Traction Installation Directorate

सत्यमेव जयते

Government of India
Ministry of Railways

Instruction No. TI/IN/0029

For

Technical instructions
on important aspects of relay settings of Vectorial Delta-I relays
as per RDSO specification No. TI/SPC/PSI/PROTCT/1982

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ISSUED BY

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1.0 Introduction & background

Vectorial delta- I relays are being provided at 25kV ac traction sub-station in IR (as per the RDSO specification No. TI/SPC/PSI/PROTCT/1982(12/2003)) to detect the high resistive fault above the set Delta-I current, even though total fault current less than rated full load current of traction transformer and the same may also be considered as a backup protection to the main feeder protection module mainly DPR & OCR element.Recently some Railways have reported mal operation cases of vectorial delta-I relay, occurring when the feeding post Insulated Overlap (IOL) is bridged by a pantograph.

There is no auto recloser function provided with Delta-I relay in newly developed C&R panel as per RDSO spc. No. TI/SPC/PSI/PROTCT/6070(9/08), therefore this situation may sometime lead to flash over (caused by pantograph passing from live to dead section) as Panto Flash over relay may also fail to open the live section CB as explained in the following Para's of this instructions.

2.0 Developments and functioning of Vectorial Delta-I relay

2.1 RDSO developed scalar Delta I relay to specification No. TI/SPC/PSI/PROTCT/1981 in 1998.This relay used to detect scalar difference of two current samples for its operation. With the advancement of protection technology for high impedance earth faults, more accurate and reliable relay for such an application was developed in 2001 as per RDSO spec. No. TI/SPC/PSI/PROTCT/1982. In this type of relay vectorial difference of two current samples is used (vectorial difference of base load current and the fault current) for its operation.

2.2 The delta I relay works on the principle of Vectorial difference between the base load current and fault current. The relay has a feature to prevent unnecessary operation by the inrush current of power transformer and due to starting of multiple numbers of electric locos in the section. The inrush currents of power transformers contain significantly high 2^{nd} harmonics currents. If the 2^{nd} order harmonic component is larger than 15% of the fundamental components, the relay blocks out, thus preventing unnecessary operation of the relay.

2.3 The relay is operated by Vectorial delta I current at the same value as of setting current notwithstanding the magnitude of base current. There is a provision of differentiation between fault current and load current. The load current normally has got a high percentage of 3^{rd} harmonic distortion as compared to the fault current. The relay sensitivity restrains according to the de-sensitivity setting at set current when Vectorial delta I current include more than 15% of 3^{rd} harmonic current (generally set for 2 times of set vectorial Delta-I current).

2.4 Relay continuously monitors the reactance (X) of OHE at the fault point and ensure its operation only when X value is below the set value of X-blinder setting provided other conditions of relay operation are fulfilled.

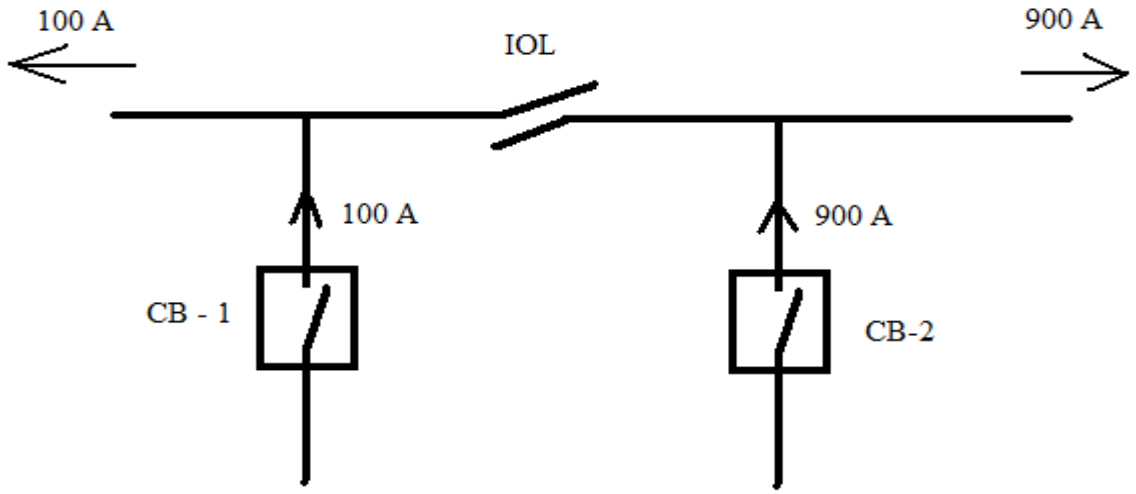
2.5 Delta-I relay is a backup protection function therefore its operating time (with settable time delays) is higher than the primary feeder protection relays.

3.0 Mal operation of Vectorial Delta I relay

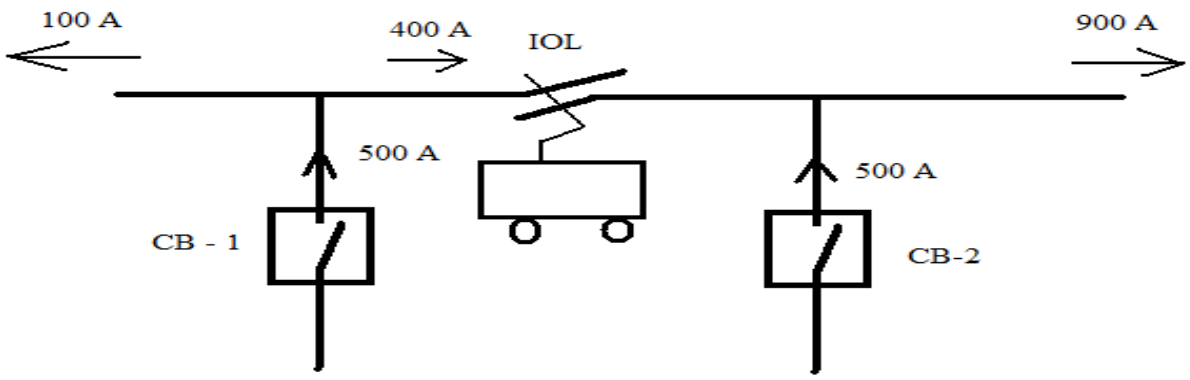
3.1 Delta I relay continuously monitors the vectorial difference between base current and fault current (vectorial difference between consuctive cycles), if vectorial difference is more than set current for set delay time and other condition for tripping also satisfy i.e. II^{nd} harmonic content less than 15% and value of X (reactance) is less than set value then relay initiate trip command.

The mal operation of vectorial Delta-I relay may result if such condition occur under normal load conditions.

3.2 Some mal operation incidences experienced by Zonal Railways and analyzed by RDSO have occurred when the loco pantograph bridges the IOL opposite FP/TSS and Delta I relay operates. This situation may arise when there is large difference in currents being fed by two feeder CB's on either side of the TSS i.e. in example shown below two feeder CB current are 100A and 900A.



3.2.1 When a loco pantograph bridges the IOL, both the feeder CB supplies are paralleled and redistribution of load currents take place wherein both the feeder CB currents are nearly equalized as depicted below. This causes sudden rise of CB-1 current from 100 A to 500 A. The vectorial difference may be higher than 400 A sufficient to trip the Delta-I relay.



3.2.2 As Delta-I relay is a backup protection provision of auto recloser is not provided. This may result in to flashover if Loco is moving from live to dead section. Even if auto recloser is activated with Delta-I relay it may not be able to prevent flashover under all conditions due to total auto recloser time of 600-700ms.

3.2.3 Panto flash over relay (with live CB tripping time of 100-110ms) may also get activated in this condition however it may also be not able to safeguard against the flashover under all conditions depending upon train speed & length of IOL.

3.3 Other cases of mal operation of Delta-I relay may be due to higher actuating Delta-I current on account of sudden variation in load current. The prevention against mal operation in such case is only restraint feature which increases the delta-I setting by 100% if 3rd harmonic content is above 15 % however 3rd harmonic content of traction load current varies widely and relay may still operate if actuating current is even more than 100% above the set value or 3rd harmonic content is less than 15% to initiate restraint action.

4.0 Performance review of Delta-I relays on IR

4.1 Tripping details and overall performance of Delta-I relays received in 2006-07 & 2010 and from Zonal Railways were analyzed for transient and high resistive fault tripping and following observations are made.

4.1.1 Tripping details of 5 Railways i.e. CR, SR, SCR, ER and WR were received in 2006-07. All Railways reported cases of Delta-I relay tripping without any fault noticed. One of the reasons for transient tripping is reported as sudden rise of load current by most of the Railways.

4.1.2 CR, SR and SCR respectively reported at least 4, 7 and 3 cases (suspected high impedance faults caused by bird faults, electrocution and insulator flashing) detected and cleared by Delta-I relay.

4.1.3 Overall performance submitted by 8 Zonal Railways (SR, SER, WR, WCR, NR, SWR, CR & SCR) was analyzed in 2010. The holding of TSS having Delta-I relay and its reported performance is as under:

Railway	Number of TSS	Number of TSS having Delta-I relay	Performance
SR	30	30	• At shoranur TSS 3 cases and 1 case at Kazhakuttam TSS of Delta-I not acted after tree fallen on OHE. • **Spurious tripping at Vridhachalam TSS & Relay dissconnected**. No spurious tripping at other TSS. • Sankaridrug TSS Delta-I acted after tree fallen on OHE. • Working satisfactory at other TSS.
SER	21	1	• No spurious tripping. • Performance satisfactory.

WR	26	15	• Although no spurious tripping reported. **Separate case of contact wire parting at IOL reported after mal operation of Delta-I.** • Performance satisfactory. Actual tripping on high resistive fault not available.
WCR	21	17	• **Spurious tripping at 4 TSS reportedly attended by firm.** • Working satisfactory at other TSS.
NR	11	11	• **No individual tripping, its always occur with DPR & OCR at BTR/TSS which means spurious operation.** • Working satisfactory at other TSS. • **Overall performance is under observation.**
SWR	2	1	• 7 times fault cleared by Delta-I relay. • No spurious tripping. • Performance satisfactory.
CR	36	36	• **Spurious tripping on 12 occasions & attended by firm.** • **At BDI/TSS 24 occasions where delta-I acted with DPR & OCR.** • Number of cases where Delta-I relay cleared the fault. • Performance is reported good at other TSS.
SCR	-	-	• **SEC division reported mal operation cases of Delta-I relay leading to contact wire parting at IOL opposite TSS.**

4.1.4 With above it is summarized that there have been reports of operation of this relay acting to detect and clear high impedance faults however there are cases of mal operation of Delta-I relays which can be addressed by reviewing its settings and at the same time.

5.0 Features & setting options of different make/models of Delta-I relays in service on IR

The different Delta-I relay developed by RDSO since 1999 along with their make & features are tabulated below.

Make / Type	Year of approval & RDSO specification	Features
M/s ALIND/ ADI -11	1999 TI/SPC/PSI/PROTCT/1981	• Monitors the scalar difference between base current and load / fault current with definite time interval and execute trip command if scalar difference more than set Delta-I current. • 3^{rd} harmonic restrain, if 3^{rd} harmonic contents in total current more than 15%, then relay will operate at 2 times of set current. • 2^{nd} harmonic blocking, if 2^{nd} harmonic contents in total

		current more than 15%, then relay will block the trip command. • Relay monitor the MTR status, if MTR status come within operating time of Delta-I relay, then relay is not executes trip command. • **Only Delta-I current setting is provided.** • No features of fault wave form recording and storage in relay memory.
M/s ALIND/ AVDI -11C	2004 TI/SPC/PSI/PROTCT/1982 (12/2003)	• Monitors the Vectorial difference between base current and load / fault current with definite time interval and execute trip command if vectorial difference more than set Delta-I current. • 3rd harmonic restrain, if 3rd harmonic contents in total current more than set value, then relay will operate at 2 times of set current. The 3rd harmonic percentage is settable from 5 to 50% in steps of 5%. • 2nd harmonic blocking, if 2nd harmonic contents in total current more than set value, then relay will block the trip command. The 2nd harmonic percentage is settable from 5 to 50% in steps of 5%. • Relay monitors the MTR status, if MTR status come within operating time of Delta-I relay, then relay is not executes trip command. • Delta-I current is settable from 1 to 6 A in steps of 0.1 A. • Forward and reverse reactance (X) is settable in the range of 0.5 to 30 ohm in steps of 0.01 ohm. • Additional time delay is settable from 0 to 250 ms in steps of 25 ms. • No features of fault wave form recording and storage in relay memory.
M/s ALIND/ AVDI -11C (AN SERIES)	2010 TI/SPC/PSI/PROTCT/1982 (12/2003)	• Monitor the Vectorial difference between base current and load / fault current with definite time interval and execute trip command if vectorial difference is more than set Delta-I current. • 3rd harmonic restrain, if 3rd harmonic contents in total current more than set value, then relay will operate at 2 times of set current. The 3rd harmonic percentage is settable from 1 to 100% in steps of 0.5%. • 2nd harmonic blocking, if 2nd harmonic contents in total

		current more than set value, then relay will block the trip command. The 2nd harmonic percentage is settable from 1 to 100% in steps of 0.5%. • Relay monitors the MTR status, if MTR status come within operating time of Delta-I relay, then relay is not executes trip command. • Delta-I current is settable from 0.5 to 10 A in steps of 0.1 A. • X blinder (reactance) is settable in the range of 0.0 to 99.99 ohm in steps of 0.01 ohm. • Additional time delay is settable from 0 to 1000 ms in steps of 10 ms. • Settable Delta-I cycle 20 to 100 ms in steps of 10 ms. • Settable 3rd harmonic de-sensitivity 0 to 100% in steps of 5%. • Provision of local breaker backup feature. • Event and Fault wave form recording and storage in relay memory.
M/s ASHIDA/ (AIDI/1C)	2004 TI/SPC/PSI/PROTCT/1982 (12/2003)	• Monitors the Vectorial difference between base current and load / fault current with definite time interval and execute trip command if vectorial difference more than set Delta-I current. • 3rd harmonic restrain, if 3rd harmonic contents in total current more than 15%, then relay will operate at 2 times of set current. • 2nd harmonic blocking, if 2nd harmonic contents in total current more than 15%, then relay will block the trip command. • Relay monitor the MTR status, if MTR status come within operating time of Delta-I relay, then relay is not executes trip command and not provided relay supplied after 2008, as this function is implemented software logic by monitoring the delta-I current within set delay time also. • Delta-I current is settable from 1 to 6 A in steps of 0.1 A. • X blinder (reactance) is settable in the range of 0.5 to 60 ohm in steps of 0.01 ohm and 0.04 to 60 ohm in steps of 0.01 ohm in relays supplied after 2008. • Additional time delay is settable from 0 to 300 ms in steps of 10 ms and 0-500 ms in steps of 20ms in relays supplied

		after 2008. • Settable Delta-I cycle 40 to 100 ms in steps of 20 ms and 20 to 100 ms in steps of 10 ms in relays supplied after 2008. • Settable 3rd harmonic de-sensitivity 0 to 1A in steps of 0.1A. • Event and Fault wave form recording and storage in relay memory.

6.0 Recommendations for setting of Delta-I relays

6.1 Existing setting guide lines of vectorial Delta – I relay

The existing guidelines were issued vide letter No.TI/PSI/PROTCT/STATIC/07 dt. 23-04-07. The highlights of this are as under.

6.1.1 Current setting of Delta-I relay is based on the assumption on number of locos entering or number of locos switched on simultaneously in the section causing sudden rise of load current to avoid the false tripping due to sudden rise of load current. The Delta-I current setting should be more than the sudden rise of load current. Assuming 2 numbers loco entering or switched on simultaneously in the section and considering load current of one loco as 150 A, setting of current was proposed as 300 A.

6.1.1.1 The setting should be done taking into account the correct CT ratio. It was also recommended that if relay gives more spurious tripping then next higher value may be selected.

6.1.2 The X-BLINDER setting is the reactance of OHE in ohms below which delta I relay shall pick up if other conditions like delta I, time delay etc. are met. Its calculation was recommended based on the OHE impedance from feeding TSS to adjacent feeding TSS considering the lowest OHE configuration (Single line OHE).

6.1.3 Second harmonic blocking & Third harmonic restraint feature setting features in different make/type of relays are explained in Para 5.0 above. Generally manufacturer set these parameters internally during relay manufacture. However some relay manufacturers made provision to set these parameters externally through knob or keypad. At present both 2nd harmonic block and 3rd harmonic restraint are set at 15 % with desenstivity set at 100% (meaning double the set delta-I current).

6.1.4 Additional time delay setting of 145 ms or higher was recommended. Moreover as the relay monitors the current samples continuously, this delta time setting i.e. time duration between the two samples was recommended as 60 ms.

6.2 Changes required to be done in settings of Vectorial Delta-I relay

In continuation of guidelines issued vide letter No. TI/PSI/PROTCT/STATIC/07 dt. 23-04-07, following changes are to be done in the setting guidelines of the Vectorial Delta-I relay for any two TSS where Delta-I relay tripping on spurious/unknown accounts are maximum. The performance should be watched and after getting a positive feedback from Railways these instructions shall be implemented for all substations.

6.2.1 Current setting of the Delta-I relay should be increased so as to correspond to 450A primary current (on 25 kV side) from existing value of 300A. This increase in relay setting has been decided based on the fault waveforms recorded by Delta-I relay spurious tripping cases at WR and SCR.

6.2.2 The setting of 3rd harmonic restraint should be done at 10% in place of 15%. This change in setting option is possible only in case of latest M/s Alind relay AVDI-11C and in all other models/makes this change shall require change in relay software which shall have to be got uploaded in the relay by relay manufacturers. This reduction in the 3rd harmonic restraint value has been taken after analysis of load data recorded at number of locations on IR (NR, ECR, WCR & NCR etc.) wherein it is observed that % of 3rd harmonic current in the load current varies in the range of 10 to 25% most of the time. By reducing the 3rd harmonic restraint it is expected that relay shall be better placed for not operating due to sudden load variations and situations like pantograph bridging the IOL.

6.2.3 3rd harmonic de-sensitivity factor should be set so as to increase the Delta-I setting by 200% (i.e. 3 times the set current value as against maximum 2 times setting done presently). This will also require change in relay software and up graded relay software shall have to be up loaded by relay manufacturers.

The above changes in setting are expected to substantially reduce cases of mal operation & spurious tripping.

7.0 Analysis of tripping caused by Vectorial Delta-I relays

Railways should examine and analyze cases of Delta-I relay tripping as explained below:

Sr. no.	Items relevant to Delta-I relay tripping analysis	Remarks and explanations
i.	Make, type & year of Delta-I relay	• Check whether scaler/vectorial type. Scaler types are more prone for maloperations.
ii.	Whether any fault located or not	• It should be clearly decided whether the relay operated due to some fault or it was a spurious tripping. This is important to judge & report the overall performance of the relay.
iii.	Past tripping History of the relay	• Past tripping history of the relay should be readily available for reporting to manufacturer & RDSO.
iv.	CT ratio	• The relay setting of Delta-I (in Amp) should properly corresponds to the correct actuating 25 kV side current therefore in relay setting calculation, put correct CT ratio as provided at respective TSS. • If CT ratio is settable in particular relay, then correct setting is also put in the relay.

v.	Download data, current and time. See fault current waveform.	• In old version relay, this feature is not available. Latest versions of relays are having features of recording and storage of latest 10 fault wave forms (50 cycles i.e. 45 before trip command is given by relay and 5 after trip command). • The tripping of Delta-I relay should be analyzed for Delta-I current, harmonics & operating time. • Check 3rd harmonic content is above/below set value and whether set delta-I current is increased as per setting of de-sensitivity. • Check power factor at the time of relay tripping and compare it with load power factor prevalent in previous cycles recorded. • Check timings of CB operation.
	Harmonic analysis of recorded fault current	
vi.	Whether any train at FP-IOL at the time of tripping	• Try to figure out if any spurious tripping are taking place at the time of any pantograph bridging the IOL opposite TSS. • Such cases are more likely where TSS/FP location is such that the feeding length or loading pattern on two sides of IOL widely varies e.g. presence of large yards, sheds & stations on one side as compared to other.
vii.	Any other feeder protection relay also tripping	• Generally Delta-I relay tripping should not accompany with DPR because it is a back up protection with time delay however if DPR picks up after giving the tripping command by Delta-I relay both can operate. • In most of the cases it may be spurious tripping of Delta-I therefore check its relay setting and time delay. • The setting and timing of DPR and CB may also be checked.