GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION
FOR
IGBT BASED PROPULSION SYSTEM
FOR
3-PHASE LOCOMOTIVES

Specification No. ELRS/SPEC/IGBT/0029 Rev. 0

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RESEARCH, DESIGNS & STANDARD ORGANISATION
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CHAPTER 1- GENERAL

1.0 OBJECT:

Indian Railways (IR) is currently manufacturing electric locomotives employing 3-phase propulsion based on the GTO technology. Considering the future trend in the development, IR proposes to introduce IGBT based 3-phase drive for evaluation and experience.

1.1 This particular specification is intended to define the technical requirements of an IGBT based 3-phase propulsion drive with associated control/subsystems suitable for retrofitment on existing WAG-9 locomotives.

1.2 DEFINITIONS:

CLW	- Chittaranjan Locomotive Works
RDSO	- Research Designs & Standards Organisation
Tenderer	- Firm/companies participating in the tender
Supplier	- The qualified tenderer for supply of the equipment
IR	- Indian Railways Administration

1.3 Scope of supply:

The scope of supply is indicated under chapter –4.

1.4 References to Various Specifications:

This Particular Specification is based on the following Normative References

1. IEC-61287	:	Electronic Power Converter mounted on board rolling stock.
2. IEC-60571	:	Specific rules concerning the electronic control part of converters.
3. IEC – 349 –2	:	Electronic converter fed alternating current motors(1993)
4. IEC-563-1976	:	Permissible limiting temperature in services for component of electrical equipment of traction vehicles.
5. IEC –505-1975	:	Guide for the evaluation and identification of insulation systems of electrical equipment.
6. IEC – 349 –1991	:	Electric Traction rotating electrical machines for rail and road vehicle.
7. IEC-349-2-1993	:	Electronic converter fed alternating current motors.
8. IEC –61375-1	:	Electric Railway Equipment-Train Bus – Part –1 : Train communication network.
9. IEEE –304	:	Insulation system for Direct current machine.
10. IEEE – 429	:	IEEE recommended Practice for thermal evaluation of sealed insulation systems for AC electric machinery

		employing form-wound pre-insulated stator coils for machines rated 6900 V and below.
11. EN : 50121-3-2 (CENELEC)	:	Railway applications – Electromagnetic compatibility – Part 3-2 : Rolling stock – Apparatus.
12. EN :50121-2 (CENELEC)	:	Railway applications – Electromagnetic compatibility – Part 2 : Emission of the whole railway system to the outside world.

1.5 **Documentation**

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

- v Schematic Circuit
- v Functional Description
- v System design concept
- v Communication protocol and software compatibility with the locomotive control system.
- v Cooling design
- v Mechanical interface diagram (Outline General Arrangement)
- v Clause by clause compliance
- v Simulated results of interference values
- v Credentials with details of supply made of such items world wide.
- v Data sheets for devices and other equipment proposed
- v Modifications needed in the present locomotive for accommodating the offered system
- v Salient features and advantages of the offered system
- v Details of technical support and training offered should cover familiarisation with equipment, its installation, commissioning, trouble shooting, software support in traction converter and auxiliary converter electronics and maintenance and repair requirements.
- v Recommended list of spares with cost for 3 year maintenance after warranty
- v List of special tools, jigs and fixtures needed for assembly, testing, commissioning, maintenance and repair.
- v Logistics proposed for warranty support. Locomotives based on IGBT propulsion system will be homed at Electric Loco Shed, Gomoh on East Central Railway or Electric Loco Shed, Ghaziabad on Northern Railway. The successful tenderer has to create a facility for warranty support at the homing shed for trouble shooting the locomotive in the event of the occurrence of fault in the propulsion

system. IR will provide necessary logistic support like provision of room, water, electricity etc. to the successful tenderer as per extant rule.

- v Long term support proposed by the tenderer for series manufacture in case IR chooses to adopt the scheme on a regular basis.

1.5.2 Following documents shall be submitted by the successful tenderer after award of contract.

- v Technical documentation explaining the complete scheme, characteristics, diagnostics, protection and control etc.
- v Detailed drawings of each system/sub-system with interface details.
- v Design calculations for selection of devices, cooling systems and various subsystems.
- v Cooling system design
- v Vendor list for subsystems
- v Procedure for parameter alteration, software downloading, diagnostic uploading, analysis etc.
- v Maintenance, Trouble shooting and repair manual.
- v Spare catalogue
- v Lubricant data

1.5.3 The successful bidder shall submit the design details to RDSO and CLW before commencing manufacturing. Only on getting the approval from RDSO in writing should the production begin.

1.6 INFRINGEMENT OF PATENT RIGHTS:

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

1.7 Warranty

1.7.1 The contractor shall warrant that everything to be furnished under the contract shall be free from defects and faults in design, material, workmanship and manufacture, and shall be of the highest grade and consistent with the established and generally accepted standards for stores of the type ordered and in full conformity with the contract and samples, if any, and shall, if operable, operate properly according to the contract.

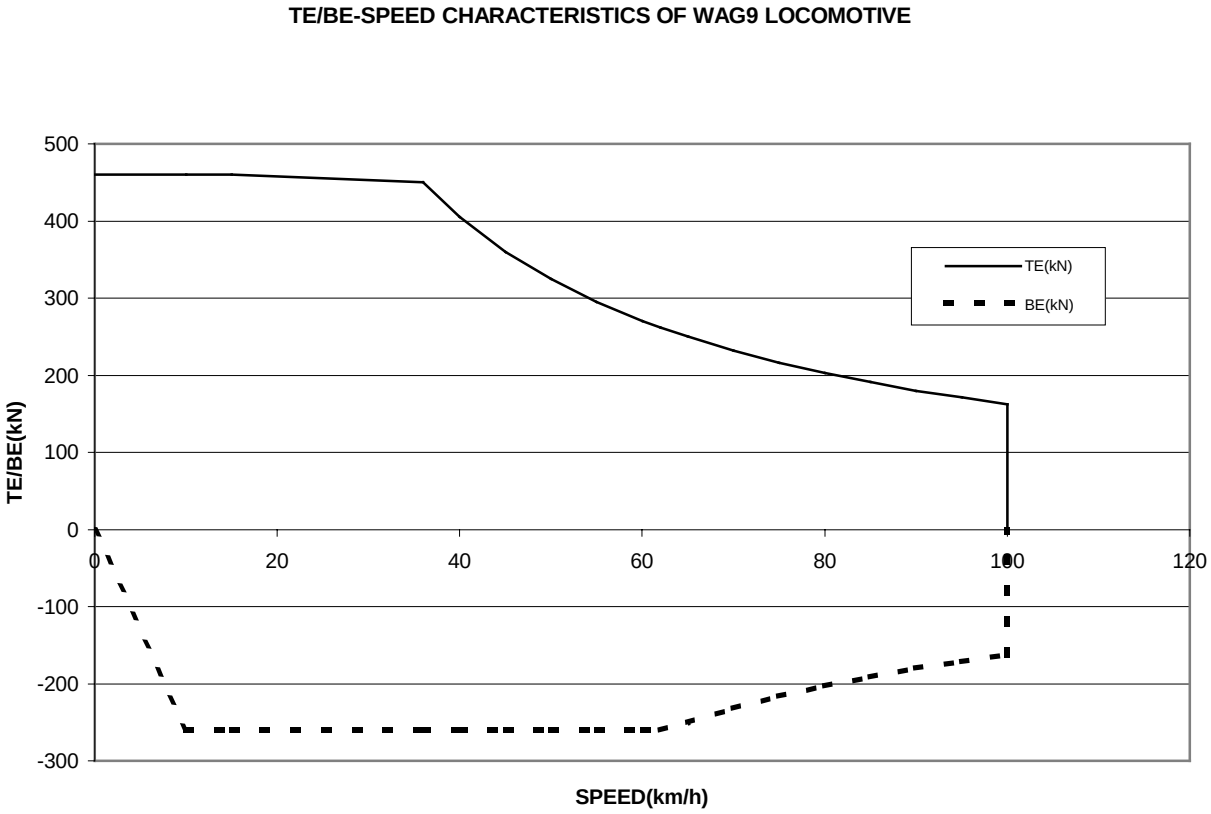
1.7.2 The warranty for the stores to be supplied under this contract shall be 72 months from delivery or 60 months from date of satisfactory commissioning and acceptance test of the stores, whichever is earlier. The contractor shall immediately on receipt of notice of defect depute his engineer to start action for rectification of defects under warranty.

1.7.3 In the eventuality of major design modifications during the currency of the warranty period, the warranty for such components shall be extended for such period as is mutually agreed upon.

CHAPTER 2- TECHNICAL SPECIFICATION

2.0 Performance Parameters

Presently, for WAG9 locomotives with GTO based propulsion, Tractive effort and adhesion characteristics are as given below:



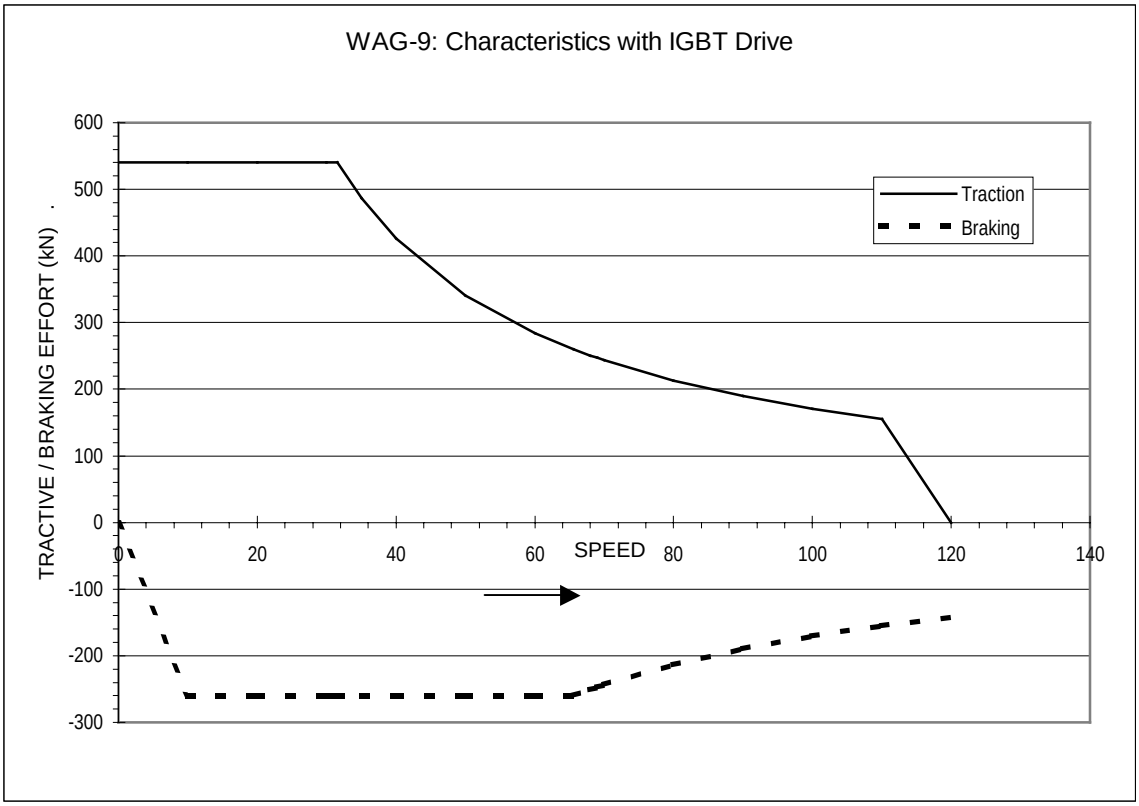
With adoption of IGBT based propulsion and the scope available for upgradation, the characteristics are sought to be upgraded.

2.1 Tractive Effort and Adhesion:-

2.1.1 Tractive/Braking Effort Requirements:

The tractive effort/braking effort- speed characteristics of the locomotive with the supplied propulsion system and drive under the conditions indicated in clause 2.2 to

2.4 with new wheels after making suitable corrections for derating under ambient conditions indicated in Chapter 3 are given below:-



The maximum starting tractive effort generated by the propulsion system should be 540 kN under dry rail conditions.

The vehicle gauge is 1676 mm broad gauge and axle load permissible is 20.5 t ± 2%. The curve given above shall be applicable for the new wheel diameter of 1092 mm ± 0.5 mm and must be ensured at Overhead traction voltage of 22.5 KV.

2.1.2 **Duty Cycle** :

Locomotive working in adverse terrain has to negotiate longer periods at lower speeds. The typical duty cycle encountered in operation could be as given below and loco propulsion system and equipment should be able to work satisfactorily under such conditions.

Speed	% of total running time of loco	Tractive Effort desired
0-10 km/h	5	>500 kN
10-30 km/h	10	450 kN
30-60 km/h	20	350 kN
60-80 km/h	50	230 kN
80-100 km/h	15	180 kN

2.1.3 Adhesion requirements:

The design of the adhesion control will be optimised for maximum utilisation of adhesion factor and should be such that it is capable of generating 540 kN of starting tractive effort by the locomotive under dry rail conditions. The Supplier will state the value of maximum starting tractive effort that will be developed under dry rail conditions and also under all weather conditions, which will be demonstrated during testing. The adhesion control system will be capable of giving high adhesion through a wheel slip control system of proven performance. The system offered will be so designed as to reduce operation of sanding substantially.

2.1.4 Continuous rated speed and continuous rated tractive effort:-

Characteristics of existing WAG-9 is such that it gives continuous speed of 50 kmph and below 50 kmph, it works on short time rating of Traction motor. This affects load hauling capacity at lower speed and, therefore, lower continuous speed will be desirable. The continuous rated speed of the Traction Motor and the corresponding continuous rated tractive effort will be indicated. The achievable running adhesion characteristics will be made available. The formulae for linking adhesion characteristics with the operating speed will be indicated.

2.2 Overhead Traction Supply

The overhead voltage is 25kV AC 50Hz, single phase. The supply voltage is fed to the traction transformer through a Vacuum Circuit Breaker (VCB). The transformer output is to be connected to the traction converter. The overhead traction supply is subjected to variations as under:

Nominal Voltage	- 25kV AC
Maximum Voltage	- 30 KVAC
Minimum Voltage	- 19kV AC
Instantaneous Minimum	-17.5kV
Supply Frequency	- 50Hz$\pm$ (6%)

The design calculations and guaranteed performance will be based on OHE voltage of 22.5 kV.

The transformer output voltage will vary in accordance with the overhead supply. The details of the VCB and transformer used are given in Appendix-1 and Appendix-2 respectively. The propulsion system offered shall be designed to withstand the voltage variations mentioned above.

2.3 **Track structure**:

The track on which locomotive with the offered propulsion system will work is to a minimum standard of 90R rails on sleepers to M+4 density and 200 mm depth of ballast cushion below sleepers (which may consist of at least 75 mm clean and the rest in caked condition) on consolidated and stable formation. (52 kg rails, which constitute the revised standard for heavy density and high speed routes, are, however, already in use on several stretches).

- Permissible track tolerances are as under :-

		BG Main lines	**BG High Speed Routes**
(i)	Unevenness (3.6 m base)	15mm	6 mm in general and 10 mm at isolated spots.
(II)	Twist (3.6m base)	3.5 mm/m	2 mm/m with isolated spots of 3.5 mm/m
(III)	Gauge variation	± 6 mm	+ 6 mm - 3 mm
(iv)	Alignment/versine on 7.2 m chord	7 mm	5 mm in general with isolated 7 mm on curves and 10 mm on straight

2.4 **S &T installations**:

The tracks over which the offered locomotive propulsion system will work may be equipped with DC track circuits, 83-1/3 Hz track circuits as well as track circuits at higher frequencies. Similarly, other devices like axle counters, block instruments, point machines, etc., may also be employed. On the communication network,

control circuits, teleprinter circuits, as well as VHF/UHF and micro-wave circuits are employed.

The design of the power electronics and control electronics provided on the propulsion system will be such as not to cause levels of interference exceeding the levels specified in clause – 2.12.

2.5 **Technical requirements**:

(i) The Main Converter within the scope of this specification shall be suitable for adoption on WAP5, WAP7 and WAG9 locomotives also with their existing three phase Taction Motors 6FXA 7059 and 6FRA 6068. The leading characteristics of these locomotives and their Taction Motors are appended at Appendix 3.

(ii) The IGBT based propulsion system to be retrofitted on locomotive will be of technology that has been applied and tested in rail traction applications with acceptable levels of performance. The details of such applications and user experience will be provided.

(iii) The system and equipments will represent proven latest technology specially adopted for application to meet the performance requirements under environmental conditions specified in this Chapter 3.Adequate margin will be built in the design, particularly to take care of condition of high ambient temperatures, dusty condition, high humidity prevailing in India.

(iv) Reliability of IGBT converter/inverter and associated control equipment will be of paramount considerations. Tenderers will submit reliability calculations indicating MTBF for different devices, cards and sub-assemblies. Adequate margin will be provided to take into account ambient conditions prevailing in India.

(v) High efficiency of equipment, high power factor, reduced interference to signalling and telecommunication circuits will be important considerations, next only to high reliability. Tenderer to furnish guaranteed values of efficiency of devices, sub-assembly and assemblies of the propulsion system.

(vi) Modular constructions will be adopted wherever considered possible for achieving the above requirements. Easy access for inspection/maintenance and low maintenance requirement will be given special consideration in design and layout. Tenderer will confirm support for obsolescence of all semiconductor devices for a minimum period of 15 years.

(vii) Semi conductor devices rating will be selected so as to provide margin of 25% vis-à-vis design/calculated current and voltage values under worst operating conditions.

(viii) The converter/inverter system will be capable of withstanding the maximum short circuit current under fault conditions and established through calculations. The converter / inverter system shall also be designed to withstand extreme disturbances like short-circuit / open circuit etc. at all points of input / output interfaces with locomotive, without any failure.

(viii) Following special features will be provided to minimise possibilities of trains being stalled on the section:

(a) Modular structure of power converter, TM and drive will be adopted so that one bogie/axle can be cut-out in the event of major faults and train worked with defective equipment isolated.

(b) Where any defect/failure of a power/control circuit component would cause complete failure of locomotive's electric system, suitable redundancy may be provided in order to avoid locomotive failure and disabling the train.

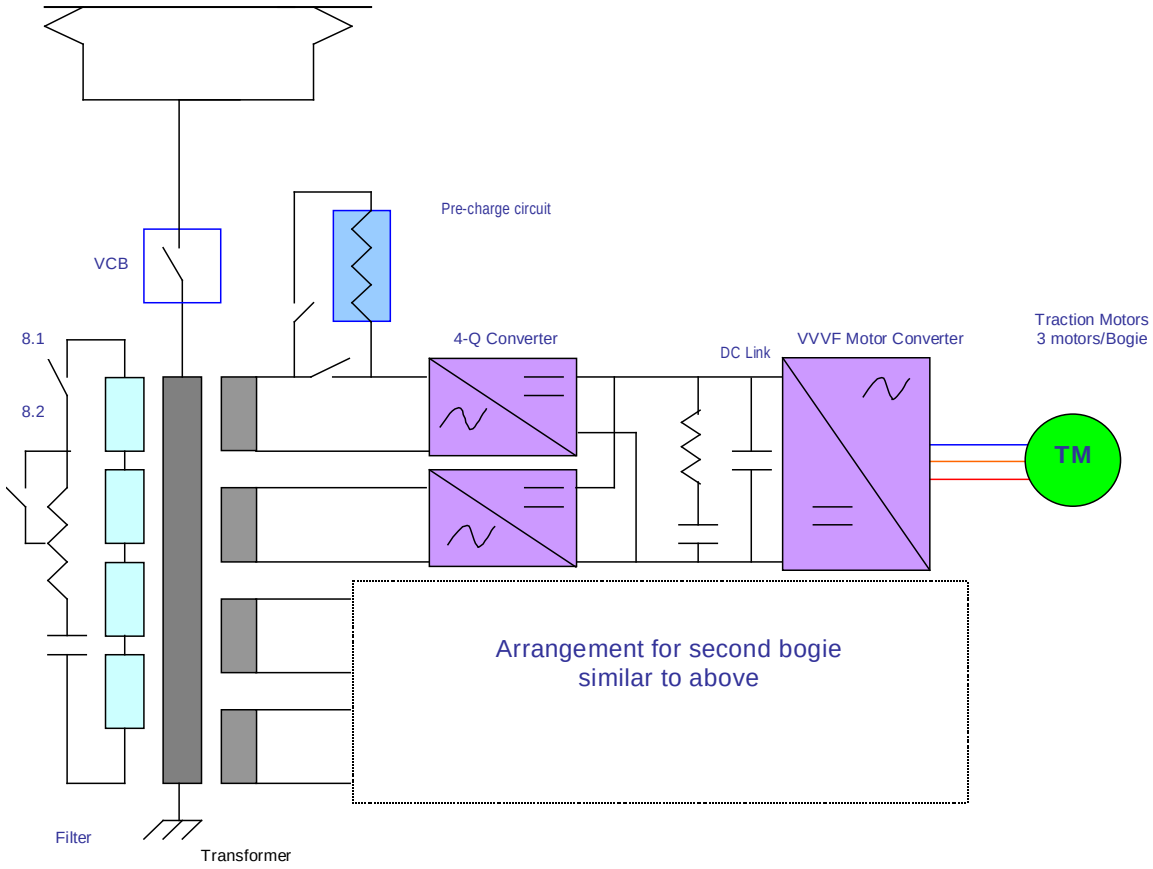
(c) Suitable margin will be provided in the equipment rating, such that under emergency condition with isolation of single traction unit, such as converters, traction motor, etc., there is no necessity to reduce trailing load on level track but the journey can be completed at reduced speeds, if adhesion conditions are satisfactory. The one hour ratings of the equipment will not be exceeded under such operations. For such purpose, short time rating of the major electrical equipments such as power converter, traction motor, etc. will be furnished.

(ix) The supplier shall make endeavour to use lubricants available in India as far as possible.

2.6 Converter Topology

Converter will have modular structure, i.e. separate converter will supply power for each bogie/axle. Each converter will consist of – 2 nos. of 4 quadrant sub converters at front end, each connected to separate traction winding of existing transformer, a DC link and voltage source inverter on load side supplying power to 3 Traction Motors of a bogie.

The existing WAG9 locomotive adopted power converter one for each bogie. The topology adopted is as indicated below:



DC link shall be designed to ensure power balance between the input and output at the specified operating range. The capacitors used shall be either oil impregnated or dry type. The tenderer shall elucidate the reasons for using the type proposed, giving merits. Traction converter must have its own pre-charging arrangement of the dc link. It should be possible to earth the dc link for maintenance, which shall be interlocked with locomotive power system.

Two Series Resonant chokes of 0.551 mH each with rating of 984 A_{RMS} are presently available in the existing transformer, which may be used if suitable. Otherwise any such equipment has to be accommodated in the converter within the prescribed envelope size of converter at Sl. No. 1 of table in clause 2.5 and supplied as a part of supply.

The inverter shall be suitable either for group drive or individual axle control. The locomotives, in which these converters are intended to be fitted, are of CoCo type. The converter shall feed the motors directly without any contactor.

Accessories like input contactor, pre-charging contactor, sensors for voltage, current, pressure, flow, temperature etc as required for the offered control and monitoring shall be provided.

2.7 Output Current Ripple

The motor converter output current ripple should be such as to keep the torque pulsations and traction motor heating to a minimum. The traction motors shall be designed to take care of the converter output current ripple in the entire operating envelope of the characteristics.

2.8 Input Current Harmonics

The 4-quadrant converter at the input shall be so configured and pulsed so as to keep the harmonics in the input current minimum. The converters shall be of PWM type with very high switching frequency to ensure low harmonics. The PWM carrier shall be phase shifted within each bogie and there shall be a further shift of carrier between the bogies. The converter control shall be designed to accept a carrier phase shift value for each bogie from a higher hierarchy i.e. vehicle control or train control level.

2.9 Converter Efficiency

The components and technology used shall ensure very high efficiency of the converter. Typical efficiency of above 98% is preferred. Tenderer shall furnish the expected efficiency with respect to vehicle load/speed.

2.10 Input Power Factor

The converter shall employ unity power factor control of the 4-quadrant input converter. The input power factor shall be settable close to unity within the line voltage range from 19kV to 30kV at all speeds of operation of the locomotive. The details of methods and instruments used for these measurements will be finalised with successful tenderer prior to type test of the equipment.

2.11 Control Philosophy

The control philosophy for power converter shall be such as to achieve best suited results in the form of minimum device losses, high dynamic response, stable constant speed operation, fast acting slip/slide control etc. The tenderer shall furnish the details of control strategy duly describing its merits.

2.12 Interferences

(i) The electric and electronic apparatus used in propulsion system will comply emission and immunity aspects of EMC to CENELEC standard – EN - 50121-3-2. The internal EMC shall cover a combination of earthing, shielding and isolation of interference sources so that conducted and radiated noises are properly segregated or suppressed and no other equipment is affected due to operation of converter.

(ii) The harmonic currents injected in the overhead supply system (as also the track return current) can introduce voltage harmonics on power supply and can interfere with signal and telecom circuits. The following interference current in the input current shall not be exceeded at any point in the operating envelope of the locomotive.

Psophometric current<=5 A
100 Hz - 400 mA
1700 ± 50 Hz - 300 mA
2000 ± 50 Hz - 300 mA
2300 ± 50 Hz - 300 mA
2600 ± 50 Hz - 300 mA
5100 ± 50 Hz - 100 mA

Emission from locomotives to outside world will be limited to level specified under CELELEC standard 50121 –2. The tenderer shall submit the simulated values of these interference currents in their offer.

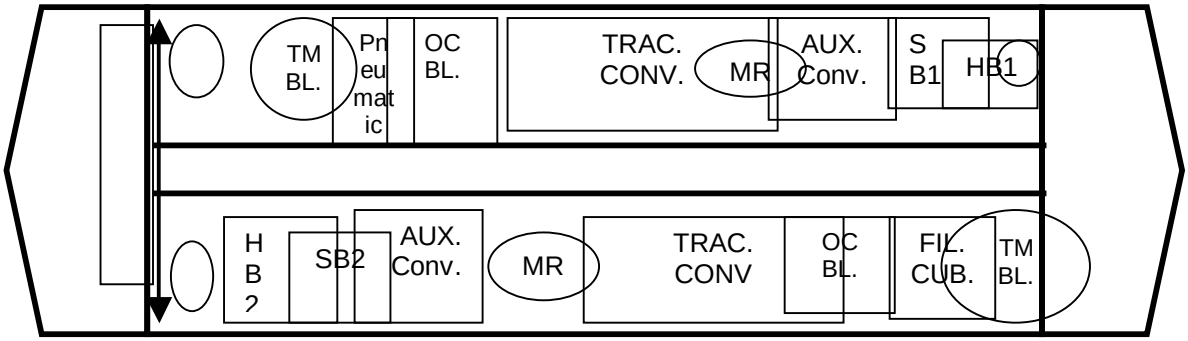
Presently, the transformer is provided with a filter winding as given in the schematic diagram. The resistance and inductance values of the windings have been given in the Appendix - 2. The filter resistor and filter capacitor ratings are 2800 V, 0.2 ohm/40 KW & 0.2 ohm/60KW and 0.4 mF, 2500V, 80A(bank capacity) respectively. During single bogie operation, filter adaptation contactor (8.2) is opened thereby introducing an additional resistor. During normal operation, contactor 8.2 remains closed. The existing harmonic filter has to be considered while designing the system for interference limits. The tenderers shall indicate clearly whether the existing filter arrangement is adequate or needs modifications. In case of any modifications, it has to be done through choosing appropriate external RC elements, which shall then be provided to IR for necessary modification in the locomotive.

2.13 Transformers, Inductors and Capacitors

Any transformers, inductors and capacitors used shall be according to the respective **normative specifications** for each of these specified in IEC-61287.

2.14 Geometrical Conformity

In existing WAG9 locomotives, traction converter alongwith associated converter control electronics for one bogie is housed in one cubicle and there are two such cubicles on locomotive. Traction transformer is underslung with the terminal bushings accessible from the machine room. The converter is positioned just above the transformer. The existing equipment layout in the machine room is shown below.



The tenderer will examine and inspect the equipments proposed to be retained and location of their terminals on existing locomotives and offer a compatible system. Tenderer will provide detailed scheme of fitment of equipment on existing locomotive indicating clearly if any modification to cable termination etc. will be involved.

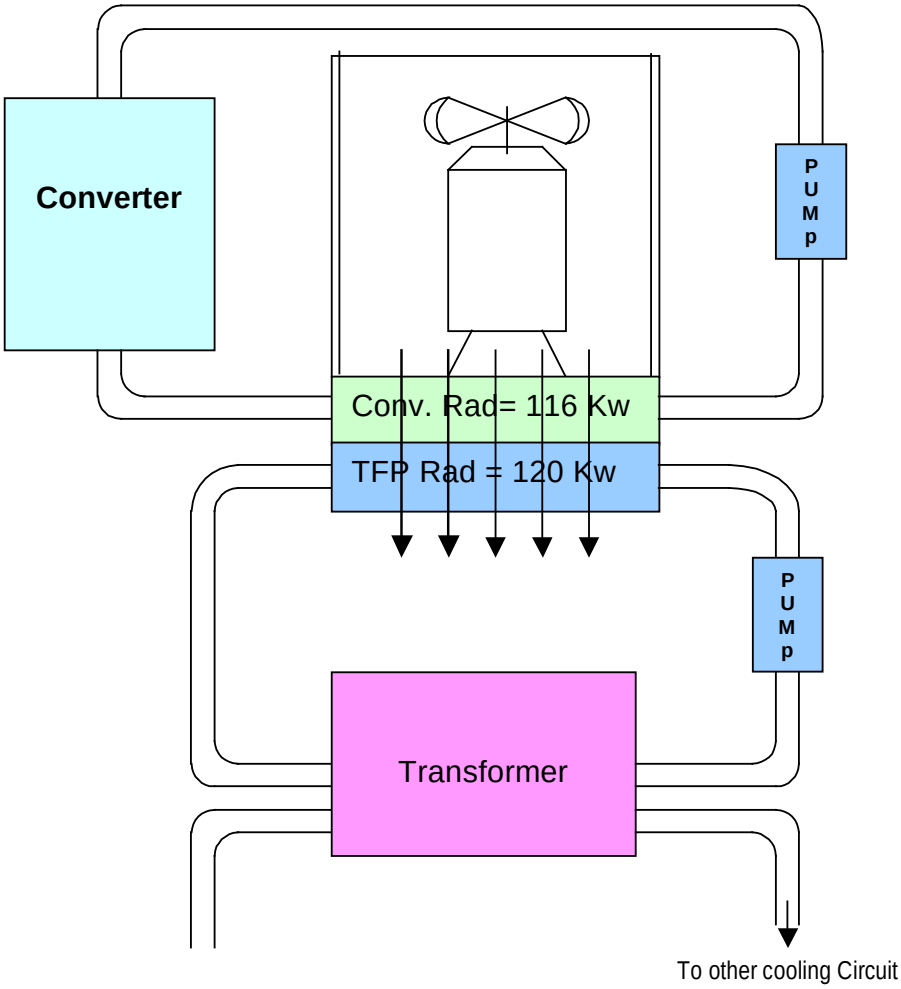
2.15 Mechanical Dimensions

Dimensions of the existing subsystems of the three phase locomotive where this converter is intended to be fitted given below: In any case, the dimensions must not exceed these specified values. Detailed dimensional drawings can be made available to the tenderers at C-D&D/CLW.

SN	Description of Item	Dimension (L x W x H) mm
1	TRACTION CONVERTER	3000 X 1100 X 2100
2	AUX.CONV BOX1- 1 x 100 KVA	1160 X 1020 X 1863
3	AUX.CONV BOX2–2 x 100 KVA	1520 X 1020 X 1863
4	BRAKE SYSTEM	800 X 767 X 1740
5	OIL COOLING UNIT	1450 X 1154 X 1510
6	FILTER CUBICLE	700 X 981 X 1753
7	PANELS (HB1/2)	830 X 690 X 1840
8	PANELS (SB1/2)	800 X 700 X 1840
9	TM BLOWER	W=1146,H= 1620, ¯ =900
10	MR BLOWER	W=800,H= 1620, ¯ =660
11	MID CORRIDOR WIDTH available	600

2.16 Cooling

Presently, forced oil cooling is adopted in IR locomotives. It has a common aluminium alloy heat exchanger module for both converter and transformer, but with different oil circuits. The blower is common. There are two cooling units, one for each bogie as per the scheme given below.



The tenderer can either use the existing radiator and cooling circuit with blower and pumps for the cooling of the Traction Converter or suggest his own scheme within the existing floor layout available. The cooling arrangement together with the radiators, the blower, coolant, cooling circuit with pumps should be of rugged construction to withstand vibrations, shock. The sealing of the cooling system should be such as to prevent spillage/Leakage of the coolant. In case the coolant used for the converter is other than oil, for example water, tenderers shall try to accommodate the new (additional) radiator at the present location utilising the same blower. Any alternative arrangement has to be clearly spelt out. The detailed drawings of the existing system can be obtained from C-D&D/CLW.

2.17 Interfaces between converter and control equipment

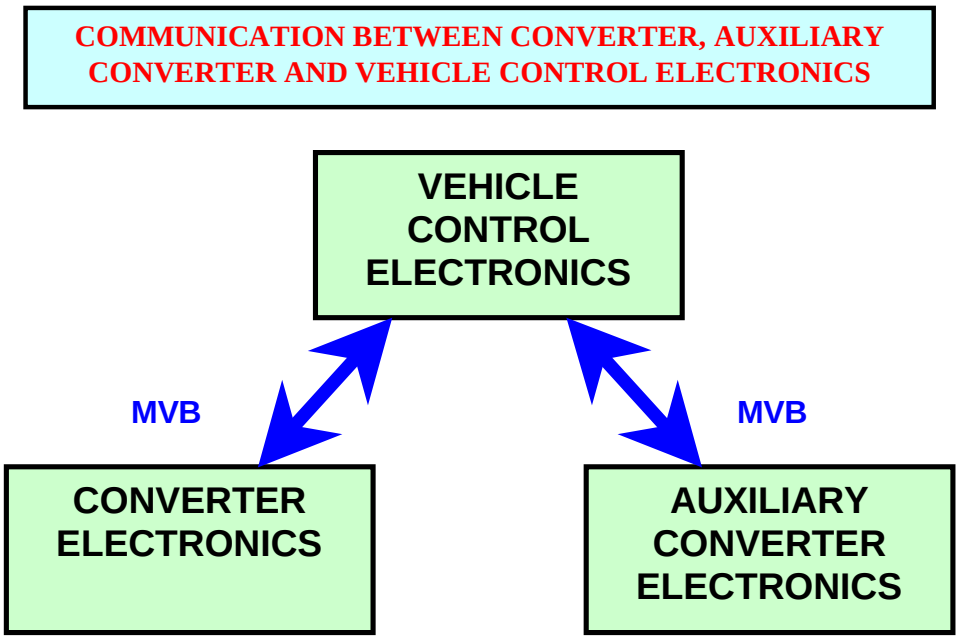
2.17.1 Hardware Interface:

The Traction converter and auxiliary converter electronics should have:

v TCN compatibility

- Be Modular – so as to facilitate field replacability and unit exchange.
- All communication interfaces should be TCN compatible as per IEC-61375 - 1 provided with MVB.
- The traction converter should have its own protection and control logic which should also be able to communicate with the Vehicle Control Unit (VCU) in the event of a fatal failure to initiate a protective shutdown of the Locomotive
- The protective shutdown in case of defined fatal conditions must be based on a predictable logic, implemented in hardware of converter electronics. The protection system offered should be such that damage to IGBT of converter is prevented in case of a short circuit at the load end.
- Facility for interfacing pc/laptop for upload/down load for diagnostics, Troubleshooting for later downloading through a pc/laptop for further fault analysis.
- The programme download must be through an online connected PC platform without the need to remove the memory chips. A FLASH EPROM based program memory is preferred.
- Facility for standalone testing may be offered, through which, it would be possible to offline test the converter by inserting a test EPROM or by downloading a test program in FLASH.
- The existing analog field signal list is given below:

SL No	Signal Description (per bogie)	Quantity
1	Traction Motor Speed (for each Motor)	2
2	Traction Motor Temperature (PT-100, 4 wire) for each motor	1
3	Converter output current (LEM sensor) 1 for each phase	3
4	Converter input current (LEM sensor) 2 for each secondary winding	4
5	DC link voltage sensor	2
6	Converter Oil pressure sensor	1
7	Converter Oil temperature sensor	1
8	Transformer oil temperature	
9	Transformer oil pressure through differential amplifier (input – output difference)	1
10	Primary current sensor	1
11	Auxiliary winding current sensor	1
12	Harmonic filter current sensor	1
13	Transformer primary voltage	1



2.17.2 Functional Interfaces

Existing Signal Groups exchanged between Traction Converter Control (TCC) and Vehicle Control Unit (VCU):

a) Communication:
- v Off /On commands of different processors of both TCC and VCU
- v Life sign of TCC processors

b) Configuration:
- v Mode of operation
- v Type of locomotive

c) Sequential control
- v Initialisation & test
- v Set-up
- v Clocking
- v Prepare pre-charging
- v Shutdown
- v Protective turning –off
- v Isolation

d) Status messages from VCU
- v VCB status message
- v Pneumatic brake message
- v Oil temperature, pressure

e) Process data from TCC
- v Motor temperature
- v Oil temperature and pressure
- v Primary Supply currents

f) Traction Converter Control

- v TE/BE generation commands
- v Firing prohibition commands

g) Storing of diagnostic messages in the non volatile memory of a dianostic processor card in the VCU for display in a Driver's Terminal or for later downloading through a pc/laptop for further fault analysis.

2.18 **Auxiliary Converter**

The 3-phase load of auxiliary machines connected and distributed between existing 3x100 KVA auxiliary converters on WAG9 locos is given under.(Clause 2.18.1) The 3-phase motors work on auxiliary converter output voltage of 415V±5% and frequency of 50 and 37 Hz. The auxiliary converters output has V/F control for current limit starting. In the existing scheme, there are three standalone auxiliary converters, each 100kVA capacity are , housed in two boxes and interconnected through changeover contactors for load distribution and there is provision of working the system with one of 3 auxiliary converters isolated, in which case load distribution will change to that indicated under clause 2.18.2, 2.18.3, 2.18.4

2.18.1 When all three auxiliary converters are working**:**

Converter-1 (functioning at variable frequency)

Oil cooler blower-1	25 KW
Oil cooler blower-2	25 KW
Total	50 KW

Converter-2 (functioning at 50 Hz)

Traction motor blower-1	25 KW
Traction motor blower-2	25 KW
Oil pump transformer -1	4.7 KW
Oil pump transformer -2	4.7 KW
Oil pump converter -1	11 K
Oil pump converter -2	11 KW
Total	81.4 KW

Converter-3 (functioning at fixed frequency)

Scavenge blower-1	3 KW
Scavenge blower-2	3 KW
Compressor -1	15KW

Compressor -2	15KW
Battery charger	12 KVA
Total	**48 KW**

2.18.2 WHEN CONVERTER-1 IS ISOLATED

Converter-2 (functioning at 37 Hz)

TM Blower –1	18.5 KW
TM Blower – 2	18.5 KW
Oil Cooler Blower-1	18.5 KW
Oil Cooler Blower-2	18.5 KW
Scavenge Blower –1	2.3 KW
Scavenge Blower – 2	2.3 KW
Total	**78.6 KW**

Converter-3 (functioning at 50 Hz)

Oil pump transformer -1	4.7 KW
Oil pump transformer -2	4.7 KW
Oil pump converter -1	11 KW
Oil pump converter -2	11 KW
Compressor -1	15 KW
Compressor -2	15 KW
Battery charger	12 KVA
Total	**73.4 KW**

2.18.3 WHEN CONVERTER –2 IS ISOLATED

Converter-1 (functioning at 37 Hz)

TM Blower –1	18.5 KW
TM Blower – 2	18.5 KW
Oil Cooler Blower-1	18.5 KW
Oil Cooler Blower-2	18.5 KW
Scavenge Blower –1	2.3 KW
Scavenge Blower – 2	2.3 KW
TOTAL	**78.6 KW**

Converter-3 (functioning at 50 Hz)

Oil pump transformer -1	4.7 KW
Oil pump transformer -2	4.7 KW
Oil pump converter -1	11 KW
Oil pump converter -2	11 KW

Compressor -1	15 KW
Compressor -2	15 KW
Battery charger	12 KVA
Total	**73.4 KW**

2.18.4 WHEN CONVERTER –3 IS ISOLATED

Converter-1 (functioning at 37 Hz)

TM Blower –1	18.5 KW
TM Blower – 2	18.5 KW
Oil Cooler Blower-1	18.5 KW
Oil Cooler Blower-2	18.5 KW
Scavenge Blower –1	2.3 KW
Scavenge Blower – 2	2.3 KW
TOTAL	**78.6 KW**

Converter-2 (functioning at 50 Hz)

Oil pump transformer -1	4.7 KW
Oil pump transformer -2	4.7 KW
Oil pump converter -1	11 KW
Oil pump converter -2	11 KW
Compressor -1	15 KW
Compressor -2	15 KW
Battery charger	12 KVA
Total	**73.4 KW**

2.18.5 To facilitate smooth retrofitment with least modification, similar arrangement with 3 x 100 KVA auxiliary converter housed in two cubicles is to be offered. Auxiliary converter will be of IGBT based design and TCN (Multifunction Vehicle Bus – MVB)compatible housed in two similar or smaller cubicles to the existing ones. These will be fed from existing auxiliary winding of the transformer. Segregation of auxiliary loads bogie-wise will be a preferred option.

2.18.6 Functional Interfaces:

Following communication will take place between auxiliary converter and VCU:

(a) Communication:

- v Off/ON commands of different processors of both auxiliary converter and VCU.
- v Life sign of auxiliary converter processor.

(b) Configuration:

Isolation message of any of auxiliary converters.

(c) Process data from VCU:

v Ventilation control.

(d) Process data for auxiliary converter.

v Battery charger status.

v Battery voltage.

v Protection parameters like current, earth fault etc.

(e) Auxilairy converter control:

v Frequency set.

v Load redistribution.

(f) Storing of diagnostic messages in the non volatile memory of a diagnostic processor in the VCU for display in the driver's terminal or for later down loading through a PC/Laptop for further fault analysis.

2.19 Traction Motor

2.19.1 General :

Three phase asynchronous type of traction motors will be used. The tenderer shall offer a suitable traction motor to fit in existing bogies of WAG-9 locos and to meet the characteristics given in this specification. **High torque and high speed motor will be desirable to get required starting TE with low gear ratio with cushion to increase it in due course if required for operational needs. The motor shall be designed for robust traction application in tropical conditions and shall be according to IEC-349-2 (1993).**

- The general design and manufacture of the motor will be done to the standard IEC 349/1991 in accordance with the modern traction practices. The design will include all features, necessary for working in the tropical climatic conditions.
- The motor will be liberally rated as per the loco performance requirements for the most severe normal service operation as defined in clause 2.2(a) of IEC 563-1976.
- The motor will be designed so as to be capable of withstanding transients such as line voltage fluctuations, switching surges and such other conditions caused by stalling and wheel-slips under different operational conditions.
- The following operational and environmental factor will be specially kept in view in the design of the motor.

  - Excessive vibrations that are experienced because of average track maintenance conditions in India.
  - Prevalence of high temperature and humidity for the most part of the year.

- Operation of the loco over a long country terrain in which the climate will vary from excessive dry heat on one end to nigh humidity on the other end or during winter months from very cold to moderately warm and humid conditions on the other end.

- Operation under highly dusty environments.

- In determining the ratings, design parameters and construction of the traction motor, full consideration will be given to the duties imposed by requirement of regenerative braking.

- The motor offered shall be a proven one already working elsewhere. The km earned by the offered motor shall be indicated along with operating railways.

2.19.2 Mechanical Design:

The details of bogie and its interface with TM mounting be inspected and necessary drawings etc. obtained from CLW.

The mechanical design of the motor, fixing arrangement on the bogies, the gears and pinions, gear case, etc. will receive particular attention.

Axle hung nose suspended drive shall be offered. The bearings used on TM and suspension system shall be so chosen as to provide expected L-10 life of not less than 3 million kilometres.

2.19.3 Insulation system:

- The insulation system to be employed will be proven design and suitable to withstand the adverse environmental conditions. Imperviousness to moisture will be a special requirement.

- The evaluation of the insulation system for thermal endurance will be made with fabricated test models by way of accelerated ageing test as per the test programme drawn up in accordance with the norms specified in IEC 505/1975, IEC 505 draft supplement and IEEE-304.

- Evaluation of the insulation system for sealing against moisture will be done in accordance with IEEE429.

- Various ageing parameters, such as heat, vibration, mechanical compressive stresses, special environmental effects of humidity, dust, metallic dust from brake shoes, etc., will be incorporated to simulate the actual working conditions as closely as possible.

- The temperature at which an extrapolated life of 20’000 hours is obtained will be treated as the thermal endurance limit (Temperature Index) of the insulation system.

- The motor will be designed such that the “hot spot” temperature under conditions such as one hour, short-time and continuous rating of loading in

any winding (stator and rotor) does not exceed the average temperature of that winding measured by resistance method, by more than 30°C.

- Having regard to the system of insulation adopted and the environmental conditions, the maximum temperature rise in traction motors will be less than temperature index minus 95°C under normal loading conditions.

2.19.4 **VENTILATION**:

In the present arrangement, 3 traction motors of a bogie are forced air cooled with the help of a traction motor blower unit of 25 KW capacity delivering 4.05 m^3/sec. of air at 2950Pa pressure. It is felt that the present cooling arrangement of the traction motors would be adequate for new traction motors to be offered by the tenderers. However, in case any additional air flow is needed, the design modification of TM blower shall be supplied by successful tenderer to IR.

2.19.5 **Harmonic/Ripple factor:** The traction motor will operate satisfactorily over the entire range of loading, with harmonics/ripples imposed from the supply system, (Transformer and IGBT converter), both during motoring and regenerative braking conditions. The manufacturer will conduct necessary tests on the traction motor to establish compliance with this requirement.

2.19.6 Following data for the Traction Motor being offered shall be furnished in the offer for evaluation.

- v Type
- v Number of poles
- v Connections (delta or star)
- v Governing Normative Standards
- v Cooling Requirement, air-flow
- v Rated continuous voltage
- v Efficiency
- v Power factor cos φ
- v Bearing Type
- v Speed range
- v Starting, short time and continuous current
- v Mass of motor
- v Starting, short time and continuous torque
- v Frequency – type frequency and range
- v Type of control
- v Details of sensors-speed, temperature
- v Insulation, temperature class
- v Interface drawings
- v Gear ratio
- v Lubrication
- v Type of conductor, winding

- v Reliability Data (MTBF,FIT etc)
- v Life time expected – TM, bearings
- v Greasing intervals

The tenderers shall submit design calculations to substantiate the suitability of the motors for the converter and to derive required tractive effort. The temperature rise calculations and safety margins shall be furnished.

2.20 Drive Assembly

Design of a suitable drive assembly will be suitable for broad gauge track of Indian Railways (1676mm) for fitment on existing WAG9 loco bogies. The outline drawing of bogie and other details can be obtained from CLW. The scope of supply includes selection of gear ratio, design of gear and pinion, gear case and suspension components like nose, suspension tube, bearings etc. The lubrication of gear pinion shall be oil based and shall be independent from lubrication of suspension bearing.

2.21 Tests & Trials

The details of the tests and trials to be done on each equipment of the propulsion system and the combined system after installation of propulsion system on the locomotive are indicated in Chapter – 5.

2.22 Additional requirements

(i) In case of international bidder, the bidder should indicate their willingness to localize, Tie-up and license manufacturing in INDIA.

(ii) The bidder should indicate the maintenance schedule, availability of spares and other subsystems over a period, requirement of onsite recommended spare parts.

(iii) Costing of different subsystems to calculate the Life cycle Cost

(iv) Standard sub systems and modules as far as possible should be used.

CHAPTER 3- CLIMATIC & ENVIRONMENTAL CONDITION

3.1 The propulsion equipment will be fitted in locomotive machine room and bogie where the temperature will be

a) Maximum temperature
} Stabled Locomotive under sun : 70 deg. C
} On board Working loco under sun. : 55 deg. C
b) Minimum temperature : 0 deg. C
c) Average temperature : 47 deg. C

3.2 Humidity: Upto 100% during rainy season.

3.3 Altitude: Upto 1000 m above mean sea level.

3.4 Rainfall: Very heavy in certain areas. The propulsion equipment shall be designed suitably.

3.5 Atmosphere during hot weather: Extremely dusty and desert terrain in certain areas. The dust concentration in air may reach a high value of 1.6 mg/cub. In many iron ore and coalmine areas, the dust concentration is very high affecting the filter and air ventilation system. The equipment shall be able to start up at the maximum specified ambient temperature inside the locomotive without any pre-cooling requirement.

3.6. Coastal area: The equipment shall be designed to work in coastal area in humidity and salt laden and corrosive atmosphere. The maximum values of the condition will be as follows:

a) Maximum pH value : 8.5.
b) Sulphate : 7 mg per litre.
c) Max. concentration of chlorine : 6 mg per litre.
d) Maximum conductivity :130 micro siemens /CM

3.7 Vibration: The equipment shall be designed to withstand the vibrations and shock encountered in service satisfactorily as specified in IEC 61287 (1995 -07) and 60571.1 (1998 - 02) (second edition) publication for the converter and electronic equipments respectively and relevant IECs as applicable to other equipment.

3.8 Electromagnetic Pollution – High degree of electromagnetic pollution is anticipated in locomotive machine room, where the equipment will be mounted. Necessary precaution should be taken in this regard.

3.9 Tilting and centrifugal forces : The cooling system shall be designed to take care of the tilting and centrifugal forces which would be encountered in service.

3.10 There is also a likelihood of working at full tractive effort for a prolonged duration but within the motor rating. The drive assembly shall be designed to take care of this aspect.

CHAPTER 4 - SCOPE OF SUPPLY

IR intends to manufacture WAG-9 locomotives employing IGBT based 3-phase propulsion system for development of IGBT based technology and system for electric locomotives. It is intended to procure only the Traction converters with its control, Auxiliary converters with its control, Traction motors with necessary speed and temperature sensors, TM suspension with suspension tube, bearings and interface with bogie, Gears, Pinions and Gear Cases. , Heat Exchanger(s) for transformer and traction converters with coolant, cooling blower along with motor, cooling circuit along with cooling pumps will also be supplied if existing equipments can not be adopted (Ref. 2.19 of Chapter-2).

The present bogies and wheel sets, circuit breaker, transformer, auxiliary machines shall be retained as it is. It is expected that the present cooling blowers of Traction Motors would be adequate. However, in case additional airflow is needed the design modification for TM blower shall be supplied by successful tenderer. Also design modification for harmonic filter resistor and capacitor shall be supplied by successful tenderer, if required (Ref. Clause – 2.14 of Chapter – 2)

The following will be scope of work for IGBT based Propulsion System.

SL No	Item Description	Quantity per locoset
1	IGBT based traction converter with its control system.	2 nos.
2	IGBT based auxiliary converter with its control system.	1 set
3	Traction Motors with temperature and speed sensors.	6 nos.
4	TM suspension with suspension tube, bearings and its interface with bogie.	6 sets
5	Gears, Pinions and Gear Case to be fitted in existing bogie of WAG-9 locomotive.	6 sets
6	Heat Exchanger(s) for cooling of transformer, traction converter, aux converter with coolant, cooling blower along with motor. Cooling circuit along with cooling pumps – if existing equipment cannot be adopted (Ref. clause 2.16 of Chapter-2).	1 set
7	Design modification for TM blower and harmonic filter resistor and capacitor (Ref. clauses 2.19.4 and 2.11 (ii) respectively of Chapter – 2)	
8	Hardware and software Interface with vehicle control Unit.	1 set
9	Laptop based software tool for downloading the software, viewing and changing the parameters, trouble shooting, in Traction Converter /Auxiliary Converter control system along with user licence.	1 set
10	Installation Drawings, Maintenance and repair manual (hard copy and soft copy both)	3 sets

11	Supplier's Documentation and Spare Parts Catalogue, Consumable data (hard copy and soft copy both).	3 sets
12	Submission of design data document for approval prior to manufacture	3 sets
13	Installation, testing and commissioning of the above equipment.	
14	Training on assembly, testing, commissioning, operation, maintenance and repair to IR personnel.	
15	Training in software parameter settings, fault diagnostic and analysis.	
16	Special tools and jigs for 3 years maintenance(the successful tenderer shall give a list with quantities)	1 set*
17	Spares for 3 years maintenance (the successful tenderer shall give a list with quantities)	1 set*
18	Type test in one unit of all equipments.	
19	Routine test in balance units of all the equipments.	

*The contractor shall quote for these items separately. These items will not come under evaluations.

The Vehicle Control Unit (VCU) will be procured separately by CLW, which will be according to IEC-61375 – 1 TCN. The Traction converter and Auxiliary converter must be compatible with the IEC-61375 - 1 TCN VCU. The signal interface between VCU and Traction converter/Aux. Converter must be spelt out clearly by the tenderer in his tender offer.

The tenderer will be involved for joint integrated testing and commissioning of entire locomotives.

The tenderer shall supply above items to CLW/RDSO and the fitment of these items will be done at CLW under the supervision of successful tenderer. The special tools, machines, instruments and other facility, which are required for installation and commissioning of system and are not available in CLW, shall be supported by tenderer.

CHAPTER 5 -TESTS & TRIALS

5.0 Tests will be conducted on the power converter, Auxiliary converter and Traction motor individually and on the complete propulsion system regarding its performance after its installation on the locomotives. The details of tests and trials are as under:-

5.1 The converter shall be tested in accordance with IEC 61287, IEC 411.5 & the control electronics shall be tested as per IEC 60571.

5.1.1 The list of tests to be carried out on the IGBT Power & Auxiliary converter is as follow:

SL NO	TEST	CLAUSE	TYPE	ROUTINE
1.	Visual inspection	IEC 61287 clause 2.4.6.1	ü	ü
2.	Tolerance & Dimension	IEC 61287 clause 2.4.6.2	ü	ü
3.	Weight	IEC 61287 clause 2.4.6.3	ü	
4.	Cooling	IEC 61287 clause 2.4.6.5	ü	
5.	Protection and Measuring	IEC 61287 clause 2.4.6.6	ü	ü
6.	Trigger Equipment	IEC 61287 clause 2.4.6.7	ü	ü
7.	Light Load	IEC 61287 clause 2.4.6.9	ü	ü
8.	Noise Measurement	IEC 61287 clause 2.4.6.11	ü	
9.	Temperature Rise	IEC 61287 clause 2.4.6.12	ü	
10.	Power Loss Determination.	IEC 61287 clause 2.4.6.13	ü	
11.	Supply Over Voltage & Transient	IEC 61287 clause 2.4.6.14	ü	
12.	Short circuit	IEC 61287 clause 2.4.6.15	ü	
13.	Sudden variation of Load	IEC 61287 clause 2.4.6.15	ü	
14.	Insulation	IEC 61287 clause 2.4.6.16	ü	ü
15.	Di Electric	IEC 61287 clause 2.4.6.17	ü	ü
16.	Partial Discharge	IEC 61287 clause 2.4.6.18	ü	
17.	Vibration and shock	IEC 61287 clause 2.4.6.21	ü	
18.	Interference	IEC 61287 clause 2.4.6.23	ü	
19.	Short time interruption	IEC 411.5 clause 4.3.8	ü	
20.	DC Link Discharge	IEC 411.5 clause 4.3.11	ü	
21.	Rated Current load	IEC 411.5 clause 4.2.7	ü	
22.	Out put Voltage & freq range	IEC 411.5 clause 4.3.3	ü	
23.	Performance test by fault simulation	IEC 60571clause 10.2.2	ü	ü
24.	Voltage Surge	IEC 60571.1 clause 10.2.6.2	ü	
25.	Electrostatic Discharge	IEC 60571.1 clause	ü	

	test	10.2.6.4		
26.	Transient burst susceptibility test	IEC 60571.1 clause 10.2.7	ü	
27.	Radio interference test	IEC 60571.1 clause 10.2.8	ü	
28.	Salt mist test	IEC 60571.1 clause 10.2.10	ü	
29.	Damp heat	IEC 60571.1 clause 10.2.5	ü	
30.	Dry heat	IEC 60571.1 clause 10.2.4	ü	
31.	Burn – in *	Clause 5.11 (d) of this spec.		

5.1.2 The suppliers shall submit complete test Programme for type and routine test to RDSO for its approval. RDSO may also decide to carry out certain special tests on the equipment, which are not covered by relevant IEC specification. Manufacturer will carry out the test as per mutually agreed test Programme at his own cost.

5.1.3 The prototype units will be inspected & tested by the engineers of RDSO at the factory premises or at mutually decided venue where all the facilities should be made available for carrying out the prototype test. The equipments will be kept in field trials for a period of six months. The RDSO engineers will associate and witness the tests in the locomotive also till they are successfully completed. Any defects noticed / design improvement found necessary as a result of the test / trial shall be carried out by the tenderer in the least possible time.

5.1.4 The individual equipments, system and sub-system as may be necessary shall be type tested and routine tested in accordance with relevant IECs.

5.1.5 Type test will be performed on one unit of given design to verify that product to meet the requirements specified and agreed upon between users & manufacturer. Subject to agreement between user and manufacturer some or all the type tests shall be repeated once in two years by RDSO and purchaser on sample basis so as to confirm the quality of the product. This will be part of revalidation of vendor approval. In addition, the manufacturer shall repeat all the type tests after 5 years without any additional cost. Type test will also be repeated in following cases.

- § Modification of equipment, which is likely to effect its function.
- § Failure or variations established during type or routine test.
- § Resumption of production after an interruption of more than two years.
- § At the time of indigenisation, if the firm has supplied the product with foreign collaboration originally.

" The type test will be carried out for the equipment/sub-assembly indigenised. The type test on the full unit in the case of indigenisation will be considered only if there is major design change."

5.1.6 Routine tests are to be carried out to verify that properties of the product corresponding to those measured during type tests. Routine test are to be carried out by the manufacturer on each equipment.

5.1.7 Investigation tests are intended to obtain additional information regarding the performance of the product. They shall be specially requested either by the user or the manufacturer.

5.1.8 RDSO may conduct surprise check on manufacturing process and quality control along with any of the test to ensure quality of product and its conformance to RDSO's specification.

5.1.9 INSTRUMENTATION –

(a) All the instruments used for testing should be duly calibrated. The calibration certificates are to be shown to inspecting authority on demand.
(b) Value of the fundamental component and THD of inverter output will be measured by power analyser during the prototype test at various mutually decided pre- set points in traction and braking mode. True value of output voltage is also to be measured for record.
(c) Input power factor and the efficiency will be measured using power analyser at rated load.

5.1.10 The following clarifications are issued on the tests included in 5.2.

(a) Visual inspection –The object of visual inspection is to check that the equipment is free from defects and the equipment are as per approved drawing. Bill of materials will be submitted. The make, rating of equipments, subassemblies will be checked with the details as per approved design proposal submitted in design proposal. If a change is needed in make or rating of important equipments, sub-assemblies, it should be intimated and should have approval of RDSO. Power and Auxiliary Converter with modified equipments, subassemblies will be given separate revision number. All the important dimensions will be measured and should be in permissible tolerance.

(b) Power loss determination test – This test will be done at voltage corresponding to 22 .5 kV in OHE. The efficiency will be measured at full and 80 % of load. The performance at other different input voltage such as 17.5 kV, 19kV, 25kV, 27kV and 30 kV will also be recorded for the purpose of record.

(c) Earth fault - Simulate the earth fault by connecting a suitable resistor between cubicle frame and output phases. The Power as well as Auxilairy Converter should not trip and earth fault indication will be in

"OFF" state till the leakage current is less than limit approved as part of design proposal submitted by the tenderer.

(d) Burn in test -- The cards used on the equipment will be subjected to burn- in as per the temperature cycle in Appendix - 4. The cards will be kept energized during the test. Functional test of each card will be carried out after the burn in test. (Pl. refer Clause 10.2.13 of IEC 60571). This will be part of internal test by manufacturer, whose results will be submitted during routine test.

(e) Cooling test – The purpose of this test is to verify that the cooling of various components / assemblies. The parameters for measurement to check efficacy of cooling system will be decided based on scheme proposed as part of design proposal.

(f) Insulation resistance and Dielectric test -- The insulation resistance with 1000 V megger shall not be less than 100 M ohms at 70 % RH for all the circuits. The dielectric test shall be carried out after shorting semiconductor device, pulse transformer earthed, earthed special cards if necessary before applying Dielectric voltage. The level of dielectric voltage will be as per IEC 61287.

(g) Temperature rise test –The Power and Auxiliary converters shall be loaded to full load for 6 hours with input OHE voltage of 19 kV and with 50% blockade of the inlet filters, if used. The temperature rise shall be recorded by temperature detectors mounted at the specified reference points on the body of semiconductors, capacitors, and other components as agreed between purchaser and manufacture. The maximum recorded temperature under worst condition shall be corrected for 55 degree C and compared with maximum permissible temperature. (for power devices at junction). The thermal margin available shall be compared with the safety margin declared by the manufacturer. The temperature of the power devices shall have a margin of minimum 10 degree C.

h) Damp heat test – Function test of each card will be carried out after the damp heat test.

5.2 Tests on Traction Motor

Type Test and Routine Tests shall be done according to IEC 349-2 (1993) in the premises of the supplier at their cost. One motor shall be type tested and the balance numbers of the order quantity shall be routine tested. The following tests will be conducted:-

Sl. No.	Tests	Clause No. of IEC 349-2	Type tests	Routine tests
1	Ventilation tests	6.1.2	√	
2	Measurement of Resistance.	A.3	√	√
3	Temp.rise test	6.1	√	
4	Short time overload test	6.1.6	√	
5	Characteristic test	6.2	√	
6	Over speed test	6.3	√	√
7	No load characteristics	7.3.1(a)	√	√
8	Short time heating run	7.2	√	√
9	Short circuit characteristics	7.3.1 (b)	√	√
10	Dielectric test	7.5	√	√
11	Vibration test	7.6	√	√
12	Check of direction of rotation.		√	√
13	Check of Thermo couples		√	√
14	Check of speed sensors		√	√
15	Checking of main dimensions.		√	

5.3 **Locomotive System Performance Tests**:

After installation and commissioning of loco with the new propulsion system, it will be subjected to the following tests and trials to judge the performance of the locomotives with the new propulsion system.

5.3.1 Oscillation Tests

The locomotive will be subjected to oscillation trials in India to prove the riding and stability performance of the locomotive at the maximum test speed of 110km/h as per the criteria indicated below on a track of standard specified in clause No.2.0; Chapter – I, with new and minimum standard wheel tread profile to be agreed with RDSO.

(i)	Maximum Lateral force (at axle box level)	4t
(ii)	Maximum vertical Dynamic augment	50%
(iii)	Maximum derailment co-efficient.	1
(iv)	Lateral and Vertical acceleration in the driving cab and at a point as close to the bogie pivot as possible.	0,35g maximum (preferably limited to 0,3g)
(v)	Maximum ride index in the driving cab at floor level.	3,75

Above values indicate the limits but the values obtained will be checked vis-à-vis those recorded with existing WAG-9 locos and preferably they should be of same level.

Instrumentation and tests will be carried out by Railways and evaluation of the results will be done by Railways in consultation with the Supplier.

5.3.2 Other Tests:

The loco with new propulsion system will be subjected to certain other tests conducted by Railways with Supplier's representative mainly to satisfy the Railways regarding operational performance, capability and safety. The following tests may be conducted in this connection on one or more locomotives with new propulsion system:-

5.3.2.1 **Rating and Performance Tests** :

Dynamometer car tests to ascertain starting and rolling resistance of the locomotive and to prove tractive effort, speed characteristics and dynamic braking effort speed characteristics of the locomotive and adhesion tests to prove the adhesive capability of the locomotive.

5.3.2.2 **Signalling and Interference tests**:-

Tests to determine the levels of interference with the traction power supply and Signal and Telecommunication equipments and facilities to prove that these are within acceptable limits (ref. Chapter – 2, clause 2.12)

APPENDIX-1

DETAILS OF VACUUM CIRCUIT BREAKER
(NOT IN THE SCOPE OF SUPPLY)

SN	Parameter	Value
1	Type	Single bottle
2	Original Design	Secheron, Alstom
3	Number of Poles	Single
4	Control system	Electro-pneumatic
5	Rated operational voltage (Ue)	27.5 Kv
6	Nominal voltage (Un)	25 kV
7	Dielectric test voltage	75 kV
8	Rated impulse withstand voltage (Uimp)	175 kV
9	Conventional free air thermal current (Ith)	1000 A
10	Rated frequency	50/60Hz
11	Rated breaking capacity	16 kA
12	Opening time	30 to 60 milli-sec
13	Auxiliary voltage	110V DC
14	Number of auxiliary contacts	4+4
15	Air supply pressure	4.5-10 bar
16	Approximate weight	140kg (Approximately)

APPENDIX –2

DETAILS OF TRACTION TRANSFORMER
(NOT IN THE SCOPE OF SUPPLY)

SN	Parameter	Value
1	Type	LOT-6500
2	Original Design	Secheron SA
3	Windings	
	Traction	4
	Auxiliary	1
	Filter	1
4	Frequency (f nom)	50±3%
5	Primary Voltage	
	Maximum	30.0 kV
	Nominal	25.0 kV
	Minimum	17.5 kV
6	Voltage Ratings (at 25.0 kV Catenary)	
	Traction	1269V
	Auxiliary	1000V
	Filter	1154V
7	Current Ratings	
	HT	261.25 A
	Traction	4 x 1142 A
	Auxiliary	334 A
	Filter	347 A
8	Thermal Ratings	
	Primary	6531 KVA
	Traction	4 x 1449 KVA
	Filter	400 KVA
9	Winding Data	
	Traction	37.0 mΩ, 2.1 mH ± 15%
	Auxiliary	60.0 mΩ, 0.43 mH
	Filter	19.0 mΩ, 0.29 mH

APPENDIX – 3

SALIENT DATA OF LOCOMOTIVES

SN	Characteristics	Unit	WAP-5	WAP-7	WAG-9
1	Guaranteed performance at 22.5 kV and half-worn wheels				
.1	Max. service speed	kmph	160	140	100
.2	Cont. rated speed	kmph	50	70	50
.3	Starting tractive effort	kN	258	322	460
.4	Cont. rated Tractive Effort	kN	220 (0-50 kmph)	228 (0-71 kmph)	325 (0-50 kmph)
.5	Cont. rated power at wheel rim	kW	4000 (80-160 kmph)	4500 (71-140 kmph)	4500 (50-100 kmph)
.6	Max. regenerative braking effort	kN	160 (10-90 kmph)	182 (10-89 kmph)	260 (10-62 kmph)
2	Axle Arrangement	-	Bo-Bo	Co-Co	Co-Co
3	Gear Ratio		3.941	3.6	5.133
4	Traction Motor type	-	6FXA 7059	6FRA 6068	6FRA 6068
5	No. of Traction Motors	-	4	6	6

CHARACTERISTICS OF EXISTING TRACTION MOTORS

SN	Characteristics	Unit	WAP-5	WAG-9
1	Continuous Rating			
.1	Shaft output	kW	1150	850
.2	Nominal voltage	V	2180	2180
.3	Current	A	370	270
.4	Speed	rpm	1585	1283
.5	Torque	Nm	6930	6330
.6	Frequency	Hz	80	65
.7	Power Factor	-	0.86	0.88
2	One Hour Rating			
.1	Shaft output	kW	1150	850
.2	Nominal voltage	V	2044	2089
.3	Current	A	396	290
.4	Speed	rpm	1485	1135
.5	Torque	Nm	7420	7140
.6	Frequency	Hz	75	57.5
.7	Power Factor	-	0.86	0.86
3	Short Time Overload Rating			
.1	Shaft output	kW	1150	850
.2	Nominal voltage	V	1540	1660
.3	Current	A	540	370
.4	Speed	rpm	1107	892
.5	Torque	Nm	9920	9100
.6	Frequency	Hz	56.5	45.7
.7	Power Factor	-	0.85	0.86
4	Max. speed	rpm	3174	2584
5	Temperature sensor	2 Pt. 100 resistance elements installed in stator tooth.		
6	Speed sensor	Wiegand transmitter system with transmitter ring for 120 pulses per rotor revolution.		

APPENDIX – 4

BURN-IN TEST