TRACTION INSTALLATION DIRECTORATE

सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Instruction No. TI/IN/0022 (February/2010)

Setting guide lines for traction transformer & 25kV shunt capacitor bank protection relay developed as per RDSO specification no. TI/SPC/PSI/PROTCT/6070(9/08) for 25 kV ac traction sub-station

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ISSUED BY

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1.0 INTRODUCTION

The existing specification no. ETI/PSI/65(1/97) of control and relay panel incorporating static type relays for 25kV ac traction sub-station has been superseded by new RDSO specification no. TI/SPC/PSI/PROTCT/6070(9/08) in March 2009. As per this specification all the protection relays are of numerical type and additional three stage definite time over current protection element have also been included on primary and secondary side of transformer to utilize the over load rating of traction power transformer at the same time providing adequate protection against overloading as per the defined overloading cycle of traction power transformers.

The numerical type protection relays also have features to set the various parameters in fine steps for achieving better coordination between different protection relay elements.

In view of the above, new setting guidelines for transformer protection relays and 25kV shunt capacitor bank has been prepared. These setting guide lines shall provide the method of calculations only, for other general parameters and relay setting procedure reference to the operation & commissioning manual of relay manufacturer shall have to be made.

2.0 Relays setting guidelines for transformer protection

2.1 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 corresponding to 190% of the rated current of the traction power transformer. The setting on the relay side may be calculated by formula given below:-

$$\text{Relay setting in Amp. } (I_{set}) = \frac{1.9 \times \text{Rated transformer primary (HV) current } (I_{pri})}{\text{CT ratio}}$$

$$\text{or relay setting in \% } = \frac{(I_{set})}{5} \times 100$$

The TMS should be selected such that the relay operation must be achieved in between 500 to 600 ms for a fault occurring on LV bus.

2.1.1 TMS (Time Multiplier Setting) calculation

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

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

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

Reflected impedance on LV bus =

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

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

$$\text{Plug setting multiplier} = \frac{\text{Fault current at LV bus} \times (kV_{sec} / kV_{pri})}{1.9 \times I_{pri}}$$

From IDMT curve of (3 sec at 10 time of setting), choose the suitable TMS for getting the relay operating time of 500 to 600 ms at calculated plug setting multiplier or calculate TMS by formula given below:

$$t = \frac{TMS \times a}{[I/I_{set}]^b - 1}$$

Where a&b are constant a = 0.14, b = 0.02
t = Operating time in second
TMS = Time multiplier setting
I = Measured current by relay
I_{set} = Set current in amp

2.2 Instantaneous over current relay

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

Current setting in A

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

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

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

The current setting of the relay should correspond to 10 % of the rated current of traction power transformer.

REF setting in Amp (I_{ref})

$$= (\text{Transformer rated current on LV \& HV side} \times 10/100)/ \text{CT ratio}$$

$$\text{\% setting} = (I_{ref} / \text{CT secondary}) * 100$$

2.4 IDMT relay on transformer LV side.

The function of this protection element is to act as a backup protection to the feeder protection relays. The reach of this relay should be as much as possible. However to obtain grading in current between HV & LV IDMT and utilization of transformer over load capacity the current setting of the relay should be selected corresponding to 180% of the rated current of the traction power transformer. The setting on the relay side may be calculated by formula given below:-

$$\text{Relay setting in amp}(I_{set}) = \frac{1.8 \times \text{Rated transformer secondary (LV side) current } (I_{sec})}{\text{CT ratio}} \quad A$$

$$\text{or Setting in \%} = \frac{(I_{set})}{5} \times 100\ \%$$

The TMS of this relay shall be selected such that the relay operating time must be achieved in between 250 - 300 ms for a fault occurring on LV bus.

2.4.1 TMS calculation

Calculate the fault current at LV bus considering the source impedance and single transformer impedance, for calculation refer the clause (2.1.1) above.

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

$$\text{Plug setting multiplier} = \frac{\text{Fault current at LV bus}}{1.8 \times I_{sec}}$$

From IDMT curve (3 sec at 10 time of setting), choose the suitable TMS for getting the relay operating time of 250 to 300 ms at calculated plug setting multiplier or calculate TMS by formula given below:

$$t = \frac{TMS \times a}{[I/I_{set}]^b - 1}$$

Where a&b are constant a = 0.14, b = 0.02
t = Operating time in second
TMS = Time multiplier setting
I = Measured current by relay
I_{set} = Set current in amp

2.5 Definite time over current protection element setting

Three stage definite times over current relay is proposed to utilize the overload capacity of traction transformer and also protect the transformer against over loading beyond the permissible time limits. The setting of each stage for HV and LV side are separately given below:

2.5.1 Current and time setting of definite time over current relay on transformer LV side

Stage setting	Current Setting	Operating Time
OL1	110% of Full Load	5 Minutes
OL2	140% of Full Load	2 Minutes
OL3	170% of Full Load	1 Minutes

The Rated LV current of transformer seen by relay (I_{LV}) in amp

= Transformer LV rated current/CT ratio

Stage 1 Overload setting in amp =

110% of rated transformer LV current **(OL1)** = 1.1 x I_{LV}

or % Setting = OL1 x 100 / Rated CT Secondary

Stage 2 Overload setting in amp =

140% of rated transformer LV current **(OL2)** = 1.4 x I_{LV}

or % Setting = OL2 x 100 / Rated CT Secondary

Stage 3 Overload setting in amp =

170% of rated transformer LV current (**OL3**) = 1.7 x I_{LV}

or % Setting = OL3 x 100 / Rated CT Secondary

2.5.2 Current and time setting of definite time over current relay on transformer HV side

Stage	Current Setting	Operating Time
OL1	120% of Full Load	6 Minutes
OL2	150% of Full Load	3 Minutes
OL3	180% of Full Load	2 Minutes

The rated HV current of transformer seen by relay (I_{HV}) in amp

= Transformer HV rated current / CT ratio

Stage 1 Overload setting in amp =

120% of rated transformer HV current **(OL1**) = 1.2 x I_{HV}

or % Setting = OL1 x 100 / Rated CT Secondary

Stage 2 Overload setting in amp =

150% of rated transformer HV current (**OL2**) = 1.5 x I_{HV}

or % Setting = OL2 x 100 /Rated CT Secondary

Stage 3 Overload setting in amp =

180% of rated transformer HV current (**OL3**) = 1.8 x I_{HV}

or % Setting = OL3 x 100 / Rated CT Secondary

2.5.3 Repeated over load protection

As per the RDSO specification of the traction transformers, the traction transformer can be overloaded 150% for 15 minutes and 200% for 5 minutes; two consecutive overloading on transformer is only permitted after the interval of 3 hours, to take care the defined transformer over loading cycle the other definite time OCR i.e post over load protection element is also proposed as under.

i) HV side

Current setting

Current setting in Amp (I_{HVpost})

= Transformer HV rated current * 1.10 / CT ratio

or % Current setting = I_{HVpost} x 100 /5

Time setting

Time setting is to be kept at 70 sec

Post over load time reset setting

Reset time is to be set at 3 Hours

ii) LV side

Current setting

Current setting in Amp (I_{LVpost})

= Transformer LV rated current / CT ratio

or % Current setting = I_{LVpost} x 100 /5

Time setting

Time setting is to be kept at 60 sec

Post over load reset time setting

Reset time is to be set at 3 Hours

2.5.4 The above proposed settings of current and time are on the safer side and are therefore much less than the overloading permitted by the transformer manufacturers because the overloading on the traction transformers is generally for very short durations and for allowing errors in the CT/PT measurements. However based on the field experience Railways may suggest to RDSO any changes if considered necessary.

2.6 Biased differential protection

The biasing and operating current setting of the numerical type differential protection relay should be calculated as follows:

(a) The percentage biased setting should be so chosen that the relay remains inoperative on differential currents resulting from (1) tap changing of traction transformer, (2) mismatch in CT ratios and (3) difference in CT saturation levels under through fault conditions. Percentage mismatches resulting from factors (1) and (2) may be calculated from actual data and an allowance of 7.5 to 15% may be made for factor (3).

(b) The operating current setting may be taken as 40%. If mal operations of the relay are observed on through faults and magnetizing inrush (switching in of power transformer), a higher setting may be considered.

2.6.1 Calculation of ICT multiplication factor setting

This factor is used to neutralize the effect of transformer bushing CTs ratio corresponding to transformer primary and secondary rated current, as the output current (CT secondary) shall be same to avoid the mal function during normal operating condition. The ICT multiplication factor individually for HV & LV shall be calculated by formula given below:

$$\text{ICT multiplication factor} = \frac{5 \times \text{Bushing CT ratio}}{\text{Transformer rated current in Amp}}$$

2.6.2 Bias & operating current setting calculation

Calculate the transformer HV current at lowest tap position i.e. -15%

$$= \frac{\text{Rated transformer MVA} * 1000}{\text{(Rated primary voltage in kV} - 15\% \text{ of rated primary voltage)}} \text{ Amp}$$

$$\text{Current read by relay} = \frac{\text{HV current at lowest tap in amp} * \text{ICT multiplication factor}}{\text{HV bushing CT ratio}}$$

Spill over Current in amp = Current read by relay – 5

$$\text{Percentage differential bias current} = \frac{\text{Spill over current in amp} * 100}{(\text{Current read by relay} + 5) / 2}$$

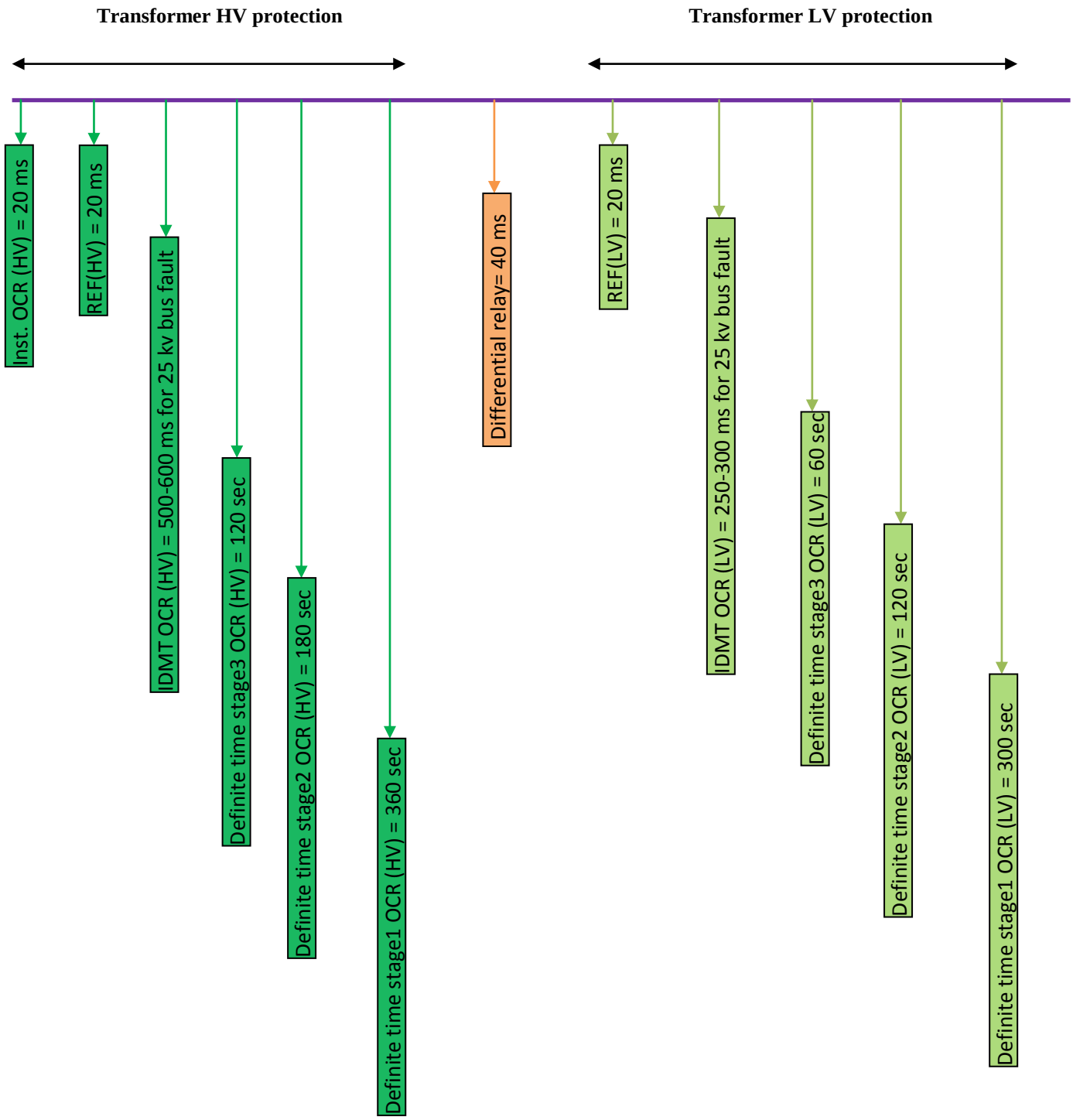
To allow the relay and CT errors, the % differential current further increased by a factor of 1.25.

The operating current shall be set at 40% of transformer rated current.

3.0 The summary of transformer protection IDMT & definite time OCR relays setting is as under

Relay element	**HV side**		**LV side**	
	Current setting in % of transformer rated current	Time setting	% Current setting of transformer rated current	Time setting
REF	10	Instantaneous i.e. 20ms	10	Instantaneous i.e. 20ms
IDMT	190	500-600ms as per curve for bus fault	180	250-300ms as per curve for bus fault
Stage-1 OCR	120	360 sec	110	300 sec
Stage-2 OCR	150	180 sec	140	120 sec
Stage-3 OCR	180	120 sec	170	60 sec
Post over load	110	5 sec	100	5 sec

4.0 Graphical depiction of time coordination of transformer protective relays



5.0 Sample calculation for transformer protection relay setting

The following assumptions are made for sample calculation:

a. Traction power transformer

i) Traction transformer rating = 21.6 MVA
ii) % impedance = 12.5
iii) No load primary voltage, V_{PO} = 132 kV
iv) No load secondary voltage, V_{SO} = 27 kV
v) Rated secondary current, I_{Sec}

$$I_{Sec} = \frac{21.6 \text{ MVA}}{27 \text{ KV}} = 800 \text{ Amp}$$

vi) Rated primary current, I_P

$$I_P = I_S \times V_{SO} / V_{PO} = 800 \times 27 / 132 = 163.6 \text{ Amp}$$

b. CT ratio

i) 27 kv side …… 750 / 5
ii) 132 kv side ……..200 / 5

(5. **Bushing CT ratio**

i) 27 kv side …… 1600 / 5
ii) 132 kv side ……330 / 5

d. **Fault MVA**
10000 MVA at 132kv base voltage.

5.1 Low (25kv) voltage side

5.1.1 Restricted earth fault relay

Current setting in amp, I_{ref}

$$= \frac{800 \times 10}{100 \times 750/5} = 0.53 \text{ Amp}$$

Setting in % = 0.53 / 5) * 100
= 10.6 % i.e. 10%

5.1.2 IDMT over current relay

5.1.2.1 Current setting

$$= \frac{800 \times 180}{100 \times 750/5} = 9.6 \text{ Amp}$$

Setting in % = (9.6 / 5) * 100
= 192 %

5.1.2.2 TMS setting

Source impedance, Z_{source} at 132kv base

$$= \frac{(132)^2}{10000} = 1.74\ \Omega$$

Loop impedance = 2 x 1.74 = 3.48 Ω
Source impedance as seen from the 25 kv bus

$$= 3.48 \times \frac{(27)^2}{(132)^2} = 0.146\ \Omega$$

Impedance of traction transformer at 27 kv base, $Z_{transformer}$

$$= \frac{(27)^2 \times 12.5}{21.6 \times 100} = 4.21\ \Omega$$

Total impedance, Z = 0.146 + 4.21 = 4.36 Ω

Fault current for 27 kV bus fault, I_f

$$= \frac{27000}{4.36} = 6192 \text{ amp}$$

Fault current reflected to secondary side of CT

= 6192 x 5/750 = 41.28 amp

To achieved the operating time 300 ms for bus fault, the TMS setting should be

$$\frac{300}{1000} = \frac{TMS \times 0.14}{[41.28/9.6]^{0.02} - 1}$$

$$\frac{300}{1000} = \frac{TMS \times 0.14}{1.03 - 1}$$

TMS = 0.0642 i.e. the available setting on the relay 0.07

5.1.3 **Current and time setting of definite time over current relay**

5.1.3.1 Stage 1 OCR

Current setting in amp, I_{OCR1}

$$= \frac{800 \times 110}{100 \times 750/5} = 5.87 \text{ Amp}$$

Setting in % = (5.87 / 5) * 100

= 117 %

5.1.3.2 Stage 2 OCR

Current setting in amp, I_{OCR2}

$$= \frac{800 \times 140}{100 \times 750/5} = 7.47 \text{ Amp}$$

Setting in % = (7.47 / 5) * 100

= 149 %

5.1.3.3 Stage 3 OCR

Current setting in amp, I_{OCR3}

$$= \frac{800 \times 170}{100 \times 750/5} = 9.07 \text{ Amp}$$

Setting in % = (9.07 / 5) * 100

= 181 %

5.1.3.4 Post over load

Current setting in amp,

$$= \frac{800 \times 100}{100 \times 750/5} = 5.33 \text{ Amp}$$

Setting in % = (5.33 / 5) * 100

= 107 %

5.2 High voltage side

5.2.1.1 Restricted earth fault relay

Current setting in amp

$$= \frac{163.6 \times 10}{100 \times 200/5} = 0.41 \text{ Amp}$$

setting in % = 0.41 / 5) * 100

= 8 %

5.2.2 IDMT over current relay

5.2.2.1 Current setting

$$= \frac{163.6 \times 190}{100 \times 200/5} = 7.75 \text{ Amp}$$

Setting in % = (7.75 / 5) * 100

= 155 %

5.2.2.2 TMS setting

Fault current for 27 kv bus fault, I_f

$$= \frac{27000}{4.36} = 6192 \text{ amp}$$

Fault current seen at HV side

$$= 6192 \times \frac{27}{132} = 1266 \text{ amp}$$

Fault current reflected to secondary side of CT

$$= 1266 \times 5/200 = 31.66 \text{ amp}$$

To achieved the operating time 600 ms for bus fault, the TMS setting should be

$$\frac{600}{1000} = \frac{TMS \times 0.14}{[31.66/7.75]^{0.02} - 1}$$

$$\frac{600}{1000} = \frac{TMS \times 0.14}{1.029 - 1}$$

TMS = 0.12

5.2.3 Current and time setting of definite time over current relay

5.2.3.1 Stage 1 OCR

Current setting in amp, I_{OCR1}

$$= \frac{163.6 \times 120}{100 \times 200/5} = 4.9 \text{ Amp}$$

Setting in % = (4.9 / 5) * 100

= 98 %

5.2.3.2 Stage 2 OCR

Current setting in amp, I_{OCR2}

$$= \frac{163.6 \times 150}{100 \times 200/5} = 6.13 \text{ Amp}$$

Setting in % = (6.13 / 5) * 100

= 123 %

5.2.3.3 Stage 3 OCR

Current setting in amp, I_{OCR3}

$$= \frac{163.6 \times 180}{100 \times 200/5} = 7.36 \text{ Amp}$$

Setting in % = (7.36 / 5) * 100

= 147 %

5.2.3.4 Post over load

Current setting in amp,

$$= \frac{163.6x\ 110}{100 \times 200/5} = 4.5 \text{ Amp}$$

Setting in % = (4.5 / 5) * 100

= 90 %

5.3 Biased differential protection

5.3.1 Calculation of ICT multiplication factor

LV Bushing CT multiplication factor

$$= \frac{5 \times 1600/5}{800}$$

$$= 2$$

HV Bushing CT multiplication factor

$$= \frac{5 \times 330/5}{163.6}$$

$$= 2.02$$

5.3.2 Bias setting calculation

Calculate the transformer HV current at lowest tap position i.e. -15%

$$= \frac{21.6 * 1000}{112.2} = 192.5 \text{ Amp}$$

$$\text{Current read by relay} = \frac{192.5 * 2.02}{330/5} = 5.89$$

Spill Over Current in amp = 5.89 – 5

$$\text{Percentage differential current} = \frac{0.89 * 100}{(5.89 + 5) / 2} = 16.34\%$$

To allow the relay and CT errors, the % differential current further increased by a factor of 1.25.

% biased setting = 1.25 x 16.34

= 20.43% i.e. 20%

6.0 Setting guide line for 25 kV shunt capacitor bank protection relay

6.1 IDMT Over current relay

6.1.1 Current setting

Calculate the capacitive reactance at rated voltage

$X_C = kV^2 * 1000 / KVAr \quad \Omega$

Calculate the effective reactance of complete capacitor & reactor unit

$X_{C1} = X_C - 0.13\ X_C \quad \Omega$

Calculate the KVA_R capacity of bank at 25 kV

KVAr rating at 25kv system voltage

$KVA_r = (25)^2 * 1000 / X_{C1}$

Calculate the rated current of capacitor bank at system voltage 25 kV

$$\text{Capacitor bank current in amp, } I_{cap} = \frac{\text{KVAr}}{\text{Rated system voltage in kV}}$$

To accommodate the CT and relay errors, the 10% higher value of above calculated current is recommended for setting of relay.

$$\text{Current setting of IDMT relay in amp } (I_{relay}) = \frac{1.10 \times I_{cap}}{\text{CT ratio}} \text{ Amp}$$

$$\text{Setting in \%} = \frac{\text{Current seen by relay } (I_{relay})}{\text{CT secondary}} \times 100$$

6.1.2 TMS setting

Calculate the fault current after reactor and select the suitable TMS to achieve the operating time of 500 ms.

$$\text{Fault current} = \frac{27000}{\text{Source Z + transformer Z + Reactance of reactor}} \text{ Amp}$$

$$\text{Plug setting multiplier} = \frac{\text{Reflected fault current to relay side}}{\text{Set current of IDMT relay } (I_{relay})}$$

From IDMT curve (3 sec at 10 time of setting), choose the suitable TMS for getting the relay operating time of 250 ms at above calculated plug setting multiplier or calculate TMS by formula given below:

$$t = \frac{TMS \times a}{[I/I_{set}]^b - 1}$$

Where a & b are constant a = 0.14, b = 0.02
t = Operating time in second
TMS = Time multiplier setting
I = Measured current by relay
I_{set} = Set current

6.2 Over voltage relay

6.2.1 Over voltage setting

The over voltage relay shall be set at 10% higher than the rated nominal no load voltage of traction transformer.

$$\text{Setting in volt } (V_{o/v}) = \frac{1.1 \times \text{Rated nominal no load voltage of traction transformer}}{\text{PT ratio}} \text{ V}$$

$$\text{Setting in \%} = \frac{\text{Setting in volt } (V_{o/v})}{\text{Rated PT secondary voltage}} \times 100$$

6.2.2 Time multiplier setting (TMS)

Calculate the plug setting multiplier by formula given below:

$$\text{Plug setting multiplier} = \frac{\text{Setting in volt } (V_{o/v})}{\text{Rated PT secondary voltage}}$$

Form IDMT curve 7sec at 1.5 times, select the suitable TMS for above calculated plug setting multiplier to obtain the operating time of approximately 1 second.

6.3 Under voltage relay

6.3.1Under voltage setting

The under voltage relay shall be provided to cut off the shunt capacitor bank from power supply when 25 kV supply fails or low voltage occurrs. The bank should not be put back in to system again before it is totally discharged. To fulfill this requirement a timer is also provided in the closing circuit, it is generally inbuilt with numerical relay, timer setting shall be set at 10 minutes. As the lowest permissible voltage in IR traction is 17.5kV, hence the under voltage relay shall be recommended to be set at 17.5kV.

$$\text{setting in volt } (V_{U/v}) = \frac{17500\ V}{\text{PT ratio}}\ V$$

$$\text{Setting in \%} = \frac{\text{Setting in volt } (V_{u/v})}{\text{Rated PT secondary voltage}} \times 100$$

6.3.2 Time multiplier setting (TMS) setting

Calculate the plug setting multiplier by formula given below:

$$\text{Plug setting multiplier} = \frac{\text{Setting in volt}}{\text{Rated PT secondary voltage}}$$

From IDMT curve 5sec at 0 Voltage; select the suitable TMS for above calculated plug setting multiplier to obtain the operating time of approximately 1 second.

6.4 Current unbalance relay

6.4.1 Current setting

This protection element is provided for internal faults in the capacitor units. At present as per RDSO specification No. ETI/PSI/67(11/96) A & C slip No. 7, each capacitor unit of 220 kVAR is rated for 8 kV, and its construction comprises of number of elements in parallel & individually protected by internal fuses. In case of failure of the element and therefore blowing of the internal fuse the voltage across the remaining healthy elements of affected and other units increases. The neutral unbalance current protection should be set so that it trips if the ratio of *the voltage across healthy elements in parallel to the failed elements in one unit* and *rated voltage of healthy element* is above 1.7. The manufacturer of the HT capacitor bank should provide the calculation for the above

based on the internal design of the capacitor unit. Generally the unbalance current generated after failure of 7-10 elements may cause the voltage appearing on the remaining healthy elements to 150-175% of the rated voltage which may damage the healthy capacitor element. A sample results of unbalance current and voltage rise produced due to failure of number of internal elements is placed at Annexure-I for reference.

$$\text{Set current in amp, } I_{UB} = \frac{\text{Recommended unbalance current}}{\text{NCT ratio}}$$

$$\text{Setting in \%} \quad \frac{I_{UB}}{\text{Rated CT secondary}} \times 100$$

6.4.2 Time setting

The time setting shall be kept at 200-400 ms.

7.0 Sample calculation for capacitor bank protection relay setting

7.1 Assumption

The following assumptions are made for sample calculation:

a. Shunt capacitor bank rating = 5500 KVAr at 40 kV

b. NCT ratio = 2/1

c. PT ratio = 27500/110

d. **Fault MVA** = 10000 MVA at 132kV base voltage.

e. **CT ratio =** 100/5

7.2 IDMT Over current relay

7.2.1 Current setting

Calculate the capacitive reactance at rated voltage

$X_C = 40^2 * 1000 / 5500$

$= 290.91 \ \Omega$

Calculate the effective reactance of complete capacitor & reactor unit

$X_{C1} = 290.91 – 0.13 * 290.91$

$= 253.09 \ \Omega$

Calculate the KVAr capacity of bank at 25 kV

$KVA_r = (25)^2 * 1000 / 253.09$

$= 2469.47$ KVAr

Rated current of capacitor bank at system voltage 25 kV

$$\text{Capacitor bank current in amp, } I_{cap} = \frac{2469.47}{25} = 98.77 \text{ amp}$$

To accommodate the CT and relay errors, the 10% higher value of above calculated current is recommended for setting of relay.

$$\text{Current setting of IDMT relay in amp } (I_{relay}) = \frac{1.10 \times 98.77}{100/5} = 5.43 \text{ Amp}$$

$$\text{Setting in \%} = \frac{5.43}{5} \times 100$$

= 108.65 i.e. 109 %

7.2.2 TMS setting

$$\text{Fault current} = \frac{27000}{4.36 + 37.82} = 640 \text{ Amp}$$

(Source and traction transformer impedance 4.36 ohm as calculated above for traction transformer setting)

$$\text{Plug setting multiplier} = \frac{640 * 5 / 100}{5.43} = 5.89$$

To achieve the operating time 500 ms for fault after shunt reactor, the TMS =

$$\frac{250}{1000} = \frac{\text{TMS x } 0.14}{[33/5.43]^{0.02} - 1}$$

$$\frac{250}{1000} = \frac{\text{TMS x } 0.14}{1.0367 - 1}$$

TMS = 0.0656 i.e. 0.07

7.3 Over voltage relay

7.3.1 Over voltage setting

$$\text{Setting in volt } (V_{o/v}) = \frac{1.1 \text{ x } 27500}{27500/110} = 121 \text{ Volt}$$

$$\text{Setting in \%} = \frac{121}{110} \text{ x}100 = 110\%$$

7.3.2 Time setting

$$\text{Plug setting multiplier} = \frac{121}{110} = 1.1$$

Form IDMT curve 7sec at 1.5 times, at 1.2 times of setting the operating time is 17 sec at TMS 1. To achieve the operating time 1 sec.

$$\text{TMS setting} = \frac{1}{17} = 0.058 \text{ i.e } 0.06$$

7.4 under voltage relay

7.4.1 under voltage setting

$$\text{setting in volt } (V_{U/v}) = \frac{17500}{27500/110} = 70 \text{ volt}$$

$$\text{Setting in \%} = \frac{70}{110} \times 100 = 63.64\ \%\ \text{i.e. } 64\%$$

7.4.2 TMS setting

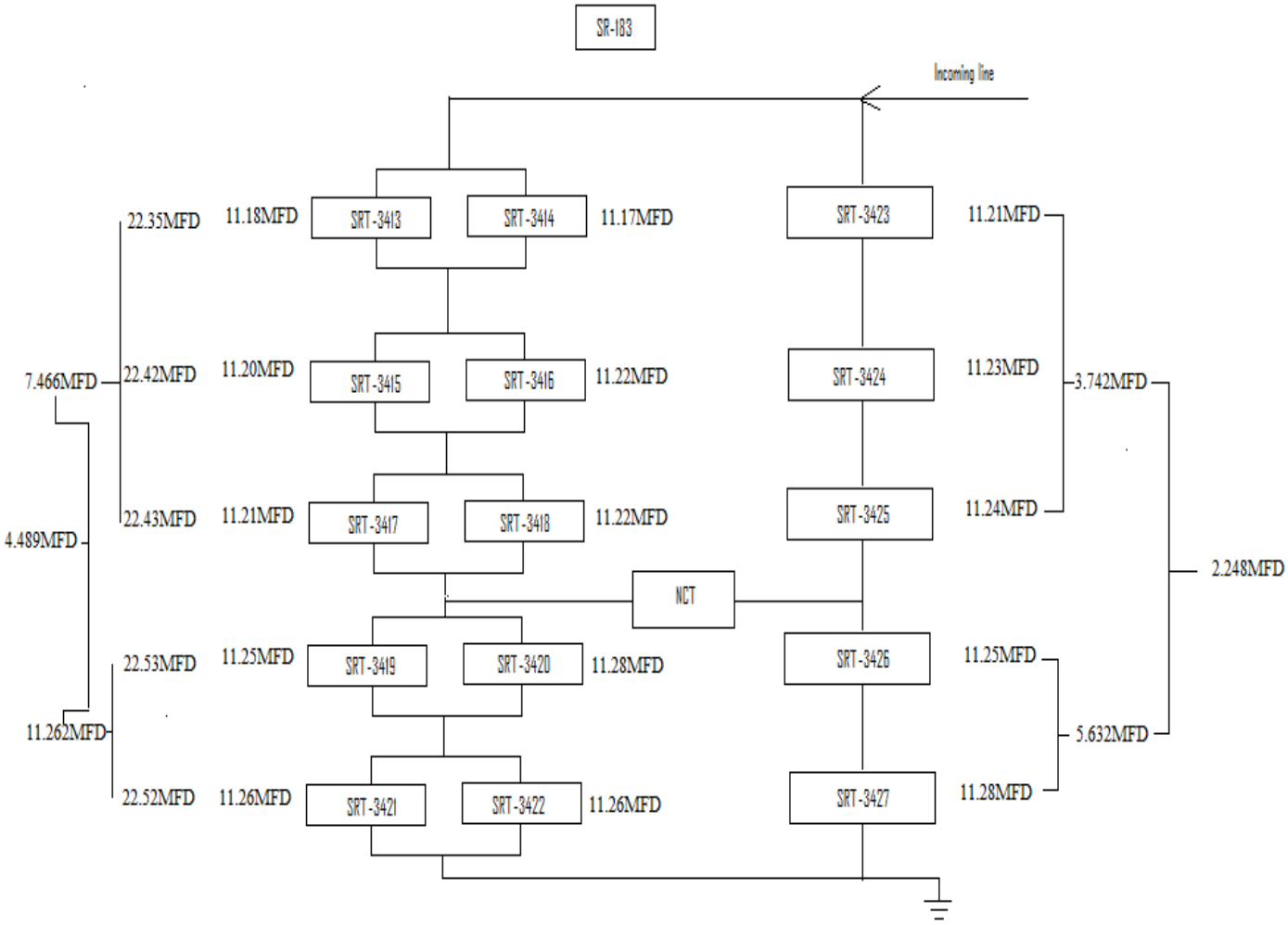
Calculate the plug setting multiplier by formula given below:

$$\text{Plug setting multiplier} = \frac{70}{110} = 0.64$$

Form IDMT curve 5sec at 0 Voltage; at 0.64 times of setting the operating time is nearly 9 sec at TMS 1. To achieve the operating time 1 sec.

$$\text{TMS setting} = \frac{1}{9} = 0.11$$

7.5 Current unbalance relay



TOTAL BANK CAPACITANCE = 6.737 MFD

BANK RATING = 3300 KVAR

7.5.1 Current setting

A sample result of unbalance current & voltage rises on healthy element and units of a capacitor bank vendor are given below:

X	In(A)	Vu/Vuo	Vel/Velo	Iu(A)
0	0.000	1.00	1.00	27.50
1	0.065	1.00	1.06	27.14
2	0.137	1.01	1.12	26.73
3	0.219	1.01	1.19	26.27
4	0.312	1.02	1.28	25.74
5	0.419	1.03	1.37	25.14
6	0.543	1.04	1.48	24.44
7	0.689	1.05	1.61	23.62
8 trip	0.863	1.06	1.76	22.64
9	1.073	1.07	1.95	21.46
10	1.333	1.09	2.18	19.99
11	1.662	1.11	2.47	18.14
12	2.094	1.14	2.86	15.70
13	2.638	1.18	3.38	12.38
14	3.536	1.24	4.13	7.58

X – Number of failed elements.
In(A) – Neutral current in Amps.
Vel – Voltage across healthy element in parallel to failed element.
Velo – Rated voltage of healthy element.
Vu – Voltage across healthy unit in series with failing unit.
Veo – Rated voltage of healthy unit.
Iu(A) – Unit current in amps.

As per the above sample result, it is seen that with the failure of 8 elements resulting voltage appeared across healthy elements parallel to failed elements is 1.76 times of rated voltage, the unbalance current above number of elements failure is 0.863 amps. This is the sample results only; it may vary manufacturer to manufacturer, therefore approach to capacitor bank manufacturer for actual permitted unbalance current.

$$\text{Set current in amp, } I_{UB} = \frac{0.863}{2/1} = 0.4315 \text{ amp}$$

$$\text{Setting in \%} \quad \frac{0.4315}{1} \times 100 = 43.15\% \text{ i.e. } 43\%$$

7.5.2 Time setting

The time setting shall be kept at 200-400 ms.