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रेल मंत्रालय / MINISTRY OF RAILWAYS

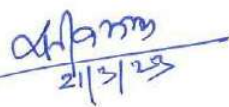
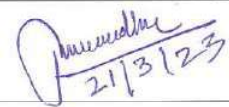
मानक सं० : आई.एस./आर.डी.एस.ओ.- टी.आई./ 0002:2023

STANDARD No. : IS/RDSO -TI/0002:2023

(माह, साल /Month, Year): March, 2023

भारतीय रेलवे में, 25 केवी और 2X25 केवी ट्रैक्शन सब-स्टेशन के लिए
पावर कालिटी रिस्टोरर (पीक्यूआर) के लिए भारतीय रेलवे मानक

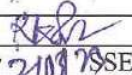
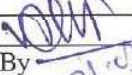

Indian Railway Standard for Power Quality Restorer (PQR)
for 25kV and 2x25 kV Traction Substation in Indian Railways

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अनुमोदित Approved by	प्रधान कार्यकारी निदेशक (पी.एस. और ई.एम.यू) Principal Executive Director /PS & EMU	 21/3/23
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- (ii) All clauses of this Specification shall be enforced from cut-off date. 21.03.2023

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FOREWORD

Research Designs & Standards Organisation (RDSO) have been accorded status of Standard Development Organisation (SDO) by Bureau of Indian Standards (BIS) to align with the "Code of Good Practices" for preparation, adoption and application of Standards issued by World Trade Organization - Technical Barriers to Trade (WTO-TBT), followed globally by all Standards Making or Standards Developing Organizations (SDO).

As per BIS guidelines, Creation of new Specification/Indian Railway Standard (IRS), requires formation of the Standard by a committee whose members shall be from various stakeholders like Institutions, Industry, Inspecting agencies, Testing labs and Regulatory bodies in addition to RDSO & Zonal Railway member.

Accordingly, this standard for Power Quality Restorer (PQR) has been prepared by a technical committee comprising members from different domain of knowledge and stakeholders. The detail of Standard Committee is as under:

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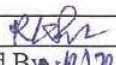
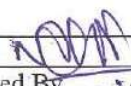
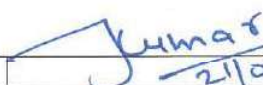
INDIAN RAILWAYS STANDARD FOR

POWER QUALITY RESTORER (PQR)

FOR 25KV AND 2X25 KV TRACTION SUBSTATION

Amendment History:

Amendment Number	Total pages including Annexures	Date of Issue	Reason for Amendment/Revision
-	-	-	-

Prepared By  SSE(D-PQ)	Checked By  ADE/TI-3	Issued By  Dir/TI-3
21/03/23	21.03.23	21/03/23

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1. SCOPE

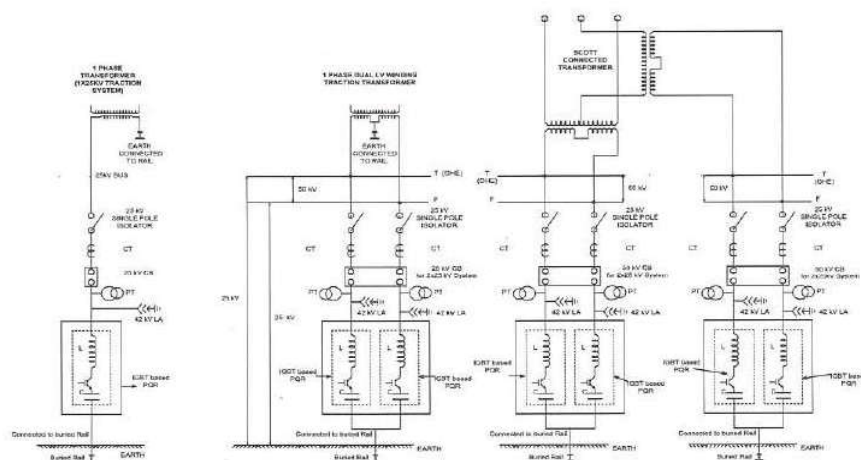
1.1. Indian Railways employ

- 1.1.1. 220 or 132 or 110 kV/27 kV ac traction substation, availing 1-phase, 50 Hz supply at 220 or 132 or 110 kV ac from the supply authorities, for supplying power to the 25 kV ac overhead lines for electric traction. Hitherto, fixed shunt capacitor banks have been provided at the traction substation for improving the average power factor.
 - 1.1.2. 220 or 132/2x55 kV, 2x25 kV ac Traction Sub-station (Scott connected & V-connected Transformer using incoming supply from 3 phase transmission line at 220 or 132kV ac from the supply authorities).
- 1.2. With a view to improving the average power factor and mitigating the harmonics fed into the supply source, the PQR is intended to be provided at the traction substation. The options for provision of PQR exists wherein it may be directly connected with 25kV ac LV bus or may be connected through step down LT transformer for PQR working on 600 or 650 V ac or any other suitable voltage.

1.2.1. OPTION-A

DIRECTLY CONNECTED TO 25KV LV BUS IN TRACTION SUB-STATION:

The PQR shall be rated for 52kV Voltage Class (insulation class) and should be capable of being connected directly on the 25 kV AC bus or across +25kV & earth and -25kV & earth in 2x25 KV Traction Sub-station provided with Scott connected transformer without midpoint earth or V-Connected Transformer. Dynamic compensation of reactive power and current harmonics should be achieved with the provision of suitably designed passive / active filters; PQR should be based on IGBTs or any further improved/advanced electronic switching devices for the purpose as necessary. Compensation may be step less or in small steps such that advantages of improved average power factor and mitigated harmonics are achieved as desired.



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1.2.2. OPTION-B




HT HARMONIC (PASSIVE FILTER) AND VAR COMPENSATORS (LT):

The manufacturer may propose an IGBT based PQR connected to 25 kV Bus through step down transformer suitably designed to provide necessary power factor improvement. The harmonic compensation for load currents through a passive filter shall be directly connected to 25 kV ac Bus.

The Voltage Source Converter input voltage shall be 600 or 650 Volt ac or any other suitable voltage). Thus, the PQR shall be a low voltage equipment (600 or 650V or any other suitable voltage) and it will be connected to the 25 kV bus through 25kV/650V step-down Transformer. The General scheme of IGBT based PQR shall be provided by the firm with details of equipment.

- 1.3. This standard covers the design, manufacture, supply, erection, testing and commissioning of the power quality restorer. It is for outdoor/indoor installation at the traction substation of 1-phase, 50Hz, 25kV ac systems including 2x25 kV ac feeding system on Indian Railways for mitigation of harmonics, improvement of average power factor and reduction of maximum demand.
- 1.4. The PQR should be complete with step-down transformer (if required), passive / active filters, control gear, protective relays, automatic power factor/ harmonic correction, relays, IGBTs and/or other advanced suitable electronic switching devices and accessories necessary for its efficient operation. All such parts and accessories shall be deemed to be within the scope of this standard whether specifically mentioned or not. The 25 kV ac circuit breakers, 25 kV ac current and potential transformers, 25 kV isolators, 42 kV ZnO lightning arresters, 25 kV bus bars and connectors, 25 kV post insulators etc. required for the RESTORER shall also be within the scope of supply against this standard. The Double Pole Circuit Breaker, Current and Potential Transformers etc. shall be according to the equipment mentioned in layout for 2x25 kV System.
- 1.5. The successful Firm/Vendor shall be required to erect and commission the equipment. The offer shall, therefore, be inclusive of all expenses including deputing engineers and supervisors by the Firm/Vendor for handling, installation, testing and commissioning of the equipment, proving the performance requirement and training the operating & maintenance staff.
- 1.6. All civil engineering works connected with foundations of power quality restorer, associated step-down transformers circuit breakers, isolators, series reactor, potential transformers, current transformers, ZnO lightning arresters and supporting steel structures, as also construction of building for housing any indoor equipment shall form part of this standard, and are part of scope of work against this standard.
- 1.7. The PQR panel should have display of the power quality parameters with storage facility and be able to ensure that Indian Railway system is able to meet the grid connectivity compliance regulations as specified in respective regulatory authority code e.g., IEEE 519-2014. PQR measures the load and source currents with the available TSS (+25kV) protection CTs which are also used for compensation (load harmonics and source harmonics) and same data is logged in the system and to cloud as well for monitoring and cross verification. The display on the PQR panel will represent/indicate the actual power quality parameters at the TSS. Hence, separate meter may not be required for power quality measurement. However, this power quality data cannot be used for actual TSS billing data. Power quality parameters as per IEC 61000-4-30 Class A to be displayed are given below. The Power Quality Parameters shall be tested as per methods mentioned in IEC 61000-4-30 ED 3.1 or latest.

- i. PQR rms current, PQR reactive current, Harmonic Currents, Grid Voltage & Frequency,
- ii. Load Side: Fundamental Current, PF, Harmonic Currents, TDDi/THDi,

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- iii. Source side: Fundamental Current, PF, Harmonic Currents, THDi/TDDi
- iv. PQR active & reactive power, Source active & reactive power, Load active & reactive power.

2. GOVERNING SPECIFICATIONS

2.1. PQR and associated equipment shall, unless otherwise specified herein, conform to the latest revision of standards mentioned below.

2.1.1.	IS : 5-1994	Colour for ready mixed paints and enamels
2.1.2.	IS:13585-1	Low voltage capacitors
2.1.3.	IS : 513-1994	Cold rolled low carbon steel sheets and strips
2.1.4.	IEC 60747-2	Diodes
2.1.5.	IEC 61071	DC Capacitors
2.1.6.	IEC 60747-9	Insulated gate bipolar transistors
2.1.7.	IEC 60747-15	Isolated power semiconductor devices
2.1.8.	IEC-60146-2(1999) Section -7	Electrical rating and characteristics of voltage source converter.
2.1.9.	IEC 62497	Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment
2.1.10.	IEC 61000-4-30 edition 3	Power quality measurement methods
2.1.11.	IS 14697	AC static transformer operated watt hour meter 0.2s
2.1.12.	IS : 800-1984	Code of practice for use of structural steel in general building construction
2.1.13.	IS : 1554 : (Pt.2)	PVC insulated (heavy duty) electric cable for working voltages from 3.3kV up to and including 11 kV.
2.1.14.	IS : 2026 (all parts)	Power transformers
2.1.15.	IS : 2099-1986	Bushing for alternating voltages above 1000 volts
2.1.16.	IS : 3070-1986	Surge arrestor for a.c. systems, non-linear resistor type
2.1.17.	IS : 3231 (all parts)	Electrical relays for power system protection
2.1.18.	IS : 3700 (all parts)	Essential ratings and characteristics of semi- conductor devices.
2.1.19.	IS : 5553-1990	Reactors
2.1.20.	IS : 11298-1991 (Pt.3/Sec.1)	Specification for plastic films for electrical purposes - polypropylene film for capacitors
2.1.21.	IS : 13947-2	Air circuit breakers
2.1.22.	IS : 12672-1989	Internal fuse and internal over pressure disconnectors for shunt capacitors
2.1.23.	IEC-60871-1/IS-13925-1	Shunt capacitors for a.c. systems having a rated voltage above 1000 V.
2.1.24.	IEC-60871-2/IS-13925-2	Shunt capacitors for a.c. systems having a rated voltage above 1000 V (endurance testing).
2.1.25.	RDSO Specification No. ETI/OHE/13(4/84)	Specification for hot dip zinc galvanization
2.1.26.	RDSO Specification No. ETI/OHE/18(4/84)	Specification for steel and stainless steel, nuts and washers steel bolts
2.1.27.	RDSO Specification No. ETI/PSI/65(1/97)	Specification for control and relay panel.

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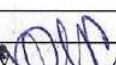

2.1.28.	RDSO Specification No. TI/SPC/PSI/CB/0000	Specification for outdoor circuit breakers for railway ac traction substations.
2.1.29.	RDSO Specification No. ETI/PSI/120 (7/88)	Code of practice for earthing of power supply installation for 25 kV a.c. 50 Hz single phase traction system.
2.1.30.	IEC 60146	Specification for semiconductor converters
2.1.31.	IEEE519:2014	IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
2.1.32.	IEC 61869-1 2007-10 IEC 61869-2 2012-09	Instrument transformers – Part 1: General requirements. Instrument transformers – Part 2: Additional requirements for current transformers.
2.1.33.	IEC 61082-1	Specification for preparation of documents
2.1.34.	IEC 62305	Specification for lightning protection
2.1.35.	IEC 61140	Specification for protection against electric shock
2.1.36.	IEC 60445	Specification for man-machine interface, marking and identification
2.1.37.	IEC 60204-1	Specification for safety of machinery-electrical equipment
2.1.38.	IEC 62477-1	Specification for safety of power electronic converter systems and equipment
2.1.39.	IEC 61000-4-30 Ed 3.1	Testing and measurement techniques - Power quality
2.1.40.	IEC 61000-4-30 Class A	Power quality monitor: Development and performance analysis
2.1.41.	IS 17036	Distribution system supply voltage quality
2.1.42.	IS:1255-1983(Reaffirmed 2016)	Code of practice for installation and maintenance of power cables up to and including 33 kV rating
2.1.43.	TI/SPC/RCC/SCADA/0133	For SCADA system for 25kV and 2x25kV AC Systems

2.2. In the case of any overlapping or conflict in contents of the above standards and this specification, stipulations of this standard shall prevail.

2.3. Deviations: Any deviation from this standard, proposed by the Firm/Vendor, intended to improve performance, utility and overall efficiency, will be given due consideration, provided full particulars of the deviation with justification thereof are furnished. In such case, the Firm/Vendor shall quote according to this standard, and the deviations proposed by him shall be quoted as an alternate/alternatives.

2.4. Site visit: The Firm/Vendors should visit the sites/sections and may carry out load and harmonic current measurements at the concerned traction substations as considered necessary so as to familiarize themselves with the local conditions and understand the technical requirements of the system in detail, and obtain clarifications as may be necessary from the Purchaser, before tendering the Bids, and ensure that their offers meet the technical, performance and other requirements specified in this standard.

2.5. The purchaser will share with eligible Firm/Vendors in regard to the particular requirements against this standard, site conditions, mode of transport, availability of site, erection and commissioning, etc. After the award of the contract, the Firm/Vendor shall be fully responsible for successful integration of the PQR with the existing traction substation equipment, and with the Remote Terminal Units (RTUs). Any items/ equipment later considered as essentially required for successful integration shall fall within the scope of the supply and work of the Firm/Vendor, and no extra price will be paid by the Purchaser on that account.

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3. ENVIRONMENTAL CONDITIONS

- 3.1. All equipment supplied against this standard shall be suitable for outdoor/ indoor use in tropical climate and in areas that are subject to heavy rainfall, pollution due to industrial and coastal climates and severe lightning surges. The maximum ambient temperature may reach 50°C in shade, with maximum humidity reaching up to 100%. However, for the design of the equipment, 50°C category of temperature shall be taken.

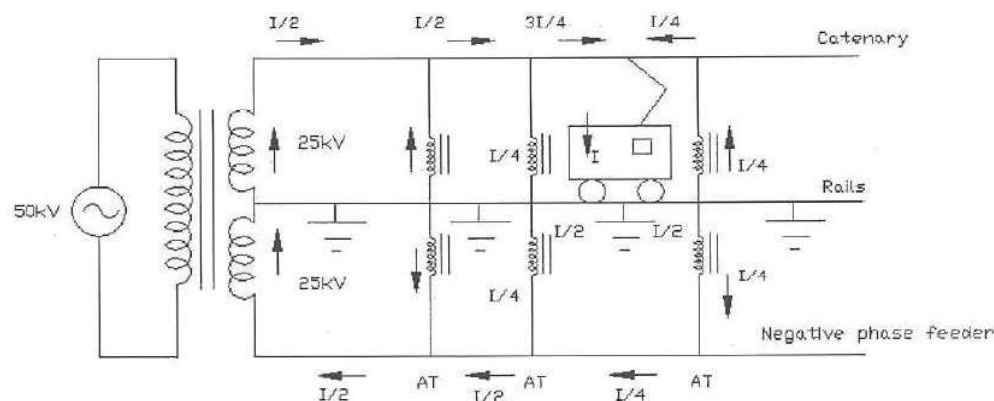
i.	Maximum temperature of Air (in shade):	50°C
ii.	Minimum temperature of Air (in shade):	(-) 10°C
iii.	Maximum relative humidity:	100%
iv.	Annual rainfall ranging from:	1750 mm to 6250 mm
v.	Maximum number of thunder storm days per annum:	85 days
vi.	Maximum number of dust storm days per annum:	35 days
vii.	Number of Rainy days per annum:	120 days
viii.	Basic wind pressure:	216 kgf/m ²
ix.	Altitude above Mean Sea level (MSL)	2000 m

- 3.2. Vibrations: The equipment is to be installed on foundations in the ground or on steel structures, located by the side of railway tracks and is subjected to vibrations due to the passage of trains. The amplitude of these vibrations lies in the range of 30 to 150 microns, with instantaneous peaks going up to 350 microns. These vibrations occur with rapidly varying time periods in the range of 15 to 70 ms.

4. TRACTION POWER SUPPLY SYSTEM

4.1. General Scheme of 2x25 kV ac Traction System

In 2x25 kV system, power is fed from the TSS at 50 kV and utilization is achieved at 25 kV by providing Auto-transformers of adequate capacity and by providing one additional conductor normally referred as feeder wire (similar to the return conductor in BT/RC system). Centre point of the Auto Transformer is connected to the earth/rail. This arrangement facilitates +25 kV Voltage between OHE and rail and -25 kV voltage between Rail/earth and the Feeder Wire.



4.1.1. Scott Connected Transformer Scheme:

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- (a) In this scheme 2 number Scott connected Transformers & 04 number Autotransformers are to be installed at a TSS along with associated switchgear for Control & protection. The two windings of a SCOTT transformer i.e., Main and Teaser windings are of equal power rating and feed either side of the TSS independently. The supply of both the windings is at a phase difference of 90 degree and separated by neutral section provided near TSS. Out of two Scott transformers only one is in operation and the other is on standby. (Annexure-6)
- (b) Scott Connected Transformer:
Scott- connected transformer of 60/84/100 MVA (ONAN/ONAF/OFAF) is used to feed power to the traction system. It has a voltage input on 220kV or 132kV, 3 phase, 50 Hz and two independent secondary winding for output at 55 kV. The Transformer has 2 secondary windings, one known as the main winding and the other known as the teaser winding. The two windings are identical in voltage and current rating but are in phase difference of 90 degree. These two windings of equal power rating i.e., Main & Teaser windings, feed power on either side of the TSS. The feed of different phase is separated by neutral section provided near TSS. The Scott Connected Transformer in ONAN Mode shall feed the 30MVA Power to each side of the TSS.

4.1.2. V Connected Transformer Scheme:

- (a) In this scheme, 3 bays of V-Connected single-phase transformers are connected to different pairs of 3 phases forming on open delta connection on the primary side. Out of the 3 sets of V-Connected single-phase transformers, one set of V-Connected transformer feeds the OHE on one side of the TSS, another set feeds the OHE on the other side of the TSS and the third set of V-Connected transformer remains as standby. The power supply on either side of TSS is at a phase difference of 120 degree and therefore separated by a neutral section provided near TSS. (Annexure-7)
- (b) V- Connected Transformer:
In the above arrangement, 3 number 38/53/63 MVA (ONAN/ONAF/OFAF) Open delta connected Transformers are to be installed at a TSS having 3 phase, 50Hz, 220kV or 132kV incoming supply along with associated switchgear for Control and protection. In these single-phase transformers, there are two secondary windings in each transformer. One terminal of these secondary windings is connected with each other and connected to Rail. The outer terminals of windings are connected to Feeder wire and overhead contact/catenary wire respectively. Two transformers shall be in operation at a time and one shall be stand by. In the V connected Scheme, each transformer in ONAN mode shall feed the 38MVA Power in either side of the TSS.

4.2. General Scheme of 25kV ac Traction System

- 4.2.1. Single phase supply (between phase to phase) is availed by Railway at 220/132/110 kV, 50 Hz from the 3-phase effectively earthed transmission network of the supply authorities. The 25 kV, 1-phase AC supply for railway traction is obtained through 220 or 132 or 110 kV, 13.5MVA or 21.6 MVA or 30 MVA step-down power transformers provided at the traction substation. The primary winding is connected across the two phases of the incoming 220/132/110 kV supply. The spacing between adjacent traction substations generally varies between 40 km and 80 km. One terminal of the 27 kV secondary winding of the transformer is connected to the overhead equipment (abbreviated as OHE). The other terminal is solidly earthed and also connected to traction rails of the running track.
- 4.2.2. The load current flows through the OHE to the locomotives and returns through rail and earth to the traction substation.
- 4.2.3. Adjacent substations are fed by different pair of phases of the 3-phase grid of the supply

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authorities so as to provide load balancing on the grid. In the middle of adjacent traction substations, a dead zone known as "neutral section" is provided in the OHE to isolate the two supplies. The power to the OHE on either side of the traction substation is fed by a separate feeder circuit breaker. OHE of each track is controlled by an Interrupter. In case of fault on the OHE, the concerned feeder circuit breaker clears the fault.

4.2.4. Brief on related equipment provided at the traction substation is given in Annexure-2. A schematic diagram of a typical arrangement, showing the "General Feeding Arrangement" of a traction system, as well as the "Schematic General Arrangement at a Traction Substation" is given in Annexure-3.

4.2.5. The incoming 220/132/110 kV AC supply may vary between +10% to -12.5% as per CEA regulation 2010. The supply frequency may vary by $\pm 3\%$ from the standard frequency of 50 Hz.

4.3. Protection system for 25 kV AC Traction System and 2x25kV AT Traction Power System

4.3.1. 25kV AC Traction System

4.3.1.1. Various relays are provided for the protection of the 25 kV AC traction power supply system. The following protective relays are provided for the protection of power transformer:

- i. IDMT overcurrent Protection on 220/132/110/66 kV side.
- ii. Restricted earth fault protection on 220/132/110/66kV side.
- iii. IDMT overcurrent on 25 kV side.
- iv. Restricted earth fault on 25 kV side.

4.3.1.2. The following protective relays are provided for the protection of OHE:

- i. Distance Protection
- ii. Instantaneous Over Current Protection.
- iii. Wrong Phase Coupling Protection.

Traction substations are now provided with static/microprocessor-based relays.

4.3.2. 2x25kV AT System

4.3.2.1. The following relays are provided for the protection of traction transformers :

- i. Differential relay.
- ii. Over current relay on 220 kV or 132 kV side.
- iii. Grounding over-current relay on 220 KV or 132 KV.
- iv. High -speed over current relay on 220 kV OR 132 kV.
- v. Phase-failure relay (to detect a malfunction of a feeder circuit breaker).

4.3.2.2. The following relays are provided for the protection of OHE:

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- i. Distance relay (with a parallelogram protection characteristics).
- ii. Delta- I type fault selective relay.
- iii. Under voltage relay.

However, relevant specifications for control & relay panel for 25kV and 2x25kV TSS may be referred for detailed information.

4.4. OHE and Traction Transformer

4.4.1. 25 kV AC

- i. The OHE generally consists of a stranded cadmium copper catenary of 65 mm² area and a grooved copper contact wire of 107 mm² area providing a total of 150 mm² copper equivalent. The loop impedance of the OHE is as under:

The values without Booster Transformer (BT) and Return Conductor–

- Single track OHE 0.41 $\angle 70^\circ$ ohms/km
- Double track OHE 0.24 $\angle 70^\circ$ ohms/km
- Triple track OHE 0.18 $\angle 70^\circ$ ohms/km

The values with Booster Transformers (BT) and Return Conductor–

- Single track OHE 0.70 $\angle 70^\circ$ ohms/km
- Double track OHE 0.43 $\angle 70^\circ$ ohms/km
- Triple track OHE 0.27 $\angle 70^\circ$ ohms/km

- ii. In some sections contact wires of 150/161/193 mm² are also used. The Firm/Vendor may obtain details of impedances from the Railway, if such wires are used.
- iii. Traction Transformer: The resistance and reactance of a typical 13.5 MVA and 21.6 MVA traction power transformer at the traction substation is (0.179 + j 5.49) ohms and (0.132 + j 4.05) ohms respectively. Only one transformer is generally in service at a time.
- iv. Clearances: A minimum clearance of 500 mm is provided in general between any live conductive parts at 25 kV and earthed structures in the 25 kV AC traction system. This clearance is not applicable for equipment like insulators (post/bracket/stay etc.), section insulators, and other equipment that have been type-tested for the BIL of the 25 kV system.

4.4.2. 2x25 kV AT System:

- 4.4.2.1. The OHE is made up of a stranded cadmium copper catenary of 65 Sq. mm. or a stranded aluminum alloy catenary of 116 sq. mm and a grooved contact wire of 107 sq. mm making up a total of 150 sq. mm or 140sq.mm copper equivalent, respectively. As a feeder wire, a stranded aluminum alloy of 240 sq. mm. is used. The impedance of upcoming system may change.

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- 4.4.2.2. The calculated OHE impedance value of AT feeding circuit (OHE: Al 116-cu 107 sq. mm feeder wire: Al 240 sq. mm) for a single-track line is $0.0601 + j0.1419$ ohms/km (at 25 kV System impedance), $Z_{50} = 0.2404 + j0.5684$ (at 50 kV System impedance) and $Z_{25} = Z_{50}/4$
- 4.4.2.3. The percentage impedance of a 60/84/100MVA, ONAN/ONAF/OFAP, 220kV/2X55kV or 132kV/2X55kV or 110kV/2X55kV or 66kV/2X55kV Scott connected transformer are (11 to 13) % (at 30MVA Base) and for 54MVA, 220kV/ (2X27) kV is 12% (at 27 MVA base). For 21.6MVA, ONAN & 38/53/63MVA ONAN/ONAF/OFAP, Single Phase transformer is (12 ± 1.2) % (at 21.6 MVA & 38MVA Base). The Traction Transformers in the system may be of secondary Centre tapped type for ensuring phase failure protection. Rating of the power transformer Rated secondary current of the Transformer of each winding 54 MVA 60MVA 21.6MVA 38MVA Continuous 500 A 545A 400 A 600A 15 Min 750 A 817.5A 600 A 800A 5 Min 1000 A 1090A 800 A 1200A

4.5. Nature of faults on the OHE system

- 4.5.1. OHE is subjected to frequent earth faults, or snapping of OHE and touching the rail/earth, or loose wires carried by birds coming in contact with OHE below over line structures, miscreant activities etc. Faults are cleared by feeder circuit breaker, which operates on distance protection relay and/or instantaneous overcurrent relay depending on the proximity of the fault.
- 4.5.2. Inadvertent coupling of two different phases between adjacent traction substations at the neutral section or at intermediate switching stations, in case of extended feed condition, is cleared by one of the feeder circuit breakers at either end of traction substation through a "Numerical Feeder Protection module having an element" known as wrong phase coupling relay.
- 4.5.3. Short Circuit Level: For different grid supply voltages, short circuit level on primary side of traction power transformer may vary depending upon the proximity of the traction substation to the generating station. The actual values of fault-level of the traction substation will be furnished by the Railways.
- 4.5.4. The power cables connected to the 25kV tubular bus bar providing supply to the PQR must comply with the provision in IS:1255-1983(Reaffirmed 2016).

4.6. Nature of load on the 25 kV / 2x25kV AT system

- 4.6.1. Traction load is of frequent and rapidly varying nature and may fluctuate between no-load and overloads. While a precise load cycle is difficult to forecast, a load curve for a typical day together with indications of the average power factor, will be supplied by the Railway. The average MVA (averaged over every 15 minutes period) versus time should also be obtained along with the summarized cycle from Railway based on which the capitalization of losses and benefits would be worked out by the Firm/Vendor, with reference to Clause 14 of this standard.
- 4.6.2. The AC electric rolling stock/AC-DC electric locomotive/EMUs/MEMUs are fitted with single-phase bridge connected silicon rectifiers with smoothening reactor for feeding the DC traction motors. The rectifiers introduce harmonic currents on the 25 kV power supply. Also, there are EMUs/MEMUs/Locomotives with GTO (Gate Turn Off)/ IGBT/pulse width modulation devices, in place of silicon rectifiers. Typical percentages of current harmonics in traction load current obtained during higher load currents of about 600 A to 800 A are as follows (during lower load currents the harmonics obtained are considerably higher than the following figures):

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S.No.	Harmonic order	With diode Rectifier (%)	3-Phase rolling stock with GTOs/IGBTs
1.	3 rd harmonic	18	Maximum harmonic current of individual harmonic at no time exceeds 0.5 A except third harmonic which may be up to 5 A. The GTO or IGBT type of Locomotives/EMU/MEMU produce substantial 2 nd harmonic currents which may be up to 10% of fundamental current.
2.	5 th harmonic	8	
3.	7 th harmonic	4	
4.	9 th harmonic	1.5	
5.	11 th harmonic	1	
THD (typical)		20	

These are only typical values and are to serve as guidelines only. Actual values at any particular traction substation could be different depending on the type of loads and loading pattern. The average power factor of the electric locomotive or electric multiple units varies between 0.7 lagging to near unity. Successful Firm/Vendor shall measure these values before submitting final design.

PQR should help limit these values within limits as specified by grid connectivity regulation specified by CEA. Input data need to include of harmonic load data as per the traction load.

- 4.6.3. In big yards and in the vicinity of electric loco sheds, a number of locomotives may be idle with only the load of their auxiliaries and drawing higher reactive power.

4.7. LT Auxiliary Power Supply

Each traction substation is generally provided with two numbers of 25 kV/240 V, 50 Hz, single phase oil filled Auxiliary Transformers. As the power from these auxiliary transformers is very limited and required for 25kV/2x25kV system operational, the firm has to supply auxiliary transformer of required capacity along with the PQR equipment and shall be installed to meet the requirement of auxiliary power for functioning of PQR along with associated devices. Necessary ACDB panel will be provided with suitable protection by the firm. No DC supply will be made available by Railways for any auxiliary power requirement of the PQR. The firm will provide the necessary DC supply system (redundant) of suitable rating meeting the requirement of the PQR for its functionality round the clock. However, 110VDC supply can be availed for switch gear and protection only.

5. TECHNICAL SPECIFICATION

5.1. Traction System Particulars

i.	System	25 kV, 1-Phase, 50 Hz AC traction system
ii.	Nominal system voltage	25 kV (Phase to Earth)
iii.	Variation in system voltage	19 kV to 27.5kV (upto 30 kV at instants) (down to 17.5 kV at instants).
iv.	Equipment voltage class (on 25 kV side/ 55kV side for 2x25kV System)	52 kV (PQR will be provided individually on +25kV & -25kV with mid-point earthed)
v.	Rated frequency	50 Hz \pm 3%
vi.	Average power factor of the traction System	Between 0.7 and 0.8 lagging.
vii.	Harmonics (typical)	Refer Clause 4.6.2.
viii.	Load cycle (typical)	Refer Clause 4.6.1

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ix.	Fault level at the 25 kV bus at the traction substation (maximum). (Neglecting supply source impedance)	The ratio of rated current of traction transformer to per-unit impedance of transformer.
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5.2. Power Quality Restorer

5.2.1. Purpose: The purpose of the PQR(PQR) to be provided at the traction substation is mainly two fold as under:

- To limit the total harmonic demand distortion for current (TDDi) within the maximum permissible limit as per clause 5.3 of IEEE 519-2014 (for system nominally rated above 69 kV through 161 kV) and systems nominally rated above 161kV, clause 5.4 will be applicable e.g. 220kV system.
- To maintain the average power factor between 0.95 lag to 0.95 lead at all loading conditions at the metering point (i.e., 220/ 132/110/66 kV bus).

5.2.2. Brief details of existing system:

5.2.2.1. **Power factor:** The traction load is continually varying in nature with a power factor of 0.7 to 0.8 for conventional locos whereas unity power factor for 3 phase locos. The higher power factor is generally obtained at higher load currents. If the Power Factor is below 0.95 (lag/lead) even at higher load currents then PQR should be capable of maintaining the P.F. between 0.95 lag to 0.95 lead. Further, if the PQR alone is not capable of maintaining the required PF then, suitable provisions should be made in PQR system to issue close/open commands to CB of 25kV fixed shunt capacitor bank such that the shunt capacitor bank is put to service for maintain the required Power factor. At present, the reactive power compensation is provided by HT (25 kV) fixed shunt capacitor bank with 13% detuned reactor. The billing power factor is calculated as the ratio of kWh to kVAh recorded during the month; for kVAh both lag and lead power factors are considered.

5.2.2.2. **Harmonic currents:** The traction load current contains harmonics generated due to rectifier type electric locomotives. The harmonic currents are predominantly odd harmonics; the percentages of harmonic currents measured during higher load currents (of about 600 A to 800A) are of the order of 18%, 8%, 4% and 1.5% for 3rd, 5th, 7th and 9th harmonics respectively; the total harmonic distortion of current is about 20%. During lower load currents, the percentage harmonics measured are considerably higher than the above-mentioned figures. As per extant CEA guidelines, the total harmonics distortion for current at maximum demand (TDDi) at metering point shall not exceed as given in Para 5(3) of CEA Notification No. 12X/STD (CONN)/GM/CEA/2018 dated 06.02.2019. The current harmonics will be measured at point of common coupling (PCC) continuously with permanent meter, complying with IEC 61000-4-30 Edition 3 Class A, as distortion limits are to be calculated based on daily and weekly percentile values. The PQR shall be designed to meet the existing and proposed requirements as above, wherein the current distortion limits are proposed to be revised based on Isc/IL at every PCC.

So far as the voltage distortion is concerned, the system owners viz. Electricity Authority are supposed to limit the total harmonics distortion for the supply voltage as given in Para No. 5(3) of CEA Notification No.12/X/STD(CONN)/GM/CEA/2018.- dated 06.02.2019 or latest guidelines issued by Central Electricity Authority (Technical Standards for Connectivity to the Grid) Regulations 2007 for the present. Notwithstanding this, the underlying assumption is that, by limiting harmonic current injection by bulk consumers like Railways, the voltage distortion can be kept below objectionable levels. In the event that, limiting harmonic currents alone does not result in acceptable levels of

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voltage distortion, Electricity Authority shall take action to modify system impedance characteristics and in such scenario, the PQR shall not throw up passive components that affect the system impedance characteristics. The limits of injection of current harmonics, point of harmonic measurement, method of harmonic measurement and other related matters shall be followed as per Central Electricity Authority (Technical Standards for Connectivity to the Grid) (Amendment) Regulations, Feb 2019 or latest. The current Harmonics limits prescribed in Table-3 & Table-4 under clause 5.3 & 5.4 of IEEE 519-2014 standard for above 69 kV through 161 kV & more than 161 respectively shall be followed.

The PQR shall be designed to meet/comply these requirements. Clause 5.1 of IEEE 519-2014 sets the values for recommended harmonics voltage limits for various applicable voltages at PCC. Accordingly clause 5.1 of IEEE 519-2014 shall also be applicable in this regard.

The absolute value of peak harmonic currents in the load current should be calculated based on rated fundamental current depending on the capacity (MVA) of transformer. The transformer impedance shall be provided by Railway.

- 5.2.2.3. **Power Data of Traction Substation:** The power data (viz. active power, reactive power, harmonic currents and total harmonic distortion (THDi) of current of the **load current should be recorded** at a traction substation. Field measurements shall however be carried out independently by the Firm/Vendor at the concerned traction substation to assess the actual details which may be at some variance from the recorded power data.
- 5.2.3. General scheme of power quality restorer: The Firm/Vendor can propose any suitable scheme for the PQR subject to the condition that it meets the purpose (refer Clause 5.2.1) and other technical & reliability requirements specified in this technical standard. The equipment may be based on passive or active or both active and passive filters – deploying suitable switching devices like IGBT/ more advanced switching devices as necessary. All switching operations shall be almost transient free.
- 5.2.4. The railway will provide the data for the harmonic content in the 25kV line (All load variations must be considered in seven days) for the particular traction substation as available to serve as guideline to the bidder. However, the bidder should verify the details (refer Clause 2.4) to size and quote for the power quality restorer. In addition, the successful Firm/Vendor shall also measure and record load variation pattern and harmonic contents in load current for seven consecutive days at the traction substation in which the PQR is to be provided, and design the equipment accordingly with the approval of the railway.
- 5.2.5. The successful Firm/Vendor shall also design the equipment and related supporting structures, including layout as per actual site conditions, which shall be approved by the railway.
- 5.2.6. Heat load calculation shall be carried out as part of the design and proper cooling system suitable to the atmospheric conditions of region to be taken care. The cooling equipment as required shall also be supplied along with power factor correction equipment.
- 5.2.7. Instantaneous and Average power factor: The instantaneous power factor on the source side of the PQR should be near to unity up to the maximum reactive power (fundamental component) that the PQR is designed to support. Further, the maximum reactive power that the PQR is designed to support should be such that, for the existing load pattern, the average power factor (kWh/kVAh computed over a month considering both lagging and leading reactive power drawl) obtained after installation of PQR shall be between 0.95 lag and 0.95 lead (or any other value specified by the purchaser in the tender document).

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