TRACTION INSTALLATION DIRECTORATE

सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Instruction No. TI/IN/0049

आरडीएसओ विशिष्टता संख्या टीआई/एसपीसी/पीएसआई/पीआरओटीसीटी/1982 A&C स्लिप-1 या विशिष्टता संख्या TI/SPC/PSI/PROTCT/6072 के अनुसार 25 केवी एसी ट्रैक्शन सब-स्टेशन के लिए डेल्टा-I और बैकअप दूरी सुरक्षा रिले के लिए दिशानिर्देश

Setting guidelines for Delta-I and backup distance protection relay provided as per RDSO Specification No. TI/SPC/PSI/PROTCT/1982 with A&C Slip-1 or Specification No. TI/SPC/PSI/PROTCT/6072 for 25 kV AC Traction Sub-station

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1.0 INTRODUCTION

The Delta-I relay was developed as per old RDSO's Specification No. TI/SPC/PSI/PROTCT/1982 with A&C slip No. 1 or RDSO's Specification No. TI/SPC/PSI/PROTCT/6072 includes Delta-I protection as well as a polygonal characteristic backup distance protection relay. In the 32nd MSG meeting held at Secunderabad, it was decided that RDSO shall issue relay setting guidelines for backup Distance Protection relay in tabular form based on the load at TSS. Accordingly, a relay setting guideline for Delta-I relay and backup Distance Protection relay for 25KV AC Traction Sub-station is issued.

This relay setting guideline gives the method of calculation only. For relay setting procedure and other general parameters setting, refer to the operation & commissioning manual of the relay manufacturer.

2.0 RELAYS SETTING GUIDELINE

2.1 Delta-I relay

Delta-I relay element is to be set in the enable mode.

2.1.1 Delta-I Current Setting

The purpose of the Delta-I relay is to detect high-resistive faults and execute trip commands to the feeder Circuit Breaker. The high resistive reach of the Delta-I relay depends on the set value of the Delta-I current. The higher the Delta-I current setting, the lesser the sensitivity of the relay against high resistive faults. Lowering the setting of the Delta-I current will result in spurious tripping due to a sudden rise in the load current above the set Delta-I current. There is also the probability of spurious tripping when the difference in both feeder CB load currents is high and the electric locomotive bridges the TSS IOL, resulting in a sudden rise in the load current of lightly loaded Feeder CB.

To calculate the Delta-I current setting, it can be assumed that two numbers of electric locomotives simultaneously entered or switched ON in the feeding zone of TSS. The normal load current of an electric locomotive may be assumed as 150 Amp. If the relay malfunctions frequently due to a sudden rise in load current, the Delta-I current setting may be increased further as per site requirements.

The Delta-I current setting on the relay side shall be calculated by the formula given below.

$$\text{Delta} - \text{I current Setting in Amp}$$

$$= \frac{2 * \text{ Normal Load Current of an Electric Locomotive}}{\text{CT Ratio}}$$

Setting in % of Delta-I current =

$$\frac{\text{Calculated Delta} - \text{I current setting in Amp}}{5} * 100$$

2.1.2 Harmonic De-sensitivity setting (DS)

A harmonic De-sensitivity setting is provided to minimize spurious tripping of Delta-I relay due to sudden rise in load current. The relay monitors 3rd harmonic components of the current. If 3rd harmonic components are more than the set value, the Delta-I relay executes the trip command as per the given below formula.

$$\text{Operating value of Delta I Current}$$

$$= \frac{\text{Set Delta I Current } * \text{ \% Desensitivity setting}}{100} + \text{Set Delta I Current}$$

De-sensitivity setting is to be set at 100%.

2.1.3 3rd Harmonic Setting

3rd Harmonic is to be set at 12%.

2.1.4 2nd Harmonic Setting

2nd Harmonic setting is provided to avoid spurious tripping of Delta-I relay due to inrush current caused by switching ON multiple electric locomotives simultaneously in the feeding zone of TSS. If 2nd Harmonic component is more than the set percentage, the relay blocks the trip command. 2nd Harmonic is to be set at 15%.

2.1.5 Delta-I Cycle (Delta-T) Setting

Delta-I cycle is the time difference between the base load current sample and the fault current sample. Delta-I cycle (Delta-T) is to be set at 60 ms.

2.1.6 X-Blinder Setting

a) Calculate the single line impedance of the OHE from the feeding post/TSS to the far end SP of the adjoining feeding post/TSS. A factor of 1.25 is to be multiplied by the total impedance to take account of the errors that arise due to CT, PT, and the relays, say this is Z_L.

$$Z_L = 1.25 * \text{calculated impedance of single line OHE}$$

b) Calculate the OHE reactance by using the given below formula. Say this is (X)

$$X = Z_L * \text{Sin of OHE impedance angle}$$

c) Calculate the reactance (X) blinder setting on the relay side by the following formula.

$$X = Z_L \times \text{Sin of impedance angle} \times \frac{\text{CT ratio}}{\text{PT ratio}}$$

d) The OHE reactance shall be calculated for either side of the feeding post/TSS separately. The X-blinder setting of the Delta-I relay provided with both feeder CBs should be set to the higher of the two calculated values.

2.1.7 Additional Time Delay (ATD)

Additional time delay setting is to be calculated as given below.

$$\text{ATD Setting (ms)} = (\text{DPR Operating Time} + \text{MTR Operating Time} + \text{CB Operating Time} + \text{Tolerance}) \text{ in ms}$$

The following operating time is to be considered to set additional time delay (ATD)

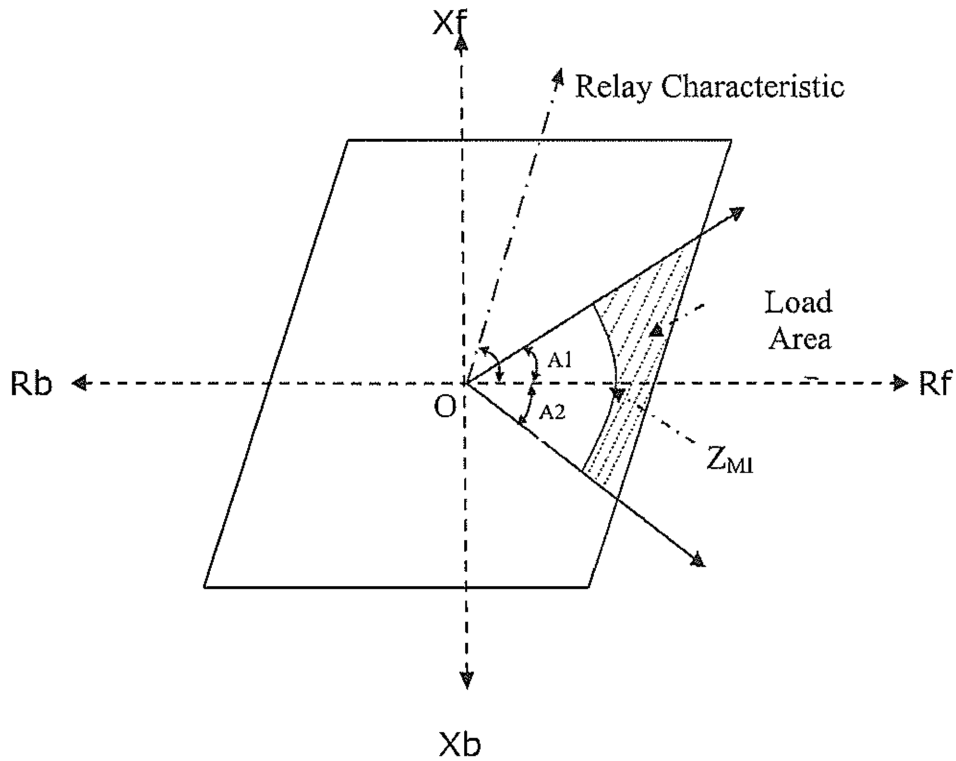
Main Distance Protection Relay (DPR)	=40 ms
Master Trip Relay (MTR)	=10 ms
Circuit Breaker (CB)	=50 ms
Tolerance	=50 ms
ATD	=150 ms

2.1.8 Delta Impedance

This relay may be kept in 'disable' mode.

2.2 Backup Distance Protection Setting (Polygonal Characteristic with Load Blinding)

Backup Distance Protection (Polygonal Characteristic with Load Blinding) relay is to be put in enable mode.



Polygonal Characteristic Distance Protection Relay

2.2.1 Minimum Operating Current

This setting is provided to prevent malfunction of the relay during OHE current and voltage are zero. With both OHE current and voltage are zero; the impedance seen by the relay will zero which may result in a malfunction of the backup DPR element. To avoid malfunction of the relay, the minimum operating current is to be set for 75A OHE current. The minimum operating current setting on the relay side is to be calculated as given below.

Minimum operating current setting on relay side in Amp(Imin)

$$= \frac{75}{\text{CT Ratio}}$$

$$\text{Setting in \%} = \frac{\text{Imin}}{5} * 100$$

2.2.2 Forward reactance setting (Xf)

The procedure given below may be followed to calculate forward reactance settings for single, double, triple lines, etc.

a) To ensure protection under all OHE configurations, calculate the single line impedance of the OHE from the feeding post/TSS to the far end SP of the adjoining feeding post/TSS. In other words, consider the maximum OHE impedance under any possible configuration considering feed extension, long yards, sidings, and feeding lines.
A factor of 1.25 is to be multiplied by the total impedance to take account of the errors that arise due to CT, PT, and the relays, say this is Z_L.

Z_L = 1.25 * calculated impedance of single line OHE

b) Calculate the OHE reactance by using the given below formula. Say this is (X)

$X = Z_L$ * Sin of OHE impedance angle Ω

c) The OHE reactance is to be calculated by following the procedure given at (a) and (b) above for the two sides of the feeding post/TSS separately. However, the backup distance protection relays of both feeders should be set to the higher of the two calculated values. This is to ensure that when one feeder breaker is taken out for maintenance, the relay shall be able to see the faults on either side of the feeding post/TSS.

d) The Forward reactance setting (Xf) on the relay side is to be calculated by the formula given below.

$$\text{Forward Reactance Setting (Xf) in ohm} = \text{Calculated OHE Reactance which is higher as said (c) above} * \frac{\text{CT Ratio}}{\text{PT Ratio}}$$

2.2.3 Backward reactance setting (Xb)

The backward reactance setting on the relay side is to be calculated by the following method

$$\text{Xb} = \text{Forward Reactance Setting (Xf)} * \frac{10}{100} \quad \Omega$$

2.2.4 Forward Resistance Setting (Rf)

This setting is recommended to be set for 30 ohm (OHE side). Forward resistance setting on relay side may be calculated by the formula given below.

$$\text{Forward Resistance Setting (Rf)} = 30 * \frac{\text{CT Ratio}}{\text{PT Ratio}} \quad \Omega$$

2.2.5 Backward Resistance Setting (Rb)

The backward resistance setting is recommended to be set at 10 ohm (OHE side).
The backward Resistance setting on the relay side may be calculated by the formula given below.

$$\text{Backward Resistance Setting (Rb)} = 10 * \frac{\text{CT Ratio}}{\text{PT Ratio}} \quad \Omega$$

2.2.6 Minimum Impedance Setting (Z_{MIN})

This setting is used to permit load on the traction power transformer. A higher setting will increase the sensitivity of the relay against high resistance faults but permit less loading on the traction power transformer. The minimum impedance setting may be calculated based on the peak load impedance of a particular Feeder CB. Zonal Railway may analyze the peak load current of feeder CBs of the TSS recorded by the SCADA system in the last 3 months and calculate Z_{MIN} setting as given below:

$$\text{Peak Load Impedance} = \frac{25000}{\text{Peak load current of Feeder CB}} \Omega$$

To accommodate CT, PT & Relay error, a factor of 0.9 is multiplied in the calculated peak load Impedance.

Minimum impedance setting on the Relay side may be calculated by the formula given below.

Minimum Impedance Setting (Z_{MIN}) =

$$0.9 * \text{Peak Load Impedance as calculated above} * \frac{\text{CT Ratio}}{\text{PT Ratio}} \quad \Omega$$

2.2.7 Angle (A1) setting

The load angle (power factor) of traction load widely varies. With higher setting of forward resistance (Rf) for better high resistive reach, the angle (A1) needs accurate setting to prevent malfunction of relay. The angle (A1) is to be set same as maximum load angle of the TSS. Zonal Railway may analyze maximum load angle of a particular TSS recorded by SCADA system in last 3 months and angle (A1) on the relay is to be set accordingly. However, this angle is not to be set beyond 50 deg in any case.

2.2.8 Angle (A2) setting

The angle (A2) is to be set the same as the angle (A1).

2.2.9 2nd Harmonic Setting

2nd Harmonic setting is provided to avoid spurious tripping due to inrush current during switched ON multiple locomotives simultaneously in the feeding zone of TSS. If 2nd harmonic component in the total load current is more than set value, the relay blocks trip command. The 2nd Harmonic is recommended to be set at 15%.

2.2.10 Additional Time Delay (ATD)

Additional time delay setting shall be calculated as given below.

$$\text{ATD Setting (ms)} = (\text{Main DPR Operating Time} + \text{MTR Operating Time} + \text{CB Operating Time} + \text{Tolerance}) \text{ in ms}$$

The following operating time is to be considered to set additional time delay (ATD).

Main Distance Protection Relay (DPR)	=40 ms
Master Trip Relay (MTR)	=10 ms
Circuit Breaker (CB)	=50 ms
Tolerance	=50 ms
ATD	=150 ms

2.3 Other Setting

2.3.1 CT (Current Transformer) Primary

CT Primary current on relay is to be set according to the CT used in the field. For example, if CT provided in field is having CT ratio is 750/5, the CT Primary current is to be set at 750

Amp. If CT ratio is 1500/5, the CT primary current is to be set at 1500 Amp.

2.3.2 PT (Potential Transformer) Primary

PT Primary Voltage on relay is to be set according to PT used in the field. For example if PT provided in field is having PT ratio is 27500/110, the PT Primary voltage is to be set at 27500 V.

2.3.3 Local Breaker Backup (LBB) or Breaker Fail or Trip Fail

This feature is used to provide backup protection against feeder Circuit Breaker faults. In other words, in case even after initiation trip command by Delta-I or Backup distance protection, the feeder CB fails to operate within set LBB delay time, an another trip command executes by the same relay to trip the transformer LV CB.

Local Breaker Backup trip delay time may be calculated as given below.

Breaker Fail delay operating time =

MTR operating time + C.B operating time + Tolerance

= 10ms+50ms+140ms

= 200 ms

2.4 After setting of relay as per above calculation, the performance of Delta-I relay shall be monitored by Zonal Railways. Based on the field experience Railways may suggest to RDSO any changes if considered necessary.

3.0 SAMPLE CALCULATION FOR DELTA-I WITH BACK UP DISTANCE PROTECTION RELAY SETTING

The following assumptions are made for sample calculation:

- Traction transformer rating = 21.6 MVA
- No load secondary voltage = 27 kV
- Rated secondary current of transformer $= \frac{21.6 \text{ MVA}}{27 \text{ KV}} = 800 \text{ Amp}$
- CT ratio = 750 / 5
- PT ratio = 27500/110
- Single-track OHE without return conductor: $0.41\angle 70^0$ Ω/Km

3.1 Delta-I relay

Delta-I relay is to be put in enable mode

3.1.1 Delta-I Current Setting

Assuming normal load current of one loco is 150 Amp and 2 (two) numbers of electric locomotives are entered or switched on simultaneously in the section.

$$\text{Delta} - \text{I current Setting in Amp} = \frac{2 * 150}{750/5}$$

= 2 Amp.

3.1.2 Harmonic De-sensitivity setting (DS)

De-sensitivity setting is recommended to be set at 100%. The 100% de-sensitivity setting means, relay will execute trip command at 2 times of set Delta-I, when 3rd harmonic is more than set value.

3.1.3 2nd Harmonic Setting

2nd Harmonic setting is recommended to be set at 15%.

3.1.4 3rd Harmonic Setting

3rd Harmonic setting is recommended to be set at 12%.

3.1.5 Delta-I Cycle (DeltaT) Setting

Delta-I cycle (Delta-T) is recommended to be set at 60 ms.

3.1.6 X-blinder setting

Let the distance between TSS1 and far end SP of TSS2=95 Km

Single line OHE impedance = $0.41 \angle 70^0$ Ω/Km

Total impedance = $95 \times 0.41 \angle 70^0$

= $38.95 \angle 70^0$ Ω

Effective impedance (Z_L) considering CT & PT error

$= 1.25 \text{ X} 38.95 \angle 70^0$

$= 48.69 \angle 70^0$

$$\therefore \text{Reactance blinder setting X} = 48.69 \text{ X } \sin\angle 70^0 \text{X } \frac{750/5}{27500/110}$$

=27.45 Ω

3.1.7 Additional Time Delay (ATD)

Main Distance Protection Relay (DPR)	=40 ms
Master Trip Relay (MTR)	=10 ms
Circuit Breaker (CB)	=50 ms
Tolerance	=50 ms

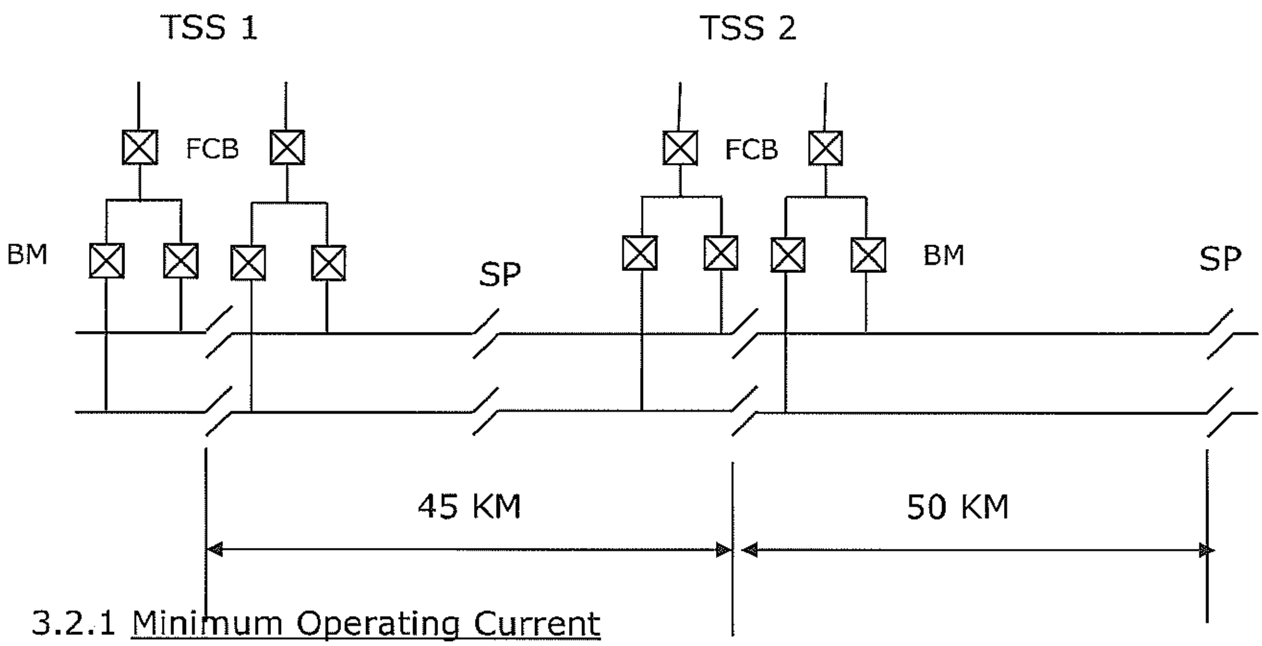
ATD Setting (ms)

$$= (\text{DPR Operating Time} + \text{MTR Operating Time} + \text{CB Operating Time} + \text{Tolerance})$$

= 40+10+50+50 ms
= 150 ms

Additional time delay may be set at 150 ms

3.2 Backup Distance Protection Setting (Polygonal Characteristic with Load Blinding)



3.2.1 Minimum Operating Current

Minimum operating current is recommended to be on the relay corresponding to 75A on OHE side.

Minimum operating current setting on relay in Amp.

$$= \frac{75}{750/5}$$
$$= 0.5 \text{ Amp}$$

$$\text{Minimum current setting in } \% = \frac{0.5}{5} * 100$$
$$= 10\% \text{ Amp}$$

If range of setting is not possible on the relay, next lower setting available on the relay may be set.

3.2.2 Forward reactance setting (Xf)

Calculate single line impedance from TSS1 to far end SP of TSS2.

Single line without BT&RC		=	95 Km
Total Line impedance		=	95 x 0.41
		=	38.95 Ω
∴ Z_L	= 1.25 X 38.95	=	48.69 Ω

$X = 48.69 * \sin 70^0\ \Omega$

$= 45.75\ \Omega$

$$\text{Forward Reactance Setting (XF) on relay side} = 45.75 * \frac{750/5}{27500/110}\ \Omega$$

$$= 27.45\ \Omega$$

3.2.3 Backward reactance setting (Xb)

$$XB = 27.45 * \frac{10}{100}$$
$$= 2.75\ \Omega$$

3.2.4 Forward Resistance Setting (Rf)

$$\text{Forward Resistance Setting (Rf)} = 30 * \frac{750/5}{27500/110}\ \Omega$$
$$= 18\ \Omega$$

3.2.5 Backward Resistance Setting (Rb)

$$\text{Backward Resistance Setting (Rb)} = 10 * \frac{750/5}{27500/110}\ \Omega$$

$= 6\ \Omega$

3.2.6 Minimum Impedance Setting (Z_{MIN})

Zonal Railway may analyse peak load current of feeder CBs of particular TSS recorded by SCADA system in last 3 months and calculate Zmin setting. Suppose peak load current on a particular feeder CB is 800 Amp.

$$\text{Peak Load Impedance} = \frac{25000}{800}\ \Omega$$

$$= 31.25\ \Omega$$

Minimum Impedance Setting (Z_{MIN})

$$= 0.9 * 31.25 * \frac{750/5}{27500/110}\ \Omega$$

$$= 16.87\ \Omega$$

Minimum impedance setting on relay with respect to load current on feeder CB

Feeder CB Load current	Calculated minimum impedance setting on relay
200 A	67.5 Ω
400 A	33.75 Ω
500 A	27.00 Ω
750 A	18.00 Ω
800 A	16.87 Ω
1000 A	13.5 Ω
1200 A	11.25 Ω

Note: The above setting is applicable for CT ratio 750/5A. If CT provided in the field of different ratio, the setting may be calculated accordingly.

3.2.7 Angle (A1) & (A2) setting

Zonal Railway may analyze maximum load angle of a particular TSS recorded by SCADA system in last 3 months and angle (A1) & (A2) on the relay is to be set accordingly. However, this angle is not to be set beyond 50° in any case.

Angle A1 & A2 setting on relay

Maximum load angle of a particular TSS recorded by SCADA system in last 3 months	Angle A1 & A2 setting on the relay
10°	10°

30°	30°
37°	37°
43°	43°
50°	50°
60°	50°
70°	50°

3.2.8 2nd Harmonic Setting

2nd Harmonic content is recommended to be set at 15%.

3.2.9 Additional time delay (ATD)

Main Distance Protection Relay (DPR) =40 ms
Master Trip Relay (MTR) =10 ms
Circuit Breaker (CB) =50 ms
Tolerance =50 ms

ATD Setting

$$= (\text{DPR Operating Time} + \text{MTR Operating Time} + \text{CB Operating Time} + \text{Tolerance})$$

= 40+10+50+50
= 150 ms

Additional time delay is to be set at 150 ms

3.3 **Other Setting**

3.3.1 CT (Current Transformer) Primary

CT Primary current setting=750 Amp (if CT provided of 750/5 ratio).

3.3.2 PT (Potential Transformer) Primary

PT Primary voltage setting = 27500 V.

3.3.3 Local Breaker Backup (LBB) or Breaker Fail or Trip Fail

Breaker Fail delay operating time =

MTR operating time + C.B operating time + Tolerance)

= 10ms+50ms+140ms
= 200ms

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