of TSD without logging out of TCMS maintainer mode but not vice-versa.

10.8.3 Operator Mode

- i) Graphics and Animations

The operator mode of TSD must include graphics and animations that shall be developed corresponding to all the failed devices, all the failure cause identifications and all the proposed corrective actions for each of the faults. These graphics shall be submitted for review of Engineer and shall be promptly updated as per his decision.

The detailed proposal for the same shall be submitted during design phase and shall include a listing of all media files being provided in the TSD library.

ii) Locational mapping

The locational mapping of these graphics files with various train equipment and various fault codes shall also be submitted. The colour highlights and transition effects possible with the graphics shall also be made part of the proposal.

10.8.4 Intelligent Analysis

The TSD shall be smart enough to group together related faults (i.e. faults that have the same root cause) and provide guidance in a combined view for such faults. The various FBD logical pathways as requested above shall be distinguished in this case with different colours.

10.8.5 Editing of TSD

Based on the operational requirements, the directory shall be regularly upgraded during the contract period. The TSD shall be editable by authorised maintenance personnel. Necessary training for the operator and maintenance personnel shall be provided.

10.9 Maintenance Tools

10.9.1 Scope of Supply

A minimum of ten notebook computers as approved by the Engineer, together with all associated accessories and preinstalled software necessary for all diagnostic and configuration editing functions for all train-borne equipment shall be provided. Two copies of all the software uploaded in the notebook computers shall also be provided separately in approved non-volatile memory.

The notebook computers shall be of rugged design, high performance having sufficiently large storage capacity, high battery backup, sufficient no. of ports required generally (like USB, LAN, serial, VGA, HDMI etc.), a DVD writer (inbuilt or separate) etc. with latest generation Processor and Operating System.

10.9.2 On-board Connectivity

A high-speed suitable communication port shall be provided in each car to interface with a notebook computer and all information on the TCMS shall be made accessible on the notebook computer. It shall be possible to download the desired data for the entire train including data logged in its subsystems through any one of these ports (single point downloading of train's faults/data).

Additionally, it shall also be possible to connect with TCMS remotely via wireless network access and download faults from any train on mainline or in depots.

10.9.3 Levels of Access

The level of access to distinct functionalities shall be controlled for the maintenance personnel. At least three levels shall be defined which shall be user name and password protected. The details shall be reviewed by the Engineer.

10.9.4 Required Features

The notebook computer shall provide full testing of and interaction with the on-board TCMS at both train and car level. The following minimum capabilities shall be provided:

- i) System monitoring, fault data retrieval and analysis,
- ii) Viewing and processing of logged TCMS data,
- iii) Uploading new operating software and parameters for all the on-train subsystems,
- iv) Uploading new train configuration data (e.g. wheel diameters, etc.),
- v) Downloading of fault and usage information,
- vi) Initiating self-test and Downloading self-test reports,
- vii) Exercising and checking of digital inputs and outputs,
- viii) Checking of train and subsystem serial links,
- ix) Checking of train data bus set-up and configuration,
- x) Retrieval of equipment identification numbers,



- xi) Initiating function testing of on-board equipment,
- xii) Force various inputs/outputs interfacing with VCC,
- xiii) Forcing internal signals of TCMS as a tool for simulation,
- xiv) Editing of fault logic (ERTS 10.7.7),
- xv) Editing data acquisition signal list (ERTS 10.3.4),
- xvi) TCMS configuration editing (ERTS 10.1.8),
- xvii) Editing DR data signals list (ERTS 10.10.3),
- xviii) Accessing depot management software,
- xix) Accessing multiuser software,
- xx) Accessing fracas software,
- xxi) Accessing document management system software,
- xxii) Running Energy Saving mode analytical tools (ERTS 10.12.3).

10.9.5 Single Point Upload/Download Provision

- i) Single point uploading of software and downloading of faults shall be possible from TCMS nodes and/or via wireless mode in each train. In-case of sub-supplier's equipment like doors, PIS, HVAC etc. also, single point uploading of software and downloading of faults on unit/car/train basis shall be ensured.
- ii) The overall time required for uploading the software and downloading fault data for all subsystems shall not be more than 15 minutes each and the same shall be demonstrated.
- iii) Contractor to ensure that all fault and associated data residing in the subsystem's internal memory shall be retrievable on specific request from the TCMS nodes/wireless terminal.
- iv) If fault data downloading is interrupted somehow, it should resume from the same point, at which it was interrupted.
- v) The trip specific data shall be dumped at the end of each trip. This data should be sent via radio network, for which suitable interface to be ensured with the designated Contractor.

10.9.6 OS Compatibility and Upgradability

All the software(s) used in train, diagnostics, monitoring or analysis purpose shall be compatible with latest Windows version and upgradable for higher versions of Windows. The Contractor shall either commit to supply upgraded versions to match with higher version of Windows, as and when available or the software(s) shall be so developed to have automatic upgradability with Windows.

10.10 Recording Features

10.10.1 Operator Commands Log

TCMS shall retain a non-volatile record of all train operators and ATP/ATO initiated commands and system responses for a minimum of 240 hours before overwriting. Overwriting shall be such that the latest information is retained.

10.10.2 Event/Fault Information Log

Adequate redundancy shall be built into TCMS. The size of On-Board Database memory for fault records shall be sufficient to hold all car level and train level events (at least 10,000 events) between normal downloading intervals of 30 days through hardware download. In case of overwriting, 'Level 3' events/faults only may be overwritten.

10.10.3 Data Recorder Log

Separate adequate sized memory shall be available in TCMS for keeping user defined data recording (DR) log files for extensive continuous data logging and fault analysis for more than 200 parameters/signals.

The list of parameters/signals and trigger conditions for recording start/stop shall be fully editable.

10.10.4 S&T Interface Signals Logs

TCMS shall also log information/signals as received/delivered from/to ATP/ATO and Train Radio equipment supplied by the Signalling and Train Control Contractor and Telecommunications Contractor respectively. Please see Appendix TD for details.



The Contractor shall also enable Signalling Contractor to record similar data/signal interfaced between Rolling Stock and Signalling. During design and interface, additional signals may have to be interfaced with Signalling Contractor to improve train performance. The same shall be implemented by the Contractor.

10.10.5 Memory Capacity Limit

For the functionalities specified in these specifications, not more than 70% of the provided memory capacity shall be utilized. Further all the memories used in TCMS shall be expandable further as required by the Employer.

10.10.6 Event Recorder

i) Redundancy

Redundant event recorder compliant with GM/RT 2472:2002 shall be provided for the train. The event recorder shall be redundant to each other and shall be type tested to demonstrate the integrity of recorded data and ability to extract data following an incidence.

ii) Capacity

The recorder shall have the provision of recording at least 200 signals of the data which should be easily retrievable either by directly connecting the Window based PC or/and the storage media shall be removable type. The recorder shall have capacity for 24 hours recording of selected data. The recording shall be on a non-volatile memory capable of retaining the recorded data with time stamp and location for at least 15 days.

iii) Integrity

The Recorder shall be fully protected against illegal tempering, shall maintain its structural integrity and integrity/retrieval of data/device during accident.

Further details shall be decided during design.

10.10.7 Files Format

The file format of all recorded data log files as above shall be submitted along with the tools required for reading and processing the same in batch mode via third party tools.

Naming convention for all different data file types shall be submitted for Engineer's review. Suitable placeholders for time, car ID, equipment ID, trip ID, train ID etc. shall be incorporated.

10.11 Wayside Wireless Communication System

10.11.1 General

The contractor shall provide equipment and install the complete system to enable:

- i) Remote access of TCMS data (as defined in ERTS 10.10) on trains present in mainline or Depot(s);
- ii) Remote downloading of TCMS data (as defined in ERTS 10.10) to wayside central server through wireless communication network of signalling/telecom using maintenance notebook computers. The Contractor shall conduct necessary interface with S&T and shall be responsible for complete set up, commissioning and satisfactory working of the system during DLP.

The facilities of remote downloading shall be in addition to the hardwire downloading.

10.11.2 Scope of Supply

i) Contractor shall supply: Central server

The data as above shall be downloaded on a central server (to be provided by Rolling stock Contractor), which in turn shall be linked to each Depot, terminal stations, OCC etc. Communication link with server, if required for the purpose, shall be provided by the Employer. However, necessary interfacing devices shall be provided by the Contractor.

ii) Wayside Equipment

Within the Depot(s), the Contractor shall install and configure wireless network (in a limited area) for accessing the diagnostic data from the Central Server/Depot Server via maintenance notebook computers. Details shall be discussed during design stage.

All equipment required within Depot(s) and OCC etc. shall be supplied by the Contractor. Any other networking equipment as defined in Appendix-TD shall also be in the scope of RS Contractor. Further details shall be worked out as approved by the Engineer during design stage.



iii) On-board equipment

Any on-board equipment/access point/switches/router etc., if required, shall be provided by Contractor.

10.11.3 Required Features

i) Download Triggers

The triggers for remote downloading to central server shall be time interval actuated, fault actuated, manual triggered from OCC/BCC and forced downloaded remotely by authorized metro personnel.

ii) High-Integrity data transfer

Integrity of the data shall not be affected during remote download and in case of any interruption or otherwise the data shall be suitably secured and retrievable.

iii) Auto Resume of failed downloads

Connection failure during data download shall not cause restart of download from the beginning. Rather, all downloads shall pickup from the point where connection was broken.

iv) Depot management tools, issue of work orders etc. shall be linked with this software.

v) The Contractor shall supply the multiuser software(s) required for analysis of the faults and predictions/judgments on likely faults/failures. The specification of the software shall be got approved from the Engineer.

10.12 Energy Consumption Measurements

10.12.1 General

The Vehicle Control Circuit shall be suitably designed to ensure that Energy Consumption values at specified points are measured, recorded and made easily retrievable. The accuracy and integrity of these measurements shall be specifically ensured as the Employer intends to use the data for getting carbon credits.

The measurements shall be:

- i) made independently at pantograph, converter, auxiliary converter and HVAC levels,
- ii) made separately for traction, coasting and regeneration modes for each train,
- iii) linked with Crew IDs (in non-UTO mode),
- iv) segregable between mainline and depot consumptions,
- v) time stamped every 5 seconds,
- vi) stored in TCMS memory for 60-day period,
- vii) retrievable on VDU as cumulative/integrated values with advanced filtering option.

10.12.2 Reporting of Measurements

i) Display on VDU

The cumulative energy values at pantograph, converter-inverter, auxiliary converter-inverter and HVAC levels with both the components viz. motoring (including coasting) & regeneration, shall be displayed on VDU. It shall also be possible to apply time and trip filters to the energy values.

ii) Relaying to OCC

Complete energy data shall be transmitted to control centre at assigned times which shall be advised during design. The data shall be stored for one week and shall be downloadable as and when required. Further details including reporting format shall be discussed and finalized during design.

iii) File Format

The Energy Consumption data shall be exportable to Microsoft Excel in the following format:

Parameter	Time ₀	Time ₅	Time ₁₀	Time ₁₅
Energy Consumed @ Pantograph (Powering)					
Energy Consumed @ Pantograph (Coasting)					



Energy Consumed @ Pantograph (Braking)					
Energy Regenerated @ Pantograph (Braking)					
Energy Consumed @ CI (Powering)					
Energy Regenerated @ CI (Braking)					
Energy Consumed @ SIV (Powering)					
Energy Consumed @ SIV (Coasting)					
Energy Consumed @ SIV (Braking)					
Energy Consumed @ HVAC (Powering)					
Energy Consumed @ HVAC (Coasting)					
Energy Consumed @ HVAC (Braking)					
Odometer Reading					
State (Powering/Braking/Coasting)					
Crew ID					
Train ID					
Trip Number					
Last Station ID					
Mainline/Depot					
Train Speed					

In above format, the values in blank cells shall only correspond to the recordings made during the 5 second interval between successive timestamps and shall not be accumulated.

10.12.3 Measurement Accuracy

i) Accuracy

All energy measurements shall have accuracy within $\pm 3\%$ of the measurements made with Standard Wattmeter and Standard Instrument Transformers connected at appropriate test point in the Vehicle Control Circuit. This shall be validated during type tests.

ii) Verification

The Contractor shall be required to submit the detailed arrangement for connecting the standard Instrument Transformers and Standard Wattmeter at the test points for measurement of Energy Consumption for all above defined parameters, during the Type Test. Further details shall be discussed during design stage.

iii) Least Count

The least count for recording data shall be 0.01 kWhr at all levels of measurement.

10.12.4 Analytical Software Tools

The contractor shall also provide suitable analytical tools to screen and analyse the energy data for:

- optimization of energy regeneration, coasting,
- right manner/energy saving manner of driving,
- educating train operators.
- identifying the areas where energy can be saved,
- calculating efficiency values of transformer, converter inverter, auxiliary converter etc.

10.13 TCMS - OCC Interface

10.13.1 Key Alarms

The contractor shall propose a list of critical/key alarms to be communicated to the OCC in real-time through the signalling network. This list shall include all alarms that are required for maintaining safe train operation.

Any repetitive, hierarchical or cascading type faults shall be suitably masked or combined together to ensure brevity of the information being presented to OCC operator. The key alarms shall also have well defined actionable procedures associated with them as finalised in the OMPD document.



10.13.2 RSC HMI

The Rolling Stock Controller (RSC) in OCC shall have facility of full TCMS functionality of any train on his workstation on demand through signalling network. Development of the HMI application in RSC workstation shall be responsibility of Rolling Stock Contractor.

10.13.3 OCC GUI

Rolling Stock Contractor shall propose a user-friendly graphical user interface in the form of a conceptual schematic/wireframe that shall include page layouts, arrangement of the GUI's content, interface and navigational elements, and a description of how they work together. This proposal shall be submitted to the Engineer for his approval well in advance and shall be jointly agreed with Signalling Contractor for implementation. The Rolling Stock Contractor shall provide detailed information of the TCMS-OCC interface as implemented in at least two recently executed UTO Projects for reference during design stage. The name of such projects shall be indicated by the Tenderer in the bid.

10.14 Deliverables

10.14.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	10.5.4	Necessary hardware and software tools for editing of VDU screens.	In each depot.
2.	10.9.1	Notebook Computers as approved by the Engineer, together with all associated accessories and preinstalled software as per clause 10.9.1	Minimum ten (10) nos.
3.	10.10.7	Tools required for reading and processing of recorded data log files as per clause 10.10.7	One set at each depot.
4.	10.12.4	Analytical Software Tools as per clause 10.12.4	One set at each depot.

Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

11. HEATING, VENTILATION AND AIR-CONDITIONING (HVAC)**11.1 General**

- 11.1.1 The HVAC system for this specification shall consist of only Ventilation and Air-conditioning. The HVAC System shall be installed on each car to provide full control of interior conditions automatically, over the full range of heat loads associated with passengers, miscellaneous electrical equipment, lighting, carbody heat transmission and solar gain as per seasonal changes.
- 11.1.2 HVAC units shall be roof mounted package type. Two identical units per car shall be suitably located to achieve the specified saloon interior conditions.
- 11.1.3 The Contractor shall submit proposals relating to measures to be incorporated to prevent unloading of air-conditioning units under the conditions of stoppage of train at the platforms and inside the tunnels due to high condenser temperature.
- 11.1.4 The units shall continue to operate at maximum capacity at condenser inlet temperatures up to 50°C and derated capacity up to 58°C.
- 11.1.5 The refrigerant used in the air-conditioning system shall be in accordance with the requirements of the Montreal Protocol. Environment-friendly refrigerants, such as R407C, R134a or R410A shall be used.
- 11.1.6 The proposed HVAC system shall be service proven in a rail-borne application, and shall achieve the requisite degree of passenger comfort. It should have minimum weight and low life cycle cost.
- 11.1.7 The estimated weight, power requirements and heat load calculations giving the parameters considered, shall be submitted by the Contractor. The specific measures taken to minimise energy consumption of the HVAC unit shall be detailed in the bid.
- 11.1.8 In order to minimize energy consumption, ventilation control based on CO₂ level measurements and/or load weigh signal shall be used for controlling the performance of the HVAC system. It shall be finalized during detailed design stage with the approval of Engineer.
- 11.1.9 All electrical and electronic components shall comply with the EMC and EMI requirements of IEEE 16, EN 55011 and IEC 61000-4 standards or other equivalent standards. Fire properties of the materials used shall comply with EN 45545.

11.2 Design Criteria – Cooling and Heating Capacity of the Unit

- 11.2.1 Passenger comfort conditions shall generally be defined according to ASHRAE 55. The HVAC units shall be designed to achieve car internal conditions for external environment conditions as listed in table 11.1 below:

Table 11.1 External/internal conditions for HVAC design

Weather Conditions	External Conditions	Internal Conditions
Summer	36°C Dry Bulb, 65% RH	25°C Dry Bulb, 60% RH
Monsoon	32°C Dry Bulb, 85% RH	25°C Dry Bulb, 60% RH

Note:

Provision of humidity control shall be there in the HVAC. Humidity control should be done as per the comfort zone as specified in EN14750-1.

- 11.2.2 The fresh air intake may be taken as 8 m³/h/passenger for AW3 condition. The CO₂ level inside the car shall not exceed 2600 PPM at any passenger location when the outside (ambient) CO₂ level is around 450 PPM.
- 11.2.3 Heat gains to be considered for each car shall be calculated according to ASHRAE Handbook Fundamentals and/ or any other acceptable guidelines and shall be mainly as follows:
- Car lighting and electrical equipment heat loads including evaporator fan motors.
 - Passenger heat load in AW3 Condition for DM/T/M car.
 - Carbody heat transmission with an assumed 10 kmph relative exterior velocity.
 - Fresh air (ventilation) heat load should include fresh air intake during the time of opening of doors after every 2 minutes for 30 seconds at the stations. Preferably, the average of actual doors open-close cycle for the train route should be considered
 - A solar load representing direct and diffused radiation, convection and radiation from window



surfaces, and absorbed heat gain from the glazing and carbody structure.

- 11.2.4 The system shall automatically control the temperature throughout the passenger area up to 25°C in cooling.

Temperature sensors for fresh air, return air, supply air, shall be inbuilt in the HVAC unit. All the data shall be logged in TCMS and retrieval on demand from TCMS.

- 11.2.5 Failure of one of the HVAC units on a car shall not adversely affect operation of the other unit. The Contractor shall submit calculations for the inside conditions with one HVAC unit out of operation.

- 11.2.6 The HVAC system shall be designed to achieve the following:

- (i) Air Discharge Velocities: The air velocities inside ducts shall not cause excessive noise and discomfort to passengers in saloon occupancy areas, and shall generally follow internationally accepted practices. The air velocities at specified points in the car, as proposed by contractor and reviewed by Engineer, shall not exceed those set out in EN14750 or any equivalent standard. The supply air discharge velocities at any outlet grille/diffuser shall not exceed 4m/s. The air velocity at any point in the car shall not exceed 0.75 m/s. The air velocity within ducts shall not exceed 8m/s. The air intake velocity at the re-circulation and exhaust grilles shall not exceed 3m/s. Details of the Contractor's proposals shall be submitted.
- (ii) Temperature Distribution: Temperature difference among all points in the same horizontal and vertical planes spread over full car length shall be minimal. It shall conform to EN 14750 or any other standard. The Contractor shall submit proposal for review of the Engineer.
- (iii) Saloon Pressure: The HVAC supply air blower fan shall pressurize the car passenger area. In car stationary car with all doors closed and vestibules blocked condition, the value of interior static pressure shall be between 15 to 40 Pa.

- 11.2.7 In the event of the failure of both HVACs on a car, an emergency ventilation system shall operate automatically to admit fresh air directly into the car to maintain the required oxygen level in accordance with ASHRAE 62. The induction of outside fresh air shall not be less than 10m³/h/person, under fully loaded train conditions. The emergency ventilation fans in the saloon shall be fed from the 110V DC supply in the event of non availability of 415V AC supply from single inverter provided in each car.

- 11.2.8 Fresh air should be filtered for human comfort and safety, in accordance with internationally accepted norms. The filter element of G3 grade as per EN 779 or better shall be provided before the fresh air damper and fixed in a metallic frame and shall be easily replaceable from inside the car. Even in the extremely dusty and humid environment prevailing in Mumbai, the cleaning of the filters shall not be required before 5000 kms or 15 days of train run. The filter shall have sufficient effectiveness to ensure that dust deposition in the air duct is bare minimum and cleaning of duct is not required in between major overhauls. Cleaning of the duct shall be simple and contractor shall suggest necessary equipment required for dust removal and sanitization against fungal growth etc. Contractor shall provide minimum two sets of duct cleaning equipments in each depot. Thermal insulation and sealing of duct shall have zero calorific value. Tapes and other adhesive materials used in ducts shall have minimal calorific value and shall be fire retardant.

The method for cleaning the filters and expected life of filter shall be furnished during detail design stage. Minimum expected life of filters provided shall be 100,000 kms.

Suitable 'Automatic filter cleaning machine' shall be designed and provided by the Contractor in each Depot.

- 11.2.9 Tenderers shall indicate the type of filters proposed to be used by them in the bid. The expected pressure drop across the filter shall be furnished. Details of suitable instrumentation to be used for measurement of pressure drop shall be provided in the bid. Two sets of such measuring instruments shall be supplied by the Contractor in each depot. Each type/ size of filter shall be interchangeable in the fleet.

- 11.2.10 Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the saloon, during an emergency condition, such as fire outside the train causing excessive heat and smoke to be drawn into the vehicle. Operation of such provision shall be made from the OCC in UTO mode of operation and from operative driving console in non UTO mode of operation. The closing time of the fresh air damper shall preferably be less than 10 seconds from the receipt of smoke signal to avoid ingress of large quantity of smoke inside the car. Location of the smoke detectors and the



logic for smoke signal shall be designed in such a way that possibility of false alarm is avoided. Full details of the system proposed shall be given. Provision shall be available to bypass the smoke detectors through TCMS.

11.2.11 Deleted.

11.2.12 The HVAC units fed by one Auxiliary Power Supply Equipment shall have staggered starting in a sequence to reduce the inrush current load due to simultaneous starting of air-con motors. This may be achieved through Programmable Logical Controller of the units and TCMS.

11.2.13 The HVAC unit shall have optimized cooling capacity control for quickly reaching and maintaining the comfort conditions with low power consumption, depending on ambient conditions and the number of commuters inside the car.

11.2.14 Employer expects that an energy efficient system comparable with the best available in the market shall be provided. Good energy efficiency shall be achieved in cooling and de-humidification operations of the HVAC. Contractor shall furnish Energy Efficiency Ratio (EER) for the offered system. In cooling mode, the Coefficient of Performance (COP) of HVAC shall be at least 2.5 in summer ambient conditions under all loading conditions from AW0 to AW3 which may be achieved by utilizing variable frequency control (if required) of compressors or any other control mechanism. The COP shall be validated as per IS8148, ASHRAE 37 or any other relevant standard, as agreed by the Engineer. The Contractor shall submit the record of proven system already functional in any metros with the specified COP. The Contractor shall furnish expected power consumption of the HVACs per car for peak Summer, Monsoon and Winter ambient conditions for AW0, AW1, AW2 and AW3 passenger loads.

11.2.15 In the event of failure of an auxiliary power supply equipment on one 3 car unit in 6 car train, the remaining 3 car unit auxiliary power supply equipment must be capable of supplying all auxiliary power to HVAC of complete 6-car train. Under such Condition, all HVAC units shall work at 50% of the rated capacity.

11.2.16 Supply air blower fan can have two speeds to give energy saving at lower passenger loads. At the lower blower fan speeds, the supply air flow rate shall not be less than 3000 m³/h each unit and the car interior pressure not less than 10 Pa.

11.3 Heating System

11.3.1 Deleted.

11.3.2 The heater shall be installed, if required in the evaporator unit, downstream of the evaporator coils, to condition the fresh air intake and for reheating to control humidity as mentioned in clause 11.2.1 above.

11.3.3 The control circuitry shall not allow the heaters to be powered unless the evaporator blowers are operating. Heater element over temperature protection shall be provided. Self-resetting thermostats shall be installed adjacent to the heaters to open the contactors when excessive temperatures are detected. A positive interlock shall be provided to open heater contactors in the event of failure of the Auxiliary Power Supply Equipment.

11.4 Roof Mounted Package Units

11.4.1 Two package type HVAC units, with all equipment required for satisfactory functioning of the system, shall be provided on each car.

11.4.2 Each unit shall be arranged on an integral stainless steel (SS 316L) frame, removable from the car as a single complete module. The integral frame housing of the unit shall be constructed in such a manner that any corrosion in service on any account is avoided and the box shall last for the lifetime of the HVAC unit without needing any attention. HVAC frame/cover shall be suitable for free movement of maintenance personnel without any consequential damage to covers/equipment. The finish of the frame shall match and will be in harmony with the car body finish.

11.4.3 The complete operation to remove and replace a unit should be simple. The Contractor shall declare the weight of the complete unit. Details of specialized mechanical handling equipment shall be provided.

All electrical connections shall be fitted with quick disconnection fittings, which would be at easily accessible locations.

11.4.4 The frame housing shall be designed and constructed so that access for inspection and routine maintenance is from roof hatches, hinged at one side, secured by captive bolts on the other, and



provided with stops to retain them securely in the lifted position when opened.

- 11.4.5 The carbody roof walls for accommodating the overhead air-conditioning units shall be a compartment in the car roof structure. Each wall shall provide a continuous watertight and weatherproof area complete with adequate water drains to prevent rain, condensate or washing water leakage into the car.
- 11.4.6 Fresh and return air shall be filtered before being passed over the evaporator coil. It shall be possible to remove and replace air filters from inside the cars conveniently without the need for removal of any cable connection.
- 11.4.7 Air-conditioned unit shall have noise less compressors & condenser fans. Condenser fan assembly and evaporator motor-blower assembly shall be balanced in two planes, in-situ, as defined in ANSI/AMCA 204, and the residual unbalance should limit vibrations at motor end bells within 0.025 mm peak-to-peak displacement, or 2.3 mm/s RMS velocity, in any direction. However, any other balancing method may be proposed by the Contractor with the approval of Engineer. This shall be a type test on prototype unit.
- 11.4.8 Fresh air velocity at the HVAC outside grille face shall not be more than 2 m/s to prevent rain water from entering the HVAC along with fresh air. Similarly, mixed air velocity at the evaporator coils shall not be more than 2 m/s to prevent condensate water travelling to heating elements and supply air plenum/ducts.
- 11.4.9 The design shall ensure easy cleaning of the drains, evaporator coils, and condenser coils without need for lifting of HVAC unit from the car roof. Filter replacement, data downloading by PTU, electrical connection cubicle, control panel cubicle etc. shall be easily accessible from inside of saloon to the maintenance personnel, but not to the passengers.

11.5 Air Ducts and Diffusers

- 11.5.1 Conditioned air from each unit shall be directly introduced into a duct running the full length of the car and be discharged into the car through ceiling outlets.
- 11.5.2 Adequate sized duct from adjacent AC to the cab shall be routed to the driving cab, control cabinets and driving console. Air turbulators shall be provided in the driving console, signaling cubicles and electrical cabinets to achieve uniform cooling.
- 11.5.3 The supply air duct shall be constructed from stainless steel or anodised aluminum. It shall be diagonally split for each HVAC unit to feeds one side of the car, so that even in case of failure of one HVAC, the other working HVAC will be able to cool the saloon passenger area uniformly. The duct shall be fully lagged with non-combustible insulation material to prevent the formation of condensation. The Duct shall be suitably designed to ensure that there is no leakage of supply air between the two halves of the duct. The metallic partition shall be preferred for this purpose. The design shall ensure that in the event of failure of cab end HVAC, the bleed of cool air is always available in the cab. The Contractor shall take into consideration the requirement of maintenance access for duct cleaning as and when required.
- 11.5.4 Two rows of air diffusers shall be mounted on each side of ceiling panel, aesthetically blending well with the car interior design. It shall be possible to adjust the air quantity coming out from the diffusers during testing and commissioning, so that uniform distribution of air supply is achieved in the passenger area (to the maximum extent possible). The details of the diffusers shall be submitted.
- 11.5.5 The design of duct shall take account of the possible need to provide a recess in the roofs of cars, to accommodate the support for the pantograph base arrangement.
- 11.5.6 Exhaust air path shall be provided in the car. If needed, exhaust air fan and/or motor controllable exhaust dampers may be provided (Refer Chapter 4).
- 11.5.7 Computational Fluid Dynamic (CFD) analysis tools should be used to optimize the air distribution within the car. This study should be undertaken to confirm that all the design air velocity and airflow rate values are being achieved and shall be validated during the design stage.

The completion and submission of CFD analysis shall be a pre-requisite for issuance of NOC for Pre-Final design

11.6 HVAC Unit Compressor

- 11.6.1 The Contractor shall provide hermetic scroll compressors proven for sufficiently long time in Metro service. Scroll compressor shall be suitable for continuous operation at high ambient temperatures of up to 50°C and limited operation at 58°C ambient. Full details of the compressor and its experience in Metro train application, particularly in high temperature, dusty and high humid



environment shall be furnished. Unloading of compressor shall be linked with the HP setting.

11.7 Condenser and Evaporator Coil

- 11.7.1 The condenser and evaporator coils shall be of copper having copper fins. Condenser fins spacing shall be no closer than 3 mm and evaporator fins shall be 2.5 mm or more apart, in order to prevent dirt/dust build up. Thickness of fins shall be minimum 0.2 mm. The coil assembly shall be mounted in a stainless steel / copper alloy frame. Cleaning of condenser and evaporator coils should not be required earlier than 6 months after putting the train into revenue service. The proposed frequency of cleaning of coils in Mumbai climate shall be furnished.
- 11.7.2 The condenser and evaporator fan motor shall work on 415V, 3 phase, 50Hz supply. However, in case of auxiliary supply failure, the evaporator fan motor shall be fed from the inverter. Dual speed condenser fan motor may be used. The fan motors shall have IP 56 protection as per IEC. There shall be separate MCBs for condenser fan and supply air fan.
- 11.7.3 A condensate drain stainless steel pan shall be provided beneath the evaporator coil. Baffles shall be provided in the pan to prevent spillage. Adequate big size drain pipe shall be provided for drainage of condensate from the drip tray to the rain gutters. Suitable means shall be incorporated for cleaning of the water drainage system.

The design of rain gutter shall ensure smooth passage of water drainage and muck.

- 11.7.4 Quality of HVAC copper tubing and joints shall be of a very high order so as to minimize chances of refrigerant leakage. 'U' or 'L' shaped pipes should be used to connect condenser/evaporator coils to headers. Long overhangs should be avoided. All brazing joints of the condenser and evaporator coils and headers shall be lap joints. The brazed joints may have to be provided with suitable coating to insulate them from environment pollution. Extra coating at the header portion shall be provided. Leakage testing of high sensitivity (should be able to detect 1 gm/year leakage) shall be done on condensers and evaporators after making them but before application of extra coating and before assembling on the HVAC unit.
- 11.7.5 Condenser coil protection of exposed headers and return bends should be accomplished by ancillary guards or shields to the coil, or to the surrounding unit structure. All protection plates should be easily removable for coil cleaning and to gain access to the tubes brazed connections for repairs.

11.8 Piping

- 11.8.1 The refrigerant piping shall be of seamless copper tubing as per ASTM B280 or B743, with suitable non-ferrous fittings. All fittings should confirm to ANSI B31.5 and the connections between the piping and equipment shall be made using capillary fittings brazed lap joints. Fittings and joints should be accessible for leak test. There may be relative movement between the terminals of the compressor and the condenser and evaporator coils resulting from vibrations. The pipe layout shall take this aspect into consideration. Long unsupported overhangs should be avoided. 'U' or 'L' shaped pipes should be used to connect two assemblies.
- 11.8.2 In order to provide adequate strength against shocks and vibrations, all tubing joints should be brazed with an alloy containing 15% silver for copper-to-copper joints and minimum 40% silver for dissimilar metal joints.
- 11.8.3 Proper refrigerant leakage testing shall be done once all the copper tubing brazing is complete, just before charging of the refrigerant. No part of the assembly under test shall show signs of refrigerant leakage greater than 3 g/year under normal working pressure and shall be tested using measuring instrument of 1 gm/year least count.

11.9 Electrical control cubicle

- 11.9.1 Electrical switchgear and control equipment for the system shall be located in a sealed cubicle, which shall be an integral part of the HVAC package unit. The electric switches, contactors and relays etc. should be proven in Metro train application. The cables shall be halogen free compliant to EN 45545 Part 1 to 7 in respect of flammability, smoke emission and toxicity requirements.

11.10 Control Equipment

- 11.10.1 Each HVAC unit shall be associated with its microprocessor control panel which shall be easily accessible from within the car. The micro-processor based system, proven in railway service environment shall be provided with loading, scheduling, diagnostic and operational data interfaced with TCMS.
- 11.10.2 The microprocessor shall have extendable memory permitting logging of faults and system events in its memory for sufficiently long durations. The microprocessor shall have suitable interface with



TCMS for data communication and display. Suitable communication shall be provided to permit logged events to be downloaded to a laptop computer.

The units shall be capable of being controlled from the OCC in UTO mode of operation and from driving console in non UTO mode of operation. Facilities for remotely cutting-out and resetting of a faulty air-conditioning unit should be provided in OCC in UTO mode of operation and in the train operator's driving console in non UTO mode of operation.

High Pressure (HP) and Low Pressure (LP) values shall be monitored by TCMS.

11.10.3 Control of passenger area comfort conditions shall be done through Solid State type temperature and humidity sensors having no moving parts. For this, following minimum number of sensors shall be provided:

- (i) One fresh air intake temperature sensor in each HVAC unit.
- (ii) One each return air inlet temperature and humidity sensors in each HVAC unit.
- (iii) Temperatures recorded by the HVACs return air temperature sensors and the humidity values recorded by the HVAC's return air humidity sensors will be the feedback to the HVAC control system for taking corrective actions for maintaining the car interior passengers comfort conditions.
- (iv) Temperature sensor in the supply duct to prevent supply air from overheating.
- (v) Heat detectors/temperature sensors shall be used and integrated to TCMS/Fire Detection Control Unit for real time monitoring of all connections/points of the HVAC cables in vicinity of return air duct.

11.11 Emergency Inverter

11.11.1 An Inverter of adequate capacity shall be provided in each car to supply 3 phase AC power from 110 Volt DC battery to power the ventilator fan motors of the car during emergency mode, when cooling is off and for supplying emergency fresh air. Inverter shall be IGBT based and tested in accordance with IEC 61287. The current rating of IGBT shall be such that the junction temperature has a minimum margin of 10°C in the worst loading conditions. The inverter shall be located in inside the HVAC unit.

11.12 Operator's Cab Air-conditioning

11.12.1 Separate cab AC unit is not envisaged. The cab, driving console and electrical cabinet in the cab shall be conditioned from the saloon HVAC. The ducts shall be suitably designed. Facility shall be available for independent air control in the cab. Separate air supply fan motor shall be provided for controlling the air supply in the cab. The temperature inside the driving console and cab shall be same as in the saloon i.e. 25° C under stipulated conditions.

11.13 Earth Fault Protection

In case of grounding in any HVAC unit, it shall be possible to isolate the defective HVAC unit without affecting the static inverter operation. Contractor shall submit the proposal for Engineer's review during design stage.

11.14 Deliverables

11.14.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	11.2.8	Automatic filter cleaning machine	In each depot.
2.	11.2.9	Suitable instrumentation for measurement of the expected pressure drop across the filter.	Two sets in each depot.

Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

12. ELECTRICAL AND CONTROL EQUIPMENT**12.1 General**

12.1.1 On-train electrical equipment and control circuits, other than those for the propulsion system, shall use one or more of the following power sources:

- (i) 415V AC, 50 Hz, 3φ, 3 wire
- (ii) 230V AC, 50Hz, 1φ
- (iii) 110V DC
- (iv) 24 V DC.

12.1.2 AC single phase levels at the load end shall be within $230 \pm 6\%$ V and $50 \pm 3\%$ Hz.

12.2 Train Control and Operational Principles**12.2.1 Modes of Operation****(A) General**

The train shall employ following modes of operation:

- (a) Unattended Train Operation (UTO) Mode: The train shall be operated without train operator under GoA4 mode. OCC will send a command to ATC system onboard to operate the train so as to align train doors with the PSDs.
- (b) Restricted Manual (RM) Mode: manual operation in forward/reverse direction at maximum specified speed (to be specified) with over speed protection from onboard ATP. This mode should be used during train shunting in the depot in the area where UTO is not operational and recovery operations during train failures online.
- (c) Standby Mode: Initialized train with minimum control functions with traction control shall be in-operative and brake shall be applied during this mode.
- (d) Coded Manual (CM) Mode: Train to be manually operated in forward direction up to a maximum speed permitted by onboard ATP. Door controls to be operated by the Train Operator.
- (e) Auto Mode (AM): Automatic driving in forward direction by Signalling systems GoA2/GoA3.
- (f) Cutout Mode: Full manual operation during cutout of signalling equipment under Employer's operational procedures. Maximum speed to be limited by a preset limit controlled by TCMS.

(B) Unattended Train Operation (UTO)

- a) During UTO mode, signalling system shall control the train with mode selector at UTO position and the UTO engagement push button in ON position activated from the cab or from trackside/OCC.
- b) The Contractor shall list down all possible operational scenarios while designing the interface with Signaling & OCC (Telecom), the Contractor shall thoroughly examine all possible operating scenarios of line 2 and 7 including those which may arise out of interface with designated Contractors. The Contractor shall prepare a detail document on possible implications of different failures and incidences that may occur during operations and responses to & from signalling and/or OCC. During such analysis the Contractor shall ensure that complete information has been transmitted to enable signalling /OCC to work correctly, safely & reliably as per interface design.
- c) The status of relevant equipment, MCBs etc. shall be relayed to Signalling/OCC and shall have remote control facility to reset the MCBs as decided by the Engineer during design stage.
- d) It shall be possible to initialize the train from OCC/DCC when UTO command is being received by the train. Within depot premises, UTO mode shall be functional within specified area and it shall be possible to launch the train after self checks including door operation and Brake dynamic test and preparatory works through OCC/DCC command. In case of failure of



the train to pass its self-test, OCC/DCC shall get the message and train shall be operable by Train Operator.

- e) Similarly, train shut down shall be implementable from OCC/DCC and any failure shall be reported back.
- f) Built in safety measures, as applicable, shall be implemented during UTO initiation /failures.
- g) Signalling system shall control door operation with in-built safety provisions which shall be documented by the Contractor. In case of any defect in door operation, OCC shall be informed with door identity.
- h) The operation of the passenger train doors shall be under the control of signaling system. If the door system detects conflicting signals, the door status shall remain unchanged and a message shall be sent to the OCC. In the event that the door is unable to close after the predetermined number of times of re-close, a message shall be transmitted to the OCC giving the identity of the train and suitable message shall be broadcasted in the train.
- i) Interface of PA & PIS system with signalling system shall include display & route update, broadcast of messages etc. Failure of signalling system shall be recorded and fall back mode shall be resorted to.
Video analytic software shall detect any abnormal condition in the car which can be recorded as emergency case.
Contractor shall prepare detail functional/ operation document. Similar document shall be prepared for interface with Telecommunication and other sub systems.
- j) In case of short stop/over-run, OCC shall be able to issue jog/creep command for signalling system to send traction/brake command.
- k) OCC shall get details of the track conditions such as rail fractures, running edge defects, rail head surface defects, missing fasteners etc. through a suitably designed Digital Line Scan Camera with automatic real time detection and warning up to 90 kmph of train speed. Such camera shall be installed on both DM cars of 4 no. of trains. Trains on which the equipment shall be installed shall be decided by the Engineer.

Similarly, a Digital Line Scan Camera with automatic real time detection and warning shall also be installed on leading (DM) cars of 4 no. of trains at appropriate place for monitoring of overhead catenary conditions and interface between OHE and pantograph, up to 90kmph of train speed.

Also, provision for a video camera on roof of each T-car at appropriate place in all trains with a view to continuously monitor and record the pantograph and OHE interaction shall be ensured. Purpose of these cameras shall be to analyse the events post failures of pantograph or OHE including panto pan entanglements or for monitoring by Train Operator or Maintenance Personnel while train is in running condition. On demand, the feed from each of these cameras (on selection) including historic data shall be available on TCMS in ATP/ATO operation and in OCC under UTO operation. Sufficient storage capacity to record these data for at least 7 days shall be ensured.

- l) OCC shall be able to selectively operate/isolate pantograph(s).

12.2.2 The control and operation shall be based on the optimized combination of the following principles:

- (i) Maximum safety,
- (ii) Maximum reliability and availability,
- (iii) Operator convenience and ergonomic design,
- (iv) Adequate redundancy,
- (v) Energy efficiency,
- (vi) Maintenance support.

- 12.2.3 The control logic shall ensure that the vital train control functions (such as couplers, door system, brakes, propulsion power removal, PEA etc.) are executed using conventional relay control and dedicated hardwired train line signals. All vital circuits including above shall be double wire, double break. The identified safety critical signals shall be carried using redundant train line pairs.
- 12.2.4 Warnings and indications that are necessary for safe operation of train shall be indicated by means of power LED lamps and shall also use hardwire system.
- 12.2.5 TCMS link shall be used to execute non-vital commands and controls of the train.
- 12.2.6 In addition, TCMS link shall be used for the identified non-vital control functions through VDU interface. TCMS link shall also be designed to provide back-up signals of certain identified vital commands to be finalized during design stage.
- 12.2.7 The Contractor shall develop overall control logic for review of the Engineer. The proposed equipment shall be service proven and reliable.
- 12.2.8 The Emergency Brake Push button (mushroom type) operation shall actuate emergency brakes without opening Line circuit breaker and lowering of the pantograph. In order to ensure that train is not stalled in the section due to defect in emergency brake application circuit, provision shall be made to by-pass the brake loop and drive the train with limited speed in either direction. Separate push button (protected against inadvertent operation) for opening circuit breakers shall be provided on driver's desk.
- 12.2.9 Provision shall be made to switch off line circuit breakers if required during emergency.
- 12.2.10 It shall be possible to independently move a single unit (with DM car) within Depot. The required switches shall be protected against any inadvertent operation and shall be placed in a cubicle near gangway. Final command for decoupling shall be given through the cab only. The switch positions shall be recorded with time stamp.
- 12.2.11 Saloon light status shall be made available in HMI.
- 12.2.12 A minimum provision of spare 10% relays, contactors, MCBs terminal blocks and contacts shall be made in the respective circuits and at their locations. These shall be duly wired up to terminal blocks. Sufficient margin may be taken by Contractor during design so that above criteria is met at the end of DLP period.
- 12.2.13 All such critical contacts which can lead to failure shall be duplicated to ensure the full redundancy i.e. double wire, double brake, paralleling of contacts etc. The Contractor shall specifically elaborate compliance to this clause during design. In case any such contacts are identified during revenue period by the Engineer, the same shall be rectified by the Contractor at no extra cost.
- 12.2.14 Any isolation / failure shall be manageable from the working cab so that the train is not held up in main line and corrective action is taken with minimum loss of time.

12.3 Trainline Electrical Connections

- 12.3.1 Electrical contact blocks, mounted on the semi-permanent coupler shall be provided. When the automatic couplers are mechanically coupled, automatic pneumatic coupling shall be affected between the mating couplers. Electrical connectors for the semi-permanent couplers shall be mechanically secured together. All couplers shall have provision of suitable plug in covers to be provided when not connected in the train formation.
- 12.3.2 The Contractor shall submit details for inter-car and inter-unit connections to meet the necessary train operation requirement. Adequate number of spare connection pins (at least 10% of each type) shall also be provided at the end of DLP. Wiring from spare pins shall be brought till the nearest cubicle in the car/cab. Contractor shall keep an extra margin of 5% so that the same may be utilized by them during DLP for carrying out hardware modifications. The Contractor shall keep sufficient margin of additional spare connection pins at design stage so that, by the end of DLP, still 5% spare is available for carrying out any hardware modification in future.

As a minimum, the following functions shall require train line controlled by 110 V DC control supply:

- (i) Brake command and emergency brake,
- (ii) Propulsion Enabling Circuits (Direction control mode etc.),
- (iii) Door Enabling (Each side),
- (iv) Safety related auxiliary commands,
- (v) Train line Integrity,



- (vi) Air gauge,
- (vii) Coupler Control,
- (viii) General fault indication for TCMS,
- (ix) Parking Brake Control,
- (x) Master Controller,
- (xi) CCTV & PA & PIS,
- (xii) Additional Train line circuits as required for train brake signaling and communication systems. Information shall be supplied and finalized at design stage.

- 12.3.3 The free end of the cabling from the electrical connector shall be terminated in a multi-pin plug (s) with compatible socket(s) at the interface with the car wiring.
- 12.3.4 All exposed cables at the exterior including the inter car jumper cables, if any shall have suitable mechanical protection.
- 12.3.5 At least 10 no. of spare train lines shall be available at the end of DLP. Suitable number of spares shall be ensured by the Contractor during design.
- 12.3.6 Design of panels for push buttons, rotary switches, MCBs & relays etc. shall be such that future addition of these components is easily possible without any modification to the main panel. Each panel shall have at least one push button/rotary switch as spare duly mounted and wired up to the main electrical cubicle terminal block. Critical circuits which have possibility of having possibility of other circuit elements getting non functional thereby leading to train detention on line, shall have independent MCBs.
- 12.3.7 Relays shall have provision to add-on auxiliary contact blocks when mounted on the train. Contractor shall have provision to provide and mount the add-on blocks if required by the Engineer during the DLP period.

12.4 Control equipment

- 12.4.1 The control equipment relays, switches connectors, terminal blocks, earth-pads, cable gland, connector plugs and receptacle, push buttons, switches, safety cut-out switches, line voltage indicators, relays, magnetic contactors, DC/DC converters and cam switches etc. provided in the panels/boxes shall be proven for Rolling Stock application. A list of all such components and manufacturer's technical catalogues for the same shall be submitted in design phase, and included in O&M Manual.
- 12.4.2 It is preferable that types of the identified control equipment are limited to a minimum.
- 12.4.3 Control equipment Panels inside the car/cab shall be with IP53 or better protection level. Main and auxiliary contacts of contactors and relays shall be with adequate protection against dust ingress. The distribution panels in the underframe shall be with IP 65 protection. The IP of display & indicators shall generally be not less than IP 53.
- 12.4.4 The panels with components shall be tested in accordance with IEC-60077, IEC-61373 and IEC 60529.
- 12.4.5 The panels/boxes shall be made of Aluminum / Stainless steel. All panels and boxes including the covers shall be individually earthed.
- 12.4.6 Wherever considered necessary by the Contractor and the Engineer, contacts shall be duplicated to provide redundancy. Inter-vehicular control couplers and data transmission pairs shall be duplicated to ensure reliability of operation.
- 12.4.7 Contractor shall use Mors Smitt BK-400 or equivalent relays for system/function as mentioned hereunder and any other safety function. Contractor shall submit complete details for review of engineer during design stage.

S.No.	System/Function
1.	Head Control/Cab Active
2.	Tail Control/Rear Cab Active
3.	Door system
4.	Zero Velocity



12.4.8 Safety relays (sealed type) shall be used for all vital commands and circuits. Safety relays shall be those relays which can lead to immobilization of the train. Contractor shall ensure that the failure of safety relays shall be on fail safe side to avoid unsafe conditions.

12.4.9 **(i) Features of Relays and Sockets:**

- All relays must have a transparent cover to ensure visual inspection from outside the relays. All relays must be equipped with a LED to visual indicate the coil activation.
- All relays must be mounted in a socket ensuring easy swapping of relays in the installation without the use of any tools. The socket or relays must be equipped with a retaining clip or snap lock ensuring proper mechanical installation under IEC 61373 conditions.
- The relay sockets shall be suitable for panel, rail or front mounting style. The wire connection shall be twin connection per relays pin with spring terminal.

(ii) Relay Testing Kit:

- Contractor shall provide two no. of portable Relay Testing Kit in each Depot to quickly identify the relay condition. It shall be capable of testing instantaneous and timer relays on correct functionality (no jammed contacts), minimum operating voltage, contact quality, operating time and delay time.
- The relay testing kit shall be suitable for various types of relays used in the Rolling Stock and shall also be able to electrically clean relays contacts.

(iii) Extension of Relay base:

Contractor shall provide two no. of tools in each Depot for extension of each type relay base (i.e. duplicating all the relay pins) for unattended system monitoring (measurement of current and voltage) without affecting the train electrical system in any way.

The tool for extension of relay base of all type of relays shall be able to fit in tightly packed relay panels and small cabinets. It shall operate unattended once fitted in electrical cabinets, enabling normal passenger operating service. The tool kit consists of:

- A Test Block -which shall be put between existing relay socket and the plug-in relay.
- Break-Out Box – All the relay pins from the Test Block shall be wired to this box for the duplication of relay pins.
- Data Monitoring and Logging Device –which shall be connected to Break-Out Box for the monitoring of relay pins (i.e. measurement of voltage, current etc.).

(iv) Dummy Relay (test switch):

The Contractor shall provide a dummy relay (test switch) for each relay type in each depot for testing, commissioning and fault finding purpose. The Plug-in test switch shall be able to simulate relay operation in an electrical installation, with latch able manual operation and voltage presence indicator.

12.4.10 Contractor to make provision for paralleling of contacts of approximately 20 different relays, which shall be finalized and approved by the Engineer during the Pre-Final Design Review.

12.4.11 Same relay's contact shall not be used in redundant loops/circuits.

12.4.12 Interlocks and auxiliary contacts connected with important protective, operation, control, auxiliary and safety circuits will be housed in dust proof enclosures either by providing the complete equipment in dust-proof cabinets and/or pressuring the cabinets or by covering the contacts only by dust-proof covers of a satisfactory design in accordance with IEC 60529.

12.4.13 The voltage range of all relays and contactors will be 77 to 138 V DC (110V DC –30%, +25%, in accordance with IEC requirements). These devices will work within this voltage range properly under their rated temperatures and contact pressures. The contact pressure will be adequate to ensure satisfactory operation under most severe working conditions.



- 12.4.14 All control equipment like relay, contactors and switches shall be installed such that they are fully accessible for inspection (from the front), repairing in situ or removal and replacement. All relay and contactors shall provide a clear visible indication of the state of the device.
- 12.4.15 The safety relay shall be rated to achieve the life expectancy for anticipated number of operations in 35 years. The relevant calculations shall be submitted to the Engineer during design stage. The other relays and contactors shall be rated to achieve a life expectancy of minimum 15 years before replacement of wear parts, adjustment or testing. The contact rating shall account for the anticipated number of operations over 15 years, system voltage, power factor or time constant of the load, switching current, nature of load separation, any use of contact in series, mounting orientation.
- 12.4.16 All push buttons and indicators shall be uniform in style and shall be arranged, size, label properly as far as possible all push buttons and indicator lamps shall be of the same manufacturer. All push button shall be of push to light type.
- 12.4.17 All push buttons switches and combination push buttons / indication shall have silver plated terminals and contacts. The contact shall be so designed that they will not weld in service when used within their rating and will not bounce closed while the car is in motion.
- 12.4.18 Contacts of critical push buttons shall be duplicated for improving reliability. Details shall be decided during design stage.
- 12.4.19 All redundant loops/circuits shall be fed from separate MCB and shall have separate supply.
- 12.4.20 All critical loops/circuits (TCMS, EB, motoring braking train lines etc) including redundant loops shall be monitored in TCMS and failure message shall be generated in case of its failure.
- 12.4.21 All critical relays, contacts, MCBs, pushbutton, Input output units, switches etc shall be monitored in TCMS. Contractor shall submit details to review of engineer during design stage.
- 12.4.22 Redundant control cables for TCMS, EB etc shall be made to pass through separate connectors.
- 12.4.23 All contact's operations shall be monitored using its auxiliary contacts. Contractor shall ensure adequate spare auxiliary contact.

12.5 Wires and Cables

- 12.5.1 All wires and cables shall be adequately protected for the maximum design and fault currents, and designed for minimum voltage drop.
- 12.5.2 The insulation of all wires and cables including those used within equipment / subsystem shall be halogen-free flame- retardant and formulated to minimise generation of smoke, noxious emissions and corrosive fumes, in the case of overheating or fire in compliance with EN 45545 (Category 4-A, Hazard level HL3) latest edition. All Cables shall comply NF F 63-808 (for low voltages), and NF F 63-826 (for high voltages) or other international standards like EN 50264(Part 1 to 3) and EN 50306(Part 1 to 4) as approved by the Engineer.
- 12.5.3 Fire resistant cables shall be proposed for circuits, which should survive for long periods during fire, as per applicable international standards. As a minimum, the cables and wires for Public Address System, emergency lighting, door opening and warning systems shall be fire resistant in compliant to EN 50200.
- 12.5.4 The system adapted to rate cable shall be fully specified for review. All de-rating factors shall be applied, together with the maximum permissible conductor temperature for the particular insulation type. In no case shall the conductor continuous temperature exceed 90°C. The maximum short circuit temperature shall not exceed 250°C. The cable insulation shall be capable of withstanding these temperatures.
- 12.5.5 The minimum cross sectional area of control cables for connections between equipment shall preferably be 1.5 mm². Any deviation from this requirement, in exceptional cases, will be subject to review by Engineer in design stage.
- 12.5.6 The proposed cables shall be proven on metro Rolling Stock. The Contractor shall submit the voltage grade, size and type of cable for different applications along with the proposed specification for the cables for review by the Engineer.
- 12.5.7 Complete cabling layout shall be designed to ensure that they are easily accessible without major



dismantling of the train/equipment so that it is possible to add-on any additional cable(s), if required to be incorporated in respective circuit. Contractor shall establish/validate the compliance during design and mock up review.

12.6 Indication Circuit

12.6.1 All hardware indications shall be with LED type. Failure of a single LED shall not cause incorrect indication. Individual cars shall have local indication of the operating status of the equipment, being remotely indicated in the VDU display, through TCMS.

12.6.2 Indication on DM Car

Backup LED indication for critical function shall also be provided in the DM Car. In addition to VDU display, the indications provided shall be for train and car level. All indications shall be provided either on the train operator's console or on the panel behind and adjacent to the driving position. The Contractor shall furnish a list of indicators including function, control and display format for review.

12.6.3 Train Lines for Indication Circuit

The Contractor shall submit proposal for train lines utilised for the indication circuits.

12.7 Circuit Protection and Earthing System

12.7.1 All electrical circuits shall be protected by fast acting, 10kA fault current rated MCB's. The Contractor shall propose a protection scheme for review. The Contractor shall submit a detailed protection scheme including calculations to demonstrate proper segregation and discrimination between the cables, fuses and the traction substation circuit breakers. Calculations shall be submitted to verify proper discrimination between different levels of the protection system.

12.7.2 All equipment shall be adequately earthed, insulated, screened or enclosed and provided with essential interlocks and keys as may be appropriate to ensure the protection of the equipment and safety of those concerned with its operation and maintenance.

In case of any loose connection which may result into overheating of incoming wires then in such scenario protection shall be so designed that it shall be able to isolate the equipment without any major fire or overheating of the sub system or its cases. This protection scheme shall be independent of the overload protection & shall be capable of acting much before the load current reaches to its set tripping level.

12.7.3 All equipment on the vehicles, except the battery boxes shall be safety grounded to the carbody structure. The safety grounding shall be distinct from power return grounding. Safety grounding points shall be of tinned copper, clean, free from paint, and of a sufficient area to ensure proper electrical contact for the grounding cable fasteners. Untinned bronze grounding points and austenitic grade stainless steel grounding points are also considered acceptable.

12.7.4 The area of any weld joining the grounding pad to a surface shall be at least equal to the cross-sectional area of the grounding cable. Grounding points will have either a tapped hole or, preferably, a clearance hole (with access to both sides) suitably sized for the lug attachment fasteners. Minimum grounding cable size will be 6mm².

12.7.5 An earth fault detection system shall be proposed by the Contractor for review. Protective devices shall also prevent fires resulting from short circuits, or other electrical defects.

12.7.6 The Earth Concept shall such that requirement in audio frequencies used in signaling track circuits is met.

12.7.7 All electrical circuits shall be fully insulated from the superstructure on both the positive and negative sides and the super-structure shall not be used as any portion of an earth return circuit.

12.7.8 Earth fault protection shall be provided on control, auxiliary and traction power circuits, so that it shall be possible to continue operation for a limited period even where there is one earth fault on the circuit. For this purpose, the earthing of the circuits may be provided through the coils of earth fault detection relays and the supply battery.

12.7.9 All electrical and electronic equipment shall be protected against surge or transient voltages caused by switching (internal or external to the Rolling Stock), lightning discharges and line voltage disturbances by the provision of suitable filters or surge suppressors.

12.8 Lighting System

12.8.1 Exterior Lighting



- (i) Exterior lights lens assemblies shall be sufficiently robust to resist the impacts of flying ballast.
- (ii) The IP protection shall be IP65, when fitted on the carbody.
- (iii) Deleted.
- (iv) Individual power LED clusters used as exterior lights shall be able to be replaced easily from track level. Replacement of individual cluster shall be possible in depot without disturbing the functioning of the light. In case, the change of cluster requires readjustment of complete light or component, facility for the same shall be provided in each depot.
- (v) Access for cleaning and the replacement and adjustment shall be possible.
- (vi) All LEDs shall conform to the minimum requirements as specified in ERTS 12.9 and its sub-clauses.
- (vii) Complete lighting system(s), their components shall generally conform to relevant ENs/IECs applicable for railway applications and shall be type tested.

12.8.2 Head and Tail Lights

- (i) Power LED based Head- and tail-lights in watertight sealed, vermin-and-insect proof integrated housings placed at approximately 3m centres and 1.5m above top of rail datum, beneath the windscreens. The units shall be "handed", left and right, so that the taillights are outboard of the headlights.

The two power LED based white light, with provision for dipper shall be mounted at the front of the driving end of the DM Car, to provide even illumination of the tunnel bore (if available), track bed and track side signal posts. It shall be possible to read the number plates provided on the OCS masts and other boards like pantograph lower / raised boards. The illumination level of the head light shall be as per the international norms. Replacement of individual cluster shall be possible in depot without disturbing the functioning of the light. In case, the change of cluster requires readjustment of complete light or component, facility for the same shall be provided in each depot.
- (ii) Each beam shall be separately adjustable both horizontally and vertically. The On/Off and Beam controls shall be switched from the train operator's console.
- (iii) Two bi- colour power LED based marker lights (tail lights) shall be provided which may be lit in both active and non-active cab. The tail lights shall be LED type. Each LED shall be dual colour of white and red which shall be selectable from cab. Alternatively, white & red LEDs may be provided within the same block/fitting and be used accordingly. In active cab the marker lights shall be white and in non-active cab it should be of red colour. During the normal train operation, white front lights shall glow and rear shall be red. However, in case of a stationary train in siding or depot, both front and rear lights shall be red.
- (iv) The taillights shall be sufficiently large and bright, to enable the lamp to be seen and acted upon by a train operator within the stopping distance of the consist travelling at maximum speed.
- (v) The control of Headlight and tail light shall be based upon the direction of train movement i.e. headlight and tail light (in white colour) should glow in the cab which is in moving direction and tail light (in red colour) should glow in the cab in the non moving direction.
- (vi) The headlights and taillights shall not be switched off when the train is passing through a neutral section.
- (vii) The Contractor shall propose to suitably indicate the front end of the train while parked at depot, or stabling sidings, by illuminating two white lights either by using dimmer position of head light or using dual colour LEDs in the tail light or by other appropriate means.

12.8.3 Flasher Light

- (i) In order to attract the attention of the train operator of the following train or a train approaching from the opposite direction, in emergency, a powerful flashing amber light in addition to the tail lamps shall be provided in the front panel of each driving car. This light shall be switched ON by the train operator in case of emergency and shall not be switched OFF even while negotiating neutral sections. Provision should also be there to manually switch ON the flasher light as per operational requirement of Train Operator.
- (ii) Flasher light when lit and flashing shall be able to attract attention at a distance of 300m under clear sunny daylight.

12.8.4 Door Indicator Lights



- (i) An amber indication lamp (power LED based) shall be located at an appropriate location near each door.
- (ii) The lamp shall remain extinguished when respective door is fully closed and locked.
- (iii) The lamp shall be illuminated when the door is in fully open condition, or when the locking mechanism has failed to register, preventing traction circuits from picking up or when the door is closed, locked and isolated.
- (iv) The lamp shall flash whenever door is opening or closing; for ex: when close announcement button from the active cab is pressed. It shall continue to flash till such time the door is closed.

12.8.5 Call-On Light Switch

A Call-On Switch shall be provided in the train operator's cab, to cater for Emergency Push-Out situations. Operation of the switch on a failed train, with the Mode Selector in OFF, shall cause the tail lights at the rear of the failed train to flash on and off, indicating to the train operator of the rescuing train that he may proceed to affect coupling.

12.9 Interior Illumination System

The lighting system shall generally conform to EN13272. The system shall be based on power LEDs and should meet following requirements in general:

- 1) The guaranteed life of the LEDs with their control system and optics/luminary shall not be less than 60000 burning hours.
- 2) The specified illumination level shall be met till at the end of the life of 60,000 hours when the illumination is not less than 70% of their original illumination level.
- 3) The colour of the LEDs shall be white (temperature 3000K). It shall be ensured that all LEDs are selected from same bin to avoid any difference in colour and performance.
- 4) The design of the heat dissipation arrangement shall be submitted in details with simulated results
- 5) Colour rendering index shall not be less than 80.
- 6) Complete light and energy simulation calculations shall be provided during design to prove validity of the proposed solution.
- 7) The system shall be designed to limit glare and ensure no glare by night time reflections in windows. Luminaries shall be designed to confirm relevant international standards.
- 8) The change of chromaticity over the lifetime of the product shall be within 0.007 on CIE 1976(u',v') diagram or equivalent.
- 9) Luminaire efficiency inclusive of LEDs/control gears & optics etc. shall not be less than 100 lm/W at the working junction temperature; higher values shall be preferred.
- 10) Design layout of LEDs & their strings/blocks should be such that the failure of one LED should not cause isolation of complete string/block. Similarly, failure of one controller on one string/block should not adversely affect other strings/blocks. Details shall be finalized during design stage.
- 11) Cars may remain unpowered in open sun and internal temperature may go up to 70°C (ERTS 3.10). Suitable protection measures shall be taken to ensure that this does not adversely affect the performance, reliability or efficiency of the lighting system and its components. Verification/validation to the above shall be proposed by the contractor during design.
- 12) Illumination within saloon with LED luminaires shall be designed so as to ensure that the desired maximum illumination level is achieved with LEDs operating at less than 50% of its rated capacity. However, driver/control unit/optics etc. shall be designed for full rating of the LEDs.
- 13) All luminaires shall be of LED type and fitting shall be protected and diffused. No exposed light sources will be accepted.
- 14) LED luminaires and control gears shall be sealed to at least IP 54, BS EN 60529:1992, to prevent the ingress of dirt and foreign objects.
- 15) After one year, two year and 60,000 operation hours, the colour temperature shall be within $\pm 5\%$, $\pm 8\%$ and $\pm 10\%$ of the initial value respectively.
- 16) LED luminaries shall be designed to withstand switch cycles of 100,000 and test shall be conducted to prove the compliance.
- 17) The Contractor shall replace all the LED lighting with a newly improved LED lighting if
 - (i) The total cumulative failure rate of the LED luminaries and control gears within DLP exceeds 5% with 20% of LEDs failed in a LED luminaire is constituted as a failure of the LED luminaire;



- or
- (ii) The illumination level at floor level of any five trains drops below 90% of the initial values at the end of two-year operation but before the expiry of DLP.

Note: The illumination of LED shall be designed assuming 15 hours daily operation and 365 days of operations.

- 18) Since LED technology is fast evolving and the Rolling Stock supply is a long drawn process, Sub-Supplier shall commit to supply new generation of improved LEDs progressively and which should be compatible with the luminaries already supplied and installed. The Contractor shall regularly update the Engineer on this aspect during the manufacture.
- 19) Noise generated by the energised LED lighting, fixtures and ballast/control gear installed in a car shall not exceed 50 dBA when measured 1m from the equipment.
- 20) LEDs manufactured by reputed manufacturers shall only be used after taking the prior approval of the Engineer during Design Review.

For indigenization of "Luminaries and Lamps" as referred in ERGS clause 1.1.8, Table 1C shall imply fitting and PCBs etc. except LEDs of the LED lights.

- 21) LED(s) shall have lumen rating as 100 lumen/LED or above.
- 22) Maximum number of LEDs which a driver/power supply can feed shall not exceed 60 LEDs.
- 23) During commissioning and subsequently, it may be desirable to adjust the lux level to 250/200 in the saloon. Provision shall be made for adjustment of the lux level within saloon. At least three levels of adjustments i.e. 200 lux/250 lux/300 lux shall be provided in the saloon illumination design as a minimum. Details shall be discussed during design review.

The selection of Vender shall be made so as to optimize the design criteria as above.

12.9.1 Saloon Illumination

- (i) Energy efficient, power LED based lights, in luminaries meeting flame, smoke and toxicity requirements shall be recessed into the ceiling panelling. The light fittings shall be simple, and arranged not to trap dirt, moisture and insects. Suitable sealing protection shall be incorporated to prevent ingress of dust etc. from AC ducts. The luminaries shall ensure to minimise the glare.
- (ii) All the saloon lights shall work on 110V DC.
- (iii) The size and number of light fittings with diffuser shall be sufficient to provide a sensibly constant level of illumination of 300lux at a height of 1.0 m above floor level, along the entire length of saloon. The complete scheme for saloon lighting including gangway area shall be decided during design stage.
- (iv) Separately protected lighting circuits shall be used, such that in the event of one tripping, the others provide evenly distributed lighting throughout the saloon.
- (v) In the elevated corridors, during daytime, the illumination level shall be controlled as per clause 12.9.1 (vii) below. 100% saloon lights shall glow in tunnel (if available) all the time and in elevated corridor during night. The changeover shall be automatic as well as driver actuated. Saloon/Emergency lights shall be supervised by TCMS. Contractor may propose an alternate proposal wherein all the LED lights may be ON but with varying intensity (current level) to match the requirements of Lux level according to ambient light condition during day and 100% intensity during night. An illumination controller would be required to be installed at car level to maintain the desired illumination level. Active dimming control with sensor count and sensor location details shall be submitted for Engineer's review and approval during design stage.
- (vi) 100% of lamps, evenly distributed over the saloon area, shall remain illuminated, energized even when the train / car passes through neutral section.
- (vii) The control logic shall ensure automatic selection, with manual over-ride, of the saloon light circuit(s) to maximize utilization of the natural light and maintain the desired illumination level. During daytime, the interior lights shall be controlled automatically through infinitely variable dimmer(s) (continuous and step less control) so as to maintain illumination level within acceptable level and reduce the energy consumption. The control of illumination intensity should be at car level with the multiple light sensor input to dimmer. The Contractor shall submit full details including the number of sensors, their location, control logic etc. for review by the Engineer during design stage.
- (viii) The Contractor shall submit service life of LED lamp during the design stage which shall be as per



the best international practices.

- (ix) The Contractor shall submit layout of fittings and control circuit for review by the Employer.
- (x) It shall be possible to replace defective LEDs/ block of LEDs with ease and minimum need for readjustments or otherwise. Any special tools required for the purpose shall be supplied as two sets to each depot.

12.9.2 Cab Illumination

- (i) The cab shall be provided with ceiling lights, providing a sensibly constant level of illumination of 200lux at 1m above floor level. It shall be operated automatically by the opening of partition door of either driving console, and extinguished manually from within the cab.
- (ii) Separate lightning of the train operator's console shall meet the requirements of UIC 651 or which stipulates a minimum of 60 lumens/m² measured at the driving control desk. Driving console light shall be operated manually from within the cab.

12.9.3 All cubicles shall have sufficient lighting arrangement for facilitating their maintenance related works and it should be supplied from battery line, duly interlocked with door of that cubicle. Lighting in the cubicles for maintenance related works shall be made available even after isolation of control supply of the train.

12.9.4 UTO/RM indicating light

One indicating light visible from side of the train indicating UTO or Restricted Manual mode status, shall be fitted on each side of the cab end.

- The switch off position shall indicate UTO not being used and safety for operation and maintenance personnel to board the train and/or to carry out coupling during rescue operation
- Switch ON would imply "train under UTO".
- Flashing would mean Restricted Mode activated.

12.10 Cab Equipment

12.10.1 Master Controller

- (i) An ergonomically designed step less Master Controller shall be provided on the train operator's console. The Master Controller shall be a fore and aft longitudinal shift type. The overall design shall ensure minimal stress on train operator hand. A rotary type deadman's device shall be provided on the Master Controller Handle. The angle of rotation shall not be more than 15deg. There shall be adequate hysteresis between motoring/coasting/braking. Driving mode will be achieved by moving handle away from the operator and conversely braking mode shall involve pulling the handle toward the operator. Design shall ensure the master controller movement remains soft, uniform and undisturbed at least up to intermediate overhaul. No greasing or lubrication requirement shall be foreseen during this period.
- (ii) The Master Controller shall be provided with deadman's safety device and the deadman mechanism have auxiliary switches.
- (iii) The Master Controller shall have following positions:
 - Off
 - Emergency Brake Application
 - Motoring
 - Braking
- (iv) The Master Controller shall have adequate number of dedicated potential free interlocks solely for ATO and ATP system operation.
- (v) At least 10% spare contacts in master controller for each position and type shall be provided and wired up to the terminal block in the main electrical cubicles.

12.10.2 Mode Selector

- (i) A Mode Selector Switch shall be provided on the train operator's console and selection of mode shall be by longitudinal, fore and aft movement.
- (ii) The Mode Selector shall be mechanically and electrically interlocked with the Master Controller.
- (iii) The Mode Selector shall confirm to the operational modes described at ERTS 12.2.
- (iv) At least 10% spare contacts in mode selector for each position and type shall be provided and wired up to the terminal block in the main electrical cubicles.

