GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Traction Installation Directorate

सत्यमेव जयते

TECHNICAL SPECIFICATION

DELTA-I TYPE HIGH RESISTIVE FAULT SELECTIVE RELAY FOR 25 KV AC SINGLE PHASE 50 HZ TRACTION SYSTEM ON INDIAN RAILWAY

SPECIFICATION NO: TI/SPC/PSI/PROTCT/1983

Issue Date:…….

ISSUED BY

RESEARCH DESIGNS & STANDARDS ORGANISATION, MANAK NAGAR, LUCKNOW-2260 11

SPECIFICATION FOR Delta I type high resistive fault selective relay for 25 kV AC single phase 50 Hz, traction system.

SPECIFICATION NUMBER: TI/SPC//PSI/PROTCT/1982

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0	Draft	26	17th May 1998
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SIGNATURES			
DATE			
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ANNEXURES

1.0 NEED FOR THE RELAY.

1.1 Electrified railways reported in the XIXth and XXth MSG Trd meeting the need for a backup protection for the existing mho relays. Cases of low current faults have led to the failure of the mho type distance relays on various Zonal Railways. Normally a distance protection relay is used to protect the faults occurring in OHE on 25 kV AC traction system; however, it is difficult to detect the earth faults having a high resistance, or the far end faults with the present mho type distance protection. In case of such faults, the fault is cleared by the transformer OCR (IDMT) and that too after a considerably longer time period which may be dangerous for the OHE and may cause OHE damage or even parting.

1.2 Far end fault current may be of lesser magnitude as compared to the starting load current and shall remain undetected by the mho type of distance protection relay. It was observed that in such cases the fault remained beyond the reach of mho protection relay. Clearing of such faults can be possible by increasing the sensitivity of the existing mho relay and the over-current relays but then the phenomena of unnecessary tripping of the CB's due to load encroachment (starting of a number of locomotives together) shall occur.

1.3 A closer look at the wave form of the starting currents and the fault currents gives a clue for distinguishing the two. The absolute value of the increasing current (Delta I current) in case of faults differ from the normal operation delta I currents of the AC locos/EMUs. On comparison of the delta I current of the fault current and the load current, it has been observed that the former is mostly a sine wave current and the latter is strain current wave which includes substantial, 2nd, 3rd & higher order harmonics.

1.4 RDSO had developed scalar Delta I relay to earlier specification No. TI/SPC/PSI//1981.This relay was detecting scalar delta I current for its operation. In this case the fault current was the sum of base load current and scalar delta I current. With the advancement of protection technology for high impedance earth faults, more accurate and reliable relay for such an application is developed. In this type of relay vector delta I current is detected which is the Vector difference of base load current and the fault current.

1.5 At present there is no back up protection for the distance relay which is used for providing protection for distance faults having currents lower than the load currents. Keeping all these aspects in view, it was decided in XIX th & XX th M.S.G TrD meetings that RDSO should develop Delta I relay as backup to distance protection in 25 kV AC conventional system.

1.6 In 31st MSG, it was decided to provide testing jack facility in the Control & Relay Panel. It is to be developed in a such way that when testing kit is connected to the testing jack, relay connections will get disconnected from main circuit automatically and connected to testing circuit. After testing and removal of testing kit from jack, relays will get reconnected to main circuit automatically.

2.0 SCOPE

2.1 This specification applies to design, manufacture and supply of Numerical communicable Delta I type fault selective relay for the protection of OHE of 25 kV ac traction system.

2.2 The relay shall be complete with all parts and accessories including auxiliary relays necessary for their efficient operation. All such parts and accessories shall deem to be within the scope of this specification whether specifically mentioned or not.

2.3 This specification supersedes specification No. TI/SPC/PSI/PROTCT/1982 with A&C Slip No.1&2.

2.4 The "Make in India" Policy of Government of India shall be applicable.

3.0 TRACTION POWER SUPPLY SYSTEM

3.1 General scheme of traction power supply system.

3.1.1 Power is received from the grid network of the state electricity board at 220kV/132kV/110kV/66 kV at individual traction substation (TSS). 25kV power supply for traction is drawn through a single-phase step-down traction transformer. The primary winding of this transformer is connected to any two nominated phases of the incoming three phase lines or to the two incoming phase lines and on the secondary side, either of the two terminals of the 25 kV winding is connected to the traction overhead equipment, while the other is solidly earthed and connected to the running traction rails.

3.1.2 Each transformer has its associated circuit breakers on the primary and secondary sides, with a separate set of 25 kV circuit breakers called “feeder Circuit Breakers” for feeding the traction OHE lines.

3.1.3 Adjacent TSS are fed from different phases of the three-phase system in rotation. Neutral sections / APSS (Automatic Phase switching Section) in front of sectioning and paralleling post (SP) are provided in the 25 kV OHE for segregating the different phases. In between the TSS and SP, sub-sectioning and paralleling posts (SSP) are provided for paralleling the UP and DN line OHE and also for sectionalizing and fault localization. The attached drawing at Annexure-5 shows the general scheme for traction power supply system.

3.1.4 The supply to the OHE can be switched ON/OFF through interrupters which do not open automatically on fault but can be closed on to a fault. The fault is cleared by the feeder circuit breaker provided at the traction substation.

3.1.5 Normally power supply from a TSS extends upto the SP on either side of the substation, but in case of an emergency necessitating total shut down of the substation, power supply from adjacent TSS on either side of the failed substation can be extended upto the failed substation by closing the bridging interrupters at the two SPs.

3.2 Nature of traction load and faults on the system.

3.2.1 The traction load is a frequently and rapidly varying one between no load and overload. The TSS equipment is subject to a number of earth faults/short circuits. On an average the number of faults/short circuits per month is about 40 but in exceptional cases the number could be as high as 120. The magnitude of fault current may vary between 40% and 100% of the dead short- circuit value.

3.2.2 The ac electric rolling stock is fitted, for conversion of ac to dc, with single phase bridge-connected silicon rectifiers with smoothing reactor for feeding the dc traction motors. The rectifiers introduce harmonic currents in the 25 kV Power supply. On few locomotives there are controlled asymmetrical thyristor bridge and GTO Pulse width modulation devices, in place of silicon rectifiers. A typical percentage of harmonics present in the traction current with electric rolling stock are as follows:

TABLE -1: Harmonic Generated by IR Locomotives

S.No	Harmonic No.	With Diode Rectifier	With Thyristor	With GTO’s
1.	3rd harmonic (150 Hz)	15%	23%	3%
2.	5th harmonic (250 Hz)	6%	14%	2%
3.	7th harmonic (350 Hz)	4%	10%	0.5%
4.	9th harmonic (450 Hz)	-	4%	0.35%
5.	11th harmonic (550 Hz)	-	3%	0.4%
6.	THD’s	16.64%	29.15%	3.68%

Indian Railways have introduced a superior breed of locomotives which has a much better harmonic profile as shown in table 1. Also, the quantum of thyristor-based locomotive too small to

affect a major increase in the harmonics. It is expected that the harmonic profile shall gradually reduce from the existing values as shown in table 2. The relay shall be so designed that it is flexible enough to cater for the future harmonic profile of India Railways also particularly when the harmonic levels of the traction system drops to 50 % of the existing system values.
The relay should have proper adjustment to cater for the present and the future harmonic profile which differ in various areas and is shown as below in table 2

TABLE 2: Actual percentage of individual harmonics present in the traction current as measured during 1990-1992 at various zonal railways

Zone	Eastern		Northern		Central		Southern		Western		All India
Harmonic	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	Average
$_3$rd	18	18	19	17	19	17	19	19	18	18	20
$_5$th	8	8	9	7	9	8	9	9	9	9	10
$_7$th	4	4	5	4	6	5	8	7	5	5	8
$_9$th	3	2	3	3	4	3	4	3	4	4	4
11th	2	2	3	3	-	-	2	2	3	2	3

A - Load current range 200-300 Amps.
B - Load current range 300-400 Amps.

~~3.2.3~~ The average power factor of the electric locomotive and electric multiple units generally varies between 0.7 and 0.8 lagging, without compensation.

3.3 Short circuit apparent power of the system

~~3.3.1~~ The short- circuit apparent power for various system voltages is as under: -

Table No. 3: Short Circuit Level

Highest system voltage Kv	**Short circuit apparent power MVA**
52	200
72.5	3500
123	6000
145	10000
245	20000

3.4 Power supplies at traction substation

~~3.4.1~~ The following power supplies are available at a traction substation.

i. 110 V +15/- 30% dc from a battery.
ii. 240Vac,50Hz, single phase from a 25/0.24 kV auxiliary transformer.

3.5 Booster Transformers

~~3.5.1~~ In order to reduce inductive interference in adjacent telecommunication circuits booster transformers on certain sections of electrified track are installed in series with the 25 kV traction overhead equipment. The primary winding of the booster transformer is connected to the 25 kV overhead equipment and the secondary winding is in series with the return conductor (RC) which is strung close to the 25 kV overhead equipment. Booster transformer with a rating of 150 or 100 kVA provide necessary voltage to force the traction return current from the rail and earth to flow through the

return conductor. The Booster transformers have a leakage impedance of about 0.15 Ohm each and are spaced about 2.66 km apart.

3.6 Protective relays at the traction sub-stations

~~3.6.1~~ For protection of transformer, substation equipment's, shunt capacitor bank feeders, the following relays are provided on control panels housed in the masonry cubicle at the traction substation (TSS).

3.6.1.1 Transformer Protection

i. Differential relay
ii. IDMT over-current relays for the primary (HV) as well as for the secondary (LV) side. The IDMT relay on the HV side is also provided with an instantaneous over-current element.
iii. Instantaneous earth leakage relays on the primary (HV) side as well as on the secondary (LV) side.
iv. High speed inter-tripping relay.
v. Auxiliary relays for transformer faults i.e. Bucholz, excessive winding and oil temperature trip and alarm and low oil level alarm.

3.6.1.2 **Overhead equipment protection**

i. Polygonal type distance protection relay.
ii. Protection against wrong phase coupling.
iii. Instantaneous over-current relay.
iv. Delta –I type fault selective relay.
v. Panto flash over protection relay.

3.6.1.3 **Shunt Capacitor Bank Protection.**

i. IDMT over-current protection relay with suitable settings.
ii. Over voltage protection relay.
iii. Under voltage protection relay with timer to enable the capacitors to discharge before re-closure.
iv. Current unbalance protection.
v. Internal fuse for each capacitor element.

3.7 Auto-re-closing of feeder circuit breakers.

~~3.7.1~~ A single shot high speed auto-re-closing scheme for 25 kV feeder circuit breaker(s) at AC traction sub-station has been adopted to facilitate re-closing of the 25 kV feeder breaker automatically once after a pre-set time delay after tripping of the circuit breaker on OHE fault. This feature will help in quick restoration of traction power supply to OHE if the fault is of a transient nature. It will also help in checking/restricting the continuance of arc in the event of the pantograph of a moving locomotive passing the overlap opposite feeding post at such moments and thus protecting the OHE, catenary in particular, from consequent damages.

3.8 Inter tripping of feeder circuit breakers.

~~3.8.1~~ In the event of failure of a traction substation 25 kV supply is extended from the adjacent substations by closing the bridging interrupters at SPs. Under such emergency feed conditions, wrong phase coupling may be caused at the overlap opposite the failed substation by the pantograph of a passing locomotive, resulting in the tripping of 25 kV feeder breaker at any one of the two substations through wrong phase coupling relay. The Feeder Breaker at the other substation also should trip with DP or OCR

simultaneously to reduce the damage due to arc on WPC. Proper relay settings shall be done considering this case also.

~~3.8.2~~ For the purpose of calculation, the values of loop impedance with earth return for the OHE are taken as under:

TABLE 4 OHE Line Impedance

1.	One OHE without BT and RC	$0.41\angle 70^\circ$ Ohms./km
2.	Two OHEs without BT and RC	$0.24\angle 70^\circ$ Ohms./km
3.	One OHE with BT and RC	$0.70\angle 70^\circ$ Ohms./km
4.	Two OHEs with BT and RC	$0.43\angle 70^\circ$ Ohms./km

3.9 Traction Power Transformer

The percentage impedance of a 21.6 MVA, 220 or 132 or 110 or 66/27 kV single phase transformer is 12%. The traction transformers are designed to carry short time overloads as the traction loads may exceed 21.6 MVA for short periods. The impedance angle for the loads at the traction substation is nearly 37^0.

3.10 Nature of faults on the overhead equipment (OHE) system.

~~3.10.1~~ OHE is subjected to frequent earth faults caused by failure of insulation, or by the OHE snapping and touching the rail or earth, or by a piece of wire dropped by birds connecting the OHE to earthed overlying structures, miscreant activities etc. These faults are cleared by the feeder circuit-breaker which operates on any one or more of the following relays:

i. Distance protection relay.
ii. Instantaneous over-current relay.

4.0 SERVICE CONDITIONS

4.1 The relays are intended for use in moist tropical climate with the following atmospheric conditions:

TABLE 5 Service Conditions

1.	Max. temperature of air	70°C
2.	Min. temperature of air	-25°C
3.	Max. temperature attainable by an Object exposed to Sun	70°C
4.	Max. and Min. relative humidity	100% & 22%
5.	Max. wind pressure	200 kg/sq.m.
6.	Altitude	2000m
7.	Average annual rain fall.	1750 to 6250 mm.
8.	Number of thunderstorm days per annum.	85 days.
9.	No. of rainy days per annum	120 days (Max.)
10.	Average No. of dust storm days	35 days per annum.
11.	Vibrations	Max: 350 microns Average: 30 – 150 microns

		time duration: rapidly varying time duration 15 - 70 ms..

4.2 The relays shall be installed in the control and relay panel at the traction substations which are normally unattended. The panels are situated close to the Railway tracks and hence the Panels are subjected to vibrations due to running trains.

5.0 DESIGN FEATURES

5.1 CONSTRUCTIONAL FEATURES

~~**5.1.1**~~ The relays shall be of the draw-out (Plug-in), switch board type, back-connected and suitable for semi-flush or flush mounting, with dust-tight covers. The enclosure class of module/relays shall be IP 54 as per IEC 60529. The measuring technique adopted should be based on digital numeric processing techniques. The analogue input received from CT and PT shall be transformed into a digital signal by using suitable A/D converter. The digital signal so obtained may be processed (with suitable signal analysis) to extract the various harmonic contents.

~~**5.1.2**~~ According to clause 1.6, the Testing Jack/ Test Switch shall be available in the Control & Relay Panel. The relay shall take care of the "Testing Jack" provided in the Control & Relay Panel for testing the relay with the help of testing kit connected through Testing Jack without removing the relay from the panel and without disconnecting the connection of CT, PT etc. manually. The communication port shall be available in testing jack for connecting the relay test kit. The relay should be compatible with the testing jack / Test Switch provided in the panel. This aspect should be considered in designing the relay back panel so that all the available necessary interfaces are meeting the requirement of Testing Jack without compromising the safety while testing through latest Relay Test Kit.

~~**5.1.3**~~ The numerical relays shall have in-built contact multiplication relays for alarm and trip conditions of CB. It shall be ensured that at least two (02) numbers of auxiliary contacts for indication/annunciation and tele-signalling functions are available.

~~**5.1.4**~~ The CT inside relay shall be rated for 5 amps and capable of withstanding $3I_n$ continuously and short time rating shall be $40I_n$ for 1 sec. where I_n is rated current. The PT shall be rated for 110V AC and capable to withstand 1.15 times of rated voltage continuously and 1.5 times for 3 seconds.

~~**5.1.5**~~ The relays shall conform to the test voltage Class -III as per IS: 8686–1977/IS 3231 or latest and product safety requirements as per IEC:60255-27.

~~**5.1.6**~~ The relays shall be designed for continuous service (auxiliary supply) voltage of 110 V DC and shall be capable of satisfactory operation for +15 % and - 30 % fluctuation in voltage.

~~**5.1.7**~~ The relays shall have name plates with rating data, serial number and manufacturer's name marked on them. The metal case shall be provided with separate earthing terminals.

~~**5.1.8**~~ The relays shall be immune to distorted power frequency waveforms. caused by the harmonics, phase shifts and transient faults and work on the principle of fundamental waveform extraction. The relays shall be immune to electro-magnetic interference and comply with IEC tests as mentioned in clause 9.2.1 (xiv). The relay manufacturer shall study the effect of harmonics present in the existing Railway traction supply system and its effect on the relay pick up values & operating time of the relay and suitable methodology shall be adopted to eliminate the effect of harmonics.

~~5.1.9~~ The relays shall be insensitive to power swings, permissible overloads and transient condition including magnetizing inrush current of locomotive transformers and shall be suitably designed to compensate the effect of fault arc resistance.

~~5.1.10~~ The numerical protection relays should have facility to record actual waveform of current and voltage along with all digital and logical status during fault condition. At a time up to 200 such waveforms. for currents & voltage shall be storable and shall be retrievable through USB communication port /or any other superior type of standard communication port through a Laptop computer. The duration of each disturbance record for current and voltage shall be at least 50 cycles (45 prior to and 5 after trip executed by relay). The disturbance recorder shall be triggered, on every trip operation of relay.

~~5.1.11~~ Suitable software shall be supplied along with the numerical relays to download and interpret the fault waveform and other data stored in the relays. The software shall be capable of analysing the peak, RMS. and average values of currents and voltage, dc component of currents, harmonic analysis of fault current waveforms. The accuracy of measurements shall be 1ms. for time, 0.1 KV for voltages and 0.1 KA for currents. The software shall also be capable of communicating with the relay and viewing and modifying the settings.

~~5.1.12~~ The numerical relay manufacturers shall provide full support for up gradation of the software time to time to maintain the satisfactory performance throughout the useful life of the relay. The software should run on one of the current operating systems.

~~5.1.13~~ The numerical relays shall provide date and time stamping up to 1ms. level for each fault. Relay shall have facility for clock synchronization through SCADA or any other similar synchronization facility like GPS etc. if available in future.

~~5.1.14~~ The numerical relays shall be capable of storing minimum 5000 events serially with date and time stamp of 1ms. accuracy. The events definitions shall be configurable and generally include tripping of different protection elements, relay pickup, relay reset, relay blocked due to harmonics or any other restraints, CB trip, CB close, changed of status input, relay setting changed, trip circuit monitoring etc. The events shall be retrievable through an external laptop/PC.

~~5.1.15~~ Operation counters shall be provided for each protection function with resetting facility.

~~5.1.16~~ The numerical relays shall have compact farm and every effort shall be made to minimize the hardwiring within the relays and maximum components shall be on the PCBs. Effort shall be made to implement SMT (Surface Mount Technology) PCBs wherever possible. Suitable conformal coating to be provided on the PCBs.

~~5.1.17~~ The design shall be fail-safe and while designing the numerical relays, adequate redundancy shall be provided in various functional elements.

~~5.1.18~~ The numerical protection relays shall have self-diagnostic features. Suitable displays for confirming the module healthiness or defects shall be available.

~~5.1.19~~ Numerical relays shall have high contrast backlit LCD display of size at least 20x4 LCD characters for display of relay status, settings, on line parameter current, voltage, resistance & reactance) etc. Bright LEDs shall be used for display of power ON conditions and trip/alarm indications of each relay element. The parameters of the module shall be settable through a membrane keypad.

~~5.1.20~~ Provision shall be available to reset the indicating LEDs of protection module from relay and from RCC through SCADA. For this purpose, suitable switch and NO/NC contact shall be provided in the module.

~~5.1.21~~ The size of the module shall be suitable for flush mounting design for fitting on existing/new control and relay panels. The actual size shall be decided at the time of design approval.

~~5.1.22~~ The relay settings and stored data shall not get corrupted/erased/changed in the event of auxiliary / control supply voltage i.e. 110 V DC failure.

~~5.1.23~~ SCADA system is available for Railway traction application. For its full utilization in controlling/ monitoring of protection system, numerical relays shall be capable of communicating with the RTU or other IED's based on standard IEC 60870-5-103 protocol for transfer of information stored in relays to the RTU. The relay shall have necessary hardware and firmware interface for this purpose.

~~5.1.24~~ Suitable password protection shall be provided on the relays to avoid unauthorized changes in the relay settings.

~~5.1.25~~ The making & breaking capacity and rated current of output contacts of the relays shall be adequate to operate the associated output relays/circuit breaker. Suitable snubber to be provided across the coil.

~~5.1.26~~ The module shall also be capable to display I (fault current), V(voltage), R(resistance), X(reactance), Phase angle, Delta-I current, fault clearing time and fault date & time (wherever applicable) of latest 200 faults at relay LCD, if it is not possible to display these parameters simultaneously on LCD display, then these parameters may accommodate in two window and displaying by pressing scroll Key . The CT's & PTs provided at TSS may have different ratios, hence to display the actual value (line value) of I, V, R, X etc. the CT primary current shall be settable in the range of 100 to 3000A in the steps of 50A and PT primary voltage shall be settable in the range of 20000V to 30000V in steps of 500V. On line current, voltage, Reactance & Resistance shall also be displayed on relay LCD.

~~5.1.27~~ The complete protection function shall be incorporated in single module. Trip, annunciation & tele-signalling contacts for all the elements viz threshold detection (ΔI) & Polygonal characteristic etc. shall be individually available on the relay for external connection.

~~5.1.28~~ Suitable NO contact of each protection function shall also be available on the relay to start/stop auto reclosure function through status input, the auto reclosure function already provided in other protection module.

~~5.1.29~~ The relay shall be suitable for operation from the 25 kV current transformers and potential transformer of the following particulars:

Current Transformer

	Rated system voltage (phase to ground)	Normal: 25 kV Maximum: 30 kV Minimum: 19 kV
	Rated transformation ratio	1000-500/5 A or 1500-750/5 A or 3000-1500/5A
	Rated burden	60VA
	Rated accuracy limit factor	15
	Class of accuracy	5P class as per IS:2705 (Part III) 1981

Potential Transformer

	Rated system voltage (phase to ground)	Normal: 25 kV Maximum: 30 kV Minimum: 19 kV
	Rated transformation ratio	25000/110V
	Rated burden	100VA
	Rated accuracy limit factor	15

	Class of accuracy	1.0 as per IS:3156 (Part II) & 3P as per IS:3156 (Part III)-1992

~~5.1.30~~ The relays shall generally conform to following standards.

	Dielectric Withstand	2kv, 50 Hz for 1 min between circuit to earth/circuit to circuit (IEC 60255-5, IS: 3231, IS: 12083 (Part II)
	Impulse voltage test	5 kV, 1.2/50 micro seconds (IS: 8686/ IS: 3231/IEC-60255-5, IS: 12083 (Part II)
	High frequency disturbance	IEC 60255-5, IS: 3231 Part-I section-III Longitudinal mode 2.5kV, 1 MHz across auxiliary dc and current/voltage sensing terminals an earth. Transverse mode 1 kV, 1 MHz across auxiliary dc and current/voltage sensing terminals.
	Contact data	IS: 3231 part-I , IS : 12083 part-I
	Current carrying capacity	5 Amps Continuously at 110 V DC/ 230 V AC
	Making & carry	30 A at 250 ac, 50 Hz for 3 seconds
	Breaking: 220V, 50-60Hz-Cos Ø 0.4 220 Vdc, L/R=45 millisecond	 5A 0.5A
	Auxiliary power consumption at 110 Vdc	<15 W – De-energised <30 W - Energised

5.2 Protection function, working Principle and settable parameters

The relay shall have following characteristics

i. Threshold Detection of Vectoral difference of current from suitable base characteristics (ΔI)
ii. Polygonal characteristic with load blinding

~~5.2.1~~ Threshold Detection of Vector difference of current from suitable base Characteristic (ΔI)

~~5.2.2~~ The relay monitors vector difference between base load current and fault current. The vector difference shall be calculated in such a manner to ensure detection of high resistance faults even if fault is not detected in current samples the same shall be detected in next sample. The time difference between base load current sample and fault current sample to calculate vector difference shall be settable in the range of 20ms. to 200ms. in steps of 5ms.. The Vector Delta-I current shall be settable in the range of 0.1A to 6A in the steps of 0.1 Amp. Vendor to give details of detection process and how the design assures resilience and improves probability of detection of a fault.

5.2.2.1 To calculate vector current difference, relay calculates current vector and save it in to a circular buffer after every 5ms., the length of memory buffer should be at least 200ms.. The relay calculates scalar and vector difference between instantaneous vector and earlier vector (as per time set on the relay). If scalar difference is positive and vector difference is more than set Delta-I current then relay start tripping timer. When tripping timer start, relay should stop base vector updating. During set operating time delay if vector difference remains more than set Delta-I current relay execute trip command.

5.2.2.2 The relay should provide a prevention circuit for unnecessary operation by the inrush current of power transformer and due to starting of multiple numbers of electric locomotives in the section. The inrush currents of power transformers contain significantly high 2nd harmonics currents. If the 2nd order harmonic component is more than set value, the relay should block tripping, thus preventing unnecessary operation of the relay. The value of second harmonic percentage to block relay trip command shall be settable from 5% to 20% in steps of 1% of the fundamental components.

5.2.2.3 The relay should operate by Vector delta-I current threshold set if 3rd harmonic components are less than set value. The relay sensitivity should restrain according to the de-sensitivity setting when Vector delta I current include 3rd harmonic components more than set limit. The value of 3rd harmonic percentage to restrain according to de-sensitivity setting shall be settable from 5% to 30% in steps of 1% of the fundamental components. If 3rd harmonic component in the current more than set 3rd harmonic percentage then relay operating value shall be automatically increased as given below. Operating value of vector Delta-I current

= [(Set Vector Delta-I current * % De-sensitivity setting)/(100) + (Set Vector

De-sensitivity setting shall be settable from 0% to 100% in steps of 10%.

5.2.2.4 The normal operating time of relays in no case shall be more than 80 ms. Additional time delays from 0 to 800 ms.. settable in steps of 10 ms. shall be provided to the relay.

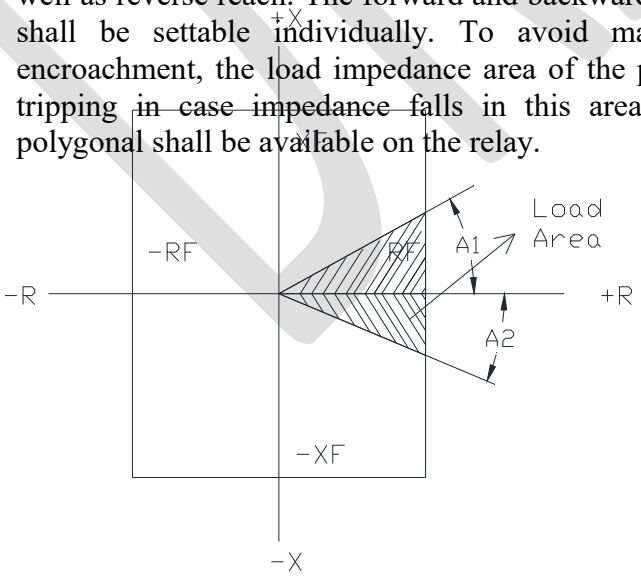
5.2.2.5 The relay shall continuously sense the status of feeder protection relay through the MTR status and give trip command to the breaker only when these relays have failed to clear the fault.

5.2.2.6 The operating value error of the relay shall not be more than ± 5 %.

5.2.2.7 Delta-I relay shall have also a feature to detect the rate of change of impedance. If tripping needed based on the rate of change of impedance may be finalized during design drawing approval by RDSO and manufacturer. The rate of change of impedance and operating time shall be settable in suitable steps.

~~5.2.3~~ Polygonal (on R-X plane) characteristic

5.2.3.1 Characteristic shall be polygonal on R-X plane characteristics having forward as well as reverse reach. The forward and backward Resistance (R) and Reactance (X) shall be settable individually. To avoid malfunction of relay due to load encroachment, the load impedance area of the polygonal shall be settable for non tripping ~~in case impedance falls~~ in this area. The following setting range of polygonal shall be available on the relay.



Setting	Range and steps
Forward Resistance (RF)	0.04 – 99.99 Ω in steps of 0.01 Ω
Backward Resistance (RB)	0.04 – 99.99 Ω in steps of 0.01 Ω
Forward Reactance (XF)	0.04 – 99.99 Ω in steps of 0.01 Ω
Backward Reactance (XB)	0.04 – 99.99 Ω in steps of 0.01 Ω
Angle (A1)	00 – 70 deg in steps of 1 deg
Angle (A2)	00 – 70 deg in steps of 1 deg
Zmin	00 – 99.99 Ω in steps of 0.01 Ω

5.2.3.2 The normal operating time of relay shall be 30 ± 10 ms. Additional time delay shall be settable in the range from 00 to 1000 ms. in steps of 20 ms.

5.2.3.3 The relay shall be blocked for operation in case 2nd harmonic component in current exceeds more than set value. The percentage of second harmonic for block the operation shall be settable from 10 to 20 % in steps of 1%.

5.2.3.4 Relay shall have local breaker backup protection (LBB) feature for threshold Detection of Vector difference Characteristic (ΔI) and Polygonal characteristic; the relay shall continuously monitor the status of closing of the feeder CB. In case the feeder CB is not tripped after a pre-set time interval settable in the range of 0 to 1000 ms., in steps of 10 ms. after initiating the trip command then another trip command shall be executed to trip upstream breaker.

5.2.3.5 The operating value error of the relay shall not be more than ± 5 % including for voltage input to the relay from 125 volts down to 0.5 Volts and current 0.5A to 100A, the frequency variations of 48 to 52 Hz and the ambient temperature variation over the range -25 ^{O}C to + 70 ^{O}C.

5.2.3.6 The relay shall have settable minimum operating current. If current less than set value of minimum operating current then relay should not execute trip command even though impedance measured by relay fall inside set polygonal on R-X plane characteristic. Minimum operating Current shall be settable in the range of 0 to 1Amp in the steps of 0.1 Amp.

5.2.3.7 The relay shall discriminate correctly the faults on the event of voltage input to the relay falling down to 0 V. The polarizing signal shall be derived from sufficient samples of the pre-fault voltage held in memory.

6.0 TESTS

6.1 General

~~6.1.1~~ Only after all the design and drawings have been approved and clearance given by Research Design and Standards Organization (RDSO)/Chief Electrical Engineer (CEE) to this effect, the manufacturer shall take up manufacture of the prototype unit for RDSO inspection. It is to be clearly understood that any changes required to be done in the prototype unit shall be done expeditiously.

~~6.1.2~~ Before giving the call to RDSO/CEE for inspection and testing of the prototype of the equipment, the manufacturer shall submit a detailed test schedule consisting of

schematic circuit diagrams. for each of the tests and nature of the test, venue of the test and the duration of the test and the total number of the days required to complete the tests at one stretch.

~~6.1.3~~ Once schedule is approved, the tests shall be done accordingly. However, during the process of type testing or even later, RDSO representative reserves the right to conduct any additional test(s) besides those specified therein, on any equipment/sub-system or system so as to test the equipment to his satisfaction or for gaining additional information and knowledge. In case of dispute or any disagreement arises between the manufacturer and RDSO/CEE during the process of testing as regards the type test results, it shall be brought to the notice of the Director General (Traction Installation), RDSO/ CEE as the case may be, whose decision shall be final and binding.

~~6.1.4~~ In the event of the tests not being carried through to completion at one stretch for any reason attributable to the successful tenderer/ manufacturer and it is required for the representative of the purchaser/ Director General (Traction Installation), Research Designs And Standards Organisation, Lucknow, to go again or more number of times to the works of the successful tenderer/ manufacturer or other place(s) for continuing and/or completing the test on the prototype(s) of the equipment, the successful tenderer/ manufacturer shall reimburse to the purchaser/ Director General (Traction Installation), Research Designs & Standards Organisation, Lucknow, the cost of the representative having to visit the works or other place(s) for the test more than once. The cost as claimed by the purchaser/ Director General (Traction Installations), Research Designs & Standards Organization, Lucknow shall be paid through demand draft to the concerned accounts officer of the Purchase/Director General (Traction Installation), Research Designs & Standards Organization, Lucknow, shall be advised to the successful tenderer manufacturer.

~~6.1.5~~ All type routine tests relevant to Vector Delta I type fault selective relays shall be conducted as per the latest version of IEC-255-3, IEC-255-5, IEC-255-6, IS-3231 and IS: 8686 and as modified or amplified as under:

7.0 TYPE & ROUTINE TESTS ON PROTECTION RELAYS

~~7.1.1~~ Type Tests

The protection relays covered by this specification shall be type tested as per IS:3231, IS: 12083 IS:8686, IEC 61000 & IEC: 60255. The following type tests shall be carried out on the prototype relays by RDSO.

i. Operating characteristics tests including verification of all relay functions/features including operating time reset time, operating and reset value.
ii. Insulation resistance test- should be 10 mega ohm or more between the electric circuit and earth with 1000 V.
iii. Measurement of burden (VA).
iv. Measurement of power consumption (watts).
v. Over load test.
vi. Impulse voltage withstand test applicable to test voltage class III.
vii. Temperature rise test.
viii. Effect of DC voltage variation (110 V DC +15 % / -30 %).
ix. Making and breaking capacity tests of contacts.
x. Dielectric test.
xi. Vibration test- as per IEC 60255-21-1, Clause-I- Frequency 10-150 Hz,
xii. Endurance test-Mechanical endurance test for 10000 operations.
xiii. Environmental test

a. Dry heat test as per IEC 60255-1/IEC60068-2-2 (This will test from +20 to +70 ^{0}C)
b. Cold test as per IEC60255-1/IEC60068-2-1 (This will test from -25 to 25^{0}C)
c. Change in temperature as per IEC60255-1/IEC60068-2-14 Nb (this will test from -25 to +55 ^{O}C)
d. Damp heat test, steady state as per IEC 60068-2-78
e. Damp heat test, cyclic as per IEC 60068-2-30

xiv. EM Compatibility tests

a. 1 MHz burst immunity test as per IEC60255-26 & IEC61000-4-18 :Common Mode : 2.5kV Differential mode : 1kV Duration : 2 sec
b. Electrostatic Discharge Test as per IEC60255-26 & IEC61000-4-2 Contact Discharge 6kV, Air Discharge 8kV.
c. Radiated, radio-frequency, electromagnetic field immunity test as per IEC60255-26 & IEC61000-4-3Frequency Range: 80MHz – 1000MHz, Modulation: 80% AM @1kHz, Field Strength 10V/m.
d. Electrical fast Transient or burst requirements as per IEC60255-26 & IEC61000-4-4.
e. Surge immunity as per IEC60255-26 & IEC61000-4-5.
f. Immunity to Conducted disturbances induces by radio frequency field as per IEC60255-26& IEC61000-4-6.
g. Power Frequency Immunity Test as per IEC60255-26& IEC61000-4-16.
h. A.C. ripples in D.C. auxiliary as per IEC60255-26 & IEC61000-4-17.

~~7.1.2~~ Type tests for which facilities of testing are not available with the relay manufacturer shall be carried out at any reputed & NABL accredited govt/ semi govt. approved laboratories and test reports of the same shall be furnished to the RDSO.

~~7.1.3~~ Only after approval of the results of the tests on the prototype is communicated by RDSO/Purchaser to the manufacturer, shall he take up bulk manufacture and future supplies of the relays which shall be strictly with the same material and process as adopted for the prototype. In no circumstances material other than those approved in the design/drawings and/or the prototype shall be used for bulk manufacture.

~~7.1.4~~ Routine tests

The following tests on the protection relays shall be carried out during routine tests by Railways/ inspecting agencies at the manufacturer's works as per this specification.

i. Visual Checks
ii. Insulation Resistance
iii. Dielectric strength
iv. Setting range and Functional tests

:

8.0 RATING PLATE

8.1 The rating plate shall contain the following information:

1. Name and Type
2. Rated current
3. Rated frequency.
4. Rated control voltage
5. Year and month of manufacture

6. Manufacture number
7. Name or abbreviation of manufacturer.

9.0 ERECTION AND COMMISSIONING TESTS

9.1 The erection and commissioning of relay shall be done by the successful tenderer who shall **arrange** all tools, plants, instruments and other material required for the purpose at his own cost. Tests shall be carried out during erection/commissioning of the relay at the site. The successful tenderer shall be required to submit to the purchaser the details of the checks and tests to be carried out during erection and commissioning. Tests shall be carried out on the relay in the presence of the purchaser's representatives to check the erection and commissioning of the relay.

9.2 Three sets of the test report shall be supplied by the manufacturer to the purchaser for records and reference.

9.3 On satisfactory commissioning of the relay the tenderer shall advise RDSO also regarding the commissioning of all such relays during the field validation period.

10.0 TECHNICAL DATA AND DRAWINGS

10.1 The tenderer shall furnish guaranteed performance data, technical and other particulars for the equipment offered in the proforma attached as Annexure-4.

10.2 The tenderer shall furnish their compliance or otherwise against each clause/sub-clause of the technical specification. If the tenderer wishes to deviate from the provision of any clause/sub -clause, he shall furnish the full details with justification for such deviation.

10.3 The tenderer shall also furnish descriptive pamphlets and specimen calculations for the recommended relay setting. The range of setting available, calibrated in terms. of single track OHE, shall be clearly stated and adjustments available for intermediate setting explained.

10.4 Successful tenderer shall be required to submit detailed outline dimensioned drawings and cut out drawings for the equipment offered as per railways standard in sizes of 210 mm x 297 mm or any integral multiple thereof.

11.0 OPERATION, MAINTENANCE INSTRUCTIONS & TRAINING

11.1 The relay shall be a maintenance free relay generally not needing any maintenance; however, the tenderer shall mention a maintenance schedule which shall be detailed enough to guarantee failure free service of the relay to the tenderer. The supplier shall supply free of cost 2 copies to the consignee of the Instruction Manuals for operation and maintenance of the equipment. The manuals shall contain full particulars of various functions, full dimensioned drawings and circuit diagrams..

11.2 The tenderer shall train free of cost 2 of the associated engineers/supervisors for 7 days in the maintenance, operation, relay setting procedure, trouble shooting and commissioning of the relay. This training shall be 3 days at manufacturer works and four days at the relay installation site.

11.3 The tenderer shall quote separately for maintenance tool, kits and test instruments if any required for satisfactory operation of the relay . The tenderer shall quote for spares required for the relay for 5 years of trouble free operation beyond the warranty period. The purchaser reserves the right to buy the kit from the tenderer or not.

11.4 The Successful tenderer shall develop a maintenance schedule and a trouble shooting chart for effective, reliable and trouble-free relay operation. The basic maintenance schedule along with the troubleshooting, diagnostic chart shall be submitted to RDSO and approved by RDSO prior to commissioning of the relay for the first time at the site.

11.5 All correspondence regarding the relay during the limited use period (i.e. the till the field validation is completed) between the zonal railways the manufacturer shall be given to RDSO for judging the extent of problems. on the relay.

12.0 All the provisions contained in RDSO's ISO procedures laid down in document No.QO-D-8.1-2 dated 06.02.2020 (Titled "Vendor change 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".

ANNEXURE 1

LIST OF ABBREVIATIONS

Abbreviation	Full Form of the Abbreviation
	NO
A	OHE
BT	RC
GTO	SP
IDMT	SR
IOL	SSP
LCD	TrD
LED	TRS
MSG	TSS
MTBF	
NC	

	Light emitting diode
Amperes	Maintenance Study Group.
Booster Transformer	Mean Time Between Failure
	Normally closed.
Gate Turn Off Thyristors	Normally open
	Over Head Equipment
Inverse Definite Minimum Time lag	Return Conductors.
	Sectioning Post
	Self Reset
Insulated Overlap	Sub Sectioning Post
Liquid crystal diode	Traction Distribution
	Traction Rolling stock
	Traction Sub Stations

ANNEXURE 2
DEFINITIONS AND EXPLANIATIONS

Item	Definition
Tenderer	The vendor , supplier who intends to quote for the tender floated by the purchaser. The agency who shall quote for tender floated by the tenderer.
Purchaser	The person / agency who has floated the tender for execution of the work on or behalf of the president of India.
Relay	Vector Delta I relay
Delta I current	In fluctuating current, delta I current is the portion of current which increases .
Vector Delta I current	It is vector difference between base load current and the fault current.
Base current	In fluctuating current, the base current is the current value immediately preceding the increase.
Second harmonic lock	Second harmonic lock is the locking operation of the relay when the second harmonic components become large
Operation time	Period of time from a fault occurs till the output- contact of the relay closes.
Third harmonic suppression	Third harmonic suppression is the suppression of the sensitivity of the relay by third harmonic components
Making capacity	The maximum current and volt -amperes the contact is able to make successfully under specified conditions without significant damage to the contact.
Breaking capacity	The maximum current and volt - amperes that the contact is able to interrupt successfully under specified conditions without significant damage to contact.
Normally open contact (NO)	A contact which is open when the relay is de-energised.
Normally closed contact (NC)	A contact which is closed when the relay is de-energised.
Contract	Means the contract resulting from the acceptance by the purchaser of the tender either in whole or part
Equipment	Means all or any equipment considered necessary by the purchaser engineers for the satisfactory operation as a whole of the installation including structure, foundations etc.
Railway	Means Railway(s) in whose territorial jurisdiction the work is to be carried out and includes the Government of India, Ministry of Railways (Railway Board), and /or general manager of the railways concerned

ANNEXURE 3

GOVERNING SPECIFICATIONS

The Delta I relays and components thereof shall , unless otherwise specified shall conform to generally to the latest edition of Specifications mentioned below:

IEC 255-151	Single input energising quantity measuring relays with dependent or independent time. independent time
IEC 255-27	Insulation tests for electrical relays
IEC 255-1	Measuring relays and protection equipment.
IS-2705 (Pt.III)	Protective current transformers
IS 3231	Electrical relays for power system protection
IS 8686	Static protective relays
RDSO spec ETI/PSI/65(1/97)	Control and relay panel for 25 kV ac traction system.
IS 3156	Protective Potential Transformer

The above specifications shall be applied in a manner altered, amended or supplemented by this specification and the latest Indian Electricity Rules wherever applicable.

Any deviations from the specifications proposed by the tenderer at the tender/prototype stage, to improve the performance, utility or efficiency of the equipment shall be given due consideration provided full details of the deviation are furnished by the tenderer to the satisfaction of the purchaser. In such cases the tenderer shall quote according to the specification as well as with the deviations from the specifications.

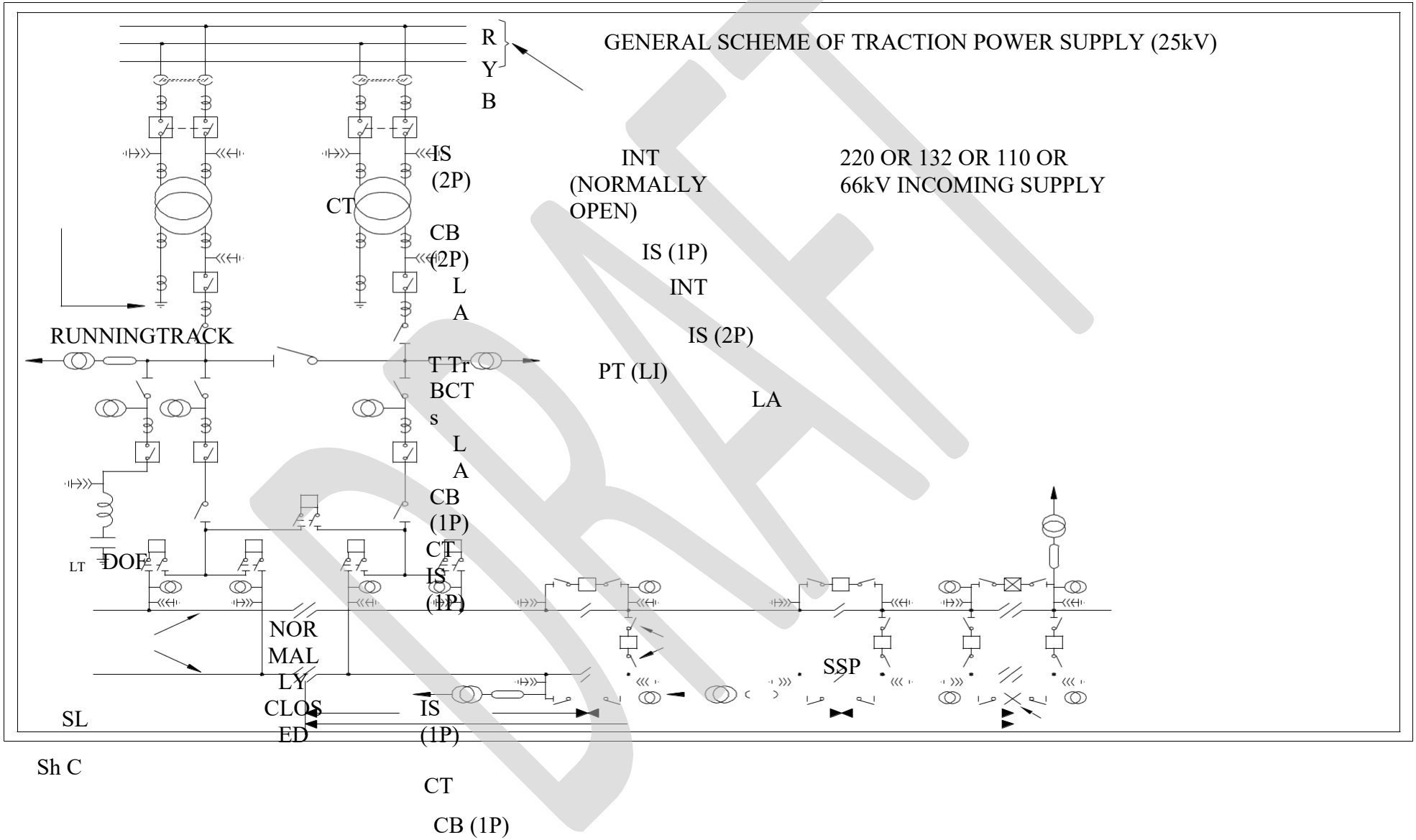
ANNEXURE 4

SCHEDULE OF GURANTEED PERFORMANCE

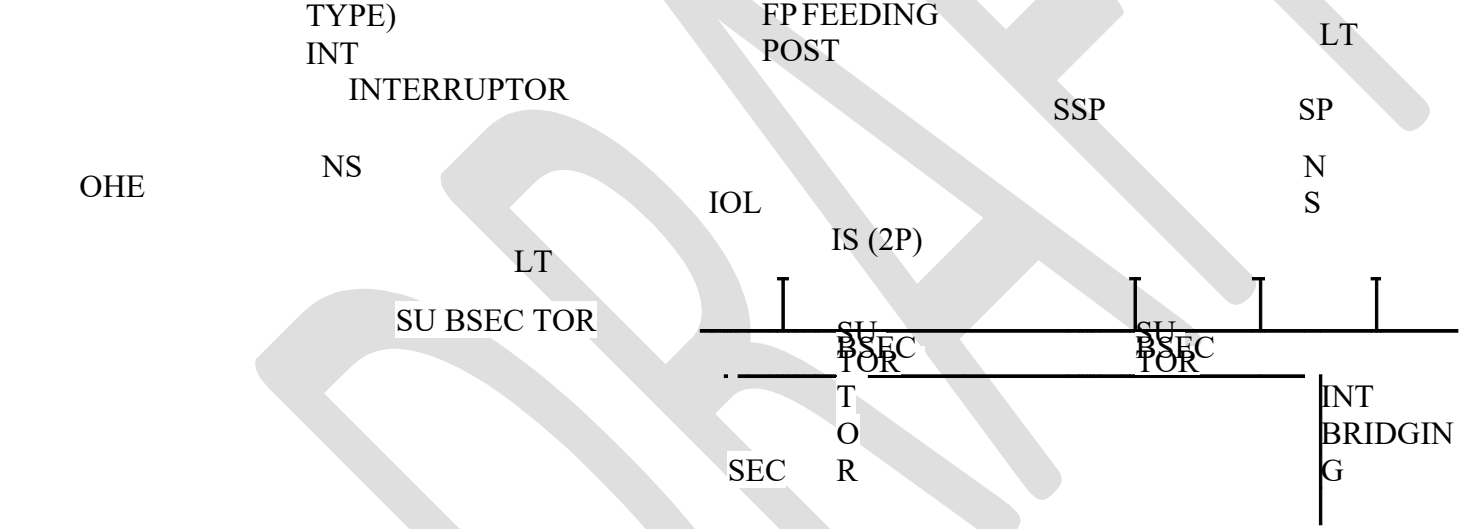
S.No.	Description	Manufacturer details	Unit of measurement
1	Name of the manufacturer		
2	Country of origin		
3	Standard governing specification		
4	Manufacturer's type designation		
5	Rated current		Amps
6	Setting range		Amps
7	Rated frequency		Hz
8	Permissible variation in frequency		%
9	X Blinder setting range		ohm
10	Error in X blinder setting		%
11	Rated short time current for 1 sec.		Amps
12	Rated dynamic current		Amps
13	Operating time (a) Normal		milli-sec
14	(b) With timer		milli-sec
15	Rated VA burden		VA
16	Power consumption of control circuit		Watts
17	Maximum percentage error		%
18	Maximum arc resistance that the relay can identify		Ohm
19	Resetting time		milli-sec
20	Rated current carrying capacity of contacts		Amps
21	Rated breaking capacity of contact		Amps
22	Rated making capacity of contact		Amps
23	Number of spare No and NC contacts		
24	Temperature rise at rated current		O C
25	Is the relay draw out type?	Yes/No	
26	Are test terminals/test switches provided?	Yes/No.	
27	Have specimen calculations for the recommended relay setting been enclosed with the offer ?	Yes/No.	
28	Rated making & breaking capacity of contacts		Amps
29	Rated D.C. voltage variation range for which relay operation is guaranteed		Volts
30	Rated relay voltage for the D.C. circuit		Volts

31	Rated relay current for the D.C. circuit		Amps
32	Number of spare No and NC contacts		
33	Are test terminals /test switches provided?	Yes/No.	
34	Have specimen calculations for the recommended relay setting been enclosed with the offer?	Yes/No.	
35	Dimensions:		
36	Length		mm
37	Width		mm
38	Breadth		mm
39	Weight of the relay		grams.
40	Rated Vibration withstand		microns

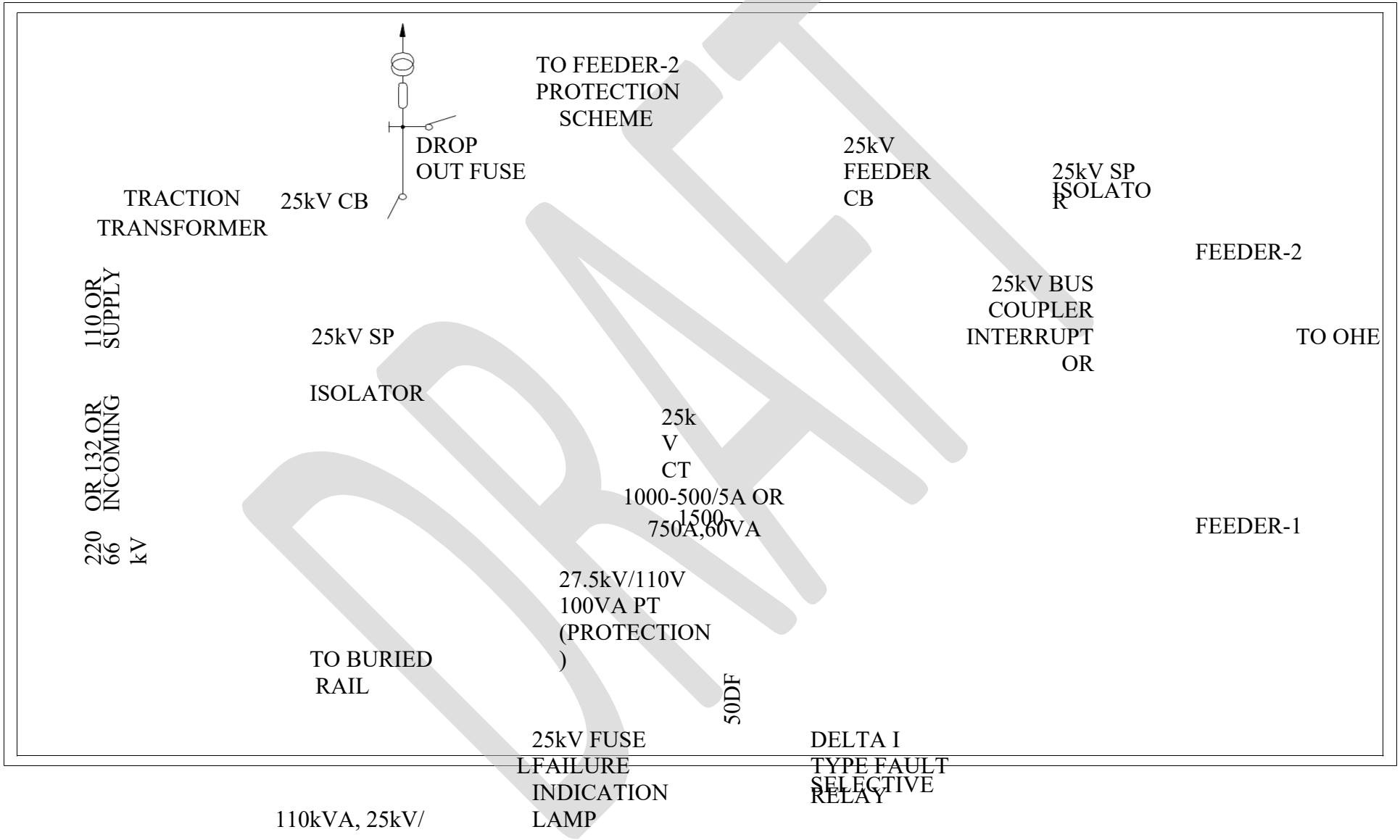
ANNEXURE 5 General Scheme Of Power Supply For 25 Kv AC System

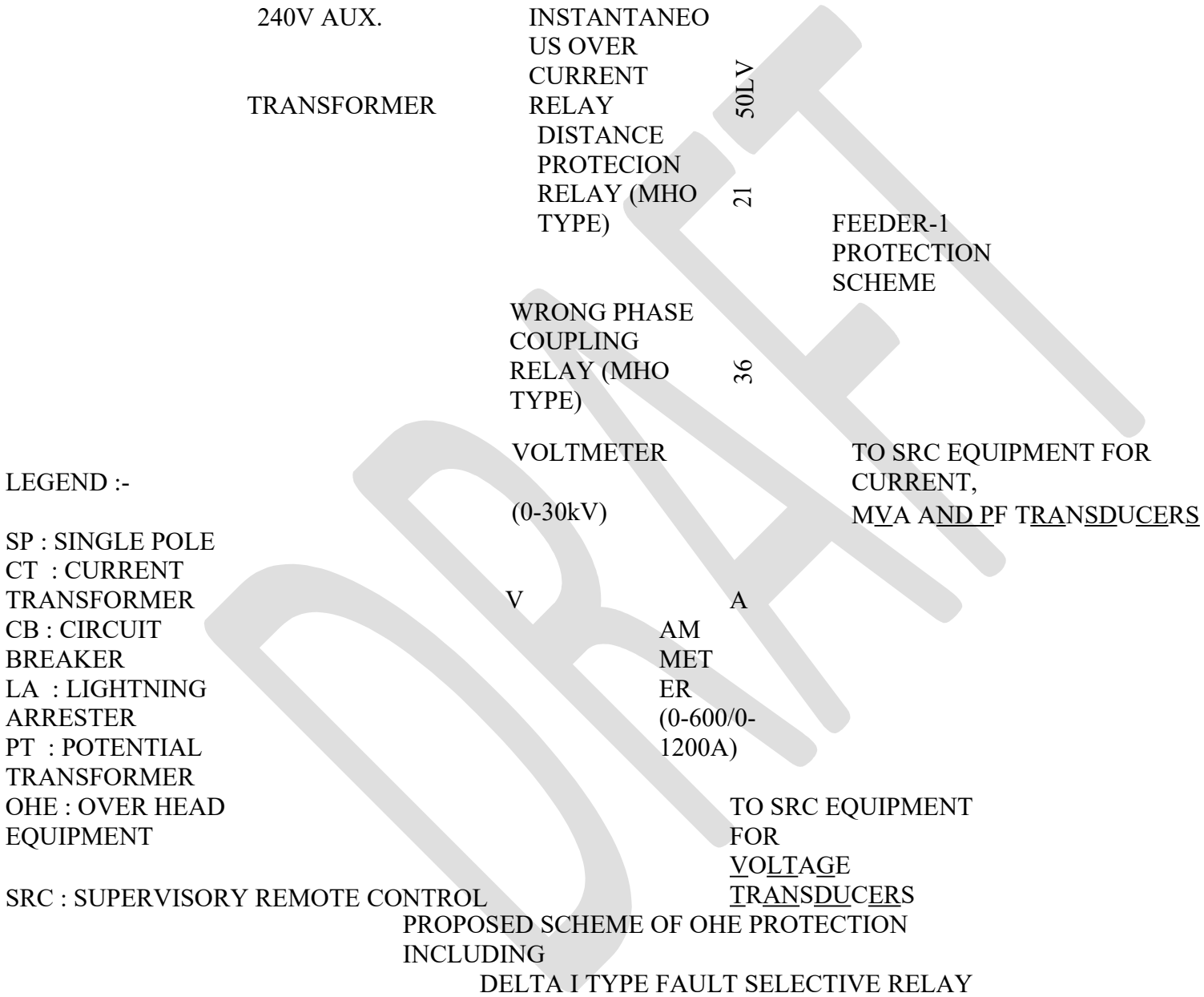


LEGEND :-
IS ISOLATOR
CT CURRENT TRANSFORMER
CB CIRCUIT BREAKER
LA LIGHTNING ARRESTER
BCTs BUSHING CTs
TTr TRACTION TRANSFORMER
PT(P) POTENTIAL TRANSFORMER (PROTECTION TYPE)
PT(LI) POTENTIAL TRANSFORMER (LINE INDICATION TYPE)
INT INTERRUPTOR
LT AUXILIARY TRANSFORMER
ShC SHUNT CAPACITOR
SL SERIES REACTOR
FP FEEDING POST
SSP SUB-SECTIONING & PARALLELING POST
SP SECTIONING & PARALLELING POST
NS NEUTRAL SECTION
IOL INSULATED OVERLAP
DOF DROP OUT FUSE SWITCH
1P SINGLE POLE
2P DOUBLE POLE



ANNEXURE 6 General Scheme Of Protection For 25 Kv AC System




240V AUX.
TRANSFORMER
INSTANTANEOUS OVER CURRENT RELAY
50LV
DISTANCE PROTECION RELAY (MHO TYPE)
21
FEEDER-1 PROTECTION SCHEME
WRONG PHASE COUPLING RELAY (MHO TYPE)
36
VOLTMETER
(0-30kV)
V
A
AMMETER
(0-600/0-1200A)
TO SRC EQUIPMENT FOR CURRENT, MVA AND PF TRANSDUCERS
TO SRC EQUIPMENT FOR VOLTAGE TRANSDUCERS
LEGEND :-
SP : SINGLE POLE
CT : CURRENT TRANSFORMER
CB : CIRCUIT BREAKER
LA : LIGHTNING ARRESTER
PT : POTENTIAL TRANSFORMER
OHE : OVER HEAD EQUIPMENT
SRC : SUPERVISORY REMOTE CONTROL
PROPOSED SCHEME OF OHE PROTECTION INCLUDING
DELTA I TYPE FAULT SELECTIVE RELAY