

संदर्भ/Ref : CC-ENGG-TB202407-1002453-SS3540-EARTHMAT-LAYOUT

Date : 30/05/2025

**From :** Anurag  
Senior DGM

**To :** Bharat Heavy Electricals Limited  
Plot No.-7, Sector-142 Noida 201305  
201305

**Cc :** MANDSAUR

**Subject :** 765kV AIS Substation Package SS43T for (a) Establishment of 765/400/ 220kV Mandsaur S/s including 400kV, 2x125MVA (3- Ph) Reactor b) Extn. of 765kV Indore(PG) for termination of Mandsaur PS – Indore(PG) 765 kV D/c Line associated with “Transmission system for evacuation of power from Rajasthan REZ Ph-IV (Part-2: 5.5GW) (Jaisalmer/Barmer Complex) Part-C” through Tariff Based Competitive Bidding (TBCB) route

**LOA Ref :** CC/T/W-AIS/DOM/A06/23/11955/NOA-1/24-108670/01 & NOA-2/24-108670/02 Dated 09/07/2024

Please find enclosed following drawings/ documents for necessary action at your end.

**Vendor Drg. No. :**

**Orgn. Drg. No. :** TB202407-1002453-SS3540-EARTHMAT-LAYOUT

**Revision No. :** 00

**Drg. Title :** 765/400/220kV MANDSAUR SS-EARTHMAT LAYOUT

**App. Category :** CAT-II

**Release Date :** 30/05/2025



Scan to verify

**Comments :** Comments marked on the document

**अनुमोदित श्रेणी/App. Category:**

- I. फेब्रिकेशन/निर्माण/टाइप टेस्टिंग हेतु जारी।  
**Approved/released for fabrication/construction.**
  - II. फेब्रिकेशन/निर्माण/टाइप टेस्टिंग हेतु अनुमोदित/जारी बशर्ते दिए गए टिप्पणियाँ एवं आशोधनों की सम्मिलित किया जाये। कृपया रिवाइज्ड दस्तावेज अनुमोदनार्थ प्रस्तुत करें।  
**Approved/released for fabrication/ construction subject to incorporation of comments and modification as noted. Revised drawing required for approval.**
  - III. टिप्पणियाँ सम्मिलित करने के उपरांत दस्तावेज को अनुमोदनार्थ प्रस्तुत करें।  
**To be resubmitted for approval after incorporating the comments.**
  - IV. सूचनार्थ एवं रिकार्ड हेतु।  
**For information and record.**
- CATREL/ निर्माण हेतु जारी।  
REL-CON **Released for construction.**

**नोट/Note:**

1. Approval/Comments conveyed herein neither relieve the contractor of his contractual obligations and his responsibilities, weights, quantities, design details assemble fits, performance particulars and conformity of the supplies with the Indian Statutory Laws as may be applicable, nor does it limits the purchaser's right under the contract.
2. The approval conveyed vide this letter does not cover the approval of make for sub-vendor items.

केन्द्रीय कार्यालय: "सौदामिनी", प्लॉट नंबर 2, सेक्टर -29, गुरुग्राम -122001, (हरियाणा) ,दूरभाष: 0124-2571700-719

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**Website:** www.powergridindia.com



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## ELECTRODE QTY CALCULATION

A ROD ELECTRODE WITH TEST PIT/LINK

SN	EQUIPMENT/FACILITY	ELECTRODE PER EQUIPMENT	SS43T-Mandsaur (New)	
			No. of EQUIPMENT	TOTAL NO. OF ELECTRODES
i)	765kV TOWER WITH PEAK	1	42	42
ii)	765kV CVT	1	12	12
iii)	624kV LA	1	29	29
iv)	for Main bus towers with shield wire on beam	1	16	16
i)	400kV TOWER WITH PEAK	1	18	18
ii)	400kV CVT	1	6	6
iii)	336kV LA	1	31	31
i)	220kV TOWER WITH PEAK	1	46	46
ii)	220kV CVT	1	33	33
iii)	216kV LA	1	36	36
				253
				269

QTY TO BE FINALIZED AS PER APPROVED DSLP LAYOUT

B ROD ELECTRODE WITHOUT TEST PIT

SN	EQUIPMENT/FACILITY	ELECTRODE PER EQUIPMENT	SS06T	
			No. of EQUIPMENT	TOTAL NO. OF ELECTRODES
i)	EARTHMAT CORNER	1	12	12
ii)	CONTROL ROOM BUILDING CORNER	5	1	5
				17

C PIPE ELECTRODE

SN	EQUIPMENT/FACILITY	ELECTRODE PER EQUIPMENT	SS06T	
			No. of EQUIPMENT	TOTAL NO. OF ELECTRODES
i)	765/400kV ICT-3ph BANK	2	3	6
ii)	765kV LINE REACTOR-3ph BANK	2	2	4
iii)	765kV BUS REACTOR-3ph BANK	2	2	4
iv)	400/220kV ICT, 3ph	2	5	10
v)	400kV BUS REACTOR, 3ph	2	2	4
vi)	LT TRANSFORMER, 3ph	2	2	4
vii)	DG SET	2	1	2

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# EARTHMAT SIZING CALCULATION BASED ON IEEE-80 : 2000

Rev-1

PROJECT : 765/400/220KV PGCIL KOPPAL II S/S

SYSTEM DATA		
System fault current	$I_f$	63 kA
Fault Duration	$t_f$	0.5 sec
Ambient Temperature	$T_a$	50 °C

FIELD DATA		
Average earth resistivity in $\Omega$ -meter	$\rho$	85.51 $\Omega$ -m
Surface Layer of switchyard		Gravel
Surface layer resistivity in $\Omega$ -meter	$\rho_s$	3000 $\Omega$ -m
Surface layer thickness in meter	$h_s$	0.15 m
	a	292 m
	b	570 m
	c	120 m
	d	420 m
	Grid spacing D	30 m
Depth of Grid	h	0.6 m

EARTHMAT DESIGN PARAMETERS		
Duration of shock	$t_s$	0.5
Fault Current Division Factor	$S_f$	0.7
Decrement Factor for entire duration of fault	$D_f$	1
No. of ground MS rods	$n_g$	6
Length of ground MS rods in m	$l_g$	3

GROUND CONDUCTOR DATA		
Type of Conductor		Mild Steel Rod
Thermal Coefficient of resistivity	$\alpha_r$	0.00423 /°C
Resistivity of Ground Conductor	$\rho_r$	15 $\mu\Omega$ /cm
Thermal Capacity Factor	$T_{CAP}$	3.749 J/cm <sup>3</sup>
Maximum Allowable Temperature	$T_m$	620 °C
$K_0$ at 0°C	$K_0$	216 °C

RESULTS		
Minimum diameter of grid conductor		26.26 mm
Ground grid conductor diameter chosen		40.00 mm
Grid resistance	$R_g$	0.083 $\Omega$
Ground Potential Rise	GPR	3662 V
Grid spacing chosen	D	30.00 m
Tolerable touch voltage	$E_{touch50}$	737 V
Tolerable step voltage	$E_{step50}$	2455 V
Calculated touch voltage	$E_m$	645 V
Calculated step voltage	$E_s$	268 V

% Margin Available In Touch Potentials **12.40 %**  
 % Margin Available in Step Potential **89.10 %**

CONCLUSION		
<i>Grid Resistance is less than 1 <math>\Omega</math>.</i>		
<i>Selected Diameter of Grid conductor is adequate.</i>		
<i>Calculated Touch &amp; Step Voltages are Less than Tolerable Touch &amp; Step Voltages, Hence Ground grid Design is Safe.</i>		
<i>Grid Spacing chosen is</i>	=	<b>30 m</b>



### EARTHMAT SIZING CALCULATION AS PER IEEE-80

$I_g$	rms symmetrical grid current in kA = $I_f \times S_f$	=	44.10 kA
$I_G$	Maximum grid current in kA = $I_g \times D_f$	=	44.10 kA
$L_R$	Total length of all ground MS rods in meter ( $l_g \times n_g$ )	=	18.0 m
$D_m$	Maximum distance between any two point on the grid $= \sqrt{L_x^2 + L_y^2} = \sqrt{(b + d)^2 + a^2}$	=	1032.2 m
$h_0$	Grid reference depth	=	1.0 m

As per equation no. (83) of cl. no. 16.5

$$K_h = \sqrt{1 + \frac{h}{h_0}} = 1.264911064$$

As per cl. no. 14.2

$L_T$	Total effective length of grounding system conductor including grid and ground MS rod, m	=	17212 m
	$= \left\{ \left(1 + \frac{a}{D}\right)b + \left(1 + \frac{b}{D}\right)a \right\} + \left\{ \left(1 + \frac{d}{D}\right)(a-c) + \left(1 + \frac{a-c}{D}\right)d \right\} + n_g \times l_g$		

As per cl. no. 14.3

$L_C$	Total length of the conductor in horizontal grid in meters	=	16774 m
	$= \left\{ \left(1 + \frac{a}{D}\right)b + \left(1 + \frac{b}{D}\right)a \right\} + \left\{ \left(1 + \frac{d}{D}\right)(a-c) + \left(1 + \frac{a-c}{D}\right)d \right\}$		

As per cl. no. 16.5

$L_P$	Peripheral length of the grid = $2(a+b+d)$	=	2564 m
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As per cl. no. 14.2

$A_R$	Area covered by ground grid conductor in $m^2 = L \times B$	=	238680 $m^2$
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As per equation no. (27) of cl. no. 7.4

$C_s$	Surface layer resistivity derating factor	=	0.8
	$= 1 - \frac{0.09 \times \left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09}$		

As per equation no. (85) of cl. no. 16.5

$n_a$	$= \frac{2L_C}{L_P}$	=	13.08
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As per equation no. (86) of cl. no. 16.5

$n_b$	$= \sqrt{\frac{L_P}{4 \times \sqrt{A_R}}}$	=	1.145447022
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As per equation no. (87) of cl. no. 16.5

$$n_c = \left[ \frac{L_x \cdot L_y}{A_R} \right]^{\frac{0.7 \cdot A_R}{L_x \cdot L_y}} = 1.11708763$$

As per equation no. (88) of cl. no. 16.5

$$n_d = \frac{D_m}{\sqrt{L_x^2 + L_y^2}} = 1$$

As per equation no. (84) of cl. no. 16.5

$$n \text{ Geometric Factor} = n_a \times n_b \times n_c \times n_d = 16.74$$

$$d \text{ Diameter of actual grid conductor selected} = 0.040 \text{ m}$$

As per equation no. (89) of cl. no. 16.5

$$K_i \text{ Correction factor for grid geometry} = 0.644 + 0.148 \times n = 3.1$$

As per equation no. (94) of cl. no. 16.5

$$K_s = \frac{1}{\pi} \left[ \frac{1}{2 \cdot h} + \frac{1}{D+h} + \frac{1}{D} (1 - 0.5^{n-2}) \right] = 0.3$$

As per equation no. (82) of cl. no. 16.5

$K_{ii}$  Corrective weighting factor for grid with ground MS rods located in the corner or on the perimeter

$$K_{ii} = 1.0$$

As per equation no. (81) of cl. no. 16.5

$$K_m \text{ Spacing factor for mesh voltage} = 0.9$$

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

As per equation no. (40) of cl. no. 11.3

$$A \text{ Cross Sectional Area of the ground grid conductor} = 541.6 \text{ mm}^2$$

$$= I_f \times \sqrt{\frac{t_f \times \alpha_r \times \rho_r \times 10^4}{T_{CAP} \times \ln\left(\frac{T_m + k_0}{T_a + k_0}\right)}}$$

$DIA$  Theoretical diameter of grid conductor in case of round conductor

$$= \frac{1}{1000} \times \sqrt{\frac{4A}{\pi}} = 0.0263 \text{ m}$$



As per equation no. (52) of cl. no. 14.2

$$R_g \quad \text{Grid resistance} = 0.083 \, \Omega$$

$$= \rho \times \left[ \frac{1}{L_T} + \frac{1}{\sqrt{20 \times A_R}} \left( 1 + \frac{1}{1 + h \times \sqrt{20/A_R}} \right) \right]$$

As per equation no. (29) of cl. no. 8.3

$$E_{\text{step50}} \quad \text{Tolerable step voltage for human with 50 kg body weight} = 2454.9 \, \text{V}$$

$$= (1000 + 6 \times C_s \times \rho_s) \times \frac{0.116}{\sqrt{t_s}}$$

As per equation no. (32) of cl. no. 8.3

$$E_{\text{touch50}} \quad \text{Tolerable touch potential for human with 50 kg body weight} = 736.8 \, \text{V}$$

$$= (1000 + 1.5 \times C_s \times \rho_s) \times \frac{0.116}{\sqrt{t_s}}$$

As per equation no. (32) of cl. no. 8.3

$$GPR \quad \text{Ground Potential Rise} = I_g \times R_g \times 1000 = 3661.6 \, \text{V}$$

From equation no. (80) & (91) of cl. no. 16.5

$$E_m \quad \begin{array}{l} \text{Mesh voltage in volts at the centre of the corner mesh} \\ \text{calculated value of maximum mesh voltage (Worst possible} \\ \text{touch voltage) = calculated touch voltage} \end{array} = 645.4 \, \text{V}$$

$$= \frac{\rho \times I_g \times K_m \times K_i \times 1000}{L_c + \left[ 1.55 + 1.22 \left( \frac{L_r}{\sqrt{L_x^2 + L_y^2}} \right) \right] L_R}$$

From equation no. (92) & (93) of cl. no. 16.5

$$E_s \quad \begin{array}{l} \text{Step voltage in volts between a point above the outer corner} \\ \text{of the grid and a point 1 meter diagonally outside the grid (} \\ \text{Calculated value of maximum step voltage which can occur)} \end{array} = 267.6 \, \text{V}$$

$$= \frac{\rho \times I_g \times K_s \times K_i \times 1000}{0.75L_c + 0.85L_R}$$



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## RESULTS

<b>MINIMUM DIAMETER OF GRID CONDUCTOR (<math>d_{min}</math>)</b>	=	<b>26.3 mm</b>
<b>CORROSION EFFECT FOR A PLANT LIFE OF 40 YEARS (<math>X_c</math>)</b>	=	<b>0.12 mm/yr</b>
<b>HENCE GROUND GRID CONDUCTOR DIAMETER (<math>d_{min} + X_c * 40</math>)</b>	=	<b>31.1 mm</b>
<b>GROUND GRID CONDUCTOR DIAMETER CHOSEN</b>	=	<b>40.0 mm</b>
<b>GRID RESISTANCE</b>	=	<b>0.083 Ohms</b>
<b>GRID SPACING CHOSEN</b>	=	<b>30.00 M</b>
<b>TOLERABLE TOUCH VOLTAGE</b>	=	<b>736.8 V</b>
<b>TOLERABLE STEP VOLTAGE</b>	=	<b>2454.9 V</b>
<b>CALCULATED TOUCH VOLTAGE</b>	=	<b>645.4 V</b>
<b>CALCULATED STEP VOLTAGE</b>	=	<b>267.6 V</b>

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## SOIL RESISTIVITY DATA

ERT No.	Average Resistivity of Soil ( $\Omega$ .m)
1	64.27
2	126.48
3	76.88
4	103.39
5	78.04
6	88.87
7	88.72
8	73.32
9	93.62
10	77.93
11	81.04
12	81.82
13	74.81
14	98.97
15	81.77
16	73.88
17	80.15
18	89.87
19	70.06
20	99.92
21	73.19
22	98
23	92.27
24	85.07
25	80.15
26	81.45
27	86.44
28	73.23
29	85.06
30	90.91
31	79.88
32	77.09
33	71.61
34	84.2
35	76.42
36	80.06
37	87.83
38	85.98
39	83.37
40	73.99
41	79.08
42	97.37
43	79.9
44	78.33
45	83.55
46	91.57
47	85.35
48	84.12
49	90.8
50	102.7
51	77.31
52	80.89
53	80.99
54	122.86
55	90.48
56	113.68
57	85.10
AVERAGE=	85.51