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No. TI/PSI/PROTCT/CONVEN/08 Date: 15.07.2008

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Sub: Guide lines on protection scheme for parallel operation of two 21.6 MVA traction transformers at a traction sub-station.

Ref : i) Railway Board letter No. 2003/R.E./161/1 dated 19.05.2008
ii)Railway Board letter No. 2002/R.E./161/8 dated 26.12.2007 addressed to CEE/NCR and copy to MD/RVNL, GM CORE, ED/TI/RDSO & CEEs all Zonal Railways.
iii) This office letter of even number dated 08.05.2008.

Please find enclosed herewith "Guide lines on protection scheme for parallel operation of two traction transformers of 2x21.6 MVA capacity". Following relays of M/s ASHIDA, Thane for traction transformer and feeder protection developed (type testing completed) for MRVC project are having all the features as stipulated in the guidelines.

OC + REF protection module for transformer comprising of IDMT, instantaneous, Definite time elements.	Type: ADR-221B
Integrated feeder protection module comprising of 3-zone DPR, WPC, Instantaneous & Definite time OCR elements etc.	Type: ADR-219B

Other relay manufacturers are also being approached for development of numerical relay modules and such relays may also be recommended for use in future subject to the design drawings and type tests clearance from RDSO.

17.7.08
(Sumit Bhatnagar)
For Director General/TI

Encl: As above

Copy to: The Secretary (RE), Railway Board, Rail Bhawan, New Delhi.

सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Instruction No. : TI/IN/0017 (July/2008)

GUIDELINES ON PROTECTION SCHEME WITH PARALLEL OPERATION OF 2 x 21.6 MVA TRACTION TRANSFORMERS

RESEARCH DESIGNS AND STANDARDS ORGANISATION
LUCKNOW-226 011

PREFACE

The power requirement to be fed into OHE from traction substations is meant to meet the loads arising from higher train density, train loads and speeds. The traction substations have been upgraded from 10 MVA capacity in early sixties to 21.6/30 MVA (ONAF) as of now. Increase in the transformer capacity has been with same percentage impedance to maintain regulation. As the ohmic value of transformer impedance decreases, elevated fault level on 25 kV bus may lead to damages during faults at the bus or on OHE within 10 km of TSS.

Numerical relay module (i.e. consisting of DPR, OCR, and WPC), used for feeder protection, clears fault in approximate 90 to 110ms (i.e. relay +Master trip relay + CB operating time). The IDMT relay on transformer LV&HV as backup protection relays will operate at about 470 to 570 ms on LV and 870 to 970 ms on HV side for faults at 25 kV bus. The operating time of IDMT relays can be reduced by using numerical relays with fine steps of TMS setting, and is thus recommended for parallel operation of two 21.6 MVA transformers at a TSS.

This report covers the time coordination of protective relays, requirement of additional relays and the obligations to employ numerical relays for protection where parallel operation of two 21.6 MVA traction transformer at a TSS is unavoidable.

The recommendations regarding protection relay settings are based on calculations & field data available. Relay settings proposed vide these guidelines have been kept on safer side and depending upon load pattern, trippings may increase on some sections initially. Based upon field experience and feedback received from Railways adjustments will be feasible.

1.0 INTRODUCTION

With the increase in transformer capacity from 13.5 MVA to 30 MVA without changing its percentage impedance, the fault current for LV bus faults has increased from 4.0 kA to 9.0 kA. Similarly the maximum fault current at LV bus with 2 transformers of 21.6 MVA rating connected in parallel shall be approximately 12 kA. These values are summarized below for various combinations.

Transformer Rating (12.5% impedance)	Prospective maximum fault current (neglecting source / earth resistance) at 25 kV bus
13.5 MVA	4 kA
21.6 /30 MVA (ONAF)	6.4 kA
30/40 MVA (ONAF)	8.9 kA
two 21.6 MVA in parallel	12.8 kA

Specification have been issued for 30/40 MVA (ONAF) transformers for future needs however, where due to non availability of 30/40 MVA transformers, parallel operation of 21.6 MVA transformers has been adopted by Zonal Railways or is so contemplated, protection scheme shall include the following.

2.0 The present protection scheme at 25 kV TSS comprises:

(a) Numerical feeder protection module comprising DPR (distance protection relay), Instantaneous OCR (over current relay), WPC (Wrong phase coupling relay) and. Local breaker backup or trip fail element, PT fuse failure relay & Auto reclosure element.
(b) Vectorial Delta-I relay.
(c) Differential protection for transformer.
(d) REF protection for transformer.
(e) IDMT OCR on LV & HV side of transformer & instantaneous OCR on transformer HV side, and
(f) Panto flash over relay

2.1 Existing protection at 25 kV TSS envisages instantaneous operation (without any additional time delays) for the main feeder protection relays (DPR, OCR) to clear faults in 90-110 ms (20 to 40 ms for DPR+ 10 ms for master trip relay (MTR) + 60 ms for CB). The backup IDMT relays on transformer LV & HV can clear the close-up faults in 470 to 570 ms and 870-970 ms respectively. But for fault current of around 12kA on 25 kV during parallel operation of transformer, a preliminary thermal study has shown that 67 sq mm catenary wire may become soft or even part, in case fault is not cleared within 300 ms. However, the best clearing time of back up feeder protection in present arrangement is at least 470 ms (400 ms for IDMT + 10 ms for MTR + 60 ms for CB), thus making the instrument stability of OHE a suspect.

2.2 In this background the protection scheme is amended such that fault must be cleared in 250-300 ms by back up protection provided by LVCB IDMT relay. The time reduction in backup IDMT relays is possible by having fine settings of TMS in the range of 0.01 to 0.1 in steps of 0.01.

3.0 The following protection elements & relays are recommended:

Recommended protection elements	**Qualifying Remarks**
Transformer & Feeder back up protection	
a) REF & OC protection relay for transformer : i) Numerical IDMT over current relays on transformer HV & LV with fine TMS setting of 0.01 to 0.1 in steps of 0.01 & instantaneous over current element on transformer HV side ii) Restricted earth fault protection relay on transformer HV & LV side. iv) Auxiliary relays for transformer alarm contact multiplication.	Fine steps of TMS setting are required to have time grading of 250 to 300 ms (LVCB IDMT) and 500-600 ms (HVCB IDMT) as backup protection for 25 kV close in OHE faults for main feeder protection.
b) Differential protection module i) Biased differential protection relay ii) Auxiliary relays for transformer trip contact multiplication.	No change in the present protection scheme for individual traction transformer is required and separate differential and auxiliary relays with trip contact multiplication for each transformer will be used.
OHE / Feeder protection relays	
a) Numerical integrated traction feeder protection module	
i) 2- Zone parallelogram characteristic distance protection element ii) Wrong phase coupling protection element iii) Definite time OCR element iv) Instantaneous over current protection element v) PT fuse failure element vi) Auto reclosure function element vii) Trip fail element	Second zone of distance protection is an additional protection element proposed for back up of zone-1. The feeder protection instantaneous OCR element is presently set at 200% of the transformer full load current. However, for far end faults on feeder, the reach of OCR is limited, hence as a backup protection, 2 zone DPR with settable time delay is proposed to be provided in place of single zone DPR. The definite time OCR is also an additional protection element proposed to be provided as a backup protection for Instantaneous OCR.

b) Vectorial Delta-I relay	Presently Delta-I relay as per RDSO specification No. TI/SPC/PSI/ PROTCT/1982 is not mandatory. This relay was developed to provide protection against high resistive faults as well as backup of DPR and OCR. However, it is now proposed to make it mandatory for parallel operation of transformers.
c) Panto flash over protection relay	No changes in present protection scheme.

3.1 The protection modules shall have features of event and fault waveforms recordings with time stamping for post fault analysis, retrievable through serial communication port with the help of computer / laptop or other specified tools.

4.0 Relays setting guidelines

4.1 Transformer protection

4.1.1 IDMT over current relay HV side

The function of this protection element is to act as a backup protection to the LVCB relays. The reach of this relay should be as much as possible, however to utilize the over load capacity of traction transformer the current setting of the relay should be selected to correspond to 160% of the rated current of the traction power transformer. The setting on the relay side may be calculated by formula given below:-

$$\text{Relay setting} = \frac{1.6 \times I_{pri}}{\text{CT ratio}} \quad A$$

$$\text{Setting in \%} = \frac{\text{Relay setting}}{5} \times 100\ \%$$

The TMS of this relay may be selected such that the relay operating time obtained is 500 ms to 600 ms for a fault occurring on LV bus.

4.1.1.1 TMS calculation

Calculate the fault current at LV bus considering the source impedance and single transformer impedance

$$\text{Fault current at LV bus} = \frac{\text{No load bus voltage (= 27 kV)}}{\text{Source impedance + transformer impedance (ohm)}} \quad A$$

$$\text{HV side source impedance} = \frac{kV^2_{pri}}{\text{Fault level at primary bus at TSS in MVA}} \quad \Omega$$

Reflected impedance on LV bus

$$= \text{HV side Source impedance} \times \frac{kV^2_{sec}}{kV^2_{pri}} \quad \Omega$$

$$\text{Impedance of transformer at 27 kV base} = \frac{kV^2_{sec} \times \%\ \text{impedance of transformer}}{\text{transformer MVA} \times 100} \quad \Omega$$

$$\text{Plug setting multiplier} = \frac{\text{Fault current at LV bus} \times (kV_{sec} / kV_{pri})}{1.6 \times I_{pri}}$$

From IDMT curve (3 sec at 10 time of setting), choose the suitable TMS for getting the relay operating time 500 to 600 ms at calculated plug setting multiplier.

4.1.2 Instantaneous over current relay

The instantaneous element may be set to correspond to a current of 1.25 times the fault current on the LV bus. The setting is proposed to avoid this relay operation for LV bus fault.

Current setting

$$= 1.25 \times \text{fault current at LV bus} \times (kV_{sec}/kV_{pri}) \times (1/\text{CT ratio}) \quad A$$

$$\%\ \text{Current setting} = \frac{\text{Current setting}}{5} \times 100\ \%$$

4.1.3 Restricted earth fault relay (HV & LV) & transformer differential protection

There shall be no change required and these relay settings should be calculated as per earlier setting guide lines issued by RDSO vide letter No ETI/SS/7 Dated 22-04-88.

4.1.4 IDMT relay on transformer LV side.

The function of this relay is to act as a back- up protection to the feeder protection relays. The reach of the relay should be as much as possible. However to obtain grading in current between HV & LV IDMT, the current setting of the relay should be selected to correspond to 150% of the rated current of the traction transformer.

$$\text{Relay setting} = \frac{1.5 \times I_{sec}}{\text{CT ratio}} \quad A$$

$$\text{Setting in \%} = \frac{\text{Relay setting}}{5} \times 100\ \%$$

The TMS of IDMT relay should be selected such that the relay operating time obtained is 250 ms to 300 ms for a fault occurring on LV bus.

4.1.4.1 TMS calculation

Refer to the fault current at LV bus considering the source impedance and single transformer impedance as already calculated in clause 3.1.1.1 above.

The Plug setting multiplier of LVCB IDMT shall be calculated as under.

$$\text{Plug setting multiplier} = \frac{\text{Fault current at LV bus}}{1.5 \times I_{sec}}$$

From IDMT curve (3 sec at 10 time of setting), choose the suitable TMS for getting the relay operating time 250 to 300 ms at calculated plug setting multiplier.

4.2 Feeder/OHE Protection

4.2.1 Instantaneous OCR element

This protection element provides primary protection to the catenary on earth faults in the vicinity of the feeding post. The current setting of the relay should be corresponding to about 220% of the continuous current rating of the single traction transformer. Assuming that a factor of 1.10 will account for the CT & relay errors and relay transient over reach, the relay will allow loads of about 220/1.10 i.e. 200% of rated load current of a single transformer.

4.2.2 Definite time OCR element

This protection element provides back up protection to Instantaneous OCR & DPR. The current setting of the relay should be corresponding to 180% of the continuous current rating of single

traction transformer. The relay operating time may be selected between 200-250 ms to avoid the transient tripping during simultaneous switching on of locos/EMUs.

4.2.3 Distance protection relay

4.2.3.1 Zone-1 setting.

There shall be no change required and these relay settings should be calculated as per earlier setting guide lines issued by RDSO report No. TI-35(7/95) July 1995 and revision to this report issued vide letter No TI/PSI/PROTCT/STATIC/07 dated 23.4.07

4.2.3.2 Zone-2 setting.

The zone-2 element of distance protection shall act as a backup protection for primary zone-I protection with comparatively higher resistive reach in comparison to zone one resistive and OCR reach.

Forward reactance (X_F) setting

X_F for zone 2 is to be taken as 1.25 times the value of X_F selected for zone1.

Forward resistance (R_F) setting

$$\text{Calculate the peak load impedance } Z_{PL} = \frac{25000 \times \text{CT ratio}}{1.5 \times I_{sec} \times \text{PT ratio}} \quad \Omega$$

In order to accommodate CT, PT & relay errors and to enhance the resistive reach as compared to zone-I

$$Z = 90\% \text{ of } Z_{PL}$$

To obtain the R_F setting a factor 0.5812 is to be multiplied to Z (as per RDSO report No. TI-35(7/95) July 1995).

$$R_F = 0.5812 \times Z \quad \Omega$$

Reverse reactance (X_B) setting.

The same value may be used as mentioned for Zone –1 setting.

Backward resistance (R_B) setting

It is should be of the same value as R_F.

Time setting

The operating time of the Zone-2 protection element may be set at 300-400 ms.

4.2.4 WPC, PTFF, Trip fail, Auto reclosure & Delta-I relay

For setting of these relay refer the existing RDSO setting guideline for feeder protection module & Delta-I relay, circulated to Zonal Railways vide RDSO report No. TI-35(7/95) July 1995 and revision to this report issued vide letter No. TI/PSI/PROTCT/STATIC/07 dated 23.4.07.