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Consulting Electrical Engineers Association of Maharashtra

CEEAMA E-NEWS

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THIS MONTH

CEEAMA President Mr. Narendra Duvedi visiting Elecrama 2023.

Electrical Consultants Newsletter
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From the Editor's Desk,

Greetings to all CEEAMA Members..!!

The positive momentum set in the market in the new year 2023 is fortunately maintained even as many negative news are disturbing the mind.

Earthquakes in Turkiye and Syria causing severe life and property damage was heart-wrenching. Within few seconds, fate of lakhs of people changed and finally fatality rose to almost 60k. Although Indian delegation of rescue team made us proud, the natural calamity reminds us about life's futility. Hope this feeling doesn't turn out to be a mere स्मशान वैराग्य but a true lesson taught by nature on universal brotherhood - वसुधैव कुटुंबकम

Life becomes cheaper not only by natural calamities but also by man-made ones especially due to ignorance and complacency of authorities who are supposed to take public utility especially electrical installations with competent and responsible personnel. Take the example of electrocution of a worker (Ashok Sonnur) early last month in Pune (Kudale Patil township) after coming close to 22kV OH power line. The concerned authorities were unfortunately quick to disown the onus of this incident.

CEEAMA has been publishing numerous articles on Safety through our eminent contributors. More work needs to be done though! Hence, urging all readers to contribute to your best possible capabilities. This is apart from the request to Associate members to come forward and contribute in the form of Advertisements to raise some revenue.

As mentioned in the previous editorial, we are Happy to announce the upcoming Technical program in April. It will be a joint program of CEEAMA and BAI Nagpur chapter on "Electrical Safety for High Rise Buildings". Our Hon. President & Secretary would be the respective speaker and co-ordinator. This will be our first program outside Mumbai/Pune/Kolhapur. Earnest request for your hearty support.

Special mention to Mr. Shashi Amin for his kind encouragement at Elecrama last month to CEEAMA through our Hon. President with his all-possible extent of help. He suggested for revival of CEEAMA activities which is possible only with active contribution of all members. Our hon. Secretary also announced at the exhibition CEEAMA's forthcoming program on EV in May 2023 and Exhibition in Feb 2024.

Our E-NEWS letter is catching attention. It came as a big compliment to see message of Mr. Anil Valia in his personal email to us. Mr. Valia is considered to be Bhismacharya in Lighting industry. Thus his compliments and valuable suggestions are big assets for us which we intent to work upon soon.

Wishing you all a very electrifying but safe journey in your life!

Subhash L. Bahulekar
Editor-in-Chief – CEEAMA

EARTHING DESIGN & CALCULATIONS

Part – 2(b)

Earthing System For Large HV/EHV Substations

In continuation of the Part-2(a) of the article, we wish to conclude the earthing topic with calculations as below:

3.0 Mathematical Calculations:

3.1 Prerequisites:

The following information is required/desirable before starting the calculations:

- A layout of the site.
- Maximum earth fault current into the earthing grid.
- Maximum fault clearing time.
- Ambient (or soil) temperature at the site.
- Soil resistivity measurements at the site (for touch and step only).
- Resistivity of any surface layers intended to be laid (for touch and step only).

3.2 Step and touch voltage criteria:
The safety of a person depends on preventing the critical amount of shock energy from being absorbed before the fault is cleared and the system de-energized. **As per the Clause 8.3 of IEEE-80, the maximum driving voltage of any accidental circuit should not exceed the limits defined as follows,**

For step voltage the tolerable limit is,

- The tolerable step voltage criterion is

$E_{Step50} = [1000 + (6 \times C_s \times \rho_s)] \times (0.116/\sqrt{t_s})$ ....(1)

For a 50 kg person

$E_{Step70} = [1000 + (6 \times C_s \times \rho_s)] \times (0.157/\sqrt{t_s})$ ....(1A)

For a 70 kg person.

For touch voltage the tolerable limit is,

- The tolerable touch voltage criterion is

$E_{Touch50} = [1000 + (1.5 \times C_s \times \rho_s)] \times (0.116/\sqrt{t_s})$ ....(2)

For a 50 kg person

$E_{Touch70} = [1000 + (1.5 \times C_s \times \rho_s)] \times (0.157/\sqrt{t_s})$ ....(2A)

For a 70 kg person

Where,

E_{step} = the step voltage in V
E_{touch} = the touch voltage in V
C_s = Surface layer derating factor (1 for no protective layer & 0.70 for 0.1 mtr of gravels of ρ_s-3000 and ρ-100 as per equation-8 given further in the article)
ρ_s = the resistivity of the surface material in Ω·m
t_s = the duration of shock current in seconds, 250 msec.

The choice of body weight (50kg or 70kg) depends on the expected weight of the personnel at the site. In this article we have considered typically a person with 70 kg.

The circuit breaker opens within 100 msec during fault clearance, however, keeping a safe margin, we shall consider t_s as 250 msec.

3.3 Grid Conductor Sizing:

Determining the minimum size of the earthing grid conductors is necessary to ensure that the earthing grid will be able to withstand the maximum earth fault current. Like a normal power cable under fault, the earthing grid conductors experience a short circuit temperature rise.

However unlike a fault on a normal cable, where the limiting temperature is that which would cause permanent damage to the cable's insulation, the temperature limit for earthing grid conductors is the melting point of the conductor. In other words, during the worst case earth fault, we don't want the earthing grid conductors to start melting.

The minimum earth grid conductor size capable of withstanding temperature rise associated with an earth fault is given by rearranging Equation 37, IEEE Std-80, is mentioned below,

$$A = \sqrt{i^2 t \left(\frac{\frac{\alpha_r \rho_r 10^4}{TCAP}}{\ln\left[1 + \left(\frac{T_m - T_a}{K_0 + T_a}\right)\right]} \right)} \qquad \text{............(3)}$$

Where,
I = Symmetrical grid current rms value in kA
A = conductor sectional size in mm²
T_m = maximum allowable temperature in °C
T_a = ambient temperature for material constants in °C
α_0 = thermal coefficient of resistivity at 0°C in (°C^{-1})
α_r = thermal coefficient of resistivity at reference temperature T_r
ρ_r = the resistivity of the ground conductor at reference temperature T_r in μΩ-*cm*
K_0 = $1/\alpha_0$ or $1/\alpha_r$ - T_r
t = time of current flow in sec (Considered as 250 msec)
TCAP = Thermal Capacity Factor

The material constants T_m, α_r, ρ_r and *TCAP* for common conductor materials can be found in the Table 1 of IEEE Std 80. For example, zinc coated steel rod has material constants as given below:

T_m = 419 ºC

α_r = 0.0032 ºC^{-1}

ρ_r = 20.1 μΩ.*cm*

K_0 = 293

TCAP = 3.93 Jcm^{-3}ºC^{-1}.

By substituting these values in the equation-3, we get A = 233.44 mm².

This gives the **minimum diameter d** of the grid conductor = **17.24 mm**

However, we shall consider a conductor with a diameter **d of 25 mm**

• Spacing factor for mesh voltage (K_m)

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

Where,
D = spacing between conductor of the grid in m
d = diameter of grid conductor in m
K_m = spacing factor for mesh voltage
K_{ii} = 1 for grids with rods along perimeter

= $1/2n^{n/2}$ for grid with no earthing rods on the corners or the perimeter.

K_h = Corrective weighting factor for grid depth (= $\sqrt{1+h}$) = 1.2649

• Spacing factor of step voltage (K_s)

$$K_s = \frac{1}{\pi}\left[\frac{1}{2h} + \frac{1}{D+h} + \frac{1}{D}\left(1 - 0.5^{n-2}\right)\right] \qquad \text{.........(5)}$$

Where,
D = spacing between conductor of the grid in m
h = depth of burial grid conductor in m
n = Geometric Factor given by equation 85 of IEEE Std-80.

$$n = n_a \times n_b \times n_c \times n_d$$

With $n_a = \frac{2L_c}{L_p}$ = 2*2280 / 360 = 12.6666

n_b = 1 for square grids, or otherwise $n_b = \sqrt{\frac{L_p}{4\sqrt{A}}}$ = 1.007

n_c = 1 for square and rectangular grids

n_d = 1 for square and rectangular grids

L_c = is the total length of horizontal grid conductors (m)

L_p = is the length of grid conductors on the perimeter (m)

From the above, n = 12.7561

3.4 Evaluation of ground resistance

A good grounding system provides a low resistance to remote earth in order to minimise the GPR. For most transmission and other large HV/EHV substations, the ground resistance is usually about 1 Ω or less.

For calculation of grounding resistance, the following formula is used. (as per clause 14.1 to 14.4 of IEEE-80)

$$R_g = \rho \left[\frac{1}{L_T} + \frac{1}{\sqrt{20A}} \left(1 + \frac{1}{1 + h\sqrt{20/A}} \right) \right] \quad \text{.......... (6)}$$

Where,
ρ = soil resistivity Ω-m
L_t = total length of grid conductor m
A = total area enclosed by earth grid m^2
h = depth of earth grid conductor m

Substituting the values in the equation-6, we get R_g as 0.5388 Ω.

3.5 Maximum Grid Current:

The maximum grid current is the worst case earth fault current that would flow via the earthing grid back to remote earth. Generally speaking, the highest relevant earth fault level will be on the primary side of the largest power/distribution transformer (i.e. either the terminals or the delta windings).

• For calculation of grid current, the equation below can be used, as per section 15.9 of IEEE-80.

$I_G = (C_s \times D_f \times S_f \times I_g)$ ....(7)

Where.

C_s = Surface layer derating factor

D_f = Decrement factor (given by equation 79 of IEEE Std-80)

S_f = Fault current division factor (ref section 15.9 of IEEE Std-80)

I_g = Symmetrical grid current

(The decrement factor D_f is given by equation 79 of IEEE-80 and typical values are given in the Table-10 of the same. = 1.039 in our case)

The surface layer derating factor C_s, can be approximated by an empirical formula as per equation 27 of IEEE Std-80)

In the most conservative case, a current division factor of S_f=1 can be applied, meaning that 100% of earth fault current flows back through remote earth.

$$C_s = 1 - \frac{0.09\left(1 - \frac{\rho}{\rho_s}\right)}{2h_s + 0.09} \quad \text{.............(8)}$$

= 1- {0.09(1-0.0333) / (0.2+0.09)}= 0.70

Where,

C_s is the surface layer derating factor

ρ is the soil resistivity, Ω-m (considered as 100 for these calculations)

ρ_s is the resistivity of the surface layer material, Ω-m. (considered as 3000 for these calculations)

h_s is the thickness of the surface layer (m), 100 mm

- For calculation of grid potential rise

$GPR = (I_G \times R_g)$ ....(9)

= 12432 V

3.6 Actual Step Potential & Touch Potential Calculations (Verification):

Now we just need to verify that the earthing grid design is safe for touch and step potential.

If the maximum GPR calculated above does not exceed either of the tolerable touch and step voltage limits, then the grid design is safe. (Please refer to the equations 1, 1A, 2 & 2A from 3.2)

However, if it does exceed the touch and step voltage limits, then some further analysis is required to verify the design, namely the calculation of the maximum mesh and step voltages as per Section 16.5 of IEEE Std-80 as given below.

Formula for calculation of mesh voltage are as given below,

$E_m = (\rho \times K_m \times K_i \times I_G) / L_T$ ....(10)

Formula for calculation of step voltage are given below,

$E_s = (\rho \times K_s \times K_i \times I_G) / L_T$ ....(11)

Where,

ρ = soil resistivity, Ω-m

I_G = Maximum Grid Current

E_m = mesh voltage at the centre of corner mesh in V

E_s = step voltage between point in V

K_m = spacing factor for mesh voltage

K_s = spacing factor for step voltage

K_i = correction factor (irregularity factor) for grid geometry, given by Eqn.-89 of IEEE Std-80

= $K_i = 0.644 + 0.148n$ = 2.5319

L_T= Total effective buried length of earth conductor in switch yard

$L_T = (L_L + L_B + L_A + L_E)$ ....(12)

Where,

L_L= Length of grid conductor along length of switch yard

L_B= Length of grid conductor along breadth of switch yard

L_A= Length of riser and auxiliary mat in switch yard

L_E= Length of earth electrodes in switch yard

The above actual mesh and step voltages, E_m and E_s given by equations 10 and 11 should be less than the tolerable limits of touch and step voltages.

In other words if $E_m < E_{touch}$ *and* $E_s < E_{step}$ then the earthing grid design is safe.

If not, however, then further work needs to be done. Some of the things that can be done to make the earthing grid design safe:

4.0 Result:

The Input Constant values for design calculations & Output results for grid construction design are given in following tables.

Table 2

Input Constant values for design calculation			
Parameters	**Symbol**	**Value**	**Units**
Ambient Temperature	T_a	45	ºC
Maximum Allowable Temperature	T_M	419	ºC
Fault Duration Time	t_s	0.250	Second
Thermal Coefficient of Resistivity at reference temperature	α_r	0.0032	$ºC^{-1}$
Resistivity of Ground Conductors at reference temperature	ρ_r	20.1	μΩ-*cm*
Resistivity of Substation Soil	ρ	100	Ω-*m*
Resistivity of Surface Material	ρ_s	3000	Ω-*m*
Thermal Capacity Factor	TCAP	3.931	$J/cm^{-3}/ºC^{-1}$
Depth of Buried Conductor	H	0.6	M
Conductor Spacing	D	7.5	M
Length of One Earth Rod	L_r	3	M

Table 3

Calculated Results of Grid Construction Design			
Parameters	**Symbol**	**Value**	**Units**
Earth Conductor Size (given by Eqn.-3)	A	233.44	mm^2
Maximum Grid Current (given by Eqn.-7)	I_G	23.0735	kA
Ground Resistance (given by Eqn.-6)	R_g	0.5388	Ω
Surface Layer Derating Factor (given by Eqn.-8)	C_s	0.70	
Minimum Diameter of Grid Conductor (Deduced from Eqn.-3)	d	17.24	mm
Selected Diameter of Grid Conductor	d	25	mm
Ground Potential Rise (GPR) (given by Eq.-9)	GPR	12432	V
Spacing Factor for Mesh Voltages (given by Eqn.-4)	K_m	0.46188	
Spacing Factor For Step Voltages (given by Eqn.-5)	K_s	0.34719	
Tolerable Step Voltage Limit (given by Eqns.-1 & 1A)	E_{step70}	4270.4	V
Maximum Attainable Step Voltage (Actual Step Voltage), given by Eqn.-11	E_s	879.345	V
Tolerable Touch Voltage Limit (given by Eqns. 2 & 2A)	$E_{touch70}$	1303.1	V
Maximum Attainable Mesh Voltage (Actual Touch Voltage), given by Eqn.-10	E_m	1145.78	V
Total Length of Earth Conductor in Switchyard (As given by main grid in Figure-3.	L_T	2355	m

5.0 Summary:

This article describes designing of a typical HV/EHV AC substation earthing system. The results for the earthing system are obtained by computational method. For earthing conductor and vertical earth electrode, zinc coated mild steel conductors are used. The step by step approach for designing a substation earthing system is presented. The step and touch voltages are dangerous for human body. Human body may get electric shocks from step and touch voltages.

When high voltage substations are to be designed, step and touch voltages should be calculated and values must be maintained within specified standard.

From the Table-3, the values of step and mesh voltages obtained for the substation are 879.34 Volt and 1145.78 Volt respectively which are within the permissible limits of 4270.4 and 1303.1 given by E_{step} and E_{touch}.

Special Note: If required, all the reference tables, formulae etc. can be made available to the readers from the draft copy of IEEE-80.

References:

1. IS: 3043 - Code Of Practice For Earthing.
2. IEEE Std 80 (2000) - Guide for safety in AC substation grounding.
3. CBIP Publication No.223 – Design of Earthing Mat for HV Substations

Contributed by

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ELECRAMA VISIT REPORT 2023

Dear Members,

We Indians know what "Kumbhmela" is. Elecrama has same status in minds of electrical engineering professionals. Incidentally I visited this electrical Kumbh and am glad to present a small report for the benefit of those who could not visit. This time the opportunity banged our doors after 4 years due to Pandemic but, believe me there was absolutely no sign of any adverse economic impact on Industry, With its usual glory, the exhibition had over 900 stalls, close to 16 halls, and OVERWHELMING but CONTROLLED RESPONSE.

All sectors had good representation as usual - Transmission, EHV, Transformers, Switchgears, Cables, Motors, Energy efficiency, Power electronics, Measuring and diagnostic equipment - every sector was present. Indian corporates and multinationals representing who's who of Industry were all present with Big Bang.

It was evident that slowly, but surely Indian switchgear Industry is going under multinational Umbrella. However many of them have manufacturing setups in India so India will not lose entire value add and will always have access to latest technologies. The scale of infrastructural projects going on at present in India and associated investments have changed the mindsets of multinationals to look at us. Parallelly our technocrats are also enjoying improved respect from these multinationals.

Substation automation and digitization of distribution at T and D level and even within Industry appears to be buzzing. Many stalls displayed their capabilities in this. Gone are the days when only V, I, PF were monitored and logged as history in so called Energy Monitoring Systems. Now energy consumption and condition monitoring of electrical assets is a reality. Artificial intelligence will use this data and predict life of asset, prompt the user on part replacement, predict dates of required preventive maintenance / failure and life expectancy etc. Tab based extensions of these systems were displayed which can be taken to asset like motor / breaker / transformer and on scanning of QR code on assets, the software can tell all above. Looking at competition displayed at Elecrama in these services, the prices will drop in near future. Price sensitive Indian Industry will start using this to advantage very soon.

ABB had displayed an IOT based Motor Monitor – which can be attached to any motor externally, which will monitor vital electrical and mechanical parameters of a working motor and sends them to cloud. Siemens had displayed parameter monitoring of switchgears starting from HV circuit breaker up to single pole last mile MCB. Parameters include even number of fault disconnects handled by breaker and their severity – co related to remaining life expectancy.

Protection appears to be completely digitized now. New communication protocols and central server driven protection settings is a reality and is available to user. Online fault monitoring and analysis was also on display. This will help in increasing uptime. Digital system simulation will avoid all approximations in electrical design while optimizing the cost. MSMEs in electrical engineering have started building world class products and are offering world class services. A conscious effort on their part was visible to acquire export market.

Looking at all above, I personally feel, consultant fraternity must transform itself to adopt all these changes which are for betterment and better safety. Young engineers should be motivated wherever possible to turn towards core engineering and help industry to adopt these new trends while bringing prosperity for themselves in future. They should be made aware that there is more sustainable future in core engineering field then in some other illusive fields around.

Looking at the show, I was convinced that BRIGHT DAYS ARE AHEAD FOR electrical engineering.

Narendra Duvedi

19th and 20th Feb 2023, Delhi.

WINNERS OF QUIZ FEBRUARY 2023

KAILAS DESHMUKH

(LFM-200)
VEDANT ELECTRICAL AND ENTERPRISES

DINESH REDEKAR

(LFM-186)
YASHADA CONSULTANTS

Congratulations

QUIZ MARCH 2023

1. Diesel Generator is mainly used for following loads

    1. Normal Loads
    2. Emergency Loads
    3. Critical Loads
    4. All of the above

2. Demand Response can be defined as a short-term reduction in electricity use driven by:

    1. Compromised grid reliability
    2. High electric market prices
    3. Both a) & b)
    4. Neither a) nor b)

3. Location of OLTC is on:

    1. HT Winding
    2. LT Winding
    3. Tertiary Winding
    4. All of the above

4. Which of the following contributes towards the system fault?

    1. Source Power
    2. Connected Motors
    3. Connected Capacitors
    4. All of the above

5. ESCOs are

    1. Energy Saving Company
    2. Energy Service Company
    3. Electrical Supply Company
    4. Essential Service Company

6. Insulated cable is not an acceptable "flexible connector" in Busduct

    1. FALSE
    2. TRUE

7. SLD does not represent

    1. Transformer winding connection (star/delta)
    2. Ratings of connected loads
    3. Panel location
    4. Transmission line neutral Conductor

8. With the increase in supply voltage, the starting torque of a 3 phase induction motor

1. Increases
2. Decreases
3. remains same
4. none of the above

9. DR Participation can involve:

1. Load Curtailment
2. Load shifting
3. Self-generation
4. Any of these

10. Which factor is not considered if we want to select between induction motor and syn. Motor?

1. power factor
2. Type of Mounting
3. Efficiency
4. Torque requirement

Rules for the QUIZ:

- The Quiz will be open for 10 days from the date of EMAIL.
- Each correct answer received on DAY 1 will get 100 points
- Next days the points will reduce as 90 – 80 – 70 and on 10th day points will be ZERO even if the
- answer is correct.
- All participants will receive E certificate signed by CEEAMA President with the points earned
- mentioned on the same.

Please use following google form link to participate in the QUIZ.

https://forms.gle/YwyKbQf7o1Gk6VY5A

"Thank you all for the overwhelming response to the E-NEWS in general and E-Quiz in particular. MCQ based quiz is always tricky and surprisingly can take us aback when we realise our conceptions (misconceptions) about the subject / system / product.

The aim of the feature was to create inquisitiveness in your mind and help you check your technical quotient

quickly. The response will also help us to present articles and webinars on subjects which are important, but which

lack enough awareness / knowledge in general.

It can open a pandora box for our discussions and arguments and probable solutions. Engineering evolves with conception. It gets fuelled with community discussions and capitalist actions. All stakeholders start realising the need to take a closer look and help improve standards as we have seen in the past century. Surely it makes the world a better place.

Wish you all a better luck this time.

Do spread the word.

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