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भारत सरकार
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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

डीज़ल इलेक्ट्रिक लोकोमोटिव हेतु आई0जी0बी0टी0 आधारित वोल्टेज रेगुलेटिंग पैनेल का विशिष्टीकरण

SPECIFICATION FOR IGBT BASED VOLTAGE REGULATING PANEL FOR DIESEL ELECTRIC LOCOMOTIVES

स्पेसीफिकेशन नं0 एम0पी0– 0.04.00-05
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FOREWORD:

The Voltage Regulating panels (VRP) is an automatic voltage regulating and current limiting panel for the auxiliary generator for the use of battery charging and to supply power for control equipment. With the technology upgradation, the power transistor is being replaced by the voltage controlled semiconductor such as IGBT (Insulated Gate Bipolar Transistor) because of the following advantages:-

i) Easy low current gate control. The drive requirement is only in the order of microamperes. Consequently, pulse transformers are not required and corresponding disadvantage of poor drive characteristic and higher space requirement may be avoided.
ii) This power transistor does not need forced commutation to switch off. This immediately removes a substantial part of the circuitry, like auxiliary thyristor SCR-2 & SCR-3 and other phase shift and delay circuits.
iii) The present technology also provides LSI integrated circuits which functions as PWM generator for implementation of the control. Discrete transistor circuits along with chokes, transformers and pulse drivers are not required.
iv) The switch mode (IGBT) controlled regulator is much more reliable than the conventional thyristor based regulator both for theoretical reason and practical observation. The theoretical reason for major improvement of reliability is because of low power dissipation and high margin of voltage and current for the power devices.

All the above reduce the circuit complexity to such an extent that multiple assemblies or printed circuit boards are not necessary so that there is no wired inter-connections through connectors or terminals between the internal components. All the components are mounted in one single PCB. Total component count is less by an order of magnitude. This generally increased the reliability of the equipment.

0.2 This specification requires reference to the following standard Specifications:-
(1) IS:616 – Safety requirements for mains operated Electronics or related apparatus for household and similar general use.
(2) IEC:60571-1998 – Electronic equipments used on Rail vehicle.
(3) ELRS/SPEC/SI/0015 (Oct.'2001) – Reliability of Electronics used in Rolling Stock application.

0.3 In order to ensure high reliability of Electronic components, the guidelines indicated in the RDSO Reliability assurance No. ELRS/SPEC/SI/0015 Oct-2001 should be implemented to full extent as possible. A mention be made in the tender offer to the relevant clause, which are not followed and relaxation is required.

1.0 **SCOPE**:

1.1 The equipment shall be able to control the field current of the auxiliary generator to achieve the regulation and current limit in a manner as prescribed.

1.2 It is designed in such a way so as to also cater to higher field current requirement of auxiliary generator type AG3101 AY-1, whose field connections are connected in 3S-2P combination.

2.0 **SERVICE CONDITION**: The VRP shall operate satisfactorily under the following condition:-

2.1 Ambient Temperature : 0 to 70 deg. C.
2.2 Relative Humidity : 100%
2.3 Atmosphere : Dusty and corrosive.
2.4 Vibrations : Vertical : 1.0 g
Horizontal : 0.5 g
Longitudinal : 3.0 g
(Where "g" is acceleration due to gravity)

3.0 **CONSTRUCTION**:

3.1 The VRP housing shall be rugged and suitable for retro fitment on the Diesel electric locomotives.
3.2 The weight of VRP shall not be more than 5 Kg.
3.3 It shall be of box type construction and dimensions shall not be more than 280 x 220 x 120 & center-to-center distance for mounting is 248±1 (height) and 197±1 (width) with 4 holes Ø 10 for M8 bolt as given in Annexure-A.
3.4 All terminal stands shall be of standard type M5, 12.5 mm long, stainless steel separated by a minimum distance of 30 mm center to center and partition wall in between the studs. Terminal shall be of DMC material. It shall also have a cover.
3.4.1 There shall be 5 terminals designated and marked as
(i) A^+ or AGA1 (Armature positive).
(ii) F^+ orAGF1 (Field positive)
(iii) G or AGA2 or AGF2(Armature & field negative)
(iv) H or 44 A (Shunt positive)
(v) J or 44 B (Shunt negative)
3.4.2 The connection scheme shall be
(i) Generator Armature between "A^+" and "G".
(ii) Generator field between "F^+" and "G".
(iii)Current shunt positive to "H" and negative to "J".

4.0 **TECHNICAL REQUIREMENTS**:

4.1 Mode of regulation : Generator Field Control.
4.2 Generator Voltage : 72 V nominal.
4.3 Range of Adjustment : 69 to 75 at 1700 RPM.
4.4 Regulation : ± 1 V from 0 A load to 180 A load,
from 800 to 2400 RPM when not in current limit.
4.5 Adequate protection against surge shall be provided.
4.6 A suitable protective device shall be provided to prevent destruction of circuits in the event of polarity inversion. Moreover, all devices (supply circuits and circuits) shall be protected against external electrical fault.

4.7 Adjustment : Potentiometer adjustment for
(i) Generator voltage (front panel).
(ii) Generator current limit (on circuit card).

4.8 Generator Current Limit: It shall be possible to adjust current limit from 150A to 200 A (i.e. from 525 mV to 700 mV).

4.9 Power Dissipation in the VRP: Less than 20 W.

4.10 Equipment shall be able to operate satisfactorily under Environmental condition specified under clause 2.

5.0 **ASSEMBLY**:

5.1 The equipment shall have single PCB within a single electronic module. The module shall contain no connectors or plug for interconnections.

5.2 One shell type circular multi pin connector with construction as per MIL-C-5015 type plug connection shall connect the electronic module to terminals.

5.3 Flexible wires (PTFE) from PCB to input/output terminals shall be used.

5.4 The electronic module shall be fixed by screw/fly nuts to enable its easy removal from the housing or the metal cabinet after disconnecting the circular multipin connector.

5.5 The card and panel are protected from damage even if the card is removed during operation by mistake.

5.6 Even if the locomotive is held up with battery switch ON, the battery drain shall be negligible.

5.7 The equipment and its mounting arrangement shall be of robust design for traction duty and shall withstand satisfactorily vibrations and shocks normally encountered in service.

6.0 **ARRANGEMENTS & FACILITIES**:

The facilities for conducting routine and acceptance tests shall necessarily exist at the supplier's premises. Certain tests included in the type testing can however, be carried out in any recognized test laboratory, in case the facilities for conducting these tests do not exist at the supplier's premises.

7.0 **REQUIREMENTS:**

The test programme requires the following:

- Adequate testing facility with auxiliary generator type AG3101AY-1 and load
- Voltage Regulator Panel with all associated hardware to be applied on board the locomotive

8.0 **TESTING DETAILS** :

This test programme is prepared for the purpose of conducting Type Test, Routine Test and Acceptance Test of the complete Voltage Regulator Panel (VRP). The complete panel shall be subjected to the following categories of test:

- Type Test.
- Routine Test.
- Acceptance Test.

8.1 The tests for which the facilities are not available with the manufacturer shall be conducted at any Govt. laboratory subject to agreement between RDSO and supplier.

8.1.1 Type Test: The type test shall be conducted on one complete panel of RDSO approved design to verify that the product meets the requirements specified for the panel.

8.1.2 Routine Test: Routine test are to be carried out to verify that properties of the product correspond to those measured during type test. Routine tests are to be performed by the manufacturers on each panel.

8.1.3 Acceptance Test:- Acceptance test are to be carried out by the inspecting authority on each panel.

8.1.4 The tests to be carried out on complete panel are given in the following Table I:

Table I

S. No.	Name of the Test	Clause	Type Test	Routine Test	Acceptance Test
1.	Visual Inspection	9.0	Yes	Yes	Yes
2.	Inspection of Control Technique	10.0	Yes	No	Yes
3.	Performance Test	11.0	Yes	Yes	Yes
4.	Cooling Test	12.0	Yes	No	No
5.	Dry Heat Test	13.0	Yes	No	No
6.	Damp Heat (Cyclic)	14.0	Yes	No	No
7.	Supply over voltage, surges & Electrostatic Discharge Test	IEC 60571 clause 10.2.6	Yes	No	No
8.	Transient Burst Susceptibility Test	IEC 60571 clause 10.2.7	Yes	No	No
9.	Radio Interference Test	IEC 60571 clause 10.2.8	Yes	No	No
10.	Insulation Test	IEC 60571 clause 10.2.9	Yes	Yes	Yes
11.	Die-electric Test	19.0	Yes	Yes	Yes
12.	Salt mist Test	20.0	Yes	No	No
13.	Vibrations, Shock & Bump Test	21.0	Yes	No	No
14.	Low Temperature Storage Test	22.0	Yes	No	No
15.	Burn-in-Test	Annex. 1 of Spec. No ELRS/SPEC/ SI/0015, Oct.'2001	Yes	Yes	No

9.0 **VISUAL INSPECTION** :

9.1 Initially the equipment shall be checked for sound construction, good workmanship, free from defects and meet all the specifications requirement including dimensional check, mounting and fastening arrangement etc.

9.2 After the different tests, the equipment shall be checked for any damage or deterioration which might have occurred resulting from test/tests performed. Check shall be made for cracks, loosening of components, loosening of nut/bolts, buckling of PCB, deterioration of surface finish of components, PCB/pealing of copper paths, damage to protective coating, dry solder, components lead breakage/crack, corrosion at the roots of components, flashover mark, sparking etc.

10.0 **INSPECTION OF CONTROL TECHNIQUES**

The voltage waveform of the output VRP connected to the generator field shall be viewed with an oscilloscope to verify PWM control. The voltage wave form should be pulse train of constant frequency with its pulse width varying with the variation of RPM to maintain the generator output voltage constant.

11.0 **PERFORMANCE TEST**

11.1 **WITH AG 3101AY-1 WITH FIELD CONNECTED IN 3S-2P COMBINATION (PARALLEL)**

11.1.1 Testing with Auxiliary Generator machine AG 3101 AY-1 :

Make connection of the regulator with machine as per fig-1.

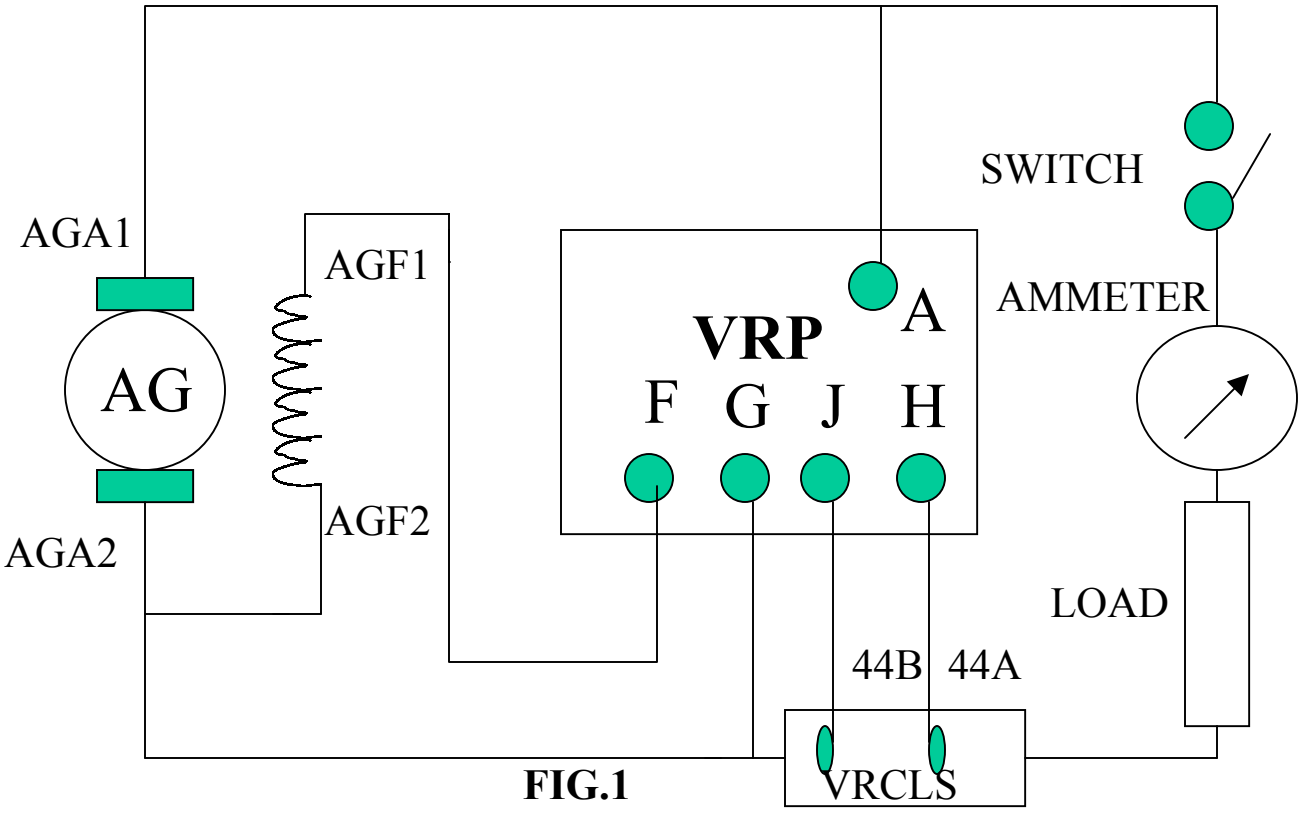


FIG.1

11.1.4 Regulation Test:

Run the motor generator set at 1700 rpm at no load conditions. Adjust potentiometer VVR provided on front panel, to achieve output voltage 72 volt DC. Measure and record output voltage of AG at speeds and load conditions given in following Table II. Output voltage shall be within 72±1 volt DC (71 to 73 volts).

Table-II

M/c RPM	Aux.Gen. Voltage (Volts)	Load current (Amps)	Remarks
800		0	
800		160	
1700		0	
1700		160	
2400		0	
2400		160	

11.1.5 Voltage adjustment range:

Run the motor generator set at 1700 rpm at no load conditions & check the following:

a. Rotate VVR potentiometer fully anti clockwise and record the out put voltage. It shall be between 64 volts to 68 volts.
b. Rotate VVR potentiometer fully clockwise and record the out put voltage. It shall be between 76 volts to 80 volts.
c. Set output voltage at 72 volts DC by adjusting potentiometer VVR.

11.1.6 Current Limit test:

Stop motor generator set. Connect external mV supply through a potentiometer between H and J, with J as positive (fig. 2). Adjust potentiometer RX so that voltage between terminal J & H is zero. Run motor generator set at 1700 rpm. Measure the output voltage. It shall be 72 volts DC. Adjust, if required by potentiometer VVR. Now increase voltage between H & J slowly with the help of external potentiometer and observe output voltage of AG. Output voltage shall drop below 64 volts, when voltage between H & J terminal is between 525 to 700 mV (i.e. 150 to 200 Amps).

11.1.7 Load thrown off test:

11.1.7.1 Run the motor generator set at 800 rpm and load it at 150 amps for 3 minutes and after 3 minutes throw off complete load. Measure and record the generator voltage at no load and full load. It shall be within 72±1 Volts.

11.1.7.2 Repeat above test at 1700 & 2400 rpm also.

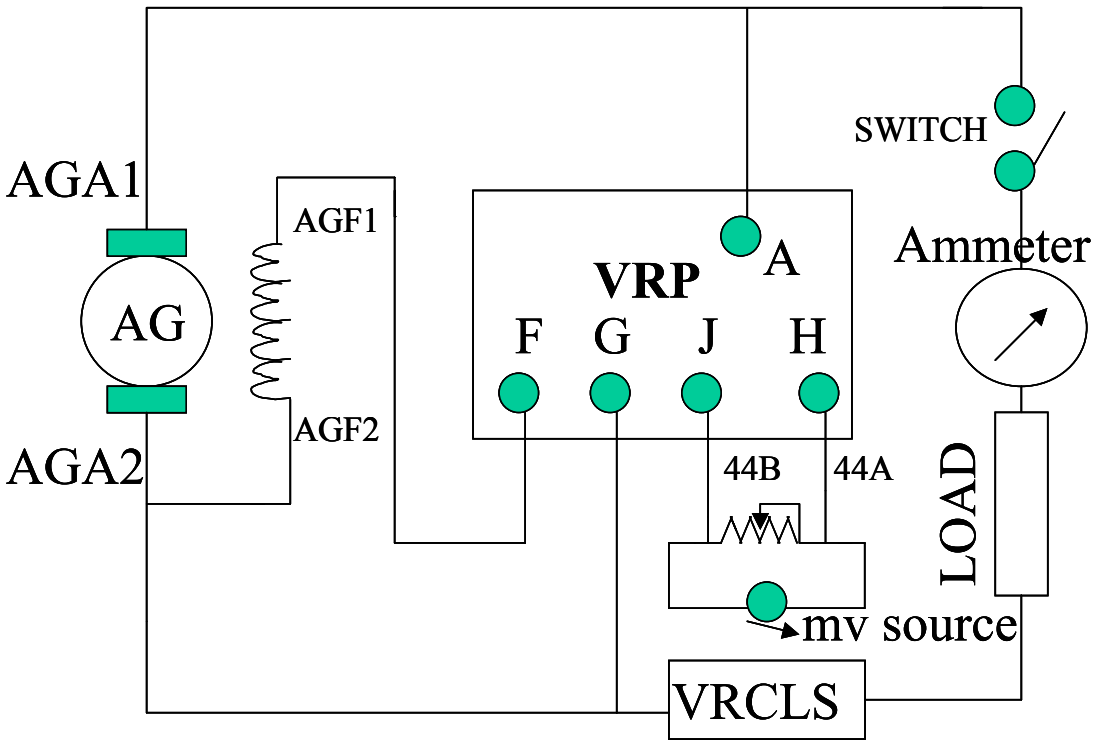

AGA1
AGF1
SWITCH
Ammeter
AG
VRP
A
F
G
J
H
AGF2
AGA2
44B
44A
LOAD
mv source
VRCLS

FIG.2

11.2 **IF AUXILIARY MACHINE TYPE AG3101AY-1 IS NOT AVAILABLE FOR TESTING THE VRP, PERFORMANCE TEST OF VOLTAGE REGULATING PANEL (VRP) OTHER THAN PARA 11.0 MENTIONED ABOVE SHALL BE CARRIED OUT AS FOLLOWS:**

11.2.1 **Performance Test under simulated condition**:

11.2.2. **Full Load Simulation**:

A load of 10 ohms in series with an inductance of 500 micro-henry rated 15 A is connected at the terminals F^+ and GJ to simulate the field current load of the auxiliary generator. An adjustable voltage of 72 V is connected at the terminals A^+ and GJ of the VRP to simulate the auxiliary generator voltage. A voltmeter is connected across the load resistance. The voltage across the A^+ and GJ is now varied up and down to observe full voltage and no voltage across the load resistance. This ensures switch mode control. Now, the input voltage is kept at a position for 20 minutes where there is full voltage across the load. No damage should occur and the VRP should continue functioning as per the following clauses.

11.2.3 To be carried out with a DC motor generator set with the following specifications for the motor and the generator.

Type	:	Separately Excited
Nominal Armature Voltage	:	110 V DC
Maximum Armature Current	:	4A DC
Nominal Field Voltage	:	110 V DC
Maximum Armature Voltage	:	150 V DC
RPM	:	Up to 2500 RPM
Type of coupling	:	Direct

For the purpose of simulation “Full load of the generator is taken as 80% of the full rated full load current, “overload” of the generator is taken as 100% of the full load current i.e. 3.2 Ampere & 4 Ampere respectively.

Connection is done as per the diagram given in the figure3. The current shunt should be chosen to give 700 mV at 4 Amp. Current i.e. 0.175 Ohms, so that current limit can be set to any where between 525mv to 700mv by adjusting the potentiometer provided on front panel of VRP.

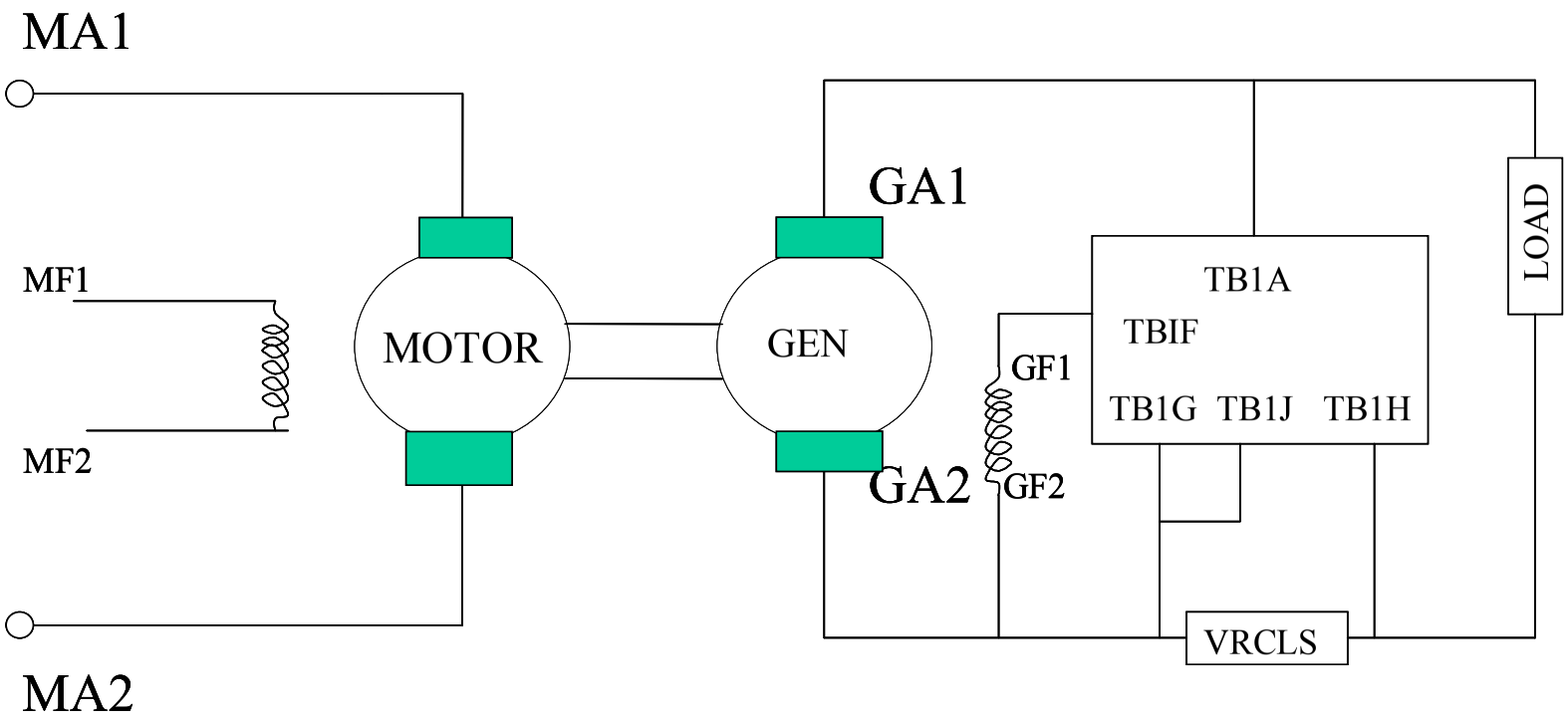


FIG.3

Circuit schematic for simulation test

All voltages are to be measured at the terminals of the VRP to avoid error due to voltage drop across the interconnecting cables.

11.2.4 Measure and record the generator voltage and current as per table given blow. Set the generator voltage to 72 V DC. Ensure that:

(i) Generator voltage is within ±1 V from no load to full load.

(ii) Generator voltage falls to below 60 V at overload current.

Table

Machine RPM	Load	Generator Voltage (Volts)	Remarks
800	No load		
800	Full load		
800	Over load		
1700	No load		
1700	Full load		
1700	Over load		
2400	No load		
2400	Full load		
2400	Over load		

11.2.5 **Regulation Test**:

11.2.5.1 Adjust the voltage setting potentiometer so that output voltage is 69 V. Start the MG set at 1700 RPM. Measure and record the generator voltage. It should be 69±1 Volts.

11.2.5.2 Repeat the test clause 11.2.4 with the above settings. The generator voltage variation should be within ±1 Volt from no load to full load. Current limit should operate at over load.

11.2.5.3 Rotated the voltage setting potentiometer clockwise, set the output voltage to 75V. Start MG set at 1700 RPM. Measure and record the generator voltage and it should be 75±1 Volts.

11.2.5.4 Repeat the test clause 11.2.4 with the above settings. . The generator voltage variation should be within ±1 Volt from no load to full load. Current limit should operate at over load.

11.2.5.5 Run MG set at 1700 RPM. Set the generator voltage at no load to 72 volts with the voltage setting potentiometer.

11.2.5.6 Lock the setting of the voltage setting potentiometer at this position.

11.2.6 **Performance Test on Locomotive: (for Prototype only)**

To be carried out in conjunction with the generator, same as one which is used in diesel loco, typically rated at 72V, 160A, 2400 RPM Maximum. The generator should be coupled to a suitable engine or a variable speed electric motor so that the following tests may be carried out.

Connect the voltage regulator to the generator as per terminal markings and commence the following tests:

Table

Machine RPM	Load (Amps.)	Generator Voltage (Volts)	Remarks
800	0		
800	120		
800	180±10		
1700	0		
1700	120		
1700	180±10		
2400	0		
2400	120		
2400	180±10		

11.2.7 **Regulation Test**: (**for Prototype only**)

11.2.7.1 Adjust the voltage setting potentiometer so that output voltage is 69 V. Start the MG set at 1700 RPM. Measure and record the generator voltage. It should be 69±1 Volts.

11.2.7.2 Repeat the test clause 11.2.6 with the above settings. The generator voltage variation should be within ±1 Volt from no load to full load. Current limit should operate at over load.

11.2.7.3 Rotated the voltage setting potentiometer clockwise, set the output voltage to 75V. Start MG set at 1700 RPM. Measure and record the generator voltage and it should be 75±1 Volts.

11.2.7.4 Repeat the test clause 11.2.6 with the above settings. . The generator voltage variation should be within ±1 Volt from no load to full load. Current limit should operate at over load.

11.2.7.5 Run MG set at 1700 RPM. Set the generator voltage at no load to 72 volts with the voltage setting potentiometer.

11.2.7.6 Repeat test clause 11.2.6. Lock the setting of the voltage setting potentiometer at this position.

11.2.8 **Current limit testing (Close Loop With Shunt)**

Connect the VRP with the generator, load and shunt as given in the schematic diagram (figure 3) for simulation test. Run the generator at 800 rpm. Rotated the current limit potentiometer provided on the front panel to fully clockwise position. Increase the load gradually 4 Amps. Turn the current limit potentiometer anti-clockwise slowly till current occurs and the voltage drops to below 60V. Repeat this test at 1700 rpm and 2400 rpm also.

12.0 **COOLING TEST** (IEC 60571 Clause 10.2.3)

The panel without any power applied shall be placed in a chamber where the temperature is progressively lowered from the ambient to –10 deg. C over a period of at least half hour. The panel shall be kept in this condition for 2 hours. After this test, the performance test shall be carried out, keeping the equipment at low temperature.

13.0 **DRY HEAT TEST** (IEC 60571 Clause 10.2.4)

The panel with power applied shall be placed in a test chamber where the temperature is progressively raised from the ambient to 70±2 deg centigrade over a period of at least half an hour. The unit shall be kept in this condition for 6 hours starting from the time when the temperature inside the chamber is uniform. At the end of this period, performance test shall be carried out as mentioned in Para 11 above.

14.0 **DAMP HEAT TEST (CYCLIC)** (IEC 60571 Clause 10.2.5)

The panel without power applied shall be placed in a test chamber where the temperature is progressively raised from the ambient to 55±2 deg centigrade over a period of 1.5 to 2.5 hours, the relative humidity being between 95% and 100%. The unit shall be kept in this condition for 10 hours. At the end of this period, the temperature is lowered to the ambient temperature over a period of 3 hours, relative humidity being between 95% and 100%. At the end of this period, performance test shall be carried out as mentioned in Para 11 above.

15.0 **SUPPLY OVER VOLTAGE TEST, SURGES & ELECTROSTATIC DISCHARGE TEST)**

It should be conducted as per IEC 60571, Clause 10.2.6. After the test, the performance test should be carried as mentioned in Para 11.

16.0 **TRANSIENT BURST SUSCEPTIBILITY TEST)**

The test should be carried out as per IEC 60571 Clause 10.2.7. The acceptance test level is 2. The sequence of the test should ensure a performance test later than this test.

17.0 **RADIO INTERFERENCE TEST**:

The test should be carried out as per IEC 60571 Clause 10.2.8. The acceptance test level is 2. The sequence of the test should ensure a performance test later than this test.

18.0 **INSULATION RESISTANCE TEST:** (IEC 60571 Clause 10.2.9)

Short all the outgoing terminals of the VRP frame together. Megger the shorted terminals to panel frame with a 500 V megger. The insulation resistance shall be more than 10 Mega Ohm, The sequence of the test should ensure a performance test later than this test.

19.0 **DIELECTRIC TEST** (IEC 60571 Clause 10.2.9.2)

Apply 1KV r.m.s with as near as possible to sine wave form & frequency at 50 Hz. between shorted terminals and the panel frame for 1 minute. The test shall be considered satisfactory if neither a disruptive discharge nor a flash over occurs after this test insulation resistance should be repeated.

20.0 **SALT MIST TEST** (IEC 60571 Clause 10.2.10)

The solution for producing the salt mist is prepared by dissolving 50±1 gm Sodium chloride (NaCl) analytical reagent quality, in distilled demineralised water to make (1±0.02) liters of final solution at 20 deg. centigrade; if the PH

does not lie between 6.5 & 7.2, the solution should be rejected. The sequence of the test should ensure a performance test later than this test.

TEST PROCEDURE:

During the test, the temperature in the test chamber shall be maintained at 35±2 Deg. C. The test chamber is kept closed & spraying of the salt solution should continue without interruption during the whole conditioning period of three hours. At the end of the test, the equipment is washed in running tap water for 5 minutes, rinsed in distilled or demineralised water, then shaken by hand to remove droplets of water and stored, under standard atmospheric condition of the testing area for a period not less than one hour nor more than two hours. After this cycle, the performance test shall be carried out as mentioned in para 11above.

21.0 VIBRATION, SHOCK & BUMP TEST

21.1 The panel shall be subjected to this test in three orthogonal planes, under ambient temperature condition of the testing area. For this test, the equipment is secured in a suitable position to a machine producing vibrations of sinusoidal form with adjustable amplitude and frequency.

21.2 Determination of resonant frequencies:

In order to determine the possible existence of critical frequencies producing resonance, the frequency shall be varied progressively from 1Hz to 100 HZ within a time of not less than 4 min. The amplitude of the oscillations 'a' expressed in mm shall be given as a function of frequency 'f' by the equations

$a = 25/f$ for values of 'f' between 1 Hz to10 Hz.
$a = 250/f^2$ for values of 'f' between 10 Hz to100 Hz.

If resonance is produced, the corresponding frequency shall be maintained for 4 minutes in each case.

21.3 Test with Sustained Vibrations:

The equipment with power applied shall be subjected to sustained vibrations for a period of a minimum 8 hours in all the three directions at the frequency-

- Either at the critical frequencies, if any such well-defined frequency has been detected
- Otherwise at a frequency of 10 Hz

In both the cases, the amplitude of the vibrating table shall be adjusted to the value corresponding to the frequency concerned.

21.4 Test to simulate the effect of shunting shocks:

The equipment with power applied shall be subjected to a series of three successive shocks at 50 Hz vibrations each corresponding to a maximum acceleration of 3g in all the three direction.

21.5 Results of tests :

The tests are considered to be satisfactory if there is no resulting damage or

abnormality in operation. The assembly shall be able to withstand successfully the performance test and dielectric test as mentioned in paras 11 & 19 above.

22.0 **LOW TEMPERATURE STORAGE TEST:**

The test should be carried out as per IEC 60571 Clause 10.2.14. The sequence of the test should ensure a performance test later than this test.

23.0 **BURN-IN-TEST** (Annexure 1 of Spec. No. ELRS/SPEC/SI/0015, Oct.'2001)

The equipment under power and fully loaded shall be placed in a chamber at temperature of 70±2 deg. C. It should be kept in the chamber for 48 hours during type test and 2 hours during routine test.

The sequence of test should ensure a performance test later than this test.

24.0 **DRAWING DATA AND SAMPLES**:

24.1 The tenderer shall submit 4 copies of drawing giving mechanical, circuit details and connection technical data, internal test results for the offered system.

24.2 The successful tenderer shall submit a prototype sample for inspection/testing and approval by the purchaser before undertaking the bulk manufacturer.

24.3 The supplier shall undertake bulk manufacturing incorporating modification/ improvements as may be considered necessary in course of service trials and as directed by purchaser with the framework of the specification. In case of major change, the unit shall be type tested again.

24.4 The final set of drawings and maintenance/operating manual is to be supplied with each order.

25.0 **GUARANTEE:**

The manufacturer shall give warrantee of 12 months from the date of installation and 18 months from the date of dispatch which ever is earlier for any manufacturing/ design defects.

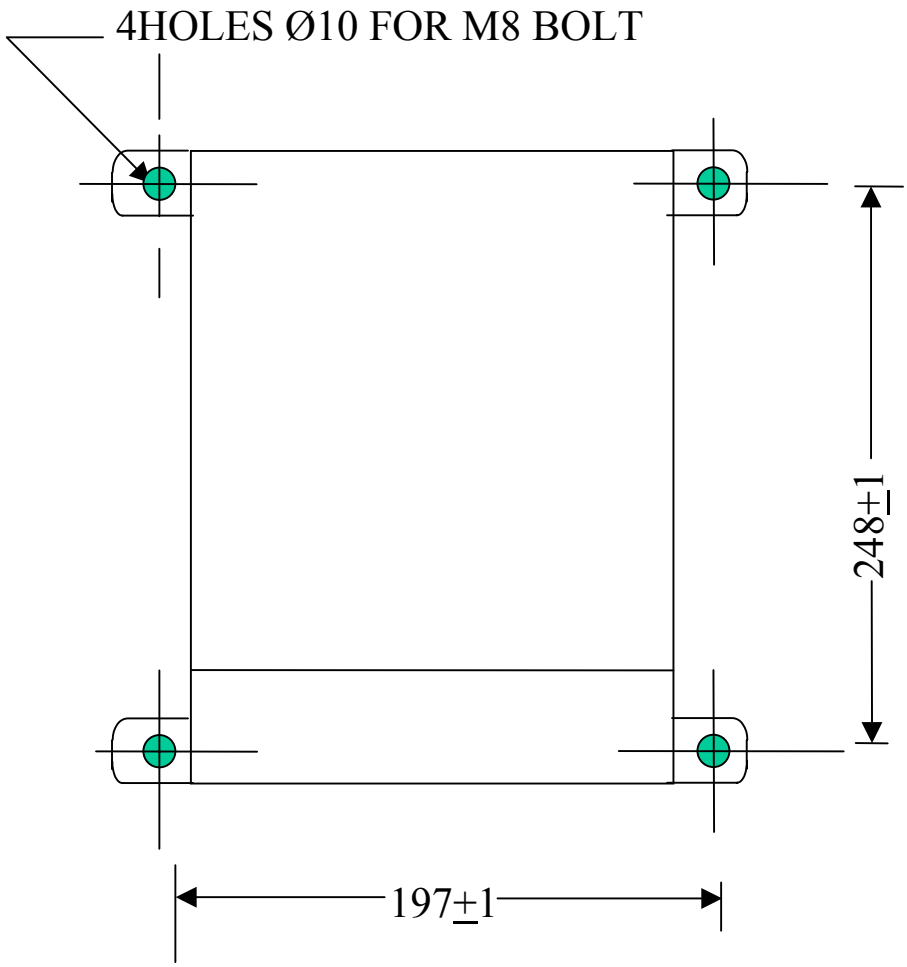
26.0 **MARKING:**

The manufacturer shall engrave/emboss/imprint/stencil permanent identification marks indicating their names/brand name/monogram/model number and also the month and year of manufacturer at a prominent place.

27.0 **WITHDRAWAL OF APPROVAL:**

The approval granted to the manufacturer is liable to be withdrawn in the event of noticing any change at a later date in the design or change from the bill of material as approved earlier without seeking RDSO's approval or using components of inferior specification/or compromising quality so as to assess reliability.

ANNEXURE-A



OUTLINE DIMENTION OF IGBT BASED VRP