

Rake Level Harmonic Measurement Test for High Speed Train set (B28)

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1 Introduction

This document is intended to Rake level Harmonic Measurement Test of High Speed Train set rake as per the specification ICF/MD/SPEC-447, ERTS, It includes the test method, the test conditions, test requirements and acceptance criteria. Test shall be conducted as per IEC 61000-3-6 & IEEE 519 and limits given in the ERTS.

2 Objective and Scope of the Test

The scope is limited to apparatus, systems and fixed installations which are intended for use in the railway environment. This test is done for currents injected in the overhead supply system (as also the track return current) and Voltage at the PCC (Point of Common Coupling) as described in the standards IEC 61000-3-6 & IEEE 519.

This test shall be done under normal & degraded conditions that prevail on the railway over which the vehicles are intended to operate and at different speeds and accelerations, in motoring and braking.

3 Introduction to the system

Train should be designed as per ICF specification ICF/MD/SPEC-447, ERTS – Employer's Requirements Technical Specifications of Project for Construction of Mumbai-Ahmedabad High Speed Rail.

3.1 System Overview

One basic unit of 4-car unit is the building block for Train Set rake formation. Each basic unit consists of one Driving Trailer Coach (DTC) at the end, two Motor Coaches(MC) and one Trailer Coach (TC).

Two such basic units can be coupled together to form one rake of 8 coaches. Formation of basic unit is shown below:

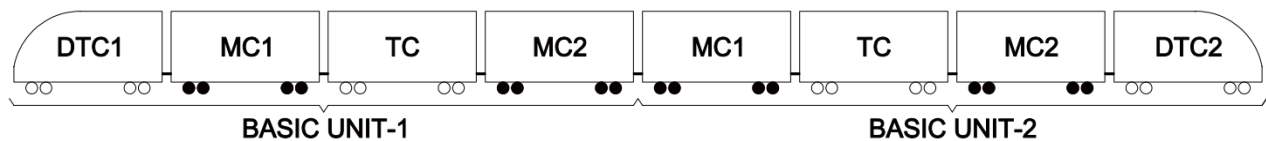


Figure 1: Train Formation

Driving Trailer Coach (DTC) is a non-powered vehicle with a Driver cab at one end. The Driver cab is furnished with a pre-fabricated Driver Desk. All driving operations are possible from Driver Desk. Feedback from all systems in all the coaches / basic units is available for viewing on the Driver Desk and certain functionalities can be controlled from the Driver Desk. In this regard a 10.4" Touch Based TFT display is provided on driver desk for showing combined status. Various gauges and indications are also provided on driver desk for knowing MR, BC and parking brake pressure. The driver will also be able to control/operate the Passenger Information System, Train Radio from the Driver Desk. It also consists of LVPS with battery charger & battery and main air compressor which are mounted underslung. Rest of the DTC apart from the Driver cab is Passenger

saloon area and vestibules. Two electrical cabinets are placed in rear wall of driver cab and one more electrical cabinet at non driving end. All passenger comfort related loads can be controlled by driver from driver cab.

Motor Coach (MC) is a powered vehicle with one Traction Motor driving each axle. The Motor Coach contains a line and traction converter unit (LTC) for each bogie mounted underslung. Transformer secondary cable for both LTC units comes from power transformer mounted in Trailer Coach through underslung mounted IV Coupler. It also consists of 2 no's electrical cabinets.

Trailer Coach (TC) contains a pantograph, vacuum circuit breaker, surge arrestors and isolator on roof. It also consists of auxiliary converter units and power transformer mounted underslung. Power to LTC units of both motor coaches is distributed from same power Transformer through Power Coupler. It also consists of 2 no's electrical cabinets.

In trailer coach there are 2 variants i.e TC coach in basic unit 2 is for executive class and the TC coach in basic unit 1 is for standard class.

All the passenger saloon areas are provided with air condition, controlled using HVAC(2no's) units mounted in each coach. All electrical cabinets, driver cab and passenger saloon areas are provided with fire detection equipment.

All the coaches are provided 4no's of airtight plug type exterior doors for passenger entry/exit. In addition all coaches are provided with automatic internal doors duly segregating passenger saloon area and door way vestibule area.

All the coaches including driver cab are provided with CCTV cameras and passenger information system.

4 List of Abbreviations used

Acronym	Description
AC	Alternating Current
DTC	Driving trailer coach
IEC	International Electro technical Commission
MAHSR	Mumbai Ahmedabad High Speed Rail
MC	Motor Coach
ERTS	Employer's Requirements Technical Specifications
NHSRCL	National High Speed Rail Corporation Limited
TC	Trailer Coach
TCMS	Train Control and Management System
VCB	Vacuum Circuit Breaker
THD	Total Harmonic Distortion
TDD	Total Demand Distortion
PCC	Point of Common Coupling

Acronym	Description
IEEE	Institute of Electrical and Electronics Engineers
PT	Potential Transformer
OHE	Overhead Electrification
VSTH	Very Short Time Harmonic
STH	Short Time Harmonic

Table 1: List of Abbreviations

5 Applicable Documents and Standards

5.1 Customer Specification

5.1.1 ICF specification ICF/MD/SPEC-447

SPECIFICATIONS AND STANDARDS FOR DEVELOPMENT OF NEW GENERATION ENERGY EFFICIENT TRAIN WITH DISTRIBUTED POWER SYSTEM (LIGHT WEIGHT STAINLESS STEEL BODIES CARS)” and its subsequent Statement of Deviations accepted by ICF/NHSRCL.

5.1.2 ERTS – Employer’s Requirements Technical Specifications of Project for Construction of Mumbai-Ahmedabad High Speed Rail

5.2 Other Standards

Standard	Description	Contains
IEEE 519_2022	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems	This document sets the quality of power that is to be provided at the point of common coupling.
IEC 61000-3-6	Harmonic Emission Limits for Customers Connected to MV, HV, and EHV	This document outlines procedures for evaluating harmonic emissions from facilities that are connected to MV, HV, and EHV systems

Table 2: Applicable standards

5.3 Clause reference from customer specification related to voltage and current harmonic

5.3.1 Clause 5.4.2.7 of ERTS

The complete map of spectrum of harmonics generated by the basic unit / Train in traction and regeneration mode shall be submitted for design approval. The same shall be verified during system test and validated during mainline 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 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.

5.3.2 Clause 3.4.2 of ERTS

Harmonic distortion limits as per the statutory requirement of state electricity board are as follows:

- (i) Harmonic Voltage distortion at Point of Common Coupling (PCC): 1.5% for the individual harmonic order & 2.5% for the Total Harmonic Distortion (THD).
- (ii) Harmonic Current at PCC: 7.5% for the Total Demand Distortion (TDD) & for individual harmonic order 6% ($h < 11$), 2.75 % ($11 \leq h < 17$), 2.5% ($17 \leq h < 23$), 1% ($23 \leq h < 35$) and 0.5% ($35 \leq h$).

6 Description of Test

6.1 Test Pre - Requisites

- The Harmonic measurement test shall be carried out on a fully equipped 8-car high speed train set on the enough long track to reach the maximum speed.
- All system and subsystem shall be energized which could contribute to electromagnetic interference.
- Before starting the test, permission shall be received from NHSRCL regarding the test.
- No maintenance work or unnecessary switching of power supply which can create noise
- OHE voltage shall be between 22.5 kV – 27.5kV AC.
- All equipment installed and commissioned according to valid manufacturer documentation.
- Auxiliary loads shall be in operation.
- All the measuring instruments shall be in scope of the testing authority.
- All the instruments shall have a calibration certificate and the same has to be submitted along with the report.

6.2 Measurement procedure

Measurements shall be carried out with the rolling stock operating on sections of track which are Representative of those of the intended routes. The test track should give the possibility to accelerate to the maximum service speed, costing and regenerative braking.

The system of 8 car rake consisting of 2 basic units each basic unit is supply by separate transformer and supply is taken from single pantograph at a time from the OHE. For the measurement of voltage the potential transformer (PT) shall be used as isolated Voltage transducer. For current measurement, current transducer/rogowski coil shall be used at appropriate location of measurement. Both Voltage and current transducers shall be connected to data acquisition unit for the capturing of the voltage and currents.

All measured values shall be captured with a digital data recorder for further post-processing. In order to prevent data losses, the measuring system on board the train shall be supplied by an uninterruptible power supply.

6.3 Test conditions

Tests are to be done under normal operating mode and degraded operating mode. The below listed

condition are operated in each operating mode.

6.3.1 Stand still condition

The rolling stock is not moving. The traction circuits shall be under voltage but not operating. The auxiliary circuits shall operate and all the relevant appliances shall be active (e.g. air conditioning/heating, lights, window heater, electric generators).

6.3.2 Dynamic condition

Following measurement shall be done in dynamic condition:

- a)** During acceleration with 100 % of Traction command
- b)** Maximum speed operation
- c)** Coasting
- d)** With 100 % braking

6.4 Harmonic Limits

6.4.1 Voltage Harmonic Limits

As per the Clause 5.4.2.7 of ERTS, the voltage harmonic limits given as “The overall harmonic voltage distortion levels viewed at pantograph shall not exceed 2% of the fundamental component under all modes of operation including regeneration.”

As per the Clause 3.4.2 of ERTS, the voltage harmonic limits given as “Harmonic Voltage distortion at Point of Common Coupling (PCC): 1.5% for the individual harmonic order & 2.5% for the Total Harmonic Distortion (THD).”

Therefore, the more stringent limit for voltage total harmonic distortion (Voltage THD) specified in Clauses 5.4.2.7 and 3.4.2 of the ERTS is considered. Accordingly, a Voltage THD limit of 2% of the fundamental component shall be maintained under all modes of operation, including regeneration.

And for the individual harmonic order 1.5% of the fundamental component is taken as limit to be followed.

The definition of THD for voltage as per IEEE 519, The ratio of the root-mean-square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding inter-harmonics, expressed as a percent of the fundamental.

6.4.2 Current Harmonic Limits

As per the Clause 3.4.2 of ERTS, the current harmonic is 7.5% for the Total Demand Distortion (TDD) & for individual harmonic order 6% ($h < 11$), 2.75 % ($11 \leq h < 17$), 2.5% ($17 \leq h < 23$), 1% ($23 \leq h < 35$) and 0.5% ($35 \leq h$).

The definition for TDD as per IEEE 519, The ratio of the root-mean-square of the harmonic content, considering harmonic components up to the 50th order and specifically excluding inter-harmonics, expressed as a percent of the maximum demand load current. The maximum demand

load current will be informed during testing time.

The definition of maximum demand load current as per IEEE 519, This current value is established at the point of common coupling (Pantograph) and shall be taken as the sum of the rms currents corresponding to the 15 min or 30 min maximum demand during each of the twelve previous months divided by 12. If 12 months of data is not available due to the length of time in service, then the maximum 15 min or 30 min apparent power demand for each month should be summed over the total number of months available, and then divided by the number of months. For situations where the installation is a proposed new installation, the maximum demand load current shall be based on the projected 15 min or 30 min maximum monthly apparent power demand over the course of the year following operation of the proposed harmonic producing loads listed on the service application.

6.5 Evaluation methods

6.5.1 Measurement window width

The width of the measurement window used by digital instruments employing Discrete Fourier Transform techniques should be 10 cycles for 50 Hz power systems. With this window width, spectral components will be available every 5 Hz (e.g., 0, 5, 10...50, 55, 60, 65, 70,... Hz). For the purposes of this document, a harmonic component magnitude is considered to be the value at a center frequency 50, 100, 150, for 50 Hz power systems, respectively combined with the two adjacent 5 Hz bin values. The three values are combined into a single rms value that defines the harmonic magnitude for the particular center frequency component.

7 Test cases

S. No.	Degraded Mode	Operating Mode	Speed (km/h)	System in operatoin
1	All Healthy	Standstill	0	Auxiliary
2	All Healthy	Motoring	0 - 249	Auxiliary and Traction
3	All Healthy	Coasting	249	Auxiliary and Traction
4	All Healthy	Braking	249 - 0	Auxiliary and Traction
5	1 BU Cutout	Standstill	0	Auxiliary
6	1 BU Cutout	Motoring	0 - 249	Auxiliary and Traction
7	1 BU Cutout	Coasting	249	Auxiliary and Traction
8	1 BU Cutout	Braking	249 - 0	Auxiliary and Traction

Table 3: List of Test Cases

8 Pass/Fail Criteria

For voltage measurements, Voltage THD limit of 2% of the fundamental component up to 50th harmonic order shall be maintained under all modes of operation, including regeneration.

And for the individual harmonic order 1.5% of the fundamental component is taken as limit to be followed.

For current measurements, the current harmonic is 7.5% for the Total Demand Distortion (TDD) up to 50th order harmonic & for individual harmonic order 6% ($h < 11$), 2.75 % ($11 \leq h < 17$), 2.5% ($17 \leq h < 23$), 1% ($23 \leq h < 35$) and 0.5% ($35 \leq h$) of maximum demand load current.