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GOVERNMENT OF INDIA

MINISTRY OF RAILWAYS

TECHNICAL SPECFICATION FOR

SHUNT CAPACITOR AND SERIES REACTOR EQUIPMENT

FOR

2X25 KV FEEDING SYSTEM

SPECIFICATION No. TI/SPC/PSI/FC&SR/1210

----------2021

This Specification supersedes the Specification No. ETI/PSI/126(08/1989) with A&C Slip No. 1 to 3.

ISSUED BY

TRACTION INSTALLATION DIRECTORATE

RESEARCH DESIGNS AND STANDARDS ORGANIZATION

(MINISTRY OF RAILWAY)

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	Prepared By	Checked By	Approved By
Signature			
Date			
Designation	SSE/TI/PQ	DTI-3	PEDTI

1.0 SCOPE:

1.1 It is to be noted that "The Make in India Policy of Government of India shall be applicable."

1.2 All the provisions contained in RDSO's ISO procedures laid down in Document No. - QO - D-8.1-11 Ver. 1.2 dated 22.06.2020 (titled "Vendor changes in approved status") and subsequent versions/amendments thereof, shall be binding and applicable on the successful vendor/vendors in the contracts floated by Railways to maintain quality of products supplied to Railways.

1.3 This specification covers design, manufacture supply, testing and commissioning of shunt capacitor equipment intended for outdoor installation on 55kV or 25 kV side traction sub - station of 2 X 25 kV feeding system on Indian Railways for improvement of power factor and reduction of maximum demand.

1.4 The shunt capacitor equipment shall be complete with control-gear, protective relays, series reactors and accessories necessary for its efficient operation.

1.5 All such items and accessories shall be deemed to be within the scope of this specification whether specifically mentioned herein or not. The equipment shall be erected by the vendor; therefore, the offer shall include deputing of engineers and supervisors by the supplier of equipment for adequate handling, installation, testing and commissioning to the satisfaction of Railway's engineers at site.

1.6 All civil engineering works connected with foundations of the capacitor banks, circuit breaker, isolator, series reactor, current & potential transformers, supporting steel structures for the equipment etc. shall also be done by the contractor (vendor).

1.7 All associated items of HT shunt capacitor bank assembly like Series reactor, CT, PT, LA, CB, isolators, protection relays & panels etc. should be procured from RDSO/CORE approved vendors.

2.0 GOVERNING SPECIFICAIONS: -

2.1 The shunt capacitor and associated items shall, unless otherwise specified herein, conform to the latest revision of RDSO specification, Indian Standard specifications/IEC Recommendations as indicated below and the Indian Electricity Rules, wherever applicable:

i.	IS:513	Cold rolled carbon steel sheets.
ii.	IS:800	Code of practice for use of structural steel in general building construction.
iii.	IS: 1554(pt. II)	PVC insulated (heavy duty) electric

		cable pt. II for voltage above 1 kV.
iv.	IS:2099	Bushings for alternating voltages above 1 kV.
v.	IS: 13925-1	Shunt capacitor for power systems.
vi.	IS: 13925-2/IEC 60971-2	Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V : Part 2 Endurance testing
vii.	IS:3070 (Pt..I)	Lightning arrestor for AC systems, Non- Linear resistor type.
viii.	IS: 3231	Electrical relays for power system protection.
ix.	IS:2026 (Part-6)	Power Transformers: Reactor.
x.	IEC 60076-6	Power Transformers: Reactor
xi.	IS:11298(pt.3/sec.1)	Specification for plastic films for electrical purposes: polypropylene films for capacitors.
xii.	IEC 60871	Shunt Capacitors for a.c. Power systems having a rated voltage above 1 000 V.
xiii.	IS- 12672	Internal fuse and internal over pressure disconnectors for shunt capacitors.
xiv.	RDSO specn. No. ETI/OHE/13(4/84) with A & C Slip No. 1 to 4.	Specification for hot-dip zinc galvanization.
xv.	RDSO specn. No. TI/SPC/OHE/FASTENERS/0120 Rev. 1	Specification for steel and stainless-steel bolts, nuts and washers.
xvi.	RDSO specn. No. TI/SPC/PSI/PROTCT/6071 with A&C slip no.1	Control and Relay panel for 25kV acts including specification for numerical type protection relays for traction transformer, 25kV shunt capacitor bank and transmission line for 25kV AC TSS on Indian Railways.
xvii.	RDSO specn. No. TI/SPC/PSI/PROTCT/7101 or latest	Control and Relay Panel including Numerical type protection relays for Scott-connected/V-Connected Traction Transformers, OHE protection and Shunt Capacitor Bank and AT Protection for 2x25 kV traction sub-station
xviii.	RDSO specn. No. ETI/PSI/MOGTLA/0101(02/15)	Metal oxide gap less type lightening arrester for use on Railway traction substations and switching stations.
xix.	RDSO Spec No. ETI/PSI/137(08/89) with A&C Slip No. 1 to 7.	Metal oxide gap less type lightning arresters for use of 220/132/110/66kV side of railway ac traction substation.
xx.	RDSO specn. No. TI/PSI/SPC/LVCBIN/0	25 kV Single pole, Double Pole, Pole mounted, outdoor Vacuum circuit

	120 (Dec,2013), Rev. 0 with A&C Slip No. 1	breaker (VCB) and vacuum Interrupter (BM) for Indian Railway.
xxi.	RDSO specn. No. ETI/PSI/120(7/87) With A&C Slip No. 1	Code of practice for earthing of power supply installation for 25 kV A.C., 50 Hz Single Phase traction system.
xxii.	IEC: 60071	Insulation co-ordination and system engineering of high voltage electrical power installations above 1.0 kV AC and 1.5 kV DC
xxiii.	IEC: 62271-1	High-voltage switchgear and control gear – Part 1: Common specifications

2.2 Any deviation from this specification, proposed by the vendor calculated to improve the performance, utility and efficiency of the equipment will be given due consideration provided full particulars of the deviation with justification therefore are furnished. In such case, the vendor shall quote according to this specification and the deviations, if any, proposed by him shall be quoted as an alternate/ alternatives.

2.3 In case of any conflict between the contents of the above IS and this specification, the stipulation of this specification shall prevail.

3.0 ENVIRONMENTAL CONDITIONS-

3.1 The shunt capacitor installation shall be suitable for outdoor use in moist tropical climate and in areas subject to heavy rainfall, pollution due to industry and marine atmosphere and severe lightning. The limiting weather conditions which the shunt capacitor and associated items have to withstand in service are indicated below:

i.	Atmospheric temperature	a. Metallic surface temperature under Sun: 75° C max. and in shade: 55 C° max. b. Minimum temperature: - 10° C (Also snow fall in certain areas during winter season) c. Maximum ambient air temperature - 50^0C d. Average ambient air temperature over a period of 24 hours - 35^0C
ii.	Maximum relative humidity	100 %
iii.	Annual rainfall	Ranging from 1750 to 6250 mm
iv.	Maximum number of thunder storm days per annum	85 days
v.	Maximum Number of	35 days

	dust storms days per annum	
vi.	Number of rainy days per annum	120 days
vii.	Atmosphere during hot weather	Extremely dusty and desert terrain in certain areas. The dust concentration in air may reach a high value of 1.6 mg/m^3. In many iron ore and coalmine areas, the dust concentration is very high affecting the filter and air ventilation system.
viii.	Coastal area	The equipments shall be designed to work in coastal areas in humid and salt laden atmosphere with maximum. pH value of 8.5, sulphate of 7mg per liter, max. concentration of chlorine 6 mg per liter and maximum conductivity of 130 micro siemens/cm.
ix.	Basic wind pressure	216 kg/m^2
x.	Altitude	Not exceeding 1000 meters.

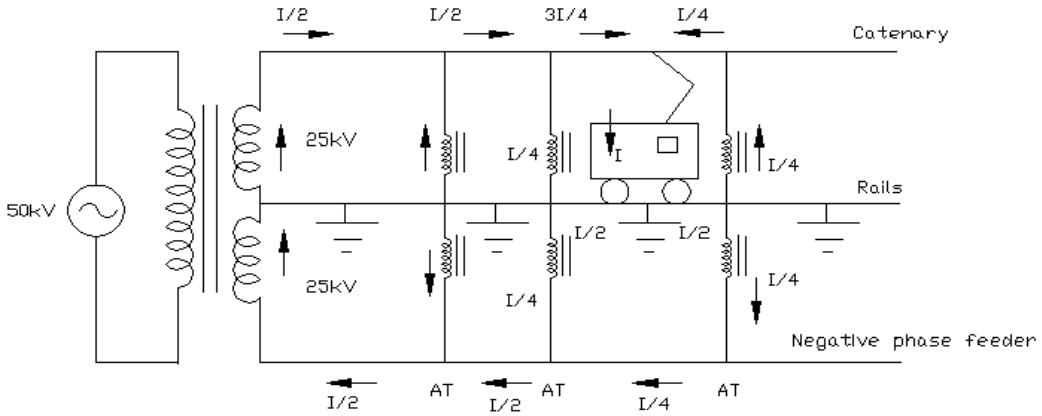
3.2 Vibrations -

The shunt capacitor installations would also be subjected to vibrations on account of trains running on nearby railway tracks. The amplitude of these vibrations which occur with rapidly varying time periods in the range of 15 to 70 ms lies in the range of 30 to 150 microns at present with the instantaneous peak going up to 350 microns.

4.0 TRACTION POWER SUPPLY SYSTEM (2X 25 KV AT FEEDING SYSTEM)

4.1 **BRIEF DESCRIPTION OF THE 2 X 25 KV SYSTEMS**.

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.



4.2 **Scott Connected Transformer Scheme**:

(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. (Pl. refer Appendix -IV)

(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.

4.3 **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.

(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 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. (Pl. refer Appendix-V)

4.4 Power Factor Improvement:

4.4.1 The average Traction load considered as 30 MW due to frequent and rapidly varying nature. The average power factor of electric traction and multiple unit trains considered 0.8 lagging without compensation and the desired power factor with capacitor bank 0.9 lagging. For Scott Connected TSS, 55kV, 4 + 4 MVAR capacitor bank (it has been divided in two equal parts one for main winding and another for teaser winding). For V Connected TSS, 25kV – 4 + 4 MVAR capacitor bank (it has been divided in two equal parts one for each working transformer).

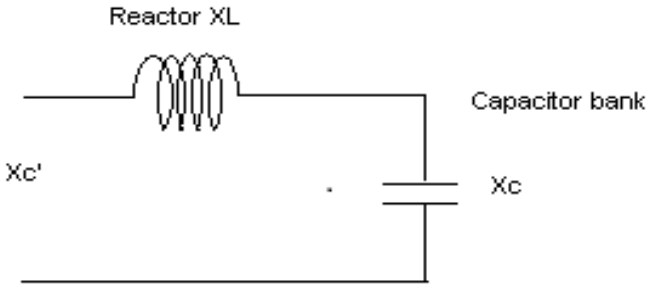
4.4.2 The conventional AC locomotives are fitted, for conversion of AC to DC, with single phase bridge connection silicon rectifiers with smoothening reactor for feeding the DC traction motors. The ripple current is in the region of 25 to 40% which introduces harmonics in the 25 kV power supply. There are some locomotives based on thyristor control, which are having higher harmonics generation.

The typical percentage of the current harmonics present in the traction system with silicon diodes locomotives are given below:

Order of harmonics	Current harmonics (%) with	
	Rectifier	Thyristor
3rd harmonics (150 Hz)	15%	23%
5th harmonics (250 Hz)	6%	14%
7th harmonics (150 Hz)	4%	10%

5.0 TECHNICAL SPECIFICATION:

5.1 Rating and other particulars:

SN	Description	55kV Scott Connected system	2x 25 kV, V-connected system
i.	Nominal system voltage	55kV	27.5 kV (phase to earth)
ii.	Equipment voltage class	72.5kV	52 kV
iii.	Rated voltage a) Capacitor bank b) Reactor	 88 kV 13%	 44 kV 13%
iv.	Rated frequency	50 Hz +/- 3%	50 Hz +/- 3%
v.	Average power factor of the traction system	Between 0.7 and 0.8 lagging (the exact value to be indicated in the tender)	Between 0.7 and 0.8 lagging (the exact value to be indicated in the tender)
vi.	Power factor desired after installation of the capacitor	0.9 lagging	0.9 lagging
vii.	Harmonics in the system	as given in para 4.4.2	as given in para 4.4.2
viii.	Location of capacitor bank	Out-door	Out-door
ix.	The Standard ratings of HT capacitor bank and reactor shall be		
		8800KVAR @ 88 kV & 13% Reactor	5500KVAR @ 44kV & 13% Reactor

5.2 Constitution of Shunt Capacitor Equipment:

5.2.1 For Scott Connected Transformer:

i. The complete HT capacitor bank (with 13% series reactor) shall have to be designed in two exactly similar parts. One bank shall be between Main winding while other bank shall be connected between treasure winding, in Scott connected system.

ii. The standard capacitor bank rating with 10S*4P combination, 220 KVAR, 8.8 kV capacitor units comes to 8800KVAR @ 88 kV in combination with 13% series reactor. (Refer to Appendix -I)

5.2.2 For V- Connected Transformer:

i. The complete HT Shunt capacitor bank (with 13% series reactor) shall consists of two halves shunt capacitor equipment, each rating voltage is 44 kV, for one phase. The one shall be connected to the OHE and rail, and the other to feeder and rail. Each half shunt capacitor equipment consists of capacitor(s) and series reactor connected in series. (Refer to Appendix-II)

ii. The standard capacitor bank rating with 5S*5P combination, 220KVAR and 8.88 kV capacitor units comes to 5500KVAR @ 44kV. (Refer to Appendix -II)

5.3 Resonant condition and inrush current

The rating of capacitor bank shall be such that it does not resonate with source impedance including transformer impedance and series reactor (parallel resonance). It shall also not resonate with the series reactor (series resonance) at any of the harmonic frequencies. It shall also be ensured that the inrush current of the capacitor banks does not exceed the maximum guaranteed value. Calculations shall be furnished with the tender in respect of the inrush current and series/ parallel resonant frequencies.

5.4 Capacitor Unit

5.4.1 Rating of the capacitor unit of the bank shall be 546KVAR, 21kV for Scott connected Capacitor bank and 220KVAR, 8kV for V-connected capacitor bank. The individual capacitor units of the bank shall be of All polypropylene (APP) self- contained, outdoor type provided with double bushing protected by internal element fuses. The bushings shall be of porcelain and shall be jointed to the case by solder sealing or any other approved technique. Each capacitor unit shall be built up of number of elements having a dielectric of plastic film (polypropylene) between the aluminum foils as electrode. The bushings shall be of porcelain and shall be jointed to the case by welding or other approved technique (except soldering). The minimum value of creepage distance for bushings shall be 25 mm per kV of appropriate class.

The capacitor elements shall be assembled in a stack closely fitted into the container in order to reduce the amount of free impregnation fluid. The container shall accommodate changes in fluid volume due to variation in the temperature. Each individual unit shall consist of a number of elements connected in series parallel arrangement. The capacitor unit shall be capable of withstanding transient over currents of high frequency and amplitude occurring at the time of their switching in the circuit.

Each element shall be protected by means of an internal fuse connected in series.

Each capacitor unit shall satisfactorily operate continuously at rated voltage and shall withstand 30% over current (rms value) due to over-voltages and harmonics. The unit shall also satisfactorily operate with traction harmonic currents as indicated in clause 4.4.2. Depending upon the actual capacitance value, which may be

maximum of the 1.15 time the rated capacitance Cn, the maximum current may reach 1.5 times the rated current.

5.4.2 The polypropylene film conforming to IS: 11298 or latest shall be checked for proper thickness, roughness, breakdown voltage besides its physical appearance.

5.4.3 The capacitor shall be impregnated with non-PCB (polychlorinated-Biphenyl) impregnation fluids which have excellent electrical characteristics, low toxicity, low bio-accumulation and are biodegradable.

5.4.4 The aluminium foil used shall be of very high purity and free from materials like rolling oil and such other defects. The thickness of aluminium foil used shall not be less than ~~6~~ 5 microns.

5.4.5 The container of each capacitor unit shall be leak and moisture-proof. The capacitor containers shall be made of CRCA steel sheets of drawing quality generally as per IS: 513 or latest. The nominal thickness of steel shall be 1.6 mm. The inside surface of the container in contact with the impregnating fluid shall not be painted and shall only be degreased and made rust free. The steel surface 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 or latest.

5.4.6 Internal element fuse for capacitor unit shall comprise very high-grade quality special alloy wire. The raw material for fuse shall comprise fuse wire, press board and insulating paper. These fuse wire shall be checked for tolerance in dimension and uniformity in finish and also for compatibility with the impregnating fluids. The element fuse shall be current limiting type which shall operate in a very short duration to isolate the faulty elements.

The fuse shall be capable of carrying both nominal current continuously and inrush current. It shall operate at the minimum available energy and should not explode while discharging maximum available energy.

The construction of internal fuse shall be such that the residue of fuse operations shall not contaminate the impregnating liquid.

The internal fuse shall be so designed that fuse operation under the worst conditions will not cause a fire inside a unit. The internal fuse shall be designed and tested as per IS: 12672 or latest and test results furnished with each capacitor unit.

5.4.7 Each capacitor unit shall be provided with a directly connected internal discharge device to drain the residual voltage from the crest

value of the rated voltage to 50 volts or less within ~~5~~ 10 minutes of disconnection of the capacitor from the source of supply.

This device shall be made from carbon resistors without lacquer coating.

5.5 Series Reactor (Harmonic suppression Reactor):

A series reactor shall be provided to limit the inrush current and surge voltage at the time of switching 'ON' of the capacitor bank. The series reactor, which is also meant to filter a part of the harmonics generated by the traction loads shall have inductive reactance (XL) equal to or greater than 13% of capacitive reactance (XC) of the capacitor bank. The series reactor shall be non-shielded, outdoor type, natural air-cooled, air cored, dry insulated type. The reactor shall be rated for the maximum current including harmonic currents that would flow through the capacitor bank under operating conditions mentioned in Clause 4.4.2 The reactor shall be so designed that the variation in milli-henry value due to manufacturing tolerance is less than + 3%.

The maximum losses in the reactor under rated current shall be approximate to 10 kW ±10%. The material composition of the reactor shall be aluminum. The reactor shall be tested for temperature rise test at maximum continuous current.

5.5.1 The Vendor shall provide complete system details of series reactor and HT capacitor bank e.g. KVAR, XL, XC, Current, Voltage etc. to the manufacturer of series reactor (OEM).

5.5.2 Reactors should be designed to facilitate easy lifting and provided with lifting eyes or similar provisions to allow safe & rapid installation.

5.5.3 Lifting and handling instructions shall be furnished by the reactor manufacturer. In case of heavy reactors, special crating and transport precautions shall be taken by the reactor manufacturer to keep stresses in the reactor within safe levels.

5.6 Basic insulation level:

The basic insulation level of the complete capacitor bank and other associated equipments shall be as follows:

Description	For 2X25kV System	For 55kV System
1.2 /50 micro second impulse withstand voltage (peak)	250 kV (P)	325 kV (P)
1-minute wet power frequency withstand voltage (rms)	105 kV	140 kV

5.7 Protection:

Technical Specification No. TI/SPC/PSI/PROTCT/7101 or latest for Control and Relay Panel including Numerical type protection relays for Scott-connected/V-Connected Traction Transformers, OHE protection and Shunt Capacitor Bank and AT Protection for 2x25 kV traction sub-station shall be referred.

6.0 GENERAL ARRANGEMENT OF CAPACITOR BANK AND ASSOCIATED EQUIPMENT.

6.1 The capacitor bank shall be of outdoor type, installed on a concrete bed or mounted on steel racks for connection to the 55kV or 25 kV bus through double pole isolator and circuit breaker. The capacitor bank 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 detailed elsewhere. The number of parallel units in each series group shall be selected so as to satisfy the conditions in clause No. 5.2 & 5.4.1. The capacitor bank shall be supplied complete with mounting steel rack assembly, inter-connectors between units, insulators, suitable earthing lugs including terminal connectors but without connecting jumper to 55kV or 25 kV bus and any other material required to make the bank complete in all respects for its satisfactory.

6.2 Mounting Arrangement:

6.2.1 The capacitor bank and the series reactor shall be suitable for mounting on steel racks which in turn shall be mounted on a concrete plinth with suitable base frames. The racks shall be complete with rack insulators and other hardware.

6.2.2 The Vendor is free to suggest any other arrangement for mounting the capacitor bank and reactor which is considered economical without sacrificing the safety of the personnel working in traction substation. Full details of such arrangements shall be furnished with the tender.

7.0 PROTECTION AGAINST LIGHTNING SURGES

A separate lightning arrestor shall be provided to protect the capacitor bank against lightning surges. The lightning arrestor shall be metal oxide gapless type 42 kV class having 10 kA discharge current for V connected System and 60kV class having 10 kA discharge current for Scott connected system. The lightning arrestor shall be designed to withstand the full energy discharge from the capacitor bank to which it is connected.

8.0 EARTHING

Earthing arrangements shall be provided for capacitor bank installation in accordance with RDSO specification No. ETI/PSI/120(02/91) with A&C Slip

No. 1 or latest code of practice for Earthing of power supply installation for 25 kV, ac 50 Hz, single phase traction system.

9.0 GALVANISING

All steel supporting frame shall be hot-dip galvanized as per Research Designs & Standards Organisation's specification no. TI/SPC/OHE/FASTENERS/0120 Rev. 1 or latest and the weight of zinc coating shall be not less than 1000 gm/m sq.

10.0 PAINTING:

All steel structures exposed to weather shall be given primer coat of zinc chromate and two coats of light grey enamel paint to shads No.631 of IS: 5. One additional coat of paint shall be given at site by the manufacturer.

11.0 FASTENERS

All fasteners of 12 mm diameter and less exposed to atmosphere shall be of stainless steel and those above 12 mm dia shall be preferably of stainless steel or mild steel hot dip galvanized to RDSO's specification No. TI/SPC/OHE/FASTENERS/0120 Rev. 1 or latest. The material of the stainless steel fasteners shall conform to IS: 1570 (Pt.V) Grade 04 Cr 17Ni 12 Mo 2.

12.0 TESTING

12.1 BEFORE MANUFACTURE OF PROTOTYPE

The Vendor has to offer drawing & design for approval of RDSO including Quality Assurance Plan (QAP), Schedule of Guaranteed Performance (SOGP) and Design Calculations as required and mentioned in the relevant Clauses of Specification.

Only after all submitted documents have been approved and clearance given to this effect by RDSO, the manufacturer shall take up manufacture of the prototype for inspection/testing by RDSO. It is to be clearly understood that if, there are any changes to be done on the prototype as required by RDSO, same shall be done expeditiously.

12.2 Before giving the call to Purchaser/DG(TI)/RDSO for inspection and testing of the prototype of the system the manufacturer shall submit a detailed test schedule of proto type testing indicating the name of the test with internal test report (Test report of Routine Test), venue of the test and the total number of days required to complete the test at one stretch. Once the schedule is approved, the test shall invariably be done accordingly.

However, during the process of type testing or even later, RDSO representative reserves the right to conduct any additional tests besides those specified herein, or any equipment/ sub-system or system so as to test the system to his satisfaction or for gaining additional information

and knowledge. In case any dispute or disagreement arises between the manufacturer and authorized representative of the purchaser/DG (TI)/RDSO, Lucknow during the process of testing as regards the type tests and /or the interpretation and acceptability of the type test results, it shall be brought to the notice of the Director General (Traction Installations), RDSO, Lucknow as the case may be, whose decision shall be final and binding. Only after the prototype of the equipment is manufactured and ready in all respects, shall the Vendor/manufacturer give the actual call for the inspection and testing with at least 15 days" notice for the purpose.

12.3 Type test shall be carried out on Prototype unit of Shunt Capacitor Bank with relevant standards as modified or amplified by this specification where applicable at the works of the manufacturer or at any Government approved testing laboratory if testing is done in India. At the works of the manufacturer the testing shall be conducted in the presence of the authorized representative of the purchaser/DG (TI)/RDSO, Lucknow. However, for the tests in the any Government approved testing laboratory if testing is done in India, the presence of representative of the purchaser/DG (TI)/RDSO, Lucknow may be decided by the RDSO, inspection and testing with at least 15 days" notice for the purpose.

12.4 For the tests which are conducted in the laboratories of Central Power Research Institute (CPRI), Electrical Research Development Association (ERDA) or any such testing house or laboratory a clear certificate to the effect that the equipment has passed the tests as per the Specification shall be obtained by the manufacturer and submitted to the Purchaser/DG (TI)/RDSO, Lucknow. Full details of the tests and the test parameters shall be furnished along with the test reports. These test reports shall be considered for acceptance, provided there is no any design change between already tested material and offered material.

In any case, the prototype tests, which can be conducted in-house at manufacturer's works shall be required to be carried out and witnessed by RDSO during initial approval.

12.5 <u>TYPE TESTS ON SHUNT CAPACITOR:</u>

The following Type Test carried out on Shunt capacitor:

SN	Description of the Test	Refer Clause
i.	Capacitance measurement.	12.5.1
ii.	Voltage test between terminals.	12.5.2
iii.	Thermal stability test.	12.5.3
iv.	Measurement of the tangent of the loss angle (tan δ) of the capacitor at elevated temperature.	12.5.4
v.	AC Voltage test between terminals and container.	12.5.5
vi.	Measurement of tangent of the loss angle (tan δ) of the capacitor.	12.5.6
vii.	Lightning Impulse voltage test between terminals and	12.5.7

	container.	
viii.	Short circuit discharge test.	12.5.8
ix.	Endurance Testing	12.5.9
x.	Tests on internal Fuses. a. Discharge test on internal fuses. b. Disconnecting test on internal fuses.	12.5.10
xi.	Test of internal discharge device.	12.5.11
xii.	Sealing test.	12.5.12
xiii.	Special tests on capacitor units with internal fuses	12.5.13

12.5.1 Test for capacitance measurement:

The test shall be carried out as per clause No. 7 of IS: 13925-1 or latest.

12.5.2 Voltage Test between Terminals:

This test shall be carried out as per clause No. 9 of IS: 13925-1 or latest.

12.5.3 Thermal Stability Test:

This test shall provide thermal stability to capacitor under overload conditions and prepare the capacitor to give reliable loss measurements. The test shall be carried out as per clause No. 13 of IS: 13925-1 or latest.

12.5.4 Measurement of the tangent of the loss angle (tan δ) of the capacitor at elevated temperature:

This test shall be carried out as per clause No. 14 of IS: 13925-1 or latest.

12.5.5 AC Voltage test between terminals and container

An AC test voltage shall be carried out as per clause No. 15 of IS: 13925-1 or latest. The voltage shall be applied between the terminals (short circuited) of each capacitor unit and its container, and maintained for a period of one minute, except that when one terminal of the capacitor is connected to the container.

12.5.6 Measurement of tangent of the loss angle (tan δ) of the capacitor:

The measurements shall be carried out as per Clause no. 8 of IS: 13925-1 or latest.

12.5.7 Lightning Impulse voltage test between terminals and container:

The test shall be carried out as per Clause No. 16 of IS: 13925-1or latest.

12.5.8 Capacitor Short Circuit discharge test:

The capacitor shall be charged by means of dc voltage equal to 2.5 times of the rms value of the rated voltage of the unit and discharged through a gap situated as close as possible to the capacitor as per clause No. 17 of IS:13925-1 or latest.

12.5.9 Endurance testing

Capacitor units shall be subjected to an endurance test as per clause 6.4 of IS 13925 -1 or latest by the manufacturer of the capacitors to ascertain that repeated over voltages stresses do not cause dielectric break down. This test shall be done in accordance with procedure laid down in IEC: 60871-2 or latest and repeated if any changes will be made in design.

12.5.10 Test on Internal Fuses:

The following type tests shall be carried out on the internal fuses as per IS: 12672 or latest:

a. Discharge test on internal fuses (Clause no. 9 of IS: 12672):
The fuses shall be subjected to ~~live~~ Five discharges within 10 minutes from a dc test voltage equal to 2.5 times the rms value of the rated voltage of the capacitor element through a gap situated as clause as possible to the capacitor without any additional impedance in the circuit. To prove that the fuses have not operated, a capacitance measurement shall be made before and after the test.

b. Disconnecting test on Internal fuses (Clause no. 10 of IS: 12672):
The disconnecting test on fuses shall be performed first at lower voltage limit equal to 0.9 times rms value of the rated voltage of the capacitor element and then as soon as possible after blowing of one fuse at the upper voltage limit equal to 2.2 times the rms value of rated voltage of the capacitor element until blowing of another fuse. After the test, Capacitance shall be measured to prove that the fuse(s) has (have) blown. A measuring method shall be used that is sufficiently sensitive to detect the capacitance change caused by the blown fuse.

12.5.11 Test of internal discharge device:

This test shall be carried out as per clause no. 11 of IS: 13925-1 or latest.

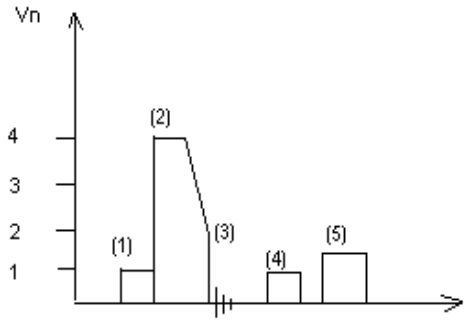
12.5.12 Sealing Test:

A sealing test shall be carried out as per clause no. 12 of IS:13925-1 or latest to demonstrate that the impregnated does

not leak from the capacitor. The test shall be carried out at 80+/- 5 degree C for a period of 3 hours.

12.5.13 Special tests on capacitor units with internal fuses.

Each capacitor unit manufactured shall be tested strictly in accordance with the IS: 13925-1 or latest. The special discharge test shall be performed to check the mechanical strength of internal fuses and discharge resistors. The internal element fuses shall be routine tested together with the capacitor units as per the diagram given below:



1. Low voltage capacitance measurement.
2. DC Voltage test (4.3 Vn 10 sec.)
3. Direct discharge from 1.7 Vn.
4. Low voltage capacitance measurement.
5. Capacitance and loss measurement (Vn)

(Vn=rated voltage of capacitor)

12.6 Routine tests:

The following tests shall be carried out as routine tests on each and every units of the shunt capacitor as per IS: 13925-1 or latest.

SN	Description of the Test	Refer Clause
i.	Visual Examination	12.6.1
ii.	Test for capacitance measurement.	12.6.2
iii.	Measurement of tangent of the loss angle (tan δ) of the capacitor.	12.6.3
iv.	Voltage test between terminals.	12.6.4
v.	AC Voltage test between terminals and container	12.6.5
vi.	Test of internal discharge device.	12.6.6
vii.	Sealing test.	12.6.7
viii.	Discharge test on internal fuses	12.6.8

12.6.1 Visual Examination:

All capacitors shall be examined for finish and marking. Verification of dimension shall also be done as per approved drawings.

12.6.2 Test for capacitance measurement:

This test shall be carried out in accordance with clause 7 of IS: 13925-1 or latest.

12.6.3 Measurement of tangent of the loss angle (tan δ) of the capacitor.

This test shall be carried out in accordance with clause No. 8 of IS: 13925-1 or latest.

12.6.4 Voltage test between terminals:

This test shall be carried out as per clause No. 9 of IS: 13925-1 or latest.

12.6.5 AC Voltage test between terminals and container:

An AC test voltage shall be carried out as per clause No. 15 of IS: 13925-1 or latest.

12.6.6 Test of internal discharge device:

This test shall be carried out as per clause no. 11 of IS: 13925-1 or latest.

12.6.7 Sealing test:

A sealing test shall be carried out to demonstrate that the impregnated does not leak from the capacitor as per clause 12 of IS 13925-1 or latest. The test shall be carried out at 80+/- 5 degree C for a period of 3 hours.

12.6.8 Discharge test on internal fuses (Clause no. 9 of IS: 12672):

The fuses shall be subjected to Five discharges within 10 minutes from a dc test voltage equal to 2.5 times the rms value of the rated voltage of the capacitor element through a gap situated as clause as possible to the capacitor without any additional impedance in the circuit. To prove that the fuses have not operated, a capacitance measurement shall be made before and after the test.

12.7 TYPE TEST ON SERIES REACTOR:

The following type tests shall be carried out on the prototype units as per IS: 2026 (part 6) or IEC 60076-6 or latest:

SN	Description of the Test	Refer Clause
i.	Measurement of winding resistance	12.7.1
ii.	Measurement of insulation resistance	12.7.2
iii.	Measurement of Impedance at Rated continuous current.	12.7.3
iv.	Measurement of loss and Q-factor at ambient Temperature	12.7.4
v.	Separate source a.c. withstand voltage test	12.7.5
vi.	Temperature rise test at rated continuous current	12.7.6
vii.	Lightning Impulse voltage withstand test	12.7.7

viii.	Short-Circuit current Test	12.7.8
ix.	Winding overvoltage Test	12.7.9
x.	Wet winding overvoltage test	12.7.10
xi.	Wet separate source A.C. withstand Voltage Test	12.7.11

12.7.1 Measurement of winding resistance:

This test shall be carried out in accordance with clause No. 10.2 of IS: 2026-1:2011 or clause no. 11.2 of IEC 60076-1:2011 or latest.

12.7.2 Measurement of insulation resistance:

The measurement of insulation resistance of the winding insulation to earth shall be carried out with 500V Insulation Resistance Tester.

12.7.3 Measurement of Impedance at Rated continuous current:

This test shall be carried out in accordance with Clause No. 8.9.5 of IS: 2026-6: 2017 or latest.

12.7.4 Measurement of loss and Q-factor at ambient Temperature:

This test shall be carried out in accordance with clause No. 9.10.6 of IS: 2026-6: 2017 or latest.

12.7.5 Separate source voltage withstand test:

This test shall be carried out in accordance with clause no. 8.9.8 of IS: 2026-6: 2017 or latest by applying specified voltage for one minute between

a) The winding and the earth and
b) The windings of different phases.

12.7.6 Temperature rise test at rated continuous current:

This test shall be carried out in accordance with Clause No. 8.9.11 of IS: 2026-6: 2017 or latest.

12.7.7 Lightning Impulse voltage withstand test:

This test shall be carried out in accordance with Clause No. 9.10.9 of IS: 2026-6: 2017 or latest.

12.7.8 Short circuit test

This test shall consist of application to the reactor of two short circuits with specified initial peak current for 10 cycles as per clause no. 8.9.13 and 9.10.10 of IS: 2026 -6: 2017 or latest.

12.7.9 Winding overvoltage Test:

This test shall be carried out in accordance with Clause No. 8.9.9 and 9.10.7 of IS: 2026-6: 2017 or latest.

12.7.10 Wet winding overvoltage test:

This test shall be carried out in accordance with Clause No. 8.9.19 of IS: 2026-6: 2017 or latest.

12.7.11 Wet separate source A.C. withstand Voltage Test:

This test shall be carried out in accordance with Clause No. 8.9.20 of IS: 2026-6: 2017 or latest.

12.8 Routine tests:

The following tests shall be carried out as routine tests on each and every units of the Reactor as per IS: 2026-6: 2017 or latest.

SN	Description of the Test	Refer Clause
i.	Measurement of winding resistance	12.8.1
ii.	Measurement of insulation resistance	12.8.2
iii.	Measurement of Impedance at rated continuous current.	12.8.3
iv.	Measurement of loss and Q-factor at ambient Temperature	12.8.4
v.	Separate source voltage withstand test	12.8.5
vi.	Lightning-Impulse voltage withstand test	12.8.6
vii.	Winding overvoltage Test	12.8.7

12.8.1 Measurement of winding resistance:
This test shall be carried out in accordance with Clause No. 10.2 of IS: 2026-1:2011 or Clause no. 11.2 of IEC 60076-1:2011 or latest.

12.8.2 Measurement of insulation resistance:
The measurement of insulation resistance of the winding insulation to earth shall be carried out with 500V Insulation Resistance Tester.

12.8.3 Measurement of impedance at rated continuous current:
This test shall be carried out in accordance with clause No. 8.9.5 of IS: 2026-6:2017 or latest.

12.8.4 Measurement of loss and Q-factor at ambient Temperature:
This test shall be carried out in accordance with clause No. 9.10.6 of IS: 2026-6:2017 or latest.

12.8.5 Separate source voltage withstand test:
This test shall be carried out in accordance with clause no. 8.9.8 of IS: 2026-6: 2017 or latest by applying specified voltage for one minute between

a) The winding and the earth and
b) The windings of different phases.

12.8.6 Lightning impulse voltage withstand test:
This test shall be carried out in accordance with Clause no. 9.10.9 of IS: 2026-6:2017 or latest.

12.8.7 Winding overvoltage Test:
This test shall be carried out in accordance with Clause No. 8.9.9 and 9.10.7 of IS: 2026-6: 2017 or latest.

12.9 Following tests shall be conducted at site to verify the performance of the complete capacitor bank installation:

i. Test on protection system:

This test shall be carried out by a simulating the fault conditions and observing the relay operation.

ii. Rise in voltage due to capacitor bank connection:
At different loads, the voltage at the 55kV or 25 kV busbar shall be recorded for 24 hours each with and without the capacitor bank. The rise in voltage due to the capacitor bank shall be assessed from these observations.

iii. Harmonic analysis:
The harmonic analysis of current and voltage waveform shall be carried out by the vendor with and without capacitor bank in circuit.

iv. Surge voltage measurement:
The surge voltage shall be measured by the vendor at the time of switching in capacitor bank. This shall be done for 20 times; the voltage peak shall not exceed 70 kVp in any case for V-Connected System and 150 kVp in any case for Scott Connected Transformer.

12.10 Schedule of pre-commissioning tests:

12.10.1 The schedule of pre-commissioning tests on the capacitor units, reactor and the complete bank, control & relay panels, circuit breakers and other items shall be mutually agreed upon by the vendor and the purchaser.

12.10.2 The HT capacitor unit and series reactor shall be inspected by OEM before being commissioned. A certificate to this extent that the installation is fit for commissioning shall be taken from the Original Equipment Manufacturers.

12.11 Bulk manufacture of the shunt capacitor shall be taken up only after specific written approval given by the purchaser to the vendor on the basis of the tests conducted on the proto type units manufactured according to approved design and drawings.

13.0 Capitalization of Losses:

13.1 In evaluating the offer, the price of the capacitors and series reactors with higher watt losses per/ KVAR shall be compared by increasing the prices by capitalization of additional losses by the formula given in the appendix- IIII. The Vendor shall for this purpose clearly indicate the losses in watts per KVAR rating of the capacitor bank and separately for the series reactor at the rated voltage.

13.2 The losses of the capacitor bank shall be made up of the losses per capacitor unit (including fuses and discharge device) multiplied by the

number of units in the bank. The overall losses of a capacitor unit shall be as low as possible and shall not be more than 0.25 W/KVAR.

14.0 Technical Data and Drawings:

14.1 The vendor shall furnish guaranteed performance data, technical and other particulars for the equipments offered in the Performa at Annexure-A. Technical details of the protection employed together with detailed calculation for the ratings of the equipment shall be furnished with the tender.

14.2 The information furnished in schedule of the guaranteed performance, technical and other particulars (Annexure-A) shall be complete in all respects. If there is any entry like: "shall be furnished later" or blanks are left against an item, the tender is not likely to be considered as such omissions causes delay in finalizing the tender.

14.3 The vendor shall specifically indicate in a statement attached with his offer, his compliance with each clause and sub-clause of this specification. If any vague remarks on any clause or sub-clause of this specification is given by the vendor, then the tender submitted by him is not likely to be considered. A separate deviation statement shall be furnished with the offer drawing to the clause (s) where the tenderer seeks the deviation giving detailed remarks/ justification thereon. If there are no deviation, a 'NIL' statement shall be furnished.

14.4 The vendor shall furnish the following calculations with their offer.

i. Detailed calculations for rating of shunt capacitor bank series reactor, inrush current, transient over voltage, parallel and series resonant frequencies.

ii. Calculations for design of supporting frame, fixing arrangement and foundation.

14.5 The following drawings shall be furnished as per IR standard in sizes of 210 mm x 290 mm or any integral multiple thereof:

a. Outline general arrangement drawing giving the overall dimensions of the capacitor bank installation.

b. Arrangement of capacitor Bank, Series reactor, circuit breaker, isolator, lightening arrestor, current and potential transformers.

c. Details of capacitor bank showing series parallel arrangement of capacitor units.

d. Arrangement of core winding and magnetic path of series reactor.

14.6 The vendor shall be required to submit for approval the following detailed dimensioned drawings as per Indian Railway Standard in the sizes of 210 mm x 297mm or any integral multiple thereof.

a. Outline general arrangement drawing of the capacitor bank installation indicating necessary dimensions, clearances and location of equipments/ fittings (all the 3 views), Name and noting plate with diagram of connections (one in English and other in Hindi).

b. Internal arrangement of series reactor including cross sectional views in both plane and elevation.

c. Schematic and wiring diagram.

d. Supporting frame with details of fixing arrangement and foundations along with calculation for their design.

14.7 After approval of designs and drawings by Director General/TI, RDSO, Lucknow, the vendor shall manufacture an acceptable prototype of shunt capacitor equipment as per approved drawings. The prototype inspection shall be carried out by the representative of RDSO. The bulk manufacture shall be taken up only after approval of prototype by the Director General (TI), RDSO, Lucknow.

14.8 After approval, 6 copies of approved drawings along with two sets of reproducible prints shall be supplied to each consignee(s). One sets of approved drawings of hard copies, shall be sent to RDSO for record.

14.9 The vendor shall supply 10 copies of instructions/maintenance manual for the capacitor bank installation and its fittings and accessories, to each consignee(s) and two copies to Director General (TI), RDSO, Lucknow.

15.0 Erection Testing and Commissioning:

The capacitor bank installation shall be erected by the vendor under the supervision of a competent engineer of the vendor/manufacturer/ supplier. The capacitor bank installation shall be subjected to the specified proving / pre commissioning tests by the Railway Engineer at site and with which the vendor/ manufacturer/ supplier shall also be associated. For this purpose, prior intimation regarding the date and location of the tests shall be given by the purchaser to the vendor/ manufacturer/ supplier.

16.0 SPARES

The vendor shall furnish along with his offer a list of spares, with cost, recommended by him for maintenance of capacitor bank installation for a period of 5 years.

17.0 TRAINING OF INDIAN RAILWAYS' ENGINEERS

The offer shall include the training of two engineers and four technicians of the Indian Railways free of cost at the manufacturer's works in India or abroad and at the traction sub-station of a railway system or other public utility where capacitor bank installations of similar/ identical design are in operation. The total duration of training for each engineer/ technician shall be 4 weeks of which approximately 2 weeks will be the manufacturer's works and 2 weeks on a railway system or other public utility. The cost of travel to the country of manufacture and back will be borne by the Indian Railways. Other details shall be settled at the time of finalizing the contract or purchase order.

18.0 WARRANTY

Each capacitor bank including all equipment supplied against a purchase order/ contract in which this specification is quoted, irrespective of origin (imported or indigenous), shall be guaranteed for trouble free and satisfactory performance for a period of 42 months from the date of supply or 36 months from the date of commissioning at the sub-station on the Indian Railways, whichever period is shorter. Details of warranty clause, the extent of responsibility and other relevant aspects shall be included in the purchase order or contract. The vendor shall furnish detailed terms and conditions in this regard in his offer.

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Annexure-A

SCHEDULE OF GUARANTEED PERFORMANCE TECHNICAL AND OTHER PARTICULARS.

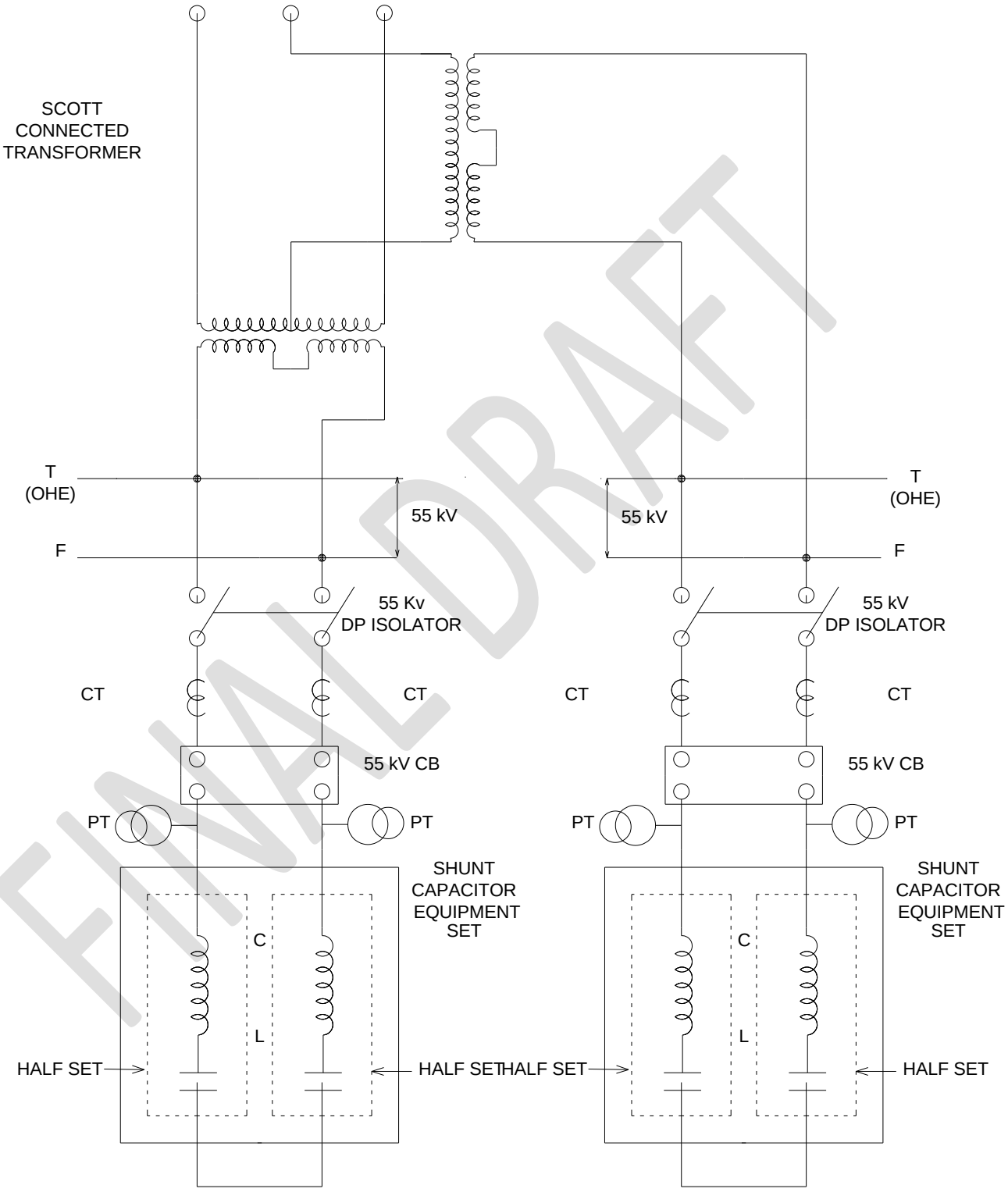
A- Capacitor Unit		
S. N.	**Description**	**Unit of measurement**
1.	Maker's Name	
2.	Country of manufacture	
3.	Manufacturer's type designation	
4.	Location of capacitor bank (outdoor/indoor)	
5.	System voltage	kV
6.	Rated voltage of unit as per IS:13925-1 or latest	kV
7.	Maximum voltage (rms) which the capacitor unit can withstand continuously	kV
8.	Rated frequency	Hz
9.	No. of phases	No.
10.	Upper limit of temperature category	Deg. C
11.	Capacity of individual unit at rated voltage of unit	KVAR
12.	Capacity of capacitor bank at 55kV or 25 kV	.
13.	Continuous current Maximum inrush current at the instant of switching in	Amps Amps
14.	Basic insulation level of unit a) Power frequency voltage withstand b) 1.2/50 microsecond impulse withstand voltage	 KV(rms) kV(peak)
15.	Basic insulation level of complete capacitor bank. a) Power frequency voltage withstand b) 1.2/50 microsecond impulse withstand voltage	 Kv(rms) Kv(peak)
16.	Transient current withstand capacity	kA
17.	Constructional details of capacitor unit. i) Dielectric material ii) Foil material iii) Impregnating liquid used and its properties. iv) Discharge resistors. v) Internal fuses.	
18.	Dielectric loss per / unit at 55kV or 25 kV and 50 C/s	watts
19.	Capacitor unit- i) No. of elements in series ii) No. of elements in parallel iii) Capacitance of each unit	 No. No. Micro Farad
20.	Capacitor bank i) Capacitance of bank ii) No. of series groups iii) No. of parallel units in each group	 Micro Farad No. No.

21.	a) Internal fuse i) Type of internal fuse elements of capacitor unit: ii) Length of fuse element iii) Cross section of fuse element iv) circumference of fuse element v) I-t characteristics. vi) Time factor (s) of internal fuse element	 mm Sq.mm Mm Sec. (under max. energy condition) Sec. (under min energy condition.)
22.	Discharge device. i) Type ii) Location iii) Time interval between de-energization and re-energization iv) Residual voltage after an interval of 5 minutes of de-energization	 Minutes Volts
23.	Bushings: i) Maker's name ii) Governing Specification iii) Wet-1 minute power frequency voltage withstand iv) Impulse voltage withstand 1.2/50 microsecond full wave. v) Creepage distance in air vi) No. of bushings in each unit	 KV(rms) kV(peak) mm No.
24.	Overall dimensions i) Capacitor unit ii) Complete capacitor bank	
25.	Weight per unit	Kg
26.	Weight of the complete bank	Kg
	B- SERIES REACTOR	
1.	Rated current and voltage	Amps/ Volts
2.	Rated frequency	Hz.
3.	Inductance of series reactor	H
4.	Rated impedance	Ohms
5.	Parallel & Series resonant frequencies of the system	Hz(parallel) Hz(Series)
6.	Value of the peak surge voltage generated at the time of switching in of shunt capacitor (calculations shall be appended)	kV
7.	Short circuit rating for 3 seconds	KA
8.	Overall dimensions of the series reactor	mm
9.	Total weight of the series reactor	Kg
10.	Maximum temperature rise: a) At continuous current b) At 130 % loading	 Deg. C Deg. C
11.	Basic insulation level: a) Power frequency voltage withstand b) 1.2/50 micro-second impulse voltage	 KV (rms) KV (peak)

	withstand	

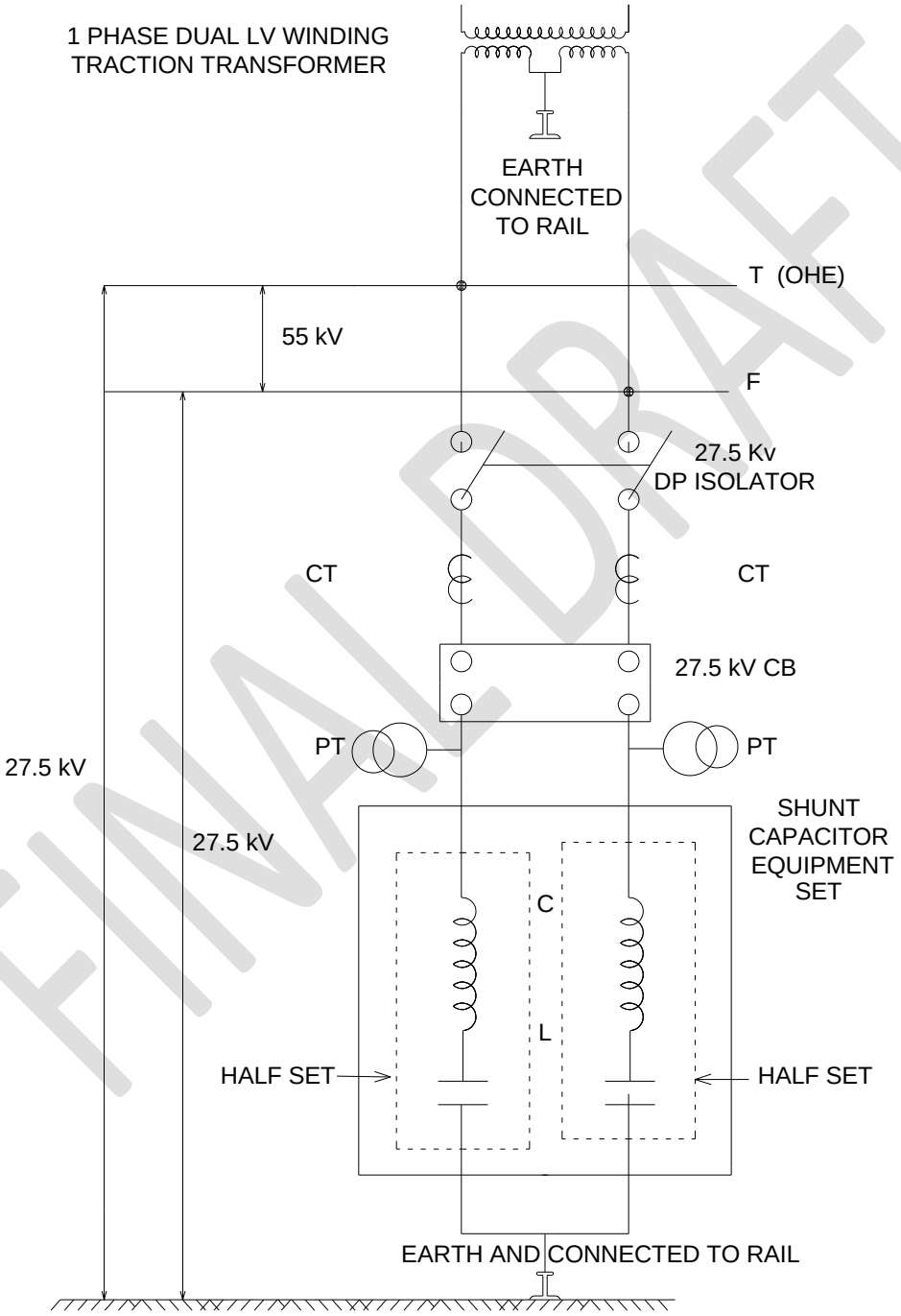
Appendix-I

Constitution of shunt Capacitor



Appendix -II

Schematic Diagram of Shunt Capacitor Bank



Appendix-III

(Referred to Clause 13.0)

Formula:

K = Present worth in Rupee

D = Annual cost of power losses

i = Rate of compound interest on unit basis @ 7% per annum.

n = Expected service life of capacitor bank in years.

PL = Power losses

T = Tariff i.e. cost of energy in Rupee per kwh.

The capitalized values for capacitor bank shall be computed as under:

$$K = \frac{D\{(1+i)^n - 1\}}{i(1+i)^n}$$

Where, $D \text{ per watt} = \frac{365 \times 24 \times T}{1000}$

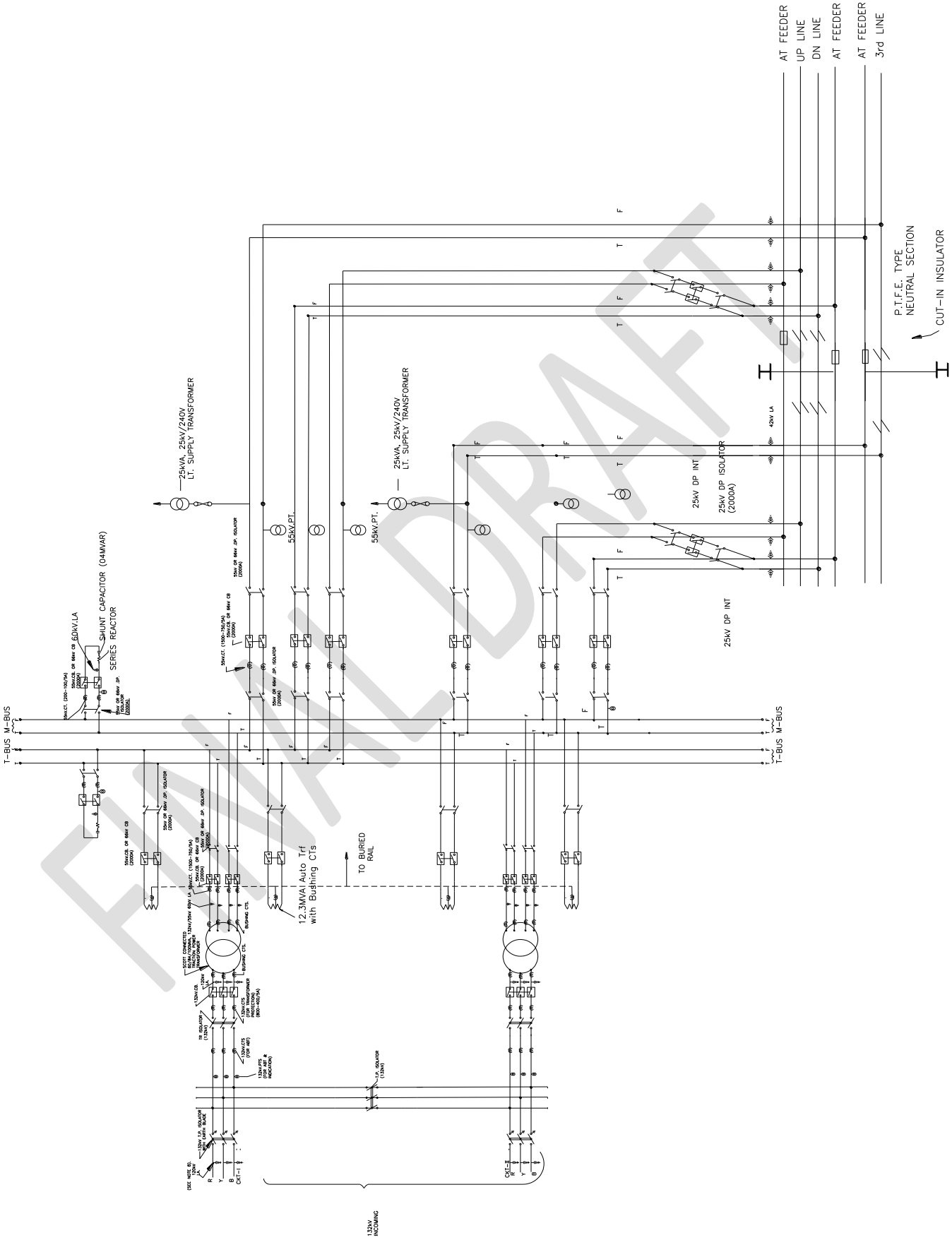
$= 8.76\ T$

thus $$K = 8.76\ T \times \frac{(1+i)^n - 1}{i(1+i)^n}$$

Hence the capitalized value in Rupees for power losses = K x PL

Appendix-IV

Schematic Diagram of Scott Connected Traction Substation



Appendix-V

Schematic diagram of V-connected Traction Transformer