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Government of India, Ministry of Railways  
Research Designs & Standards Organisation  
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TI/ PSI/HARFIL/DEV/09

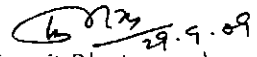
Dt: 29.09.09

Chief Electrical Engineer,

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2. Eastern Railway, Fairlie Place, Kolkata-700 001
3. Northern Railway, Baroda House, New Delhi - 110 001
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5. South Central Railway, Rail Nilayam, Secunderabad - 500 371
6. Western Railway, Churchgate Stn. Bldg, Mumbai - 400 020
7. Central Railway, 2<sup>nd</sup> floor, Electrical Branch, Parcel Office Bldg. Mumbai - 400 001
8. South West Railway, DRM's Office, Hubli (Karnataka)
9. West Central Railway, Jabalpur (MP)
10. East Coast Railway, B-Rental Colony, Chandrashekharapur, Bhubaneshwar (Orissa)
11. East Central Railway, Hajipur (Bihar)
12. North Central Railway, Block-A, Subedarganj, Allahabad 211 033
13. South East Central Railway, Bilaspur (Chattisgarh)
14. Northeast Frontier Railway, Guwahati
15. North West Railway, Jaipur (Raj.)

**Sub: TI/IN/0019 (09/09) rev.'0' "Instruction for Load profile, current & voltage harmonics measurement and recording in a 25 KV ac traction substation".**

Please find enclosed herewith the "Instruction for Load profile, current & voltage harmonics measurement and recording in a 25 KV ac traction substation". It is advised to go-through the instructions and record the parameters. The data generated shall be useful in future for dealing with the different tariff conditions, if imposed by utilities related to the limits on harmonic distortion etc.

  
(Sumit Bhatnagar)  
for Director General, TI

Encls: As above

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**INSTRUCTION No. TI/IN/0019(09/09) rev.0**

**GOVERNMENT OF INDIA  
MINISTRY OF RAILWAYS**



**सत्यमेव जयते**

**INSTRUCTION  
FOR  
LOAD PROFILE, CURRENT & VOLTAGE HARMONICS MEASUREMENT  
AND  
RECORDING IN 25 KV AC TRACTION SUBSTATION**

**SEPTEMBER' 2009**

**ISSUED BY**

**TRACTION INSTALLATION DIRECTORATE  
RESERARCH DESIGNS & STANDARDS ORGANISATION  
LUCKNOW – 226 011**

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## Load profile, current & voltage harmonics measurement and recording in a 25 KV ac traction substation

### 1.0 Introduction

With the introduction of new electricity act 2003, lots of changes had taken place in the power sector in India e.g. open access facility in transmission and distribution sectors, bigger role of central & state regulatory commissions for consumer grievances and enforcement of performance, power quality parameters for all concerned. Instructions related to generation, transmission, distribution, grid operations and metering etc. are now being issued by different authorities like CEA, CERC and state regulatory commissions in the form of codes, guidelines and regulations. The documents like supply codes, grid connectivity guidelines etc. refers to the power quality parameters & their limits to be maintained by the power supply licensee's and the consumers. Summary of some regulations issued by CEA & state regulatory commissions is placed at Annexure – III for reference.

In addition to the above, some Railways have reported that their respective utilities start charging for low PF/MD penalties by implementing logic of addition of leading kVAR.

In order to respond for such conditions it becomes necessary to evaluate the effect of various tariff conditions on the traction bill (e.g. treatment to leading kVAR, low PF & MD penalties, incentives for high PF etc.). This requires accurate analysis of load variation & power quality data at TSS.

Railways may also record short term voltage variations (sag, swell etc.) and capacitor switching transient wave forms depending upon local conditions e.g. equipment failures suspected on account of wide voltage fluctuations, size of capacitor bank, load pattern etc.

During the process of development of Dynamic reactive compensation systems RDSO with the assistance of different vendors collected load variation and other Power Quality related data from various TSS on IR and based on these following recommendations/guidelines have been made. Railways may also offer their suggestions to improve these guidelines based on the field experience.

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## 2.0 Scope of the measurement and recording at a TSS

Initially online measurements and data logging may be carried out at one TSS which is considered representative of a particular area/division and following parameters measurement & recording must be ensured.

- 2.1 RMS voltage, Current, Active, Reactive, Apparent Power & Energy and Harmonics at HV side of Traction Transformer (Location-1 as shown in Annexure-II) if TSS has got facility & access of HV side measurement through a step-down PT at  $110/\sqrt{3}$  V and suitable CT secondary current 5A otherwise at LV side –(Location 2 as shown in Annexure-II).
- 2.2 The preferable location of measurement is at the HT side which is also the point of common coupling (PCC) with the utility.
- 2.3 RMS Current and Reactive power delivered at 25KV by existing capacitor bank if any (Location 3 as shown in Annexure-II).
- 2.4 Logging of Fundamental & Individual Harmonic Currents and Voltage preferably up to minimum 25<sup>th</sup> Harmonics should be ensured. The measurement of harmonics and analysis should generally be in accordance with IEEE 519 guidelines.
- 2.5 The measurements should be recorded with or without existing Capacitors banks (if feasible) preferably spread over a week duration. A sample format of data to be recorded is shown in Annexure-I
- 2.6 The possible location and arrangements are depicted in pictorial form in Annexure-II. The results obtained must be analyzed correctly in terms of the location of the measurements e.g. the measurements recorded at location 2 and 4 shall provide the compensated and uncompensated readings respectively.
- 2.7 The continuous readings of V, I, kW, kVA, kVAR and PF must be finally available in data spreadsheet for desired time duration and scale for analysis. While preparing the load pattern graphs the minimum time interval should be selected based on the window period adopted by the utilities (generally 15 minutes) for calculation of apparent power, MD and average chargeable PF. The recording time interval should be adjustable to accommodate any special tariff condition and to clearly understand the load variation.
- 2.8 Voltage harmonic distortion of supply voltage (THD) at Point of common coupling (PCC) without traction load should be measured to get full idea of harmonic pollution already present at PCC.

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### 3.0 Requirements of Power Quality analyzer & Data logger Instrument

- 3.1 The equipment should be portable facilitating easy field testing.
- 3.2 The equipment should have both measurement, display and recording facilities and it should be able to record sampled data.
- 3.3 The CT/PT output should be connected to the equipment with or without any interface depending upon the type of equipment.
- 3.4 The equipment must be able to measure and record minimum up to 25<sup>th</sup> harmonic current & voltage distortion (individual as well as total).
- 3.5 The equipment should be capable of continuously logging all voltage and current waveforms on internal memory of at least 8 GB. The data should be stored with suitable Data Compression Technology.
- 3.6 The equipment with modern communication features should have wide bandwidth, high sampling rate for accurately capturing waveforms, at high resolution and fast data storage.
- 3.7 The equipment should have suitable LCD type user interface/ display arrangement and it should be supplied with data analysis software (including any other support software to clearly depict recorded data as bar graphs, vectors and lists). It should also support variety of display formats like numeric, wave, bar, trend or their combinations etc.
- 3.8 The equipment should have necessary communication interface to collect the data from the devices to the central processing computer, by means of GPRS, Modem or Ethernet connection.
- 3.9 The equipment should be capable of providing the following system parameters continuously
  - (a) Active power and energy i.e. KWh
  - (b) Reactive power and energy, KVARh
  - (c) Apparent power and energy, KVAh
  - (d) Power Factor
  - (e) Current and voltage Harmonics (individual as well as total).

### 4.0 Analysis of the data recorded

Railways shall have to analyze the data to calculate the requirement of reactive compensation. In addition any violation of tariff condition on account of pf, MD and power quality parameters like harmonic distortion must also be examined.

Sample format of data recording

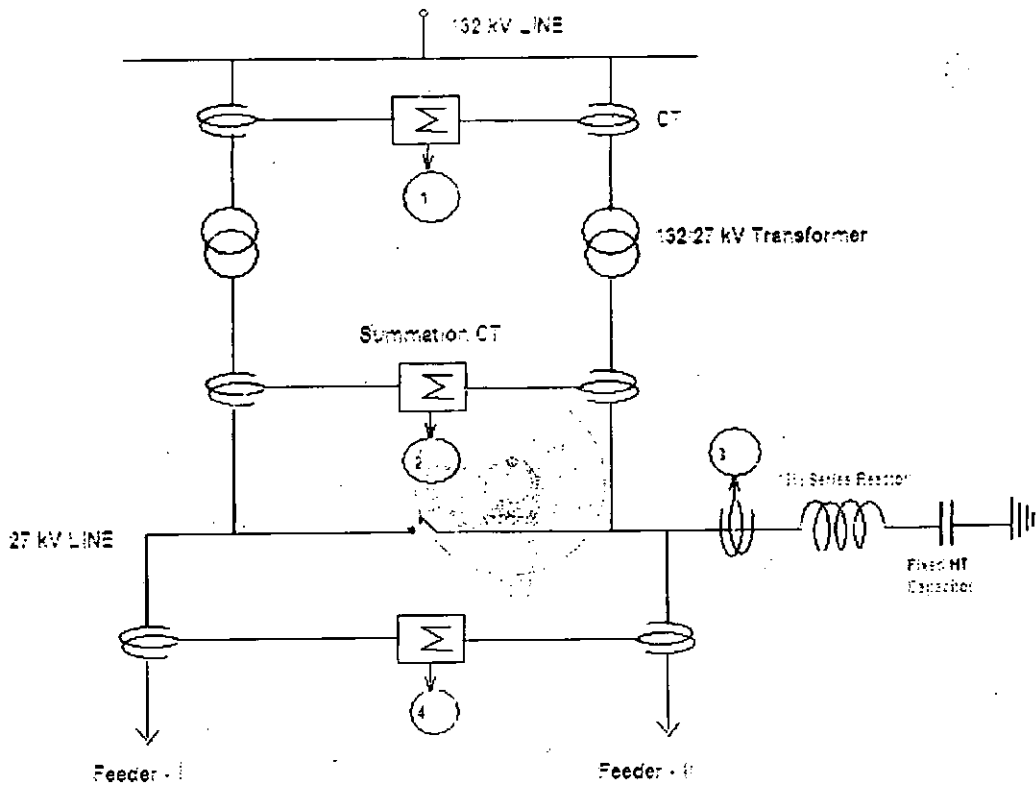
Date	Time	Frequency	V <sub>rms</sub>	V <sub>THD*</sub>	A <sub>rms</sub>	A <sub>THD</sub>	kW	kW-hours	KVAR	kVAR-hours	kVA	kVA-hours	Power Factor
		Hz	V	%	A	%	kW	kWh	KVAR	kVARh	kVA	kVAh	

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THD :- Total Harmonic Distortion

Pl note that generally all the instruments record individual harmonic current and voltage components up to 25<sup>th</sup> or higher order however columns are not shown in above table due to space constraint.

ANNEXURE-II



General Scheme for Load profile, current & voltage harmonics measurement and recording in a 25 KV ac traction substation

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Annexure-III

Regulations, Codes and guidelines on limits of harmonic distortion in different states

	Supply/Distribution Code summary												
CEA	<p>Technical standards for connectivity to the grid regulations-2007/dt 21-02-2007</p> <ul style="list-style-type: none"> <li>• THD for voltage not to exceed 5% at PCC. Individual harmonic distortion not to exceed 3%.</li> <li>• THD for current not to exceed 8% at PCC.</li> </ul>												
Rajasthan	<p><b>The Rajasthan Electricity Regulatory Commission (Transmission Licensee's Standards of Performance) Regulations, 2004</b> &amp; "Rajasthan Electricity Regulatory Commission (Rajasthan Electricity Grid Code) Regulations 2008"</p> <ul style="list-style-type: none"> <li>• Harmonic measurement shall conform to IEC Std. 1000-4-7 or IEEE Std. 519</li> <li>• The Total Harmonic Distortion (THD) determined in accordance with IEC Std. 1000-4-7 shall not exceed 1% at the inter-connection point of EHV system in the Final Phase. The measurement should be taken at 10 minutes interval and shall last for 1 week per site. Licencee shall measure the THD at strategic such inter-connection points which it consider prone to harmonic voltage generation at regular interval of 6 months. RVPN shall intimate the programme to RVUN or Distribution Licensee as the case may be at least 7 days in advance and their representative may be present during such measurements. Wherever THD exceeds the limit or individual harmonics exceed 0.5%, RVPN shall measure harmonics with and without load/generating station to ascertain the origin.</li> </ul> <p><b>CURRENT UNBALANCE</b></p> <ul style="list-style-type: none"> <li>• Current unbalance shall not be more than 3%. Current unbalance shall apply on all the feeders of a voltage class emanating from a sub station taken as a group. In case of railway traction it shall apply on 3 sub stations in a row taken as a group. Distribution Licencee shall be given at least 12 hours to remedy current unbalance. Failure to meet this criterion shall be discussed in committee proposed under grid code and remedial measures agreed there on.</li> <li>• <b>As per clause 6.6.4.3 of grid code Voltage and Current Harmonics:</b> Voltage Harmonics: The maximum limit of total harmonic distortion for voltage shall be:-</li> </ul> <table border="1" data-bbox="400 1533 1357 1727"> <thead> <tr> <th>Nominal System Voltage</th> <th>Total Harmonic Distortion (THD)</th> <th>Individual harmonic of any particular frequency</th> </tr> </thead> <tbody> <tr> <td>400 kV</td> <td>2.0%</td> <td>1.5%</td> </tr> <tr> <td>220 kV</td> <td>2.5%</td> <td>2.0%</td> </tr> <tr> <td>132 kV</td> <td>3.0%</td> <td>2.0%</td> </tr> </tbody> </table> <p>Current Harmonics: The total harmonic current drawn from the transmission system at any point shall not exceed 8% of the fundamental frequency current.</p>	Nominal System Voltage	Total Harmonic Distortion (THD)	Individual harmonic of any particular frequency	400 kV	2.0%	1.5%	220 kV	2.5%	2.0%	132 kV	3.0%	2.0%
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400 kV	2.0%	1.5%											
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<p><b>Maharashtra</b></p>	<p align="center"><b>MAHARASHTRA ELECTRICITY REGULATORY COMMISSION</b>  <b>Maharashtra Electricity Regulatory Commission (Electricity Supply Code and Other Conditions of Supply) Regulations, 2005</b></p> <p><b>12. Power factor / Harmonics</b></p> <p>12.1 It shall be obligatory for the consumer to maintain the average power factor of his load at levels prescribed by the Indian Electricity Rules, 1956 with such variations, if any, adopted by the Distribution Licensee in accordance with Rule 27 of the Indian Electricity Rules, 1956 and in accordance with the relevant orders of the Commission. Provided that it shall be obligatory for the HT consumer and the LT consumer (Industrial and Commercial only) to control harmonics of his load at levels prescribed by the IEEE STD 519-1992, and in accordance with the relevant Orders of the Commission.</p> <p>12.2 The Distribution Licensee may require the consumer, within a reasonable time period, which shall not be less than three months, to take such effective measures so as to raise the average power factor or control harmonics of his installation to a value not less than such norm, in accordance with Regulation 12.1 above: 18 Provided that the Distribution Licensee may charge penalty or provide incentives for low /high power factor and for harmonics, in accordance with relevant Orders of the Commission.</p>
<p><b>MP</b></p>	<p align="center"><b>MADHYA PRADESH ELECTRICITY REGULATORY COMMISSION</b>  <b>(PERFORMANCE STANDARDS) REGULATIONS, 2004 ( REVISION- I, 2005)(No.RG-8 (I) of 2005)</b></p> <ul style="list-style-type: none"> <li>• Licensee shall monitor harmonics at regular interval at strategic points in respect of HT consumers, which it considers prone to harmonic voltage generation and ask the user to comply with the specified standards.</li> <li>• The harmonic currents drawn by various consumers shall be measured and its records shall be maintained. The following is a non-exhaustive list of harmonic generating equipment: <ul style="list-style-type: none"> <li>a) Salient pole synchronous generating units</li> <li>b) Transformers operated with core saturation</li> <li>c) Rolling mills</li> <li>d) Induction furnaces</li> <li>e) Welding equipment</li> <li>f) Static power loads incl. computers &amp; television sets</li> <li>g) Inverters/Power Rectifiers</li> <li>h) Railway Traction Loads</li> </ul> </li> <li>• The Distribution licensee shall follow the Voltage and Current Harmonics distortion limit as specified by the Authority in the Grid Connectivity Standards applicable to the Distribution Systems.</li> </ul> <p align="center"><b>Madhya Pradesh Electricity Grid Code (Rev-I), 2005</b></p> <ul style="list-style-type: none"> <li>• Discoms and Open access users shall ensure that their loads do not affect STU system in terms of causing any:</li> </ul>

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	<p>1. Unbalance in the phase angle and magnitude of voltage at the interconnection point beyond the limits prescribed by Transmission Performance Standards.</p> <p>2. Harmonics in the system voltage at the interconnection point beyond the limits prescribed by Transmission Performance Standards.</p> <p><b>MADHYA PRADESH ELECTRICITY REGULATORY COMMISSION (TRANSMISSION PERFORMANCE STANDARDS) REGULATIONS, 2004 (Revision 1, 2005) (No.RG-9 (I) of 2005)</b></p> <ul style="list-style-type: none"> <li>• Harmonic measurement shall conform to IEC Std. 1000-4-7 or IEEE Std. 519. The Total Harmonic Distortion (THD) in voltage waveform determined in accordance with IEC Std. 1000-4-7 shall not exceed 1% at the interconnection point of EHV system.</li> <li>• The measurement should be taken at 10 minutes interval and shall last for 1 week per site. State Transmission Utility /Transmission Licensee shall measure the THD at strategic such interconnection points which it consider prone to harmonic voltage generation at regular interval of 12 months.</li> <li>• State Transmission Utility /Transmission Licensee shall intimate the programme to Generating Companies or Licensee as the case may be at least seven (7) days in advance and their representative may be present during such measurements. State Transmission Utility /Transmission Licensee will compile a list of all metering points, which are prone to harmonic generation for taking remedial measures.</li> </ul>
<b>Tamil Nadu</b>	<p><b>Tamil Nadu Electricity Supply Code as amended upto 31.7.2008</b></p> <ul style="list-style-type: none"> <li>• Additional charges on harmonic dumping, the consumer shall provide adequate harmonic suppression units to avoid dumping of harmonics into distribution system.</li> <li>• Licensee may provide suitable metering equipments to measure harmonic level, consumer failing to provide harmonic suppression shall be liable to pay compensation.</li> </ul>
<b>Chhattisgarh</b>	<p><b>“Chhattisgarh State Electricity Supply Code-2005”</b></p> <p><b>Para 6.47 Harmonics</b></p> <p>If the licensee detects and proves to the consumer that the consumer’s system is generating harmonics above acceptable limits, the licensee may ask the consumer to install appropriate harmonic filter within a reasonable period of time . The tolerance limits of harmonic injections are as follows:-</p> <p style="text-align: center;">EHT – THD – 3%, HT – 4%, LT – 6%</p>
<b>Punjab</b>	<p>Punjab State Electricity Regulatory Commission (Electricity Supply Code and Related Matters), Regulations, 2007</p> <p><b>Harmonics</b></p> <p>(a) The Licensee will monitor harmonics in respect of those EHT/HT consumers, which it considers prone to generation of harmonic currents and</p>

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	<p>require such consumers to comply with standards as may be specified by the Commission.</p> <p>(b) The harmonic currents generated by a consumer will be jointly measured by the Licensee and the consumer and its record maintained.</p> <p>(c) Consumers contributing harmonic distortion in excess of the specified standards will be liable to pay penalty, as may be specified by the Commission.</p>
<b>Delhi</b>	<p><b>DERC supply code and performance standards</b></p> <p><b>Harmonics</b></p> <p>Requirements will be specified separately at an appropriate time after conducting a detailed study.</p>

- Note: (1) The above details have been collected from the information available on the websites of respective Electricity regulatory commissions.**
- (2) The Railways have to interact with their respective utilities/regulatory commissions for latest amendments/ revisions to the guidelines/codes.**