

5.2.8. RATINGS

The PQR as per this standard may comprise of active filter, fixed and variable compensation, depending upon the requirement at a particular traction substation. The ratings indicated below are only typical values; the desired ratings of PQR based on the actual requirement at a particular traction substation shall be furnished by purchaser/railway.

5.2.8.1. Step-down Transformer, 1-phase (if required):

i.	Rated primary voltage	27.5 kV
ii.	Rated Secondary Voltage	600 V (or 650 V or any other suitable voltage if proposed by the Bidder).
iii.	No-load voltage on the 25 kV bus (without any traction load)	27.5 kV without any compensating equipment. Sometimes, it may touch 30 kV.
iv.	Rated frequency	50 Hz $\pm$ 3%
v.	Rated power frequency withstand voltage of windings	Primary: 95 kV for 1 min. Secondary: 3 kV for 1 min (for 433 V secondary).
vi.	Rated lightning impulse withstand voltage	Primary: 250 kVp. Secondary: Not applicable.
vii.	Rated output	1.5 times capacity required by PQR
viii.	Rated impedance [Measured values to be used for resonance evaluation]	6% primary to <u>each</u> secondary on 3 MVA base ( $\pm$ 10% tolerance).  Less than 1.5% secondary to secondary on 3 MVA base.
ix.	Operating magnetic flux	1.6 T (or less) at 27.5 kV primary voltage. The transformer should not saturate when the 25 kV bus voltage touches 30 kV.
x.	No-load loss	0.4kW/MVA
xi.	Load loss at full-load at 75°C	3.9kW/MVA
xii.	Type of cooling	ONAN
xiii.	Off-circuit tap changer	$\pm$ 7.5% in steps of 2.5% on primary winding
xiv.	Noise level at 1 m distance from transformer	75 dB (A) (maximum)

**Note:** The rated capacity of the transformer to be used as step down transformer should meet the required capacity to meet out the reactive power & harmonics generated by the traction load. If it requires 4 MVA then 1.5 times would be 6 MVA and should be available round the clock irrespective of time of overloading. Hence, the rated capacity of the transformer should be about 1.5 times the maximum load being fed by the transformer. For example, 4 MVA load, the transformer capacity should be 6 MVA continuous.

5.2.8.2. **HT Harmonic and Var Compensators (HT-HVC):** The Firm/Vendor may propose a PQR based on IGBT (or any better / more advanced switching device) based HT Voltage Source Converters directly working at 25 kV designed to provide necessary power factor improvement and harmonic compensation for load currents. Design considerations similar to those specified in Clauses 5.2.8.3, 5.2.8.4 and 5.2.8.5 shall apply (except the rating of a modular panel). The Firm/Vendor should furnish in his offer complete design details and ratings of various equipment proposed.

5.2.8.3. **Harmonic and Reactive Power Compensation:** The PQR shall be designed (unless otherwise specified) to provide (i) dynamic reactive power compensation for improvement of average power factor, and (ii) filter harmonic currents from load current for restricting the

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

current harmonic demand distortion within specified limit on the source side at the point of common coupling. The power factor shall be considered as 0.8 lag at fundamental rated current of the traction transformer. The rating of the PQR shall be in multiple of 1/2/3 MVA or any other suitable rating considering the compensating current for Harmonics filtering and Power factor (0.8 to .99) improvement. However, the firm shall measure the power factor and harmonics content for a specified period of the TSS where the PQR is to be provided, and the total capacity of the PQR in multiple of the units specified above shall be decided accordingly.

- 5.2.8.4. **Total Demand Distortion (TDD):** Total Demand Distortion should be less than as given in Para 5(3) & 5(4) of CEA Notification No. 12/X/STD(CONN)/GM/CEA/2018 - dated 06.02.2019. The PQR equipment should have the functionality to set/modify the TDD & PF setting/priority as well as configure individual harmonic limit according to the latest CEA guidelines. Priority of compensation shall be decided by consumer and the same should be settable/programmable. The firm should ensure the adequacy of the harmonic compensation provided, considering the actual maximum demand current at the traction substation. The value of maximum demand current will be indicated by the Railway. Adequate margin should be provided to cater to growing demand. Load should be based on the average last 12 month maximum demand of the TSS.
- 5.2.8.5. In existing TSS having capacitor banks, provisions should be made in PQR system to issue close/open commands to fixed capacitor bank for maintaining unity power factor with IGBT or any further improved/advanced electronic switching to meet the PF and Harmonic requirements. For new TSS, the active solution shall be provided.
- 5.2.8.6. **Fixed HT shunt capacitors with variable Active Power Converters:** The Firm/Vendor may propose a PQR based on fixed HT shunt capacitors (with suitable detuning reactor, say 13%, for power factor improvement) connected on the 25 kV bus/+25kV & -25kV bus in conjunction with IGBT based voltage source converters (to generate lagging as also leading reactive power for power factor improvement, and to provide harmonic compensation for load currents).

With this type of system, the following design requirements shall be taken care of:

- The voltage and current ratings of the HT shunt capacitors and detuning reactors shall take into account the no-load voltage of 30 kV at the 25 kV bus.
- The voltage and current ratings of the HT shunt capacitors and detuning reactors shall take into account the peak load current and its harmonics.
- The voltage and current ratings of the DC link capacitor and associated reactor of the voltage source converter shall take into account the no-load voltage of 30 kV at the 25 kV bus.
- The converters should be designed to provide required harmonic compensation for load currents to ensure that the total current harmonic distortion in source is within the specified limit. Calculations to this effect should be furnished along with the offer.
- There shall be no resonance (series or parallel) in the system for all possible working combinations. The possible variations in source impedance shall be taken care of in the design.

#### 5.2.9. Control of Power Quality Restorer

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The control of the PQR should be based on the reactive power and harmonics generated by the traction load. Measurement of reactive power shall form part of the control circuitry. For this purpose, the feeder currents (through 1500- 750A/5A CTs), and the  $\pm 25$  kV bus voltage (through 25 kV/110 V PT) should be utilized as input to the control circuit. Injection of capacitive/inductive kVAR can be either step-less or in suitable small steps to closely control the Power Factor.

Changes in the kVA ratings of PQR with changes in the 25 kV bus voltages should be taken care through control circuit. The power factor of the traction load usually varies from 0.70 to 0.90 (lagging). It will need to verify during execution based on actual traction load.

The compensation for the harmonics should be step-less and should adapt to the changing load requirements, so that the specified Total Demand Distortion (TDD) is achieved at all loads.

- 5.2.9.1. **Failure of a traction substation:** During failure of a traction substation, supply is extended from the adjacent traction substation. In case of such feed extension, the traction transformer current of the failed substation will be zero, and whereas the two feeder currents of the failed substation will be of same magnitude but opposite in direction. During such cases, the PQR of the failed substation will operate based on the two 25 kV feeder currents and 25 kV bus voltage of the failed substation so as to provide necessary reactive power as also harmonic current compensation. The PQR should be capable of computing absolute value of both CT current detecting automatically such cases of feed extension based on the two feeder currents and the traction transformer current; however, provision should also available for manually setting (either from remote or local mode) the failed substation and choosing the direction of feed. As such the PQR should have current feed backs not alone from the traction transformers' currents but also from the 25 kV feeder currents.



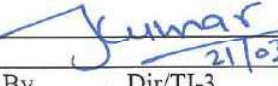
5.2.9.2. **Control of Filters in PQR**

The Active Filters shall be modular in design. The current capacity of each filter panel shall be assessed by the maximum RMS current (as seen from the 25 kV bus) it can feed when the 25 kV bus voltage is 25kV; the RMS current of each panel shall be assessed as:

$$I_{rms} = \sqrt{\sum_{i=1}^{i=50} I_i^2}$$
, where i is the order of the harmonic being compensated (including fundamental). The Active Filters shall also be designed to compensate for leading reactive power by providing inductive reactive power in case of any overcompensation due to fixed capacitors in the system.

In case of active filter, it shall be possible to choose the fundamental and/or any harmonic currents with individual current setting (maximum) and priority for compensation; alternatively, it shall also be possible to compensate for the fundamental and/or any harmonic currents in the ratio specified by the user. Each of the filter panels shall be designed for programming the above parameters (i.e., setting of currents and priority thereof, or the current ratios) individually.

The control of harmonic and fundamental currents shall normally be such as to ensure that the total demand distortion of current (TDDi) is within the specified limit, and to provide reactive power compensation to the maximum extent possible (after harmonic compensation) utilizing the total capacity of the active filter installations. The current sharing between the panels in circuit shall nearly be equal within a reasonable limit so as to ensure maximum utilization of capacity.

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## Explanatory Note:

- A. Say, there are four active filter panels installed with a rating of 60 A rms each (at 25 kV). Say, the current compensation requirement at a particular time is as under:

$$I_1 = 80 \text{ A}; I_3 = 16 \text{ A}; I_5 = 10 \text{ A};$$

$$\text{Now, } I_{\text{rms}} = \sqrt{(80^2 + 16^2 + 10^2)} = 82.2 \quad (1)$$

Since the individual filter panel rating is 60 A, two panels are required to be in operation.

Alternative-1: First panel feeds 60 A reactive power. Second panel feeds 20 A reactive power, 16 A third harmonic, and 10 A fifth harmonic.

$$\text{Now, } I_{\text{rms}} \text{ of first panel} = 60 \text{ A}; I_{\text{rms}} \text{ of second panel} = \sqrt{(20^2 + 16^2 + 10^2)} = 27.5$$

$$\text{A. Total rating utilized} = 60 \text{ A} + 27.5 \text{ A} = 87.5 \text{ A} \quad (2)$$

Note that the value at (2) is higher than at (1).

Alternative-2: Divide the current between the two panels equally; that is:  $I_1 = 40 \text{ A};$

$$I_3 = 8 \text{ A}; I_5 = 5 \text{ A for each panel.}$$

$$\text{Now, } I_{\text{rms}} \text{ of each panel} = \sqrt{(40^2 + 8^2 + 5^2)} = 41.1 \text{ A}$$

$$\text{Total rating utilized} = 41.1 \text{ A} + 41.1 \text{ A} = 82.2 \text{ A} \quad (3)$$

Note that the value at (3) is the same as at (1).

Thus, Alternative-2 uses lower capacity from the two panels (as if there is a single panel of total capacity) as compared to Alternative-1. Hence, Alternative-2 should be used for current compensation.

- B. Say the maximum demand current is 800 A at 25 kV side, and the THDi of load current at 800 A is 20% at a given time. Then, the PQR should reduce the TDDi below 8% at source side.

Let the PQR be set to reduce the TDDi to 7%. Considering the rating of 6 MVAR (i.e. 240 A at 25 kV) for the PQR, the net reactive power available from the PQR after controlling the TDDi to 7% (by reducing the individual load current harmonics flowing to source by a factor of 7/20) is given by:

$$I_1 = \sqrt{\{240^2 - [(20 - 7) * 800/100]^2\}} = \sqrt{(240^2 - 104^2)} = 216.3 \text{ A}$$

That is, the MVAR available after harmonic compensation is:  $216.3 \text{ A} * 25 \text{ kV} / 1000 = 5.4 \text{ MVAR}$ . This reactive power rating shall be available irrespective of the type of PQR (i.e., active, passive or hybrid).

- C. Say the maximum demand current is 800 A at 25 kV side, and the THDi of load current at 1200 A is 16% at a given time. Then, the PQR should reduce the TDDi below 8% at source side.

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Let the PQR be set to reduce the TDDi to 7%; this corresponds to an RMS value of 56 A (i.e., 7% of the maximum demand current of 800 A) of the harmonic currents flowing to source.

Now RMS value of load harmonic currents is 192 A (i.e., 16% of 1200 A). This value needs to be reduced to 56 A; in other words, each load harmonic current needs to be reduced by a factor of  $56/192$  – which is about 0.3.

Considering the rating of 6 MVAR (i.e., 240 A at 25 kV) for the PQR, the net reactive power available from the PQR after controlling the TDDi to 7% (by reducing the individual load current harmonics flowing to source by a factor of 0.3) is given by:

$$I_1 = \sqrt{(240^2 - 136^2)} = 197.7 \text{ A}$$

That is, the MVAR available after harmonic compensation is:  $197.7 \text{ A} \times 25 \text{ kV} / 1000 = 4.9$  MVAR. This reactive power rating shall be available irrespective of the type of PQR (ie, active, passive or hybrid).

- D. The net reactive power available at the PCC will vary from the above calculated figures, and it can accurately be assessed using the network parameters of the particular traction substation concerned.

#### 5.2.10. Series Reactor (Damping Reactor)/Surge Suppression Circuits

In case of fixed shunt capacitors being used for reactive power compensation, a series reactor shall be provided to limit the inrush current and surge voltage at the time of switching on the capacitor bank and also to reduce the load harmonics. The switching surge voltage shall not exceed 70 kVp on 25kV side. The series reactor shall be natural air-cooled, air-cored, dry insulated and outdoor type. The reactor shall be rated for the maximum current including harmonic currents that would flow through the capacitor bank under various operating conditions. The reactor shall be so designed that the variation in milli-henry value, due to manufacturing tolerance, is less than  $\pm 3\%$ .

#### 5.2.11. Basic Insulation Level (BIL)

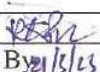


The Basic Insulation Level of equipment at the 25 kV side and at the LT side shall be as follows (unless a different BIL is recommended by the Firm/Vendor for the PQR with detailed justification and relevant standards thereof): The individual PQR with provision of earthing shall be connected to +25kV and -25kV w.r.t buried rail for 55kV system, hence BIL will remain as 250kVp.

##### 25 kV Equipment

- |  |        |
|--|--------|
| i. 1.2/50 $\mu$ s Impulse withstand voltage                | 250kVp |
| ii. One-minute wet power frequency withstand voltage (rms) | 105 kV |

The individual PQR with provision of earthing shall be connected to +25kV and -25kV w.r.t buried rail for 55kV system, hence BIL mentioned above shall be applicable for 2x25 kV system also.

##### For LT Equipment

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- i. 1.2/50  $\mu$ s Impulse withstand voltage Not applicable
- ii. One-minute wet power frequency withstand voltage 3kV

#### 5.2.12. Protection of Power Quality Restorer

The offer shall include design and supply of a comprehensive protection scheme for the equipment offered by the Firm/Vendor. Full details, including relay characteristics of the protection scheme offered for the step-down LT Transformer, capacitor bank, IGBT or any other switching device etc. shall be fully explained in the offer giving necessary details and diagrams.

The protective relays offered shall be properly coordinated with the existing scheme of protection specified in the specification no. TI/SPC/PSI/PROTCT/5070 or latest, TI/SPC/PSI/PROTCT/4050 or latest & TI/SPC/PSI/PROTCT/7101 or latest for Control & Relay Panel for 25kV ac Single Phase Traction power supply, 25 kV Traction Power Supply system in Mumbai Sub-urban area and 2x25kV AT System.

The protection for fixed shunt capacitor bank (if capacitive kVAR injection is through fixed capacitor bank) shall include protection against overcurrent, overload, overvoltage and unbalance.

Each capacitor element shall be individually protected by means of internal fuses. The fuse shall be connected in series with each capacitor element inside the capacitor unit to limit the effects of dielectric failures. If puncture of dielectric occurs, only one element shall be disconnected so that the capacitor unit continues to operate. While selecting the fuse rating, it would be necessary to choose proper time current characteristics, which in turn significantly depend upon the cross section and circumference of the fuse. Fuses chosen shall have adequate thermal capability and comply with relevant IS/IEC specifications.

The protection for IGBT and other electronic switching devices shall include protection against overvoltage, overcurrent etc. The firm is liable to provide necessary protection in case of failure of any equipment associated with functioning of PQR without impacting the traction power supply continuity to the running locos in the section.

The protection system for the 27.5 kV/600V+600V (or any other suitable voltage), single phase, step-down transformer shall include differential protection, earth leakage protection, overcurrent protections in primary side as well as secondary side in each individual panels, apart from the under voltage and overvoltage protection at 25 kV bus side.

- 5.2.13. **Noise level:** The noise level measured at a distance of 1 meter from step-down transformer and /or indoor/ outdoor panel of PQR shall not exceed 75 dB (A).
- 5.2.14. **Control room ambient air temperature:** In case PQR panels are provided indoor, then the ventilation of the room shall be such that the indoor ambient air temperature does not exceed the outside ambient air temperature by more than 5 K, except conditions where temperature increases is aimed to control high humidity conditions. Providing necessary/ required ventilation system/fans/ blowers/ heat exchangers/ cooling system arrangement shall be within the scope of work against this standard.
- 5.2.15. **Limits for System losses:** The overall losses of a PQR System should be less than or equal to 1.2% of the rating at full load of the unit.

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## 6. GENERAL ARRANGEMENT OF POWER QUALITY RESTORER

- 6.1. The PQR may be of either outdoor or indoor type for connection to the 25 kV bus. The layout drawing with cross sectional details of the equipment shall be furnished by the Firm/Vendor, taking into account the existing layout of other equipment at the traction substation.
- 6.2. The capacitor bank, if any, shall consist of groups of individual capacitor units, connected in series- parallel combination to deliver the rated output at nominal rated system voltage, rated frequency and other system conditions. The capacitor bank and the series reactor shall be supplied complete with mounting steel rack assembly, inter-connectors between units, fuses for unit and group protection, insulators, suitable earthing lugs (including terminal connectors) and any other material required to make the bank complete in all respects for its satisfactory operation. The steel racks shall be mounted on a concrete plinth with suitable base frames. The racks shall be complete with rack insulator and other hardware.

## 7. CONTROL/ POWER PANELS/ CABINETS OF POWER QUALITY RESTORER

### 7.1. General Particulars

- 7.1.1. The control /Power & relay panel / cabinet for the protection of step down (LT) transformer and LT bus and control panel with requisite relays (if any) for the control of power quality restorer, shall be installed in the control room of unattended remote controlled traction substation. The control panel shall be of vertical mounting, self-supporting steel construction. Stove enameled painting shall be done on the panel. The colour of the panel shall be "Eau de Nile green" conforming to shade 216 of IS:5-2007, on the exterior and white on the interior surfaces.
- 7.1.2. The control panel shall be fabricated from a frame made of steel section of 3 mm thick and covered by door, side cover and top cover made of 2 mm thick CRCA steel sheet. Suitable cable entries shall be provided from the bottom of the control panel for which suitable opening shall be provided on the bottom plate. The Control/Power and Panel/Cabinet, including the relay housing, shall be dust, vermin and moisture proof. The overall size of the Control/Power and Panel /Cabinet shall be subject to the approval of Railway.
- 7.1.3. There shall be provision for fixing a 240 V suitable lamp for interior lighting. The lamp shall be switched ON/OFF with the help of a door switch mounted at suitable location inside the panel.
- 7.1.4. The front panel shall have the suitable control switch, LCD Displays, indication light emitting diodes (LEDs), annunciation label, alarm cancellation push button and a mimic diagram indicating connections of various equipment.

### 7.2. Measuring Instruments

- 7.2.1. Measuring instruments for measurement of voltage, current, active power, reactive power, energy (kWh, kVAh and kVARh) and frequency shall be provided on the control panel. These measurements shall be provided individually for each of the following (as applicable to the system offered by the Firm/Vendor):
- Parameters on the primary side (25 kV side) of the step-down transformer.(if provided)
  - Parameters on the primary side (25 kV side) of the HT harmonic filters.
  - Parameters on the primary side (25 kV side) of fixed shunt capacitor banks.

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Multi-function, digital, LCD display (multi-line) type meters of adequate accuracy (as approved by the Railway) shall be provided for the purpose.

The instruments shall generally conform to IS 13875 (Part 1-3)-1993, Class A Industrial grade accuracy. Its circuits shall be capable of withstanding 20% overload for 8 hours. It will be subjected to a high voltage test of 2 kV rms for one minute. The Instruments shall be with dust-tight case with IP-51 enclosure class or better as per IEC 60529-1 and finished in dull black enamel.

#### 7.2.2. Smart metering with cloud-based communication:

Smart metering shall form part of this standard. It shall monitor all relevant electrical parameters and product parameters like fault logging as under:

- i. The source side current, THDi, TDDi and power factor on the 25 kV bus.
- ii. The 25 kV bus voltages and its harmonics.
- iii. The HT capacitor/filter circuit current and its harmonics,
- iv. The fundamental current, harmonic currents and kVA of individual modules of voltage source converter.
- v. The kW, kWh, kVAR and kVARh of the total PQR.
- vi. Fault logging of IGBTs, individual VSC modules, etc. as necessary. Average values calculated over every discrete Ten minutes interval shall be stored for the various parameters like voltage, current, current/voltage harmonics, average power factor, kW, kVA, THDi and TDDi.

The smart metering shall have cloud-based monitoring system. No-Sequel DBMS (Data Base Management System) along with the virtual RTOS (Real Time Operating System) is preferred for monitoring to have better security on the IoT (Internet of Things). It shall be possible to see the data for last 3-years for analysis at any point of time.

The Firm should submit a non-disclosure agreement (NDA) that the PQR data and other energy data's collected from Railways are proprietary data of Indian Railway and should not be shared with any 3rd party without the explicit approval of IR. Further, the PQR data should be accessed by the firm only during the warranty and AMC period.

#### 7.2.3. Suitable spring return type control switch with pistol grip handle having three positions, ON/OFF/Neutral, shall be provided. The Switch shall have a sequence device to prevent two successive movements to the same position. Following indication LEDs shall be provided for indication of circuit breaker:

- |      |                             |   |        |
|------|-----------------------------|---|--------|
| i.   | Circuit Breaker "Closed"    | - | Red    |
| ii.  | Circuit Breaker "Open"      | - | Green  |
| iii. | Circuit Breaker "Auto-trip" |   | Amber  |
| iv.  | Trip circuit "Healthy"      | - | Yellow |

Low consumption, extra bright, 5mm diameter light-emitting diodes shall be used wherever required. LEDs shall be suitably wired to glow on 110 V dc supply. LEDs shall be housed in

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suitable holders with glazed/polished surface to act as reflector. The holders shall be screwed to the panel from inside.

- 7.3. A suitable two position (Local/Remote) "Change Over Switch" shall be provided on the control panel for operation of circuit breaker from control panel in "local" mode and from remote control center in "remote" mode of this switch.

7.4. Mimic Diagram

The scheme of connections at the traction substation showing the incoming isolator, circuit breaker, step-down (LT) transformers (if any), series reactor, IGBT or any other switching device, the capacitor bank etc. shall be represented by a single line Mimic Diagram on the control panel. The colour of the mimic diagram shall be golden yellow to shade 356 of IS:5-2007.

Automatic semaphore relay shall be incorporated in the mimic diagram to indicate the position of the circuit breaker.

The open / close position of 25 kV isolators shall be accommodated within multi-functional HMI. Push buttons and yellow indication LEDs shall be provided on the control panel to monitor the availability of 110 V DC/24VDC supply on the panel, and the continuity of trip circuit for the circuit breaker.

7.5. Annunciator

Suitable annunciation labels (back lit by LEDs) shall be provided on front side of the control panel for visual alarm of various working and fault conditions.

The visual alarm shall be of flasher type i.e., concerned LED shall flicker and shall not become stable till the alarm is accepted.

The alarm accepting and annunciation testing buttons shall be provided under the annunciator label on the control panel at a convenient height.

Along with visual alarm, there shall be provision for an audible alarm. Audible alarm bell shall work with 110 VDC /24VDC. This bell shall be mounted inside the control panel. The alarm bell shall continuously ring when a fault is there and shall not stop ringing till the alarm is acknowledged. A suitable disconnection switch shall be provided for disconnection of the bell.

Latest Fire alarm system with provisions for smoke detection and hooter indication at TSS with auto shutdown facility complying with international standards should be installed. In case of any fire, Fire Alarm indications should be given to TPCs also.

7.6. Remote operation

- 7.6.1. PQR data has to be transmitted to RCC through SCADA RTU at TSS which requires a port in the CPU of the SCADA RTU. The PQR data shall be interfaced to the RTU over Modbus TCP (Ethernet)/Modbus RTU (RS485) protocols. Necessary provisions for providing additional PORT for the above facility in SCADA RTU functioning as per Spec. TI/SPC/RCC/SCADA/0130 (Rev.2) and TI/SPC/RCC/SCADA/0133 along with suitable modification of firmware in CPU and SCADA software in RCC should be included in the scope of work.

Note:

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- A) RTU functioning in SCADA Spec: TI/SPC/RCC/SCADA/0130 (Rev.2), the no. of communication port available: RS232- 1 no. (min), RS485- 2 nos., Ethernet port-2 nos.
- B) RTU functioning in SCADA Spec: TI/SPC/RCC/SCADA/0133 (effective from 29.01.2022), the no. of communication port available: RS232- 1 no. (min), RS485- 6 nos., Ethernet port- 4 nos.
- i) A separate OWS (Operator Work Station) should be provided at RCC for viewing PQR real time data.
- ii) The cable provided between PQR and RTU shall be of twisted pair.
- iii) Manufacturer of PQR shall provide the Modbus register addresses for the required parameters.
- 7.6.2. The control of PQR shall normally be switched in or out by control commands issued by traction power controller of the remote-control center. These tele-commands shall be issued with the help of Supervisory Remote Control and Data Acquisition System, hereafter called SCADA system provided at remote control center.
- 7.6.3. For the purpose of tele-commands and tele-signaling, suitable terminals shall be provided on terminal block(s), which shall be duly wired for the following:
1. Tele-signal for supervision of secondary fuse of potential transformer.
  2. Tele-command for operation of circuit breaker of power quality restorer.
  3. Any other tele-signals required for monitoring the healthiness of the transformer, capacitor units, IGBT or any other switching device as recommended by the Firm/Vendor.
- 7.7. Suitable terminal blocks, including testing terminals, shall be mounted conveniently inside the control panel. The current rating of the contacts shall be 30 A continuous at 110 V dc. The current terminals shall be provided with short circuiting links or another suitable device. The potential terminals shall be housed in narrow recesses of the moulded insulation block to prevent accidental short circuit. Terminals on the blocks shall be stud type crimped terminal or lugs, securely tightened with nuts and spring washers. AC and DC Terminals shall be separate. Each Terminal shall be completely shrouded.
- 7.8. All panel wiring shall be done with switchboard type 1100 V grade PVC insulated single core stranded tinned annealed copper cable. The AC and DC circuits shall be kept separate.
- 7.9. Suitable space heaters to operate on 230 V, single phase, AC supply with "ON" and "OFF" switches shall be provided inside the control panel to prevent condensation of moisture in humid weather.
- 7.10. One combined three pin switch plug, 5 A rating shall be provided inside the panel for using 230 V hand lamp.
- 7.11. Wherever required, only HRC type cartridge fuses of appropriate rating shall be used in the control panel at easily accessible places.
- 7.12. Control Panel for IGBT or any other switching device control
- The control equipment for the control of PQR scheme may preferably be housed in a separate control panel / control box, the details of which shall be furnished by the Firm/Vendor along with the offer. The control equipment shall be built up of modular units to enable easy maintenance and replacement.

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## 8. CURRENT AND POTENTIAL TRANSFORMERS

Suitable current and potential transformers required for the protection of step-down transformer, capacitor bank and IGBT or any other switching device shall be supplied by the Firm/Vendor. Full technical particulars of such transformers shall be furnished in the tender offer.

## 9. PROTECTION AGAINST LIGHTNING SURGES

The PQR offered shall adequately be protected against lightning surges. The ratings of lightning arresters, required for the equipment offered, should be clearly indicated in the tender offer. The lightning arrester shall be metal oxide gapless type. For 25 kV system, 42 kV class 10 kA discharge current lightning arrester shall be used. The lightning arrester shall be designed to withstand the full energy discharge from the capacitor bank, if any or IGBT based equipment to which it is connected.

## 10. EARTHING

Earthing arrangements shall be provided for each apparatus in accordance with RDSO specification No. TI/SPC/PSI/ERTHING/0210 "Specification for earthing of power supply installation for 25 kV & 2x25kV AC, 50 Hz, single phase traction system".

## 11. PAINTING

### 11.1. Painting of structure

All steel structures exposed to weather shall be given a primer coat of zinc chromate and two coats of light grey enamel paint as per Shade 631 of IS:5-2007.

### 11.2. Painting of cabinet

The cabinet shall be given a primer coat of zinc chromate and two coats of light grey paint as per Shade 631 of IS:5-2007.

### 11.3. Painting of capacitor tank

The inside surface, in contact with insulation, shall be painted with suitable anti-rust synthetic enamel primer and two coats of heat resistant, oil insoluble, insulating varnish. The steel surfaces, exposed to weather, shall be given a primer coat of zinc chromate and two coats of light grey paint as per Shade 631 of IS:5-2007.

### 11.4. Painting of transformer (if provided)

All steel surfaces which are exposed to weather, shall be given one primer coat of zinc chromate and two coats of light grey paint as per Shade 631 of IS:5-2007.

## 12. FASTENERS

All fasteners of 12 mm dia and less and exposed to atmosphere shall be of stainless steel and those above 12 mm dia shall be preferably be of stainless steel or mild steel hot dip galvanized to RDSO's specification No. ETI/OHE/18 (4/84).

## 13. TESTING OF POWER QUALITY RESTORER

### 13.1. General

The detailed designs and drawings shall be furnished by the successful firm to RDSO.

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Only after all the designs and drawings have been approved by RDSO and a written advice given to that effect, Firm/Manufacturer shall take up manufacture of the equipment as per this standard for prototype. Any change or modification required during prototype testing shall be incorporated in the drawing and final drawing shall be submitted to RDSO for approval for regular manufacturing of the equipment. The softcopy of design document, manual etc. and softcopy of drawings in CAD files (.dwg format) shall also be submitted to RDSO. All future PQR shall be manufactured as per the RDSO approved drawing and designs and shall be verified by the purchaser.

### 13.2. Testing of equipment

- 13.2.1. Test Schedule: Prior to giving a call to the RDSO for inspection and testing of the prototype, the successful Firm/Manufacturer shall submit a detailed "Test Schedule" consisting of Schematic Circuit Diagrams for each of the tests and the number of days required to complete all the tests at one stretch. Once the schedule is approved, the tests should invariably be done accordingly.
- 13.2.2. However, during the process of testing or even later, the RDSO reserves the right to conduct any additional test(s) besides those specified herein on any equipment/item, so as to test the equipment/item to their satisfaction or for gaining additional information and knowledge.
- 13.2.3. In case any dispute or disagreement arises between the successful Firm/ Manufacturer and representative of the RDSO during the process of testing as regards the procedure for the tests and/or the interpretation and acceptability of the results of tests, it shall be brought to the notice of the RDSO, whose decision shall be final and binding.
- 13.2.4. Only after the prototype PQR is complete and ready in each and every respect, the successful Firm/Vendor/Manufacturer shall give the actual call for the inspection and testing with at least 15 days' notice for the purpose.
- 13.2.5. All relevant tests, as considered necessary by RDSO, as per latest IS/IEC Specifications applicable shall be conducted by RDSO on the various equipment/ components and sub-assemblies of the total system offered. The tests shall cover acceptance/ routine tests, apart from any type tests that may be considered necessary by RDSO. The equipment to be tested include step-down (LT) Transformers, shunt capacitors, series/shunt reactors, active/passive filters, control panels, IGBT based voltage source converter panels, CTs, PTs, circuit breakers, etc., depending on the type of system offered.

### 13.3. Pre-commissioning tests

In addition to the above tests, the following tests (as applicable) shall be conducted, at site, by the successful Firm in presence of concerned railway authorities to verify the performance and design adequacy of the "Power Quality Restorer":-

#### 13.3.1. Efficacy of the discharge device

The efficacy of the discharge device shall be tested as per Clause 6 & 7 of IS:13585 (Part 1):1994.

#### 13.3.2. Efficacy of the power quality restorer

- i. Average power factor and current harmonic compensation: Before connecting the P Q R, the power factor and current harmonic distortions shall be measured on the 25 kV bus continuously for at least 7 days.

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The harmonic analysis of the current waveform as well as of the voltage waveform shall be carried out with and without the PQR equipment at various load currents.

After connecting the PQR, the power factor and current harmonic distortions shall be measured continuously for at least Seven days. The load current shall be recorded every 10/15 minutes in each case. The improvement in power factor and total harmonic distortion in source side current and total demand distortion (TDD), at different loads, shall be assessed from these observations.

- ii. Rise in 25 kV bus voltage due to power quality restorer: At different loads including no-load conditions, the voltage at the 25 kV bus shall be recorded with and without PQR. The rise in voltage due to the PQR shall be assessed from these observations.
- iii. Adequacy of ratings: The adequacy of the voltage and current ratings of the various components used in the PQR system shall be checked based on these measurements. Deficiencies in ratings, if any, shall be set right free of cost by the Firm/Vendor.
- iv. Guaranteed Efficiency: Active energy consumed by the PQR system with guaranteed efficiency as per the power rating of the system supplied and the same should be verifiable through measurement of KWH consumption of by certified high precision energy meter provided by the firm. The verification shall be based on test in Laboratory or Site. For the efficiency of the individual equipment, Test Certificate (TC) of equipment may be accepted.

Sample calculation: For 6MVA PQR system

$$\text{Input} = 6000 \times 24 \times 30 = 4320000 \text{ kWh}$$

For generating rated current of 140A (reactive power) of fundamental frequency, 2 stack PQR system at rated condition losses will be 6 kWh (checked with 1 kV DC source with 6A).

$$\text{In TSS 2*3 MVA system with 22 stacks consuming} = 66 \times 24 \times 30 = 47520 \text{ kWh.}$$

$$\text{Efficiency of PQR} = (\text{input} - \text{losses}) / \text{input} = (4320000 - 47520) / 4320000 = 0.989 = 98.9\%$$

### 13.3.3. Efficacy of the protection system

Tests shall be done to ascertain the effectiveness of the protection system provided in the PQR system. In case of shunt capacitor, one of the capacitors in one of the limbs shall be short circuited and its effect shall be observed.

### 13.3.4. Temperature Rise

The PQR and/ or capacitor bank shall be kept on for 24 hours and the temperature of one capacitor in each of the limbs shall be recorded hourly. The temperature rise of power transformers, step-down transformers, current transformer, potential transformer and other equipment shall also be observed hourly during this period. The efficacy of the cooling system provided for various equipment shall be checked and verified.

13.3.5. Matching of characteristics of shunt capacitor with that of over-voltage relay shall be verified.

### 13.3.6. Surge voltage measurement:

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The surge voltage shall be measured at the time of switching on the capacitor. This shall be done 20 times. The voltage peak shall not be more than 70 kVp in any case.

13.3.7. Feed extension:

The proper working of the PQR during feed extension in case of failure of a traction substation shall be verified as part of pre-commissioning tests (refer Clause 5.2.10.1).

13.3.8. Schedule of pre-commissioning tests on step-down (LT) Transformers, IGBT and the balance equipment shall be mutually agreed upon between the successful Firm/Vendor and the Purchaser.

13.4. IGBT based equipment:

Following additional tests may be required to be conducted for IGBT based equipment as per IEC: 60146-2 (1999), Section-7. List of Tests, required typically for 400V, +/-350A single panel, single phase IGBT based "Power Quality Restorer" based on above applicable guidelines are as below. The single panel is to be treated as part of the total number of IGBT based panels supplied by the Supplier/Contractor.

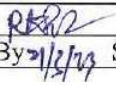

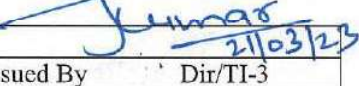
13.4.1. Routine tests

Manufacturing process to assure the use and proper mounting of correct sub-assemblies, components, wiring/cabling and their routing, ferruling, use of correct lugs and their tightness, etc.

- i. Visual inspections: Components Data/Ratings etc., as per General Arrangement inclusive of Auxiliary Devices.
- ii. Wiring checks: As per the wiring table/schematic.
- iii. Insulation test: By using 1000 V Megger.
- iv. Basic functional tests which include power up sequence, control logic correctness & protective control circuit functionality check at given input voltage and final pulse delivery from controller but hardware pulse delivery to IGBT's withheld.
- v. IGBT pulse delivery and checking the "zero" current mode for IGBT based Power Quality Restorer.
- vi. Checking the dynamic response with the external current command circuit.
- vii. Rated output test of the panel at rated voltage.

13.4.2. Type tests:

- i. HV/Insulation Test.
- ii. Heat run test for 48 hours or one hour after the temperature rise is steady whichever is earlier for capacitive mode and 24 hours or one hour after the temperature rise is steady whichever is earlier for inductive mode and temperature rise.
- iii. Checking rated output of each panel by external current command delivery and checking of actual IGBT based Power Quality Restorer, current flowing the same in both capacitive and inductive mode.

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- iv. Input current distortion check for Distortion Factor close to unity for both, capacitive and inductive modes.
- v. Any other tests, if agreed, between the manufacturer and the customer.

13.4.3. Optional tests (to be agreed before the supply)

- i. Dynamics +350 A to -350 A at rated voltage (Dynamics not specified by IEC).
- ii. Heat run of each panel for full load for 2 hours (One hour in capacitive mode and one hour in inductive mode). Not specified by IEC.
- iii. Visual input current distortion checks with respect to given waveforms (Distortion factor close to unity).

**14. CAPITALISATION OF LOSSES AND BENEFITS**

- 14.1. The benefits derived by installation of PQR shall be compared against capitalization of its cost of procurement, installation and commissioning, annual maintenance contract (AMC) charges, to obtain a capitalized cost, detailed calculations for which shall be submitted by the Firm/Vendor along with the offer using the method given in Annexure-5. The Firm/Vendor shall for this purpose clearly indicate the losses of the PQR and expected benefits in the format given in Annexure-4.
- 14.2. Savings due to reduction in maximum demand, reduced losses in the traction power transformer due to power factor improvement, avoidance of low power factor penalty where applicable, and avoidance of current harmonic distortion surcharge where applicable, and expenditure due to various losses introduced by the PQR system shall also be capitalized as indicated in Annexure-5.
- 14.3. The various losses due to PQR to be considered are as under:
  - i. Losses in all capacitor banks, including fixed/variable, dynamic etc.
  - ii. Losses in the active/ passive filters (like voltage source converter).
  - iii. Switching losses and conduction losses in IGBTs or any other switching devices (if not considered elsewhere)
  - iv. Losses in the series/shunt reactors.
  - v. Energy consumption for ventilation/cooling.
  - vi. Losses in the step-down transformers used for the compensation scheme.
  - vii. Any other losses that may be of significance.
- 14.4. **Device/Equipment data sheets to be attached with offer:** The Firm/Vendor shall submit along with his offer detailed calculations and the proof of Device/Equipment data sheets to support the calculations of losses/benefits of PQR as provided by him. For the DC link capacitors used in voltage source converters, data sheets shall be provided – indicating rated voltage/current, type and make of capacitor, the loss angle, operating temperature, ageing details etc.

**15. TECHNICAL DATA AND DRAWINGS TO BE SUBMITTED WITH OFFER**

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- 15.1. The Firm/Vendor shall furnish Guaranteed Performance Data, Technical and other Particulars for the equipment offered in the format attached as Annexure-1. The firm shall also furnish the complete protection scheme for the PQR and layout drawings with cross sectional details for the PQR along with their offer. Technical details of the protection employed, together with detailed calculation for the ratings of the equipment shall also be furnished with the tender offer.
- 15.2. The Firm/Vendor shall furnish the following calculations/details with their offer.
- The details as called for in Clause 14.3 above for capitalization of losses, etc.
  - Detailed calculations for rating of capacitor bank, series/shunt reactor, inrush current, transient over-voltage, parallel and series resonant frequencies.
  - Details of protection scheme offered.
  - Details of supporting frame, fixing arrangement and foundation.
  - Details of building requirement for housing indoor equipment of the PQR.

All civil works involved with provision of PQR, including any exclusive building, shall form part of this standard. The masonry building of suitable height, width & length for placing indoor equipment of the PQR should have RCC roof and 9" Thick wall. The door shall be ensured for easy movement of PQR equipment. The sufficient exhaust fans/ blowers shall be provided to keep the inside temperature suitable for satisfactory working of PQR equipment without failure.

- 15.3. The following Drawings shall be furnished as per Indian Railway Standard (in sizes of 210 mm x 297 mm or any integral multiple thereof):-
- Schematic circuit diagram (with description of function and working of each component) of the power quality restorer.
  - Outline General Arrangement Drawing giving the overall dimensions of various equipment of the power quality restorer. The total area required (both indoor and outdoor) shall be brought out clearly.
  - Arrangement of capacitor bank, IGBT/other switching devices, transformers, series/shunt reactor, circuit breaker, isolator, lightning arrester, current and potential transformers.
  - Arrangement of core winding and magnetic path of series reactor and transformer.
  - General arrangement of circuit breaker, showing mounting arrangement and overall dimensions

## 16. DESIGNS AND DRAWINGS APPROVAL:

- 16.1. The successful Firm/Vendor shall be required to submit for approval the following detailed drawings as per RDSO standard (in sizes of 210 mm x 297 mm or any integral multiple thereof) in latest version of CAD.
- Outline general arrangement drawing of the PQR installation indicating necessary dimensions, clearances and location of equipment/fittings (all the 3 views).

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- ii. Internal arrangement of series/shunt reactor and transformer including cross-sectional views in both plan and elevation.
  - iii. Schematic circuit diagram (with description of function and working of each component), wiring diagram and dimensional drawings of various panels, complete with the ratings of various components.
  - iv. Supporting frame with details of fixing arrangement and foundations along with calculation for their design.
  - v. Technical data sheets for all major components (like series/PWM reactor, shunt reactor, IGBT/other advanced switching devices, shunt capacitor, DC link capacitor, filter components,) used in the system. The justification for the adequacy of the ratings shall also be submitted.
  - vi. Design drawings for the step-down transformer.
  - vii. Foundation and earthing requirement
- 16.2. The Firm/Vendor shall visit the traction substation, if necessary, and collect any additional data/ details required for the design of the Power Quality Restorer. It is the responsibility of the Firm/Vendor to visualize the problems and understand the system conditions before evolving a suitable Design.

## 17. INSPECTION AND TESTING OF PROTOTYPE

- 17.1. Prototype: After approval of designs and drawings by RDSO, the firm shall manufacture an acceptable prototype of PQR as per approved drawings. The prototype inspection shall be carried out by the representatives of the RDSO. The bulk manufacture shall be taken up only after approval of prototype by RDSO.
- 17.2. Routine inspection shall be carried out by the representatives of Railway at the manufacturer's works.
- 17.3. The successful firm shall supply 3 copies of Instruction/Maintenance Manual of the PQR installation and its Fittings and Accessories to each Consignee(s) along with approved drawings.

## 18. ERECTION, TESTING AND COMMISSIONING

The PQR shall be erected by the successful Firm/Vendor under the supervision of competent engineers of the successful Firm/Vendor/ manufacturer/ supplier. The equipment shall be subjected to specified proving/ pre-commissioning tests by the Railway engineer at site and with which the successful Firm/Vendor/ Manufacturer/Supplier shall also be fully associated. For this purpose, prior intimation regarding the date and location of the tests shall be given by the purchaser to the successful Firm/Vendor/manufacturer/supplier.

- 18.1. Storage and preservation procedure:

Observe the following remarks concerning storage time and precautions to prevent corrosion or deterioration to the equipment.

- The equipment contains corrosion –prone components and the storage time must be considered accordingly.

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