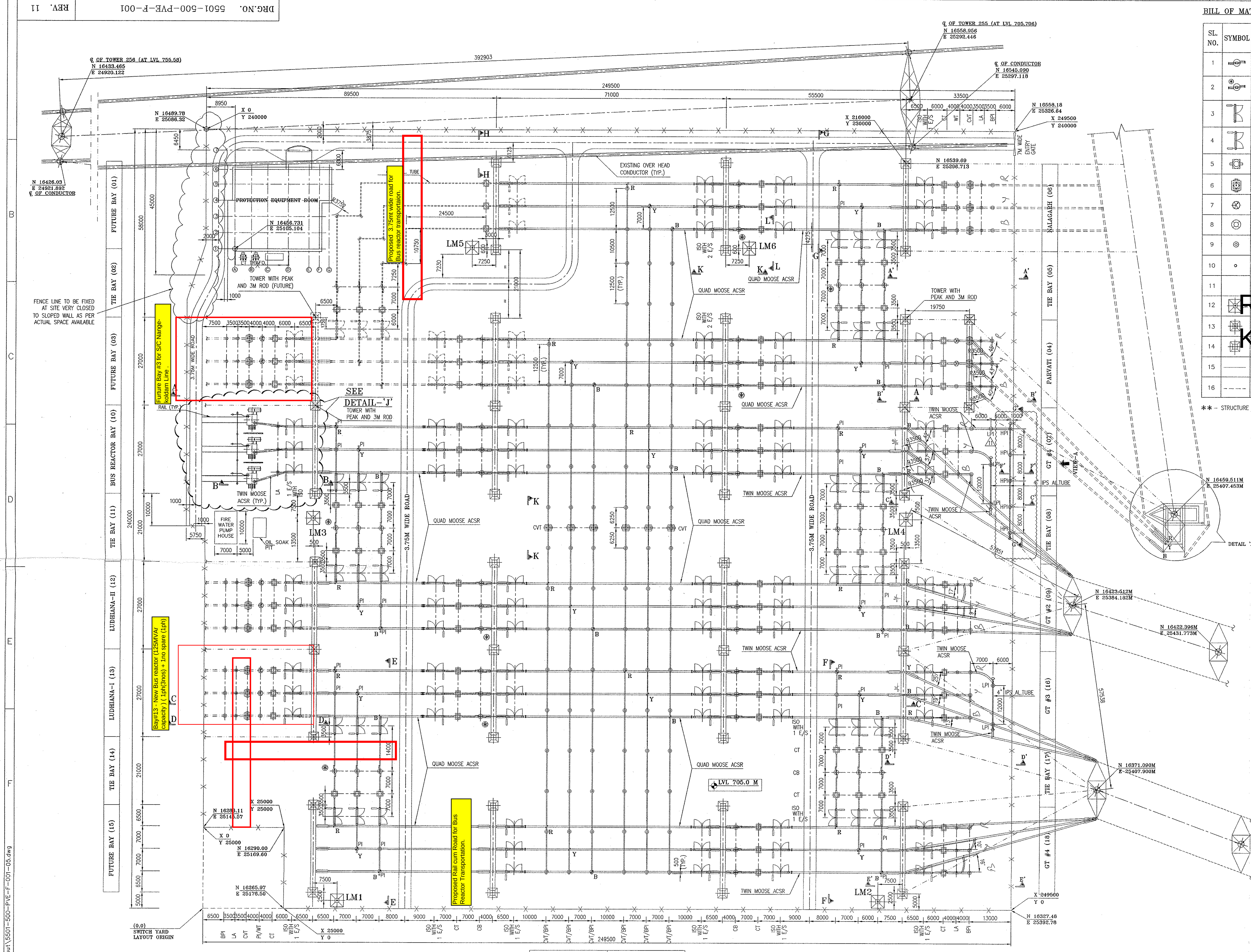
For Koldam S/s



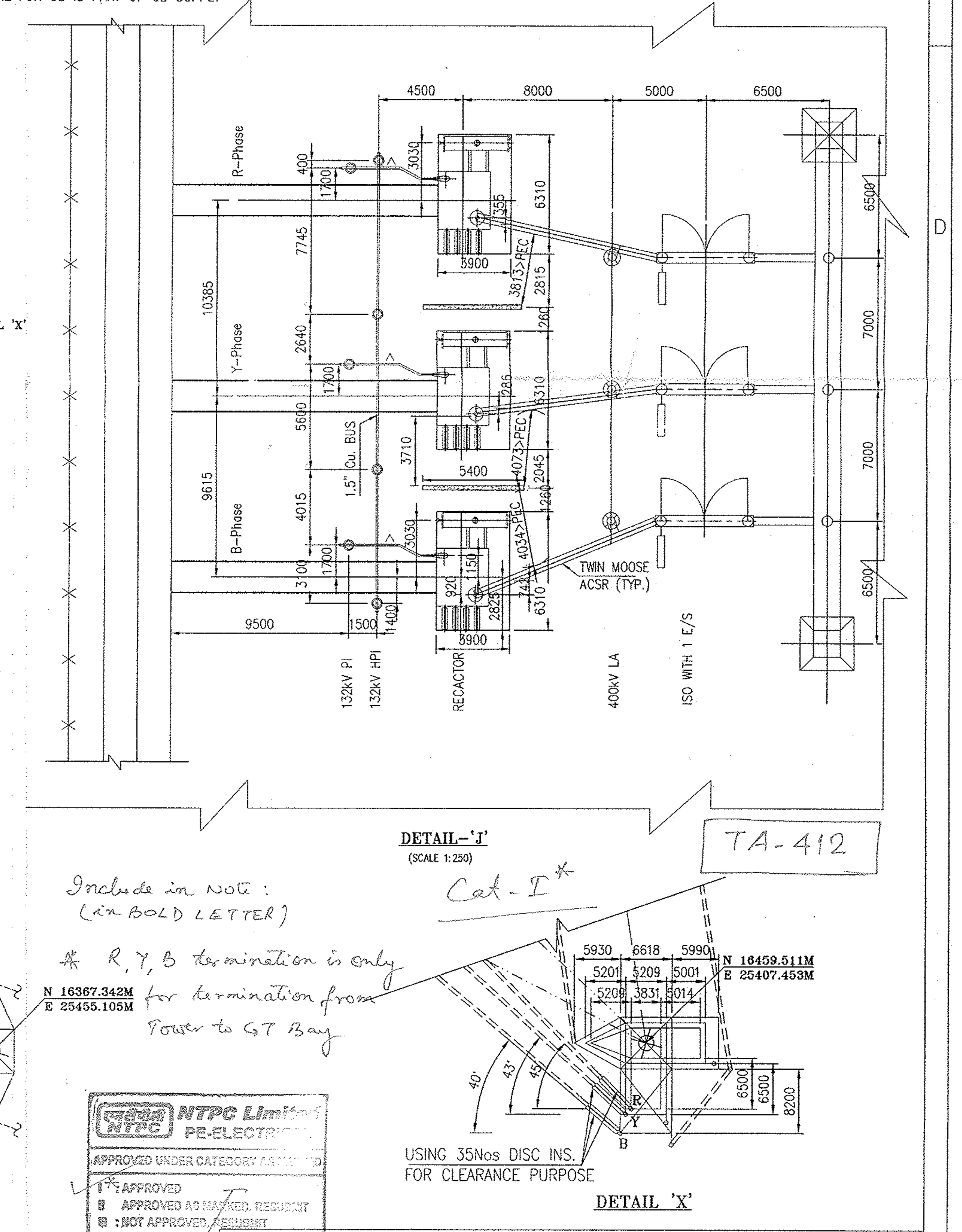
BILL OF MATERIAL SWITCHYARD

SL. NO.	SYMBOL	ITEM DESCRIPTION	RATING	QUANTITY EQPT.	STR.	FDN.
1		CIRCUIT BREAKER (3ø)	400kV, SF6, 2000A, 40kA/1 SEC.	7 NOS	7 NOS **	7 NOS
2		CIRCUIT BREAKER WITH CLOSING RESISTOR (3ø)	400kV, SF6, 2000A, 40kA/1 SEC.	7 NOS	7 NOS **	7 NOS
3		CENTRE BREAK ISOLATOR WITH ONE EARTH SWITCH (3ø)	400kV, HCB, 2000A, 40kA/1 SEC.	36 NOS	36 NOS	36 NOS
4		CENTRE BREAK ISOLATOR WITH TWO EARTH SWITCH (3ø)	400kV, HCB, 2000A, 40kA/1 SEC.	2 NOS	2 NOS	2 NOS
5		CURRENT TRANSFORMER (1ø)	400kV, 5 CORE, 2000A, 40kA/1 SEC.	78 NOS	78 NOS	78 NOS
6		CAPACITIVE VOLTAGE TRANSFORMER (1ø)	400kV, 3 CORE, 2000A, 40kA/1 SEC.	18 NOS	18 NOS	18 NOS
7		WAVE TRAP (1ø)	400kV, 2000A	8 NOS	8 NOS	8 NOS
8		SURGE ARRESTOR (1ø)	400kV, 10kA/20kA GAPLESS	27 NOS	27 NOS	27 NOS
9		BUS POST INSULATOR	400kV	153 NOS	153 NOS	153 NOS
10		BUS POST INSULATOR	132kV	7 NOS	7 NOS	7 NOS
11		BUS REACTOR (1ø)	26.67 MVAR, 400kV, 1 PHASE ONAN COOLED	[illegible]	[illegible]	3 NOS
12		LIGHTNING MAST		[illegible]	6 NOS	6 NOS
13		TOWER WITH PEAK		–	17 NOS	17 NOS
14		TOWER WITHOUT PEAK		–	20 NOS	20 NOS
15		PRESENT SCOPE		–	–	–
16		FUTURE / OTHERS		–	–	–

** – STRUCTURE FOR CB IS PART OF CB SUPPLY

RAVI KUMAR KURA

Digitally signed by RAVI KUMAR KURA
DN: cn=RAVI KUMAR KURA, c=IN, st=TELANGANA, o=NTPC LIMITED, ou=NTPC BHAVAN, serialNumber=C1249883BEFB691287A7F4D358D58D5CBAC5C7665A12C1D1E0634EB106976B9C
Reason: sign and save
Date: 2022.11.12 16:22:48 +05'30'



APPROVED UNDER CATEGORY
I : APPROVED
II : APPROVED AS MARKED. RESUBMIT
III : NOT APPROVED, RESUBMIT
IV : FOR INFORMATION & RECORDS
SIGN. & DATE 26/02/09
DESIGNATION

NO.	DATE	REMARKS	BY	APPD.	DRG.NO.	TITLE
11	13.02.2009	REVISED BASED ON CIVIL FOUNDATION LAYOUT	SSL	KKJK		
10	30.06.2008	REVISED AS PER NTPC COMMENTS DTD. 18.06.2008	SSL	KKJK		
09	04.06.2008	REVISED AS PER NTPC COMMENTS DTD. 12.05.2008	SSL	KKJK		
08	24.04.2008	REVISED FOR GT & LINE TERMINATION WITH SWITCHYARD	SSL	KKJK		NTPC & PGCIL MOM DT: 04.10.2007
07	14.05.2007	REVISED INCORPORATING CLEARANCE DIAGRAM FOR REACTOR AREA	KVRN	KVRN		GT1, GT2, GT3 & GT4 SURVEY REPORT
06	13.04.2007	REVISED REACTOR AREA IN LINE WITH REACTOR GA DRAWING	SSV	KVRN	5501-500-PVE-F-014 (R-00)	CLEARANCE DIAGRAM FOR REACTOR AREA – PLAN & SECTION
05	18.01.2007	REVISED AS PER NTPC TELECON DATED 18.01.07	SSV	KVRN	5501-500-PVE-F-002 (R-00)	400kV SWITCHYARD SECTIONS
04	14.06.2006	REVISED AS PER NTPC COMMENTS DTD. 05.06.2006	SSV	KVRN	5501-500-PVE-P-001 (R-00)	400kV SWITCHYARD – SINGLE LINE DIAGRAM
03	31.05.2006	REVISED AS PER DISCUSSION WITH NTPC ON 18.05.2006	SSV	KVRN	5501-500-POE-A-001 (R-B)	SINGLE LINE DIAGRAM FOR 400kV SWITCHYARD. (TENDER DRAWING)
02	07.02.2006	REVISED AS PER NTPC COMMENTS DTD. 13.01.2006	SSV	HVB	SKETCH-A (R-0)	OVER ALL PLOT PLAN (TENDER DRAWING)
01	27.12.2005	REVISED AS PER NTPC COMMENTS DTD. 20.12.2005	SSV	HVB	SKETCH-B (R-0)	400kV SWYD G.A (TENDER DRAWING)
00	16.11.2005	FOR APPROVAL / FIRST SUBMISSION	HVB	DM	DRG.NO.	TITLE
NO.	DATE	REMARKS	BY	APPD.	REFERENCE DRAWINGS	

NOTES:

1. ALL DIMENSIONS ARE IN mm AND LEVELS ARE IN METRES
2. THIS DRAWING SHALL BE READ IN CONJUNCTION WITH DRG. NO.: 5501-500-PVE-F-002
3. FOLLOWING CLEARANCES ARE ADOPTED (MINIMUM)

	400kV	132kV (AS PERIS 10118)
PHASE TO PHASE	4000mm	1300mm
PHASE TO EARTH	3500mm	1300mm
SECTION CLEARANCE	6500mm	4000mm
GROUND CLEARANCE	2550mm	2550mm

4. CONDUCTOR DETAILS
   LINE BAY : QUAD MOOSE GENERATOR BAY : TWIN MOUSE
5. LOCATION OF WAVE TRAPS ARE INDICATIVE ONLY AND THE EXACT LOCATION WILL BE BASED ON PLCC REQUIREMENT.
6. PI SHALL BE INSTALLED FOR THE 3RD. PHASE WITHOUT WAVE TRAP. HOWEVER, FOUNDATIONS SHALL BE SUITABLE FOR WAVE TRAPS
7. NORMAL TENSION FOR CONDUCTORS
   TWIN MOOSE : 2T/CONDUCTOR – 4T/PHASE
   QUAD MOOSE : 1.5T/CONDUCTOR – 6T/PHASE
8. NEW TOWER & GANTRY SHALL BE DESIGNED AS PER ANGLE OF DEVIATION
9. POWER GRID LINE DEAD END TOWER SHALL BE MADE & POSITIONED AS INDICATED TO ACHIEVE ADEQUATE CLEARANCE
10. THE MAXIMUM CONDUCTOR TENSION ON THE O/G PHASE CONDUCTOR SHALL BE SUCH THAT THE TENSION VALUES SHALL NOT EXCEED THE FOLLOWING VALUES
    a. MAX. TENSION/CONDUCTOR IN THE DIRECTION PERPENDICULAR TO THE GURDER IN HORIZONTAL PLANE = 2.0 MT
    b. MAX. TENSION/CONDUCTOR IN THE DIRECTION PARALLEL TO THE GURDER IN HORIZONTAL PLANE = 1.0 MT
11. R,Y,B PHASE SEQUENCE LINE & GT FEEDERS SHALL BE CONFIRMED BY NTPC.
12. TO OBTAIN THE PHASE TO EARTH CLEARANCE WE PROPOSE TO PROVIDE ONE PLATFORM AT 25 M LEVEL FOR LM5 AND LM6

RELEASE STATUS	SIGN	DATE
PRELIMINARY		
FOR TENDER ONLY		
FOR APPROVAL/REFERENCE/INFORMATION		
FOR CONSTRUCTION		
APPROVED BY: MECHANICAL		
APPROVED BY: ELECTRICAL		
APPROVED BY: CIVIL & STRL.		

एन टी पी सी NTPC
एन टी पी सी लिमिटेड
NTPC Limited
A Govt. of India Enterprise
(Formerly National Thermal Power Corporation Ltd.)

PROJECT : KOLDAM HYDRO ELECTRIC POWER PROJECT (4x200MW)
PACKAGE : 400kV SWITCHYARD PACKAGE (CS-5501-500-2)

LARSEN & TOUBRO LIMITED
ECC Division – EDRC

CODE	SOURCE	SCALE		DSN.	DRWN.	CHKD.	APPRD.
		1 : 600	DATE	27.10.05	28.10.05	14.11.05	16.11.05
			NAME	SSV/VTN	AGS	HVB	DM

TITLE: 400kV SWITCHYARD LAYOUT – PLAN

DRAWING NO. 5501-500-PVE-F-001 REV. 11

Drawings\Ags\05101-E-SY (NTPC-KOLDAM)\Deliverables\Layout\5501-500-PVE-F-001-05.dwg

PROJECT	400 kV SWITCHYARD PACKAGE KOLDAM HYDRO ELECTRIC POWER PROJECT - (CS-5501-500-2)	DOCUMENT NO 5501-500-PVE-U-003		DATE 17/03/2006
TITLE	400kV Switchyard Earth mat Calculation	PREPARED VTN	CHECKED SSV	SHEET 1 of 7

CALCULATIONS ARE BASED ON IEEE Std 80-2000

1.0.0 PURPOSE AND SCOPE

The purpose of the document is to design the Earthmat for the 400 kV Switchyard. The important aspect is that the design should achieve "Tolerable Touch and Step potential " with the Earth grid resistance less than 1 ohm.

2.0.0 DESIGN INPUT

2.1.0 SYSTEM PARAMETERS

2.1.1	System Voltage		=	400 kV	
2.1.2	System Grounding		=	Solid	
2.1.3	Maximum Fault Current		=	40000 A	*(Spec CH -E0, Cl 4.00.00 e)*
2.1.4	Current Distribution Factor		=	53.64%	*(Refer Annex-B)*

(Current Distribution factor is considered as per Cl 15.0 of IEEE-80,2000 and Methodology is as per IEEE Transaction on Power Apparatus and systems "Current for Design of Grounding System" ,Vol PAS .103,No.9,Sep 1984)

2.1.5	Maximum Fault Current considered		=	40000 x 0.5364	
			=	21455 A	
2.1.6	Duration of Fault Current	t_s	=	0.50 s	*(Typical value (> Operation time of Numerical Relays+ CB))*

2.2.0 ENVIRONMENTAL PARAMETERS

2.2.1	Soil Resistivity	ρ	=	464.00 ohm.m	*(Refer Annex-D-Average Value)*
2.2.2	Top Layer resistivity (Crushed rock)	ρ_s	=	5000 ohm.m	*IEEE-80,Table-7 Washed Granite ,similar to Pea Gravel*
2.2.3	Length of Switchyard	L	=	254 m	*(Drg .5501-500-PVE-F-001)* (2m outside fence - Spec CH E13,Cl 4.00.08)
2.2.4	Breadth of Switchyard	B	=	244 m	*(Drg .5501-500-PVE-F-001)* (2m outside fence - Spec CH E13,Cl 4.00.08)

2.3.0 OTHER DETAILS

2.3.1	Conductor diameter	d	=	0.040 m	*(Spec.Part-IICh.E13,Cl 2.00.00)*
2.3.2	Conductor Area		=	1257 Sq.mm	
2.3.3	Depth of burial (minimum)	h	=	0.6 m	*(Spec.Part-IICh.E13,Cl.e3.00.01)*
2.3.4	Depth of Top Layer	h_s	=	0.15 m	*(Assumed)*
2.3.5	No of electrodes		=	95	
2.3.6	Length of electrode	l	=	3 m	(Spec.Part-IICh.E13,Cl 2.00.00)
2.3.7	Diameter of electrode	d_1	=	40 mm	(Spec.Part-IICh.E13,Cl. 2.00.00)

3.0.0 CALCULATIONS

3.1.0. CALCULATIONS - PRELIMINARY

3.1.1 Area of Switchyard A_g = L x B

= 254 x 244

= 61976 Sq.m

3.1.2 Spacing of Conductors D_s = 6.0 m

3.1.3 No: of grids in X direction N_x = $(L/D_s)+1$

= 254/6+1

= 44

3.1.4 No: of grids in Y direction N_y = $(B/D_s)+1$

= 244/6+1

= 42

3.1.5 Total length of conductors L_c = $L.N_y + B.N_x$

= 254 x 42 + 244 x 44

= 21404 m

3.1.6 Total length of electrodes L_r = 95 x 3

= 285 m

3.1.7 Peripheral length of Grid L_p = 2 x (L + B)

= 2 x (254 + 244)

= 996 m

3.1.8 Maximum distance between two points on grid D_m = $\sqrt{(L^2 + B^2)}$

= $\sqrt{(254^2 + 244^2)}$

= 352 m

3.1.5 Geometric factor n

n_a = $2.L_c/L_p$ (Eqn. 85 in page 93)

= 2 x 21404 / 996

= 43.0

n_b = $\sqrt{(L_p/(4 \times \sqrt{A_g}))}$ (Eqn. 86 in page 93)

= $\sqrt{(996/(4 \times \sqrt{61976}))}$

= 1.0

$n_c = (L.B/A_g)^{0.7 A/(L.B)}$ (Eqn. 87 in page 93)

$= (254 \times 244/61976)^{0.7 \times 61976/(254 \times 244)}$

$= 1.0$

$n_d = D_m/\sqrt{(L^2+B^2)}$ (Eqn. 88 in page 93)

$= 352/\sqrt{(254^2+244^2)}$

$= 1.0$

$n = n_a \cdot n_b \cdot n_c \cdot n_d$ (Eqn. 84 in page 93)

$= 43.0 \times 1.0 \times 1.0 \times 1.0$

$= 43.7$

3.2.0 TOLERABLE TOUCH POTENTIAL

E_{touch} = $(1000 + 1.5\, C_s\, \rho_s) * 0.116 / \sqrt{t_s}$ (Eqn. 32 in page 27)

C_s = $1 - 0.09\,(1 - \rho/\rho_s) / (2\, h_s + 0.09)$ (Eqn. 27 in page 23)

= 1-0.09*(1-464/5000)/(2*0.15+0.09)

= 0.7906

E_{touch} = $(1000 + 1.5\, C_s\, \rho_s) * 0.116 / \sqrt{t_s}$

= $(1000 + 1.5 * 0.7906 * 5000) * 0.116 / \sqrt{0.5}$

= **1136.83** V

3.3.0 TOLERABLE STEP POTENTIAL

E_{step} = $(1000 + 6.0 * C_s * \rho_s) * 0.116 / \sqrt{t_s}$ (Eqn. 30 in page 27)

= $(1000 + 6.0 * 0.7906 * 5000) * 0.116 / \sqrt{0.5}$

= **4055.18** V

3.4.0 TOUCH POTENTIAL ATTAINABLE

E_{mesh} = $\rho\, K_m\, K_i\, I\ /\ L_m$ (Eqn. 80 in page 91)

L_m = $L_c + L_r$ (Eqn.90 in page 94)

= 21404+285

= 21689 m

$$K_m = \frac{1}{2\pi}\left\{\ln\left[\frac{D_s^2}{16\,hd} + \frac{(D_s + 2h)^2}{8\,D_s\,d} - \frac{h}{4d}\right] + \frac{K_{ii}}{K_h}\ln\left[\frac{8}{\pi(2n-1)}\right]\right\}$$

(Eqn. 81 in page 93)

K_{ii} =
- 1.00 for grids with ground rods in perimeter (Page 93)
- $1/(2n)^{2/n}$ for grids with no ground round rods or grids with only a few ground rods

Here we consider grids with ground rods in perimeter

h_o = 1.00 m (reference depth of grid)

K_h = $\sqrt{(1+h/h_o)}$

= $\sqrt{(1 + 0.6 / 1.0)}$

= 1.2649

K_m = $\frac{1}{2\pi}\left\{Ln\left\{\frac{6.0^2}{16*0.6*0.04} + \frac{(6.0+2*0.60)^2}{8*6.0*0.04} - \frac{0.6}{4*0.04}\right\} + \frac{1}{1.26}\left\{\frac{8}{464\,(2*43.7-1)}\right\}\right\}$

= 0.3145

K_i = 0.644 + 0.148 * n (Eqn 89 in page 94)

= 0.644 + 0.148 *43.7

= 7.1095

E_{mesh} = $\rho\, K_m\, K_i\, I\ /\ L_m$

= 464 * 0.3145 * 7.1095 * 21455 / 21689.00

= **1026.37 V**

3.5.0 STEP POTENTIAL ATTAINABLE

E_{step} = $\rho\, K_s\, K_i\, I\ /\ L_s$ (Eqn 92 in page 94)

L_s = $0.75\, L_c + 0.85\, L_r$ (Eqn 93 in page 94)

= 0.75 *21404.00+ 0.85* 285.00

= 16295.3 m

n = 44 (Higher of the no.of grids in X & Y direction)

K_s = $\frac{1}{\pi}*\left\{\frac{1}{2h} + \frac{1}{D_s+h} + \frac{1}{D_s}(1-0.5^{(n-2)})\right\}$ (Eqn. 94 in page 94)

= (1 / 22/7) * { 1 / (2 * 0.6) + 1 / (6.0 + 0.6) + 1 / 6.0 * (1 - 0.5^(44 - 2) }

= 0.3665

E_{step} = $\rho\, K_s\, K_i\, I\ /\ L_s$

= (464.00 * 0.3665 * 7.1095 * 21455) / 16295.3

= **1591.99 V**

4.0.0 CALCULATION OF GROUNDING RESISTANCE

4.1.0 RESISTANCE OF GROUND RODS

$R_e = \frac{\rho}{2\pi n L_r}\left\{\ln(4 l/d) - 1 + \frac{2 K_1}{\sqrt{Ag}}(\sqrt{n}-1)^2\right\}$ (Eqn. 55 in page 66)

$K_1 = \begin{cases} 1.41-0.04x & \text{for } H = 0 \\ 1.20-0.05x & \text{for } H = 1/10\sqrt{A_g} \\ 1.13-0.05x & \text{for } H = 1/6\sqrt{A_g} \end{cases}$ (Fig 25(a) in page 67)

H = 0.6 m

K_1 = 1.41-0.04x

= 1.41-0.04(L/B)

= 1.41-0.04*254.00/244.00

= 1.3684

R_e = 464.00 / (2 * 95 * 22/7 * 3.0) * { ln (4 * 3.0 / 0.0400) - 1 + 2 * 1.368 * (3 / sqrt(61976)) * (sqrt (95)-1)^2]

= 1.8726 ohm

4.2.0 RESISTANCE OF GROUND GRID

$R_s = \frac{\rho}{\pi L_c}\left\{\ln(2 L_c / h) + \frac{K_1 L_c}{\sqrt{A_g}} - K_2\right\}$ (Eqn. 54 in page 66)

$K_2 = \begin{cases} 5.50+0.15x & \text{for } H = 0 \\ 4.68+0.10x & \text{for } H = 1/10\sqrt{A_g} \\ 4.40-0.05x & \text{for } H = 1/6\sqrt{A_g} \end{cases}$ (Fig 25(b) in page 67)

K_2 = 4.68+0.10x

= 4.68+0.10(L/B)

= 4.68+0.10*254.00/244.00

= 4.78

h' = √(d . h) (Page 66)

= √(0.04 * 0.6)

= 0.155 m

R_s = (464.00 / (22/7 * 21404)) * [ln (2 * 21404 / 0.1549) + 1.368 * (21404 / sqrt (61976.00)) - 4.784]

= 0.8523 Ohms

4.3.0 MUTUAL RESISTANCE BETWEEN GROUND GRID AND GROUND RODS

$$R_{se} = \frac{\rho}{\pi L_c}\left\{\ln(2 L_c / L_r) + \frac{K_1 L_c}{\sqrt{A_g}} - K_2 + 1\right\}$$ (Eqn 56 in page 66)

= 464.00 / (22/7 * 21404) * [ln (2 * 21404 / 3.0) + 1.368 * (21404.00 / sqrt (61976.00)) - 4.784 + 1]

= 0.6246 ohms

4.4.0 COMBINED RESISTANCE OF GROUND GRID AND GROUND RODS

$$R_g = \frac{R_g \cdot R_s - R_{se}^2}{R_g + R_s - 2R_{se}}$$ (Eqn. 53 in page 66)

$$= \frac{1.8726 * 0.8523 - 0.6246^2}{1.8726 * 0.8523 - 2 * 0.6246}$$

= 0.8171 Ohm

THIS IS LESS THAN THE RECOMMENDED VALUE OF LESS THAN 1.0 OHM

5.0.0 RESULTS

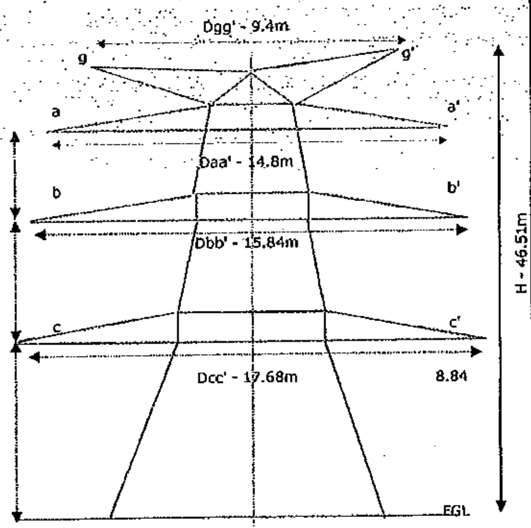
5.1.1	Spacing of conductors	D_s	=	6 m	
5.1.2	Total length of conductors	L_c	=	21404 m	
5.1.3	Attainable step potential		=	1591.99 V	
5.1.4	Attainable touch potential		=	1026.37 V	
5.1.5	Tolerable step potential		=	4055.18 V	
5.1.6	Tolerable touch potential		=	1136.83 V	

Thus Attainable Emesh is less than Tolerable Etouch and Attainable Estep is less than Tolerable Estep

5.1.7	Combined resistance of Grid & ground rods		=	0.8171 ohm	<1.0 ohm

A.1 Input Data

A	=	8.3	m	
B	=	8.3	m	
G	=	21.86	m	
H	=	46.51	m	
Dgg'	=	9.4	m	
Daa'	=	14.8	m	
Dbb'	=	15.84	m	
Dcc'	=	17.68	m	
Design Temperature	=	50	deg.C	
No. of sub conductors N	=	4		(QUAD)
Radius of conductor r	=	0.03177	m	(ACSR MOOSE)
Subconductor Spacing S	=	100	m	(Tech Spec CH -EO, Clause 1.01.09)
Resistivity of earth ρ	=	100	ohm-m	(Typical Value for Transmission Line)
System frequency f	=	50	Hz	



TYPICAL D/C 400kV TOWER

A.2 METHODOLOGY

IEEE Transactions on Power Apparatus and Systems, Vol. PAS-103, No.9 September 1984.

The mutual and self impedance of a system can be calculated as follows.

Mutual Impedance Z_{gm} = $0.000988 * f + j\,0.0028938 * f * \log_{10}(De/GMD)$ ohms/ km -------1

Self Impedance Z_g = $Rc + 0.000988 * f + j\,0.0028938 * f * \log_{10}(De/GMR)$ ohms/ km -------2

Where	Rc	: Resistance of ground wire
	GMD	: Geometric Mean Distance
	GMR	: Geometric Mean Radius
	De	: Equivalent depth of earth return

A.3 Calculation of Equivalent Depth of Earth Return (De)

De = 658.4 √(ρ / f)

= 658.4 * √(100 / 50)

= 931.12 m

A.4 Calculation of Geometric Mean Radius (GMR)

Bundle radius A = S/2 * sin (π / N)

= 0.0354 m

GMR of bundled conductor GMRb = $(N\ r\ A^{N-1})^{1/N}$

= (4 * (0.03177) * 0.0354^(4-1))^ 1/4

= 0.0487 m

Dsa = √(GMRb * Daa')

= 0.8488 m

Dsb = √(GMRb * Dbb')

= 0.8781 m

Dsc = √(GMRb * Dcc')

= 0.9277 m

Geometrical Mean Radius = ³√(Dsa . Dsb . Dsc)

= ³√(0.8488 *0.8781 * 0.9277)

= 0.8843 m

A.5 Calculation of Geometric mean Distance (GMD)

From the above GA of tower ,

Dab = Da'b' =	8.32 m	Da'b =Dab' =	17.42 m	(From Tower Geometry)
Dbc = Db'c'=	8.35 m	Dbc' =Dcb' =	18.70 m	
Dca = Dc'a'=	16.66 m	Dca' =Dac' =	23.22 m	

Dab = $(Dab . Da'b . Dab' . Da'b')^{1/4}$

= (8.32 *17.42 * 17.42 * 8.32)^ 1/ 4

= 12.04 m

Dbc = $(Dbc . Db'c . Dbc' . Db'c')^{1/4}$

= (8.35 *18.70 * 18.70 * 8.35)^ 1/ 4

= 12.50 m

Dca = $(Dca . Dc'a . Dca' . Dc'a')^{1/4}$

= (16.66 *23.22 * 23.22 * 16.66)^ 1/ 4

= 19.67 m

Geometrical Mean Diameter = ³√(Dab . Dbc . Dca)

= ³√(12.04 *12.50 * 19.67)

= **14.36** m

A.6 Calculation of Ground Conductor resistance (Rc)

DC resistance at 20 Deg. C Rdc20 = 1.32 ohms/km (Typical Data)

M constant for Steel = 153.85

DC resistance at Design Temperature = Rdc20 $\frac{(M+t2)}{(M+t1)}$ ohms/km

Rdc50 = 1.5460 ohms / km

AC resistance by considering Skin effect

Rdc50 = 1.7006 ohms / km

No. of earth conductors in a TL Path = 2

Hence equivalent resistance Rc = 0.8503 ohms/ km i.e. Rac50 / 2

A.7 Calculation of Mutual & Self Impedance of Ground Wire (Refer Annexure-D)

Zgm = 0.000988 * 50 + j 0.0028938 * 50 * Log10(931.12 / 14.357)

= 4.94E-002+0.26217i ohm/ km

Zg = 0.8503 + 0.000988 * 50 + j 0.0028938 * 50 * Log10(931.12 / 0.884)

= 0.89969+0.43731i ohm/ km

LARSEN & TOUBRO LIMITED ECC Division - EDRC (Electrical)				
PROJECT	400 kV SWITCHYARD PACKAGE KOLDAM HYDRO ELECTRIC POWER PROJECT - (CS-5501-500-2)	DOCUMENT NO Annex-B to 5501-500-PVE-U-003		DATE 16/03/2006
TITLE	DETERMINATION OF CURRENT DISTRIBUTION FACTOR	PREPARED VTN	CHECKED SSV	SHEET 1 of 2

According to the IEEE transactions on Power apparatus and systems vol. PAS-103, No.9, september 1984, page 2633-2635, The total fault current will not flow through the substation ground as part of the current will be diverted by ground wires due to induction and conduction.

B.1 INPUT DATA

Distance between towers	Lspan	=	0.3 km	Typical Data
Tower footing resistance	Rt	=	10 ohm	

B.2 DIVERSION OF CURRENT DUE TO INDUCTION

Ratio of Mutual to self inductances |m| = |Zgm/Zg|

= |(4.94E-002+0.26217i)/(0.89969+0.43731i)|

= |0.15899+0.21412|

= 0.2667 i.e, 26.67% of fault current will be induced in earth wire

Current diverted due to induction Il = |m|*If

= 0.2667*40000

= 10668 A

B.3 DIVERSION OF CURRENT DUE TO CONDUCTION

Self impedance of one span of ground wire Zspan = Zg * Lspan

= 0.89969+0.43731i * 0.3

= 0.269907+0.131193i ohm

Admittance of the ladder network Y = $\frac{1}{\frac{Zspan}{2} + \sqrt{Zspan * Rt}}$

= $\frac{1}{\frac{0.269907+0.131193i}{2} + \sqrt{(0.269907+0.131193i * 10)}}$

= 0.41353025499967-0.120817747455646i

|Y| = 0.4308 mho

Current diverted due to induction Il = 10668 A

Hence Balance current I_G' = 29332 A

Current diverted due to conduction I_C = $I_G' - I_G' * \frac{1/Y}{Rg+1/Y}$

= $29332 - 29332 * \frac{(1/0.4308)}{(0.8523 + 1/0.4308)}$

= 7877 A

B.4 FAULT CURRENT ENTERING GROUND

Fault current entering ground = Maximum Fault current - Current diverted due to Induction & Conduction

= 40000 - 10668 - 7877

= 21455 A

Current Distribution factor = 21455 / 40000

= 53.64%

NOTE: Though there are four Outgoing Lines from the Switchyard,we have considered fault current diverted by Shield wires of one line for conservative design.

IEEE Transactions on Power Apparatus and Systems, Vol. PAS-103, No. 9, September 1984

CURRENT FOR DESIGN OF GROUNDING SYSTEMS

S. Thapar
Punjab Engineering College
Chandigarh.

Sunil K. Madan
Punjab State Electricity Board
Chandigarh (India).

Abstract - A simple method to estimate the current for calculating the size of the grounding conductor and for evaluating the step, touch and transferred potentials, is presented. The factors effective in making these currents different from the total fault current have been indicated. Various types of substations, different fault locations and a wide range of parameters of aerial ground wire encountered in practice are considered. Data presented emphasizes the saving in grounding design costs that can be realised by using maximum realistic ground currents rather than maximum calculated total fault currents for evaluation of step & touch potentials.

INTRODUCTION

For the design of grounding systems in high voltage stations it is necessary to evaluate the realistic value of the fault current to be used in determining (a) the size of the grounding conductor and (b) the step, touch and transferred potentials. For determining the size of the grounding conductor it is necessary to know the maximum current, I_C, that would flow in any section of the grounding system and for evaluating the potentials the maximum current, I_G, that would be discharged by the grounding system to the ground is required.

Only single line to ground fault is considered as this gives the highest zero sequence current in most cases. The total fault current returns to the system through a number of paths. Only the current flowing through the grounding system at the station to the ground constitutes the current I_G. Accurate analytical methods to determine the fault current distribution between soil and ground conductor are available[2,3,4]. These methods require the use of the computer and the values of the network parameters which may not be easy to measure with certainty. For the design of grounding systems, high degree of accuracy is not necessary because of the uncertainty of basic data like soil resistivity. This paper presents a directly applicable simple method, to estimate I_C and I_G. Because of their extensive use only overhead transmission lines are considered in this paper.

FAULT LOCATION

The fault location which produces the maximum I_C and I_G may be either on the higher voltage side or lower voltage side of the station transformer. It may be either inside or outside the station on a transmission line. Inside the station, the current supplied to the fault by the local transformer circulates in the station itself and does not form part of I_G; whereas the current supplied to the fault through the transmission lines has to return to the system through the grounding system and ground or through the aerial ground wires on transmission lines. When a fault is outside the station the current supplied to the fault through the transmission line from the other stations has negligible contribution to I_G. The component of fault current supplied by the local transformer returns to the system via (i) overhead ground wires which have metallic connection to the neutral through the station structure and (ii) the tower footing and grounding system of the station. The current flowing via path (ii) constitutes I_G. If the fault is near a station, major part of the current supplied by station will return via path (i) and if the fault is far away from the station the magnitude of the fault current supplied by the station will be less because of the line impedance. Therefore, in most cases maximum I_G will be obtained for faults inside the station.

The substations in an electric power system for purposes of determining I_C and I_G may be classified into following categories.

1 Step up station at generating station, transformer connected in delta-wye.
2 Intermediate station (Power source on both sides).
   i) Wye-wye connected transformer.
   ii) Auto transformer.
   iii) Delta-delta connected transformer.
   iv) delta-wye connected transformer.
3 Terminal station (Power source only on H.V. side). This can be considered as a special case of the Intermediate Station when the contribution of the fault current fed from the lower voltage lines is zero.

Wye-wye connected transformers and autotransformers may have a tertiary winding. The analysis presented in this paper can be applied to stations having transformer with or without the tertiary winding.

Fig. 1 gives the components of line to ground fault current in various paths for fault on higher voltage or lower voltage side of the transformer in various categories of substations. Notations used for the currents shown in the figure are:

$I_{FH}, I_{FL}, I_{FW}, I_{FD}$ = Total fault current for fault on higher voltage side, lower voltage side, wye side and delta side of the transformer respectively.

I_{HH}, I_{HL} = Current fed from other stations on higher voltage lines when the fault is on higher voltage side and lower voltage side of the transformer respectively.

I_{LL}, I_{LH} = Current fed from other stations on lower voltage lines when the fault is on lower voltage side and higher voltage side of the transformer respectively.

84 WM 167-5 A paper recommended and approved by the IEEE Substations Committee of the IEEE Power Engineering Society for presentation at the IEEE/PES 1984 Winter Meeting, Dallas, Texas, January 29 - February 3, 1984. Manuscript submitted August 26, 1983; made available for printing November 28, 1983.

0018-9510/84/0900-2633$01.00

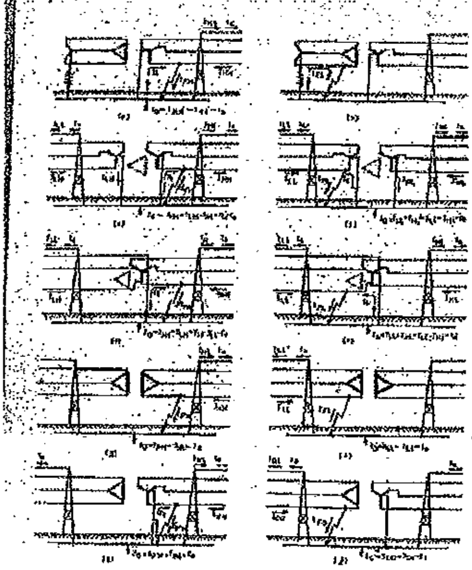


Fig. 1.(a) Step up station-fault on higher voltage side.
(b) Step up station-fault on lower voltage side.
(c),(e),(g) Intermediate station - fault on higher voltage side.
(d),(f),(h) Intermediate station-fault on lower voltage side.
(i) Intermediate station-fault on wye side.
(j) Intermediate station-fault on delta side.

I_{WW} = Current fed from other stations on wye connected side of the transformer when the fault is on wye connected side.

I_{DD} = Current fed from other stations on delta connected side of the transformer when the fault is on delta connected side.

I_t = Current supplied by local transformer.

I_{Hi}, I_{Wi} = Current diverted on ground wires of higher voltage lines and wye connected lines respectively due to induction.

I_{Li}, I_{Di} = Current diverted on ground wires of lower voltage lines and delta connected lines respectively due to induction.

I_a = Current diverted from station through conduction by the ground wires of all the transmission lines terminating on the station and having their ground wires connected to grounding system of the station.

A perusal of fig. 1 will indicate that the maximum value of I_c in all cases is the total fault current on higher voltage side or lower voltage side. The higher value of the two is to be considered. However if care is exercised and it is ensured that the total fault current will have atleast two paths to follow, I_c may be safely taken as half of the total fault current or even less depending on the actual configuration of the system. Maximum value of I_G in terms of various components of the fault current in each case is given in table I.

It is observed that in all cases maximum value of I_G is given by sum of the currents (in amps) supplied by other stations to the ground on all transmission lines minus the current diverted by the ground wires due to induction and conduction.

DIVERSION OF CURRENT DUE TO INDUCTION

Fault current flowing in the line conductor I_L, induces current, I_i, in the overhead ground wires, of the same line.

TABLE I
CURRENT FOR DESIGN OF GROUNDING SYSTEMS

S.No.	Type of station	I_G
1	Step up station	$I_{HH}-I_{Hi}-I_a$
2	Intermediate station wye-wye or auto-transformer	$I_{HH}+I_{LH}+I_{Hi}-I_{Li}-I_a$ $I_{LL}+I_{HL}-I_{Li}-I_{Hi}-I_a$
3	Intermediate station delta-delta	$I_{HH}-I_{Hi}-I_a$ $I_{LL}-I_{Hi}-I_a$
4	Intermediate station delta-wye	$I_{WW}-I_{Wi}-I_a$ $I_{DD}-I_{Di}-I_a$
5	Terminal station	Same as for intermediate station-contribution of fault current from low voltage lines is zero.

Notes: 1. Where more than one current is mentioned select the one that has the higher value.
2. All currents are to be taken in amps and not in p.u. values.

$$I_i = m\, I_L \qquad (1)$$

where $m = Z_{gm}/Z_g$

Z_{gm} = Mutual impedance between phase conductor and the ground wires-ohms/km

Z_g = Self Impedance of ground wire with ground return-ohm/km.

Z_{gm} and Z_g given by[6]:

$$Z_{gm} = 0.000\,988\, f + j\, 0.002\,8938\, f \log_{10} \frac{D_e}{GMD_{separation}} \text{ ohms/km} \qquad (2)$$

$$Z_g = r_c + 0.000\,988\, f + j0.002\,8938\, f \log_{10} \frac{D_e}{GMR_{(GW)}} \text{ ohms/km} \qquad (3)$$

here D_e = Equivalent depth of earth return
= $658.4\sqrt{\rho/f}$ - m

r_o = Resistance of ground wire-ohms/km

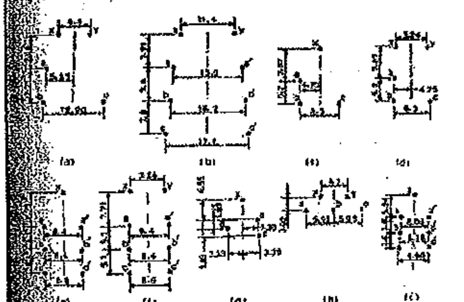
ρ = Resistivity of earth - ohm-m

f = Frequency - H_z.

The ratio m was calculated for the following ground wires and for all the configuration conductors shown in Fig.2.

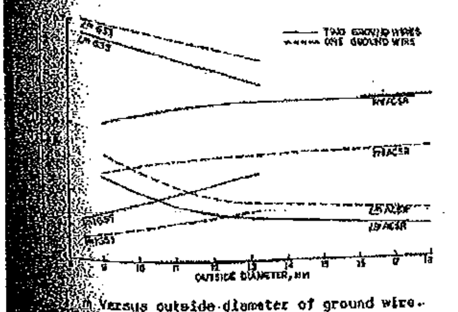
S. - 7/2.794, 7/3.15, 7/4.064, 19/2.642
SR - (6Al+1St)/3.0, (6Al+1St)/3.66,(6Al+1St)/4.09,(12Al+7St)/2.924 ,(18Al+19St)/2.591.

…sistivity of earth was assumed to be 100 ohm - m. …riation of the earth resistivity from 50 to …00 ohm-m will not cause an error of more than …% in the value of |m|.



…2. Disposition of phase and ground conductors for various transmission lines-132 kV,220 kV and 400 kV (Dimensions in meters).

…he results of calculations showed that …variation in configuration of conductors …number of circuits, within practical limi…ad negligible effect on the ratio m. The …meters that mainly affect m are material, …and number of the ground wires. Fig. 3 …variation of m with diameter of ground …or GSS and ACSR conductors.



…m Versus outside diameter of ground wire.

DIVERSION OF CURRENT DUE TO CONDUCTION

Overhead ground wires and tower footing resistance form a ladder network. If the number of towers is 20 or more the length of the line can be considered as infinite for the purpose of determining the admittance Y of the ladder network which is approximately given by[4,7,8].

$$Y = G+jB = \frac{1}{\frac{Z_{span}}{2}+\sqrt{Z_{span} \times R_t}} \qquad (4)$$

Where Z_{span} = The self impedance of one span of ground wire with ground return-ohms/km.

R_t = Average tower footing resistance for the first 20 towers-ohms.

Z_{span} can be determined with the help of (3). The resultant admittance Y' of all the lines connected to the station can be determined by considering the ladder networks of all the lines in parallel. Y' and the station grounding resistance, R_g, act in parallel. The current discharged to the ground from the station is given by:

$$|I_G| = |I_G'| \left|\frac{(1/Y')}{R_g+(1/Y')}\right| = |I_G'| \cdot \alpha \qquad (5)$$

Where I_G' is the sum of currents supplied by other stations to the ground over all transmission lines minus the current diverted by the ground wires due to induction.

G,B and α have been computed for a large range and number of practical values of the various parameters. The charts shown in Figs.4 to 6 have been generated with the results obtained from the computer. Figs. 4 & 5 give the value of G & B respectively as functions of the diameter of the ground wire, span length, tower footing resistance and the number of ground wires used. To use the charts one selects the diameter on the left ordinate & follows along a horizontal line where it intersects the required curve of the span. One then proceeds vertically upto the intersection with the curve representing the tower footing

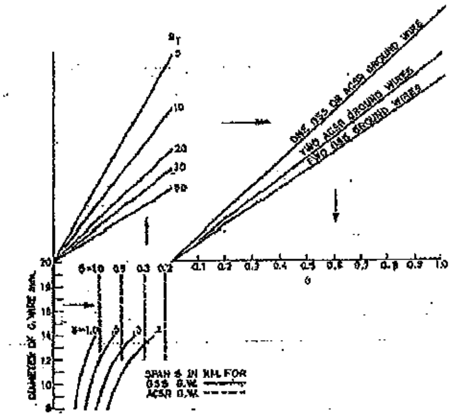


Fig. 4. Value of G for overhead lines.

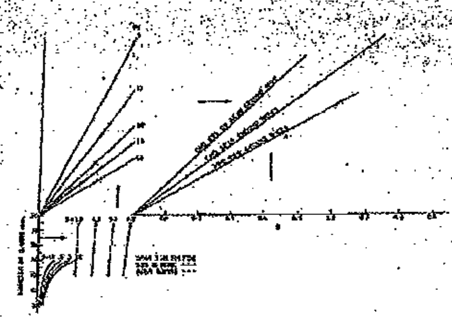


Fig. 5. Value of G for overhead lines.

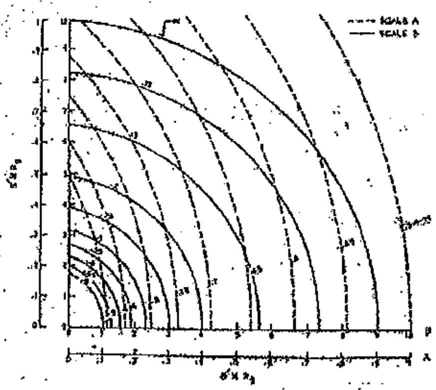


Fig. 6. Value of α for substations.

resistance, then continues from this intersection horizontally to the right until the curve representing the number of ground wires is reached. From this point one follows vertically down and reads G or β. The resultant value of G' and β' of all the lines connected to the station can be determined by directly adding the values of G & B respectively for all those lines.

Fig. 6 gives the value of α as function of G', B' and the station grounding resistance, R_g. To use this chart one selects the $(G' \times R_g)$ on the horizontal axis and $(B' \times R_g)$ on the vertical axis & locates the point given by these co-ordinates. The value of α can then be determined from the values given on the circular arc. Either scale A or scale B is to be used on both horizontal and vertical axis.

CONCLUSIONS

1. Current diverted through induction in the ACSR ground wires is about 3 times the current diverted through induction in GSS ground wires under similar situations for ACSR & GSS wires having about the same tensile strength.

2. In all cases the total fault current governs the size of the conductor for the grounding system.

3. The current to be adopted for calculating the potential gradient is equal to the sum of currents supplied by other stations to the ground through transmission lines minus the current diverted by the ground wires due to induction and conduction.

4. Maximum realistic currents I_C and I_G when adopted for design calculations can result in substantial saving in the cost of grounding system.

REFERENCES

1 "IEEE Guide for safety in substation grounding", IEEE std. 80, 1976.

2 S.A Sebo, "Zero sequence current distribution along transmission lines", IEEE Transactions PAS, Vol. PAS 88, 1969, pp 910-919.

3 F. Dawalibi, "Ground fault current distribution between soil and neutral conductors", IEEE Transactions, PAS, Vol. PAS-99, 1980, pp 452-459.

4 F. Dawalibi, D.Bensted, D.Mukhedkar, [illegible] Effects on ground fault currents", [illegible] Transactions, PAS, Vol. PAS-100, [illegible] 3442-3450.

5 S.K. Madan, "Current for design of grounding grids in substations", M.Sc. [illegible] Engg. Thesis, Panjab University, [illegible]

6 C.F. Wagner, R.D. Evans, "Symmetrical Components", McGraw-Hill Book Co., New York, 1933 (Book).

7 J.R. Alderton, P.C.Anderson, [illegible] "Calculation and measurement of [illegible] ance of an ehv substation", [illegible] Vol. 125, 1978 pp 1367-1375.

8 R. Verma, D. Mukhedkar, [illegible] current distribution in [illegible] and ground wire", IEEE Trans. [illegible] Vol. PAS-98, 1979, pp 724-730.

D.1 Soil Resistivity Test Report at Location-1

SOIL RESISTIVITY TEST REPORT-1

Project: KOL DAM PROJECT

Megger Type: Earth tester

Client: NTPC

Megger Sl.NO 987641

Megger Battery Condition: Good

Area Of the Plot: 60000 SQ MTS

Temperature: 25celsius

Type Of Soil: ~~Rocky~~ Compacted Random Rock fill (Vishal)

Test Date: 11/01/2006

Cordinate : N - 16466.533
E - 26223.016

Test Location: Switch yard

Sl.No.	Direction	Spacing Between Electrodes(m)								Remarks
		a-2		a-5		a-10		a-15		
		R	Pa	R	Pa	R	Pa	R	Pa	
1	North	60	754	24	754	11	691	7	660	
2	North East	57	716	31	974	11	346	6	283	
3	East	43	540	15	471	5	157	5	236	
4	South East	25	314	15	471	8	251	7	330	
5	South	23	289	8	251	12	377	6	283	
6	South West	25	314	13	408	14	440	8	377	
7	West	27	339	19	597	12	377	5	236	
8	North West	34	427	9	283	11	346	6	283	

Where a- Spacing between adjacent electrodes(m).
R- Resistance in Ohms(Megger).
Pa-Soil Resistivity(ohm-m).

Test Conducted By		Test Witnessed By	
L&T-ECC		NTPC	
Signature	: Vishal B	Signature	: [signature]
Name	: VISHAL BHATNAGAR	Name	: MANOJ KR THAKUR
Date	: 12/1/06	Date	: 12/01/06

D.2 Soil Resistivity Test Report at Location-2

SOIL RESISTIVITY TEST REPORT -2

Project: KOL DAM PROJECT

Megger Type: Earth tester

Client: NTPC

Megger Sl.NO: 987641

Megger Battery Condition: Good

Area Of the Plot: 60000 SQ.MTS

Temperature: 25 Celsius

Type Of Soil: ~~Rocky~~ Compacted Random Rock fill Vish

Test Date: 12/01/2006

Cordinate : N – 16351.200
E – 25256.086

Test Location: SWITCH YARD

Sl.No.	Direction	Spacing Between Electrodes(m)								Remarks
		a-2		a-5		a-10		a-15		
		R	Pa	R	Pa	R	Pa	R	Pa	
1	North	21	264	10	314	9	565	4	377	
2	North East	25	314	17	534	11	346	5	236	
3	East	15	188	19	597	10	314	5	236	
4	South East	77	968	21	660	26	817	6	283	
5	South	60	754	29	911	26	817	4	188	
6	South West	59	741	24	754	12	377	5	236	
7	West	45	565	20	628	11	346	6	283	
8	North West	69	867	13	408	28	880	7	330	

Where a- Spacing between adjacent electrodes(m).
R- Resistance in Ohms(Megger).
Pa-Soil Resistivity(ohm-m).

Test Conducted By
L&T-ECC
Signature : Vishal B
Name : VISHAL BHATNAGAR
Date : 12/1/06

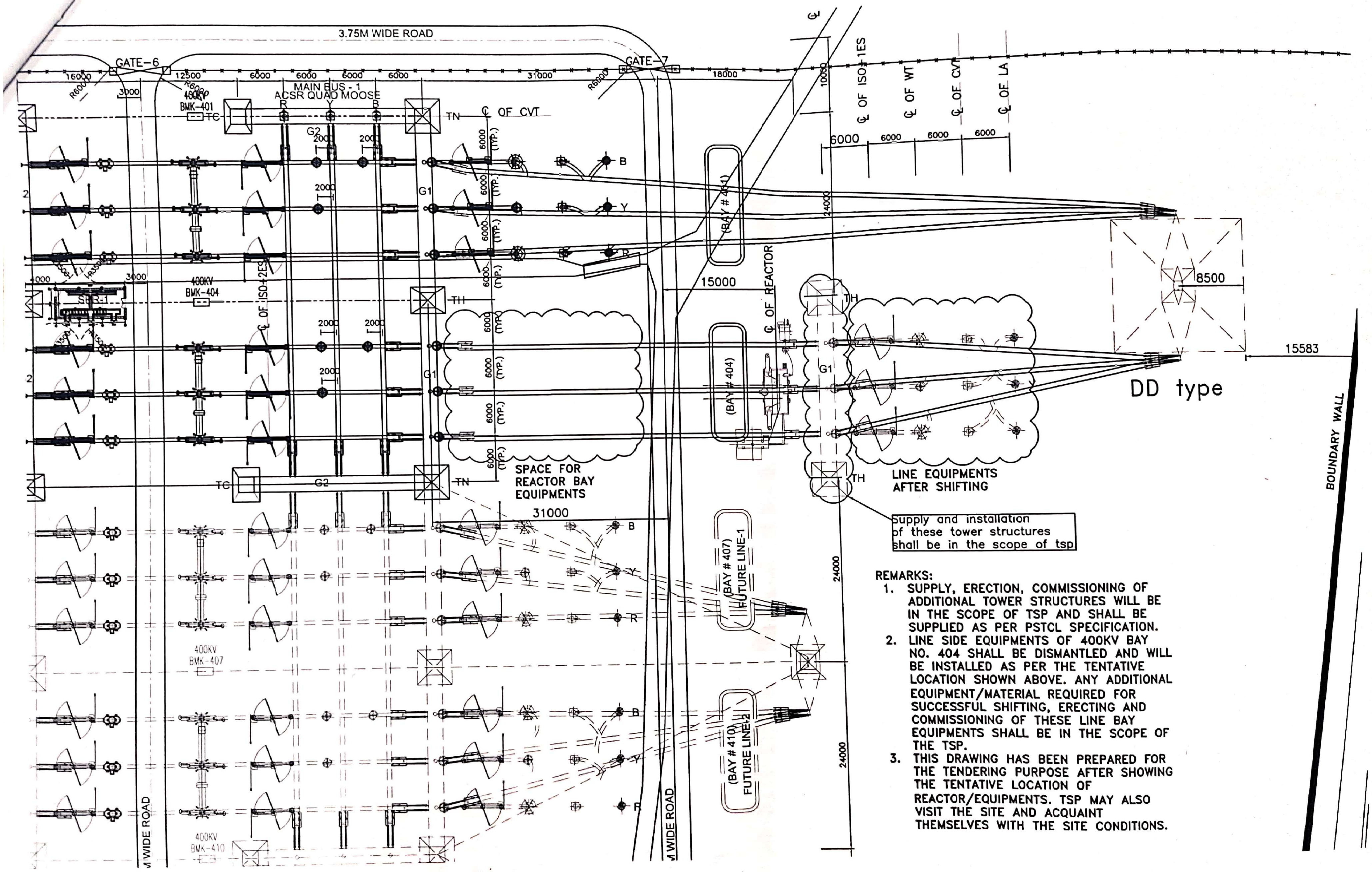
Test Witnessed By
NTPC
Signature: Manoj Kr Thakur
Name: MANOJ KR. THAKUR
Date: 12/01/06

D.3 Calculation of Average Soil Resistivity

Spacing / Direction	Location-1				Location-2			
	2m	5m	10m	15m	2m	5m	10m	15m
North	754	754	691	660	264	314	565	377
North East	716	974	346	283	314	534	346	236
East	540	471	157	236	188	597	314	236
South East	314	471	251	330	968	660	817	283
South	289	251	377	283	754	911	817	188
South West	314	408	440	377	741	751	377	236
West	339	597	377	236	565	628	346	283
North West	427	283	346	283	867	408	880	330

Average Soil Resistivity = 464 ohm-m

For Ropar S/s



REMARKS:

1. SUPPLY, ERECTION, COMMISSIONING OF ADDITIONAL TOWER STRUCTURES WILL BE IN THE SCOPE OF TSP AND SHALL BE SUPPLIED AS PER PSTCL SPECIFICATION.
2. LINE SIDE EQUIPMENTS OF 400KV BAY NO. 404 SHALL BE DISMANTLED AND WILL BE INSTALLED AS PER THE TENTATIVE LOCATION SHOWN ABOVE. ANY ADDITIONAL EQUIPMENT/MATERIAL REQUIRED FOR SUCCESSFUL SHIFTING, ERECTING AND COMMISSIONING OF THESE LINE BAY EQUIPMENTS SHALL BE IN THE SCOPE OF THE TSP.
3. THIS DRAWING HAS BEEN PREPARED FOR THE TENDERING PURPOSE AFTER SHOWING THE TENTATIVE LOCATION OF REACTOR/EQUIPMENTS. TSP MAY ALSO VISIT THE SITE AND ACQUAINT THEMSELVES WITH THE SITE CONDITIONS.