Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Overhead busbar design for 220/66 kv GIS substation

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Abstract -- The paper is assigned to design a 220/66 KV HV GIS sub-station. It considered incoming power at 220 KV and the power was transferred to main bus through isolator- circuit breaker combination in GAS INSULATED SUBSTATION. The power from GIS was fed into two 100 MVA transformer which stepped the voltage down to 66 KV. The power is then fed into a 66 KV bus from which different loads were tapped and further distributed to respective station. This paper includes brief details about the busbar design and its calculation required in substation to the extent they relate to substation layout. It also covers the effect of temperature rise on different parameters of busbar.

Keywords-- Substation, GIS, busway, busbar, ACSR zebra conductor

I. INTRODUCTION

A bus bar (also spelled busbar, buss bar or busbar), is a strip or bar of copper, brass or aluminium that conducts electricity within a switchboard, distribution board, substation, battery bank or other electrical apparatus. Its main purpose is to conduct electricity, not to function as a structural member.

Busbars are typically either flat strips or hollow tubes as these shapes allow heat to dissipate more efficiently due to their high surface area to cross-sectional area ratio. A hollow section has higher stiffness than a solid rod of equivalent current-carrying capacity, which allows a greater span between busbar supports in outdoor switch yards.

Busbars may be connected to each other and to electrical apparatus by bolted, clamp, or welded connections. Often joints between high-current bus sections have matching surfaces that are silver-plated to reduce the contact resistance. At extra-high voltages (more than 300 kV) in outdoor buses, corona around the connections becomes a source of radio-frequency interference and power loss, so connection fittings designed for these voltages are used.

Busbars are typically contained inside switchgear, panel boards, or busway. Distribution boards split the electrical supply into separate circuits at one location. Busways, or bus ducts, are long busbars with a protective cover. Rather than branching the main supply at one location, they allow new circuits to branch off anywhere along the route of the busway.

The issues that need to be addressed in the design of busbar systems are:

Temperature rise due to energy losses
Energy efficiency and lifetime cost
Short-circuit current stresses and protection
Jointing methods and performance
Maintenance.

II. DIFFERENCE BETWEEN COPPER AND ALUMINIUM CONDUCTOR FOR USING AS BUSBAR

It is a common misconception that electrical equipment built using aluminium conductors will always be larger than the same equipment using copper conductors. While the actual conductor within the equipment will be larger with aluminium, many times the enclosure for the equipment is the same size whether copper or aluminium conductors are used. The biggest size impact for electrical equipment when copper and aluminium conductors are considered is for busway. Since the actual conductor is the primary component within the busway, the size difference will be more apparent. Even though the size for the aluminium bus is larger than for the copper bus, the weight difference is more dramatic and favours the aluminium bus. When considering the differences between copper and aluminium conductors in electrical equipment, size must be acknowledged, but for most equipment types the size is not a delineating feature. The weight of the equipment is generally not apparent, but can be big difference in terms of labour and material for the installation and support of the equipment.

III. CURRENT CARRYING CAPACITY

The current-carrying capacity of a busbar is usually determined by the maximum temperature at which the bar is permitted to operate, as defined by national and international standards such as British Standard BS 159, American Standard ANSI C37.20, etc. These standards give maximum temperature rises as well as maximum ambient temperatures.

IV. FEATURES / CHARACTERISTIC OF BUSBAR

4.1 Busbars Reduce System Costs

A laminated busbar will lower manufacturing costs by decreasing assembly time as well as internal material handling costs. Various conductors are terminated at customer specified locations to eliminate the guesswork usually associated with assembly operating procedures. A reduced parts count will reduce ordering, material handling and inventory costs [2].

4.2 Busbars Improve Reliability

Laminated bus bars can help your organization build quality into processes. The reduction of wiring errors results in fewer reworks, lower service costs and lower quality costs [3].

4.3 Busbars Increase Capacitance

Increased capacitance results in decreasing characteristic impedance. This will ultimately lead to greater effective signal suppression and noise elimination. Keeping the dielectrics thin and using dielectrics with a high relative K factor will increase capacitance.

4.4 Eliminate Wiring Errors

By replacing a standard cable harnesses with busbars, the possibility for miss-wirings is eliminated. Wiring harnesses have high failure rates relative to busbars, which have virtually none. These problems are very costly to repair. Adding busbars to your systems is effective insurance.

4.5 Busbars Lower Inductance

Any conductor carrying current will develop an electromagnetic field. The use of thin parallel conductors with a thin dielectric laminated together minimizes the effect of inductance on electrical circuits.

4.6 Busbars Lower Impedance

Increasing the capacitance and reducing the inductance is a determining factor in eliminating noise. Keeping the dielectric thickness to a minimum will accomplish the highly desired low impedance.

4.7 Busbars Provide Denser Packaging

The use of wide, thin conductors laminated together led to decreased space requirements. Laminated bus bars have helped decrease total system size and cost.

4.8 Bus bars Provide Wider Variety of Interconnection Methods

The flexibility of bus bars has allowed an unlimited number of interconnection styles to choose from. Bushings, embossments, and fasten tabs are most commonly used.

4.9 Bus bars Improve Thermal Characteristics

The wide, thin conductors are favourable to allowing better airflow in systems. As package sizes decrease, the cost of removing heat from systems has greatly increased. A bus bar cannot only reduce the overall size required, but it can also improve airflow with its sleek design.

V. CONDUCTOR AREA CALCULATION

For Rated current = 1000 Amp
Fault current =Ifc = 50KA for 1 sec
Permissible temperature rise= 40 ºC
Busbar material =aluminium alloy E91E
De-rating factor due to material =1
De-rating factor due to temperature rise =0.86
De-rating factor due to enclosure =0.75
Total de-rating factor = 1*0.75*0.86=0.66
Minimum cross section area required to withstand short circuit for 1 sec.
= (Ifc *√t)/0.08
Where, Ifc = fault level current in KA
t= 1 second
Area A = (50*√1)/0.08 = 625 sqmm
Considering all de-rating factor, A = 625/0.66 =946.97
Say, cross sectional area per phase = 1000 sqmm
For neutral, cross sectional area per phase = 500 sqmm

VI. TEMPERATURE RISE

During the short circuiting, the bus bar should be able to withstand the thermal as well as mechanical stress. When a sort circuiting takes place, the temperature rise is directly proportional to the squire of the rms value of the fault current. The duration of short circuiting is very small i.e. one second till the breakers opens and clears the fault. The heat dissipation through convection and radiation during this short duration is negligible and all the heat is observed by the busbar itself. The temperature rise due to the fault can be calculated by applying the formulae [8].

$T = K *(I/A)^{2} *(1+\alpha\theta)\ 10^{-2}$

T=temperature rise per second, A= conductor cross section area,
α = temperature coefficient of resistivity at 20 ºC/deg
C= 0 .00393 for copper
= 0 .00386 for aluminium
K = constant
=0.52 for copper
=1.166 for aluminium
θ=temperature of the conductor at the instant at which the temperature rise is being calculated.

VII. BUS-BAR SIZING CALCULATION

Table 1. Standard given data[12]

DESCRIPTION	SYMBOL	UNIT	VALUE
Short Time rating of the system		KA	25
Conductor diameter	D	M	28.62
Temperature	T_0	ºC	20
DC resistance at 20 ºC temperature	R_{dc}	Ω/km	0.069

Constant of mass temperature coefficient of resistance of conductor per °C	A	/°C	0.00403
Ambient Temperature	T_1	°C	50
Final Equilibrium Temperature	T_2	°C	85
Wind Speed	V	m/s	0.6097
Emissivity co-efficiency in respect to black body	Ke		0.5
Solar radiation absorption co-efficient	Γ		0.5
Intensity of solar radiation	Si	W/sq m	900
Stefan-Boltzmann constant	S	$W \times m^{-2} \times K^{-4}$	5.67E-08
Thermal conductivity of air film in contact with conductor, assumed constant	Λ	$W \times m^{-1} \times K^{-1}$	0.02585
Frequency	F		50

VIII. CALCULATION

8.1 Heat Balance equation

$P_j + P_{sol} = P_{rad} + P_{conv}$

Where,

P_j = Heat generated by Joule Effect

P_{sol} = Solar heat gain by conductor surface

P_{rad} = Heat loss by conductor radiation

P_{conv} = Convection heat losses

8.2 Solar Heat Gain

$P_{sol} = \gamma \times D \times Si$

$= 0.5 \times 28.62 \times 10^{-3} \times 900$

= 12.879 Watt/Mtr

8.3 Heat loss by radiation of conductor

$P_{rad} = s \times \pi \times D \times K_e (T2^4 - T1^4)$

8.4 Convection Heat loss

$P_{conv} = \lambda \times Nu \times (T2 - T1) \times \pi$

Where,

$\lambda = 0.02585\ W \times m^{-1} \times K^{-1}$

Re = Reynolds number and Nu = Nusselt number

$Re = 1.644 \times 109 \times v \times D \times [(T1 + 0.5(T2 - T1)]^{-1.78}$
$Nu = 0.65 \times Re^{0.2} + 0.23 \times Re^{0.61}$
$Pconv = \lambda \times Nu \times (T2 - T1) \times \pi$

8.5 DC Resistance at 85°C

$R_{T2\ dc} = R_{dc} \times (1 + \alpha \times (T2 – T0))$
Now k = 1.011. This value is derived from the skin effect table given as per IEC 61597.

8.6 AC resistance at 85°C

$R_{T2\ ac} = R_{dc} \times K$

FROM HEAT BALANCE EQUATION:

$$P_j + P_{sol} = P_{rad} + P_{conv}$$
$$I^2 \times R_{T2\ ac} + P_{sol} = P_{rad} + P_{conv}$$
$$I = \sqrt{\frac{Prad + Pconv - Psol}{RT2ac}}$$

(This is the current carrying capacity of single ACSR Zebra conductor)
For Twin ACSR Zebra Conductor= 2*I

CHECK FOR SHORT TIME RATING OF ACSR ZEBRA CONDUCTOR:

Conductor Ambient Temperature T_1=*50*° C = 323° K
Conductor Temperature at the beginning of a short circuit $T_2 = \theta_b$ = 85 ° C = 358° k
Conductor Temperature at the end of a short circuit θ_e = 200 ° C
(As per Table 6 of IEC - 60865-1)
Rated short time withstand current density for 1 sec S_{th} = 80 Amp/mm2
(As per Fig 13 of IEC - 60865-1)
= 80 x I

Standard Short Circuit Rating

-Upto 400A rated current: 25KA for 1 sec.
-600 to 1000A rated current: 50KA for 1 sec.
-1250 to 2000A rated current: 65-100KA for 1 sec.
-2500 to 5000A rated current: 100-225KA for 1 sec.

VIII. SUMMARY OF RESULT

DESCRIPTION	SYMBOL	UNIT	VALUE
Value of K	-	-	1.0111
DC Resistance at 85°C Temperature of conductor	RT2 dc	Ω/km	0.08667
AC Resistance at 85°C Temperature of conductor	RT2 ac	Ω/km	0.08750
Calculated Ambient Temperature	T1	K	323
Calculated Final Equilibrium Temperature	T2	K	358
Nusselt number	Nu	-	17.0352

Reynolds number	Re	-	892.317
Heat loss by radiation	Prad	W	14.125
Convection heat loss	Pconv	W	48.420
Solar heat gain	Psol	W	12.879
Current Carrying Capacity (Twin ACSR Zebra Conductor)	Iccc	Amps	1505.66

Now, the Short Time Current Withstand Capacity of ACSR Zebra Conductor Is
80 * I= 80*752.83 A = 60.222 KA

60.222 > 50.00 KA

Hence the Design is SAFE

IX. CONCLUSION

Substations form an important element of transmission and distribution network of electric power system. Basically, these provides points for controlling the supply of power on different routes by means of various equipment such as transformers, compensating equipment, busbar, circuit breakers, isolators etc. the various circuits are joined together through these components to bus bar system at the substations. The evaluation study of the life cycle presented here demonstrate the advantages of SF6 insulation (GIS) compared to air insulated switchgear (AIS) to a level distribution [1] . Equipment is, however, only to a very small for a global warming potential contribution. According to research, GIS is more reliable, multi-component and maintenance free as it need very less space as compare to AIS. It also describes the primary insulation medium Sulphur hexafluoride (SF_6) gas (used in GIS equipment) and its properties. This paper has been undergone through several study and analysis for designing and engineering of receiving substation and thus carried out different overhead busbar sizing calculations which helps in knowing much about parameters to be considered while designing overhead busbar for a substation. From the calculation it has been concluded that the Designed Short Time Current Withstand Capacity of ACSR Zebra Conductor is greater than rated Short Time Current Withstand Capacity of ACSR Zebra Conductor, Hence the design is SAFE.

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