SUBSTATION :-

220/33kV SUBSTATION

TITLE:-

BUSBAR DESIGN CALCULATION

BUSBAR DESIGN CALCULATION

1.0	**SYSTEM DATA-220kV**			**220kV S/S**	**Unit**
1.1	Highest System Voltage	V	-	245	kV
1.2	Short circuit current	Isc	-	40000	Amps
1.3	Duration of Fault	t	-	1	sec
1.4	Factor of Peak short circuit current	κ	-	1.81	
1.5	System frequency	f	-	50	HZ
1.6	Design Ambient Temperature	T	-	50	^0C
1.7 a)	Centre Line distance between conductors for Strung bus	a	-	4.5	m
b)	Centre Line distance between conductors for Equipment bus	a	-	4	m
1.8	Wind Pressure on conductor (Ref. Annexure-I)	P	-	148.002	Kg/m^2 (Refer. Annexure-1)
1.9	Maximum distance between two supporting points for 4" EH IPS Al.Tube.	L	-	8.05	m
1.10	Line to ground distance of 4"EH IPS Al Tube.		-	6	m
1.11	Line to ground distance of "TWIN MOOSE ACSR".		-	6/11.7/16.7/26.2	m

2.0	**BUSBAR DATA:-**			**STRUNG BUS**	**BETWEEN EQPTS SCHEDULE 80**	
2.1	Busbar Used			**MOOSE ACSR**	**4" EH IPS Al. Tube**	
2.2	Outer diameter	Do	-	31.77	114.3	mm
2.3	Inner diameter	Di	-	----	97.18	mm
2.4	Area of Cross - section	A	-	528.5	2844	mm^2
2.5	Moment of Inertia	J	-	----	399.998	cm^4
2.6	Weight per unit length of conductor	m'	-	1.999	7.678	Kg/m
2.7	Section modulus	Z	-	----	69.989	cm^3
2.8	Young's modulus	E	-	6.9000E+10	6.5727E+10	N/m^2
2.9	Yield point	$R_{p0.2}$	-	----	161.865	N/mm^2
2.10	Ultimate Bending stress of Al.Alloy		-	----	201.105	N/mm^2
2.11	Intial temp.of busbar before short circuit	θ_I	-	75	85	^oC
2.12	Final temp.of busbar before short circuit	θ_F	-	200	200	^oC

3.0 REFERENCES:-

1 IEC 865 - Short circuit currents - Calculation of effects.
2 IEC 909 - Short circuit current calculations in three phase AC systems
3 Indal Aluminium busbars book.
4 IS:802-Code of practice for Use of structural steel inoverhead transmission line towers.
5 Electra-68-1980

CALCULATION FOR 220kV S/S:-

1.0 CHECK FOR MAX. CONTINUOUS CURRENT CARRYING CAPACITY OF ' MOOSE ' ACSR CONDUCTOR:

Conductor used	=	TWIN Moose ACSR for Main Bus I & Main Bus II		
Continuous current rating of " Single Moose ACSR " at 75°C	=	836	Amps	(As per diamond cables catalogue page no:79)
Hence current carrying capacity of "TWIN MOOSE ACSR"	=	1672	Amps	
Full load current on the 220kV side of 10MVA Trf.(3ϕ)	=	$10 \times 10^6/(\sqrt{3} \times 220 \times 10^3)$		
	=	26.2	Amps	
Total current on Main bus,Considering 2 Nos of 3ϕ Transformers.	=	2X26.2		
	=	52.5	Amps	

Hence "TWIN MOOSE ACSR" for main bus is adequate

2.0 CHECK FOR SHORT TIME RATING OF MOOSE ACSR:

1)	Conductor Temperature at the beginning of a short circuit θ_b	= 75°C		
2)	Conductor Temperature at the end of a short circuit θ_e	= 200°C	(As per table 6 of IEC-865-1)	
3)	Rated short time withstand current density for 1sec. S_{th}	= 82	Amp/mm²	(As per Fig 13 of IEC-865-1)
4)	Hence short time withstand rating of MOOSE ACSR	= 82 x 528.5		
		= 43337		Amps
5)	Short Circuit Rating of 220KV System	= 40000		Amps

HENCE SAFE

3.0 CHECK FOR SHORT TIME RATING OF AL.TUBE:
Required area of cross-section of AL.Tube(A)

$$A = \frac{I_{sc} \times \sqrt{t}}{2.17 \times 10^4 \times \sqrt{\mathrm{Log}\{\theta_F + 258/\theta_1 + 258\}}}$$

As per INDAL AL. busbar Book.

Where

- A - Required area of Aluminium conductor in cm²
- Isc - Symmetrical short circuit currents in Amps
- t - Duration of fault in seconds
- θ_1 - Initial temperature before short circuit in °C
- θ_F - Final temperature after short circuit in °C

$$A = \frac{40000 \times \sqrt{1}}{2.17 \times 10000 \times \sqrt{\mathrm{Log}\{(200+258)/(85+258)\}}}$$

A = 5.2018 cm²

A = 520.18 mm²

Area of cross - section of selected busbar.

a) 4" IPS AL.Tube (SCH.80) = 2844 mm²

HENCE SAFE

4.0 CHECK FOR CONTINUOUS CURRENT RATING OF AL. TUBE:

Busbar used	=	4" EH IPS Al. Tube (SCH.80)		
Current carrying capasity of 4" EH IPS Al. Tube for Temp. rise of 50 Deg.C over an ambient of 35 Deg.C	=	3590	Amps	(As per INDAL AL. busbar Book.)
Correction Factor for temp. raise of 35 Deg.C over an ambient of 50 Dec.C	=	0.815	(As per Table 5 of INDAL AL BUSBAR BOOK)	
Continuous current rating of Al. Tube for 35 Deg.C temperature rise over 50 Deg.C Ambient.	=	3590 x 0.815		
	=	2925.85	Amps	
Max. Bus Bar Rating	=	1600	Amps	

Hence 4" EH IPS Al.Tube is adequate.

5.0 CHECK FOR VOLTAGE GRADIENT:-

5.1 Average voltage gradient at the surface of the bundled conductors

$$E_a = \frac{V}{n \times r \times \ln(2 \times he / re)} \quad \text{kV/cm}$$

Where,

$$re = r \times [\, k \times s / r \,]^{n-1/n} \quad \text{cm}$$

$$he = \frac{h \times d}{\sqrt{[(2h)^2 + d^2]}} \quad \text{cm}$$

Where,

V - Highest line to ground voltage in kV
- 141.5 kV

n - No.of conductors in the bundles
- 2 for twin conductors
- 1 for Single conductors

r - radius of the individual conductor in cm
- 3.177/ 2 = 1.5885 cm (Moose ACSR)
- 11.43/2 = 5.715 cm (4" EH IPS Al.Tube)

k - constant
- 1 for Single & twin conductors

s - Sub conductor spacing in the bundle in cm
- 25 cm

h - Line to ground distance in cm.
- 600 cm For Equipment Bus
- 1170 cm For Main Bus
- 1670 cm For Main Bus
- 2620 cm For Jack Bus

d - Phase to phase spacing in cm.
- 400 cm For Equipment Bus
- 450 cm For Strung bus

re - Eqivalent single conductors of bundled conductors in cm

he - Eqivalent single phase line to ground distance of a three phase system in cm

5.2 Equivalent single conductors of bundled conductors(re)

ForTwin Moose ACSR(Main Bus) conductor

$$re = 1.5885 \times \left[\frac{1 \times 25}{1.5885}\right]^{[2 - 1]/2}$$

= **6.3 cm**

5.3 Eqivalent single phase line to ground distance of a three phase system (he)

a) For 4"EH IPS Al.tube bus at 6.00 m level

$$he = \frac{600 \times 400}{\sqrt{[(2 \times 600) \times (2 \times 600)] + [400 \times 400]}}$$

= **189.74 cm**

b) For TWIN MOOSE ACSR at 6.0 m level

$$he = \frac{600 \times 400}{\sqrt{[(2 \times 600) \times (2 \times 600)] + [400 \times 400]}}$$

= **189.74 cm**

c) For TWIN MOOSE ACSR at 11.7 m level

$$he = \frac{1170 \times 450}{\sqrt{[(2 \times 1170) \times (2 \times 1170)] + [450 \times 450]}}$$

= **220.95 cm**

d) For TWIN MOOSE ACSR at 16.7 m level

$$he = \frac{1670 \times 450}{\sqrt{[(2 \times 1670) \times (2 \times 1670)] + [450 \times 450]}}$$

= **222.99 cm**

e) For TWIN MOOSE ACSR at 26.2 m level

$$he = \frac{2620 \times 450}{\sqrt{[(2 \times 2620) \times (2 \times 2620)] + [450 \times 450]}}$$

= **224.17 cm**

5.4 Average voltage gradient at the surface of the bundled conductors (Ea) / 4"EH IPS Al.Tube :

a) For 4"EH IPS Al tube at 6.00 m level

$$Ea = \frac{141.5}{1 \times 5.715 \times \ln\left(\frac{2 \times 189.74}{5.715}\right)} \text{ kV/cm}$$

= **5.9 kV/cm**

b) For TWIN Moose ACSR conductor at 6.0 m level

$$Ea = \frac{141.5}{2 \times 1.5885 \times \ln\left(\frac{2 \times 189.74}{6.3}\right)} \text{ kV/cm}$$

= **10.87 kV/cm**

c) For TWIN Moose ACSR conductor at 11.7 m level

$$Ea = \frac{141.5}{2 \times 1.5885 \times \ln\left(\frac{2 \times 220.95}{6.3}\right)} \text{ kV/cm}$$

= **10.48 kV/cm**

d) For TWIN Moose ACSR conductor at 16.7 m level

$$Ea = \frac{141.5}{2 \times 1.5885 \times \ln\left(\frac{2 \times 222.99}{6.3}\right)} \text{ kV/cm}$$

= **10.46 kV/cm**

e) For TWIN Moose ACSR conductor at 26.2 m level

$$Ea = \frac{141.5}{2 \times 1.5885 \times \ln\left(\frac{2 \times 224.17}{6.3}\right)} \text{ kV/cm}$$

= **10.44 kV/cm**

Allowable voltage gradient at the surface of the conductor is **20kV/cm.**

HENCE SAFE

5.5 Average voltage gradient at the surface of the Single conductors

$$Ea = \frac{V}{r \times \ln(2 \times h / r)} \text{ kV/cm}$$

Where,

V - Highest line to ground voltage in kV
- 141.5 kV

r - Radius of conductor in cm.
- 1.5885 cm

h - Line to ground distance in cm.
- 2620 cm (For Strung bus)
- 600 cm (For Equipment bus)

a) For Single Moose ACSR conductor at 26.2 m level

$$Ea = \frac{141.5}{1.5885 \times \ln\left(\frac{2 \times 2620}{1.5885}\right)} \text{ kV/cm}$$

= **11 kV/cm**

b) For Single Moose ACSR conductor at 6.0 m level

$$Ea = \frac{141.5}{1.5885 \times \ln\left(\frac{2 \times 600}{1.5885}\right)} \text{ kV/cm}$$

= **13 kV/cm**

Allowable voltage gradient at the surface of the conductor is **20kV/cm.**

HENCE SAFE

6.0 CALCULATION FOR FIBRE STRESSES ON TUBULAR BUSBAR(4" EH IPS .SCH:80):-

6.1 CALCULATION FOR MAXIMUM SPAN WITH ONE END RIGID AND OTHER END SIMPLY SUPPORTED

6.1.1 Maximum force acting on the central conductor during 3 phase short circuit (F_{m3}) is

$$F_{m3} = \frac{0.2 \times 0.87 \times i^2_{p3} \times L}{a} \quad N$$

Where

i^2_{p3} = Peak short circuit current in kA

$$= \frac{Isc \times 1.81 \times \sqrt{2}}{1000}$$

= **102.0 kA**

Therefore,

$$F_{m3} = \frac{0.2 \times 0.87 \times 102 \times 102 \times 8.05}{4} \quad N$$

= **3643 N**

6.1.2 Natural frequency of the tubular busbar of a single conductor

$$fc = \frac{\gamma}{L^2} \times \sqrt{\frac{E \times J}{m'}} \quad HZ$$

Where

γ - Factor of natural frequency estimation
= **2.45** (From table -III of IEC 865-1)

β - Factor for main conductor stress
= **0.73** (From table -II of IEC 865-1)

E - Young's modulus of Al.tube in N/m^2
= **65727000000 N/m^2**

J - Moment of Inertia in m^4
= **0.00000399998 M^4**

m' - mass per unit length of conductor in Kg/m
= **7.678 Kg/m**

L - Distance between two supporting points of Al. Tube
= **8.050 m**

Therefore,

$$f_c = \frac{2.45}{8.05 \times 8.05} \times \sqrt{\frac{(65727 \times 10^6) \times (399.998 \times 10^{-8})}{7.678}}$$

= **7.00 Hz**

6.1.3 Ratio f_c/f :

$$f_c / f = \frac{7}{50}$$

= **0.14**

From the f_c/f value, the factors Vσ and Vr are calculated as follows:

a) Ratio of dynamic and static main conductor stress
Refer page no 109 of IEC-865-1

for 0.04< fc/f < 0.8

V_σ = 1

$V_{\sigma 1} = 0.756 + 4.49 e^{-1.68\kappa} + 0.54 \log (fc/f)$

Where

κ = 1.6 for κ>1.6

$V_{\sigma 1} = 0.756 + 4.49 e^{-1.68\kappa} + 0.54 \log (fc/f)$

= 0.756 + 4.49 x Exp - (1.68 x1.6) + 0.54 log (0.14)

= 0.600

$V_{\sigma 2}$ = 1.0

Therefore,

$\mathbf{V_\sigma}$ = **0.600**

b) Ratio of stress for main conductor with three phase auto-reclosing (V_r):-
Refer page no 109 of IEC-865-1

for 0.05 < fc/f < 1.0

V_r = 1.0 - 0.615 log (fc/f)

= 1.0 - 0.615 log (0.14)

= **1.525**