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The selection of bar and executive instruction of Busbar

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Abstract. Due to the high amount of normal and short-circuit current in power systems, using of busbars is inevitable. The combination of copper and aluminum and aluminum copper alloys as conductor are used. One of the most important points in the design of power systems is the right choice of conductor.The proper selection of conductor is dependent on several factors such electrical, mechanical, chemical, environmental and weather conditions. In order to choose a conductor, amount of current, height from sea level, temperature, voltage level, level of short circuit current and it s duration, The positioning of busbars and number of them in each phase, to be bared or not to be and resistivity of any conductor must be assessed. for better longevity of the busbar and flow continuity of current at nominal value, corresponding guidelines must be done, also the distance between the equipment are energized and distance between energized equipment and ground should be noted.

Keywords: Select the busbar, Calculation bars, Executive points busbar

1. INTRODUCTION

Easier access of technicians, engineers and senior engineers to practical tips for projects and classification of each part of the power system design and selection could facilitate engineering effort for a designer or inspector, etc. One of the design and implementation process of power system is selection and calculation of the busbar conductor. With regard to the selection and implementation of conductors is depende on several factor, in this article we try to explain required instructions for Selection, calculation and execution of the busbar.

2. SELECTION OF BAR

Busbar cross-section has no effect on the bending strength but Specifies the flow capacity of conductor. skin effect and other factors of alternating current increase the resistance of conductor. the resistance value should be kept small by proper selection of the cross-bar, kind of this bars is indicated with subscript of F. typically between F25 to F37 are used more. the greater F-value is equivalent to more impurities witch make greater mechanical strength while the electrical conductivity decreases. Consequently in systems with high short-circuit power, appropriate F (for example F30 to F37) must be used Because the bar must withstand the force caused by short circuit. selection of bars are dependent on factors such as: 1- amount of current, 2- the ambient temperature and bar operating temperature 3- voltage level 4- height from sea level 5- positioning of the bars 6- level of short circuit current and it’s duration 7-type of bar coverage 8- resistivity of the conductor.According to above parameters and following tables Bar calculation can be done. Calculations should be at least 15% greater than the current rate is calculated. One of the reasons for the increase in cross section is associated with the IP electrical Switchgear. Particularly for high IP panels that makes it harder for the bar to heat exchange. busbar arrangements are done in two ways:

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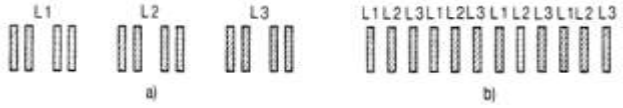

Figure 1. Busbar arrangement

the following tables are based on 50 Hz, for other frequencies following equation must be used.

$$I_x = I_{50}\sqrt{\frac{50}{f_x}} \quad (1)$$

All values and calculations are based on the height of 1000 meters above sea level. By increasing the height, air pressure reduces witch causes to reduce flow capacity. Then the cross section is selected accordance to where the bar is installed. for example cross section of the bars of switchgears is installed in Abadan city with a height less than 1000 m from sea level is different from electric panel in northern Tehran, with a height of more than 2500 meters.

The first factor: for different heights and to exert pressure and flow capacity change the following table should be used.

Table 1. Height coefficients above sea-level for indoor & outdoor switchgears**.**

Height above sea-level (m)	indoor	outdoor
1000	1	0.98
2000	0.99	0.94
3000	0.96	0.89
4000	0.9	0.83

For example in outdoor switchgears,if the height is greater than 2000 m

The amount of current flowing in the calculations should be devided to 0.94.

The second factor: another important parameter in the selection of the appropriate bar is ambient and operating temperature of busbar

The following groups can be used to select the appropriate coefficient.

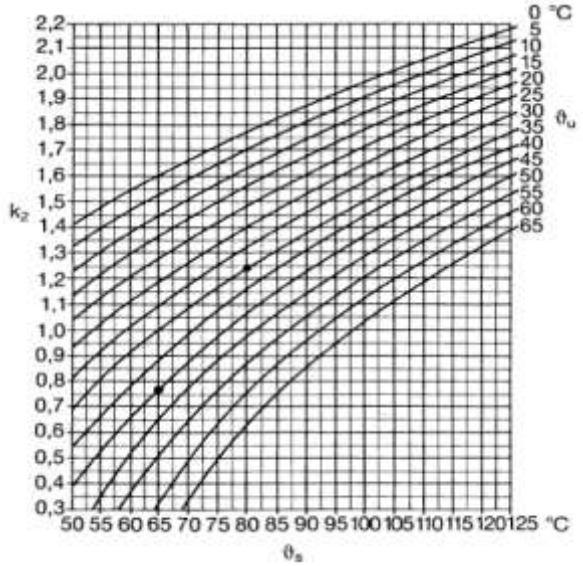

Figure 2. Ambient temperature and the temperature coefficient

On the right side of figure groups of ambient temperature and the bottom of figure bar operating temperature and the on left side of figure coefficient related to busbar selection are expressed. Depending on the ambient temperature and the temperature of bar in the catalog (technical specification sheet) the appropriate factor could be found then select the desired busbar. for example bar with a maximum operating temperature of 65^{o}c and maximum ambient temperature 45^{o}c has coefficient equal to 0.75. The maximum continuous temperatur according to DIN43670, DIN 43671 standards is as follows: Oxide and oil-free bars To a temperature about 120 °, Coated with silver or tin bar or similar about 160 °, for insulated bushing 85^{o}, for terminal equipment 90^{o}, the best method for monitoring temperature especially for thermal overload is use the color temperature sensor That changes it's color with temperature rise, By the high temperature, strength of the copper conductor decreases and the decrease in strength aluminium is more than copper. for temperatures above 160^{o} degrees aluminum strength is dependent on the duration of heat .During short circuit, aluminum conductor temperature should not exceed 150^{o}c to 200^{o}c.(accordance to VDE0103 standard).the maximum temperature during the short circuit that conductor can tolerate accordance to IEC60621-2, DIN VDE 0100 PART 540 DIN VDE01.heat parameter effects on other equipment, but not as much as bars or not for all equipment. In some cases precedes the two bus bar connected that have not thermal insulation and coupling, approaches should be considered for this condition. methods consistent with applicable restrictions can be seen in the instructions. For example,with useing a over load protection relay between two busbar Upon increasing the temperature and approaching to operating temperature busbar, trip relay and act. systems that can not be interrupted for any reason, sensors and monitoring or other methods can be used. other examples, such as short-circuit current which may not the same between the two busbars are connected and one has lower short circuit level. In this conditions, occurrence of short circuit in main busbar that has higher short circuit level, other busbar that has lower short circuit level damaged and cause great damage in a short circuit time. to avoid this problem, it is better to place an appropriate fuse between two busbar, to the short-circuit current of the bus bar fault not damage another busbar that has less tolerance against short circuit. Islimiters can be also a good choice. advanced equipments help us in action but simplest way presented in this article is using a suitable fuse between two busbar.The third factor:it is selected according to bar coating, due to the cross bar and bar covering and the bar number in each phase, appropriate factor is selected.

Table 2. Correction coefficient bars in terms of coverage

Number of bar	Width bar	Bar thick	Colored loading factor	Discolored loading factor
1bar	50-200	5 – 10	0.9	0.85
2bars	50-100	5 – 10	0.85	0.8
3bars	50 – 80 100 – 200	5 - 10	0.85 0.8	0.8 0.75
4bars	100 – 160 200		0.75 0.7	0.7 0.65

Coloring bars especially for color plascoat and having black coat and not yellow, red, blue and etc, results in better heat transfer and higher flow capacity .Coat type or bar color should be an arc-proof type and note that in connection must not be used any color, coat or insulation.in other words, in fact the toolkit must be manipulated so that the isolator could be removed from the connection place.The method presented in this paper is use of black coat for better heat exchange not as often different color such as (yellow, red, blue) is used in practice. also it is better to mark bus with lable not on a bar because heat generated after a while may eliminate sticking lables on bar. Select a suitable location for lable is better done with sufficient precision in assembly and installation.

The fourth factor: the more number of busbar in each phase reduce skin effect, eddy currents, and the inductive voltage drop. Using two busbar for each phase is usually good while a greater number can be used. if 4 busbar or more is used,it is better to put distance between each one, 70 mm distance is a good choice.the relative current un the individual conductors differ by only +7%.

Table 3. The loading on the four conductors.

4	3	2	1	Conductor
26.7	23.3	23.3	26.7	**current carried as % of toal current**

When the current is high, it is better to use multi bars if possible. this action reduce skin effect and often it is economical and implementation is easier.Current of each phase for 7 busbar is as follow:

Table 4. Loading on the seven conductors

7	6	5	4	3	2	1	Conductor
25.6	14.2	7.5	5.4	7.5	14.2	25.6	**Relative current%**

One reason for the high percentage of first and last bus is easier heat exchange from surface of conductor that causes to increase it s current capacity

Fifth factor: conductor position has significant impact on bus capacity that for horizontal and vertical busbar more than two meter, aluminium DIN43670, combination of copper and aluminium DIN43670 PART 2, copper DIN 43671, can select the corresponding coefficient.

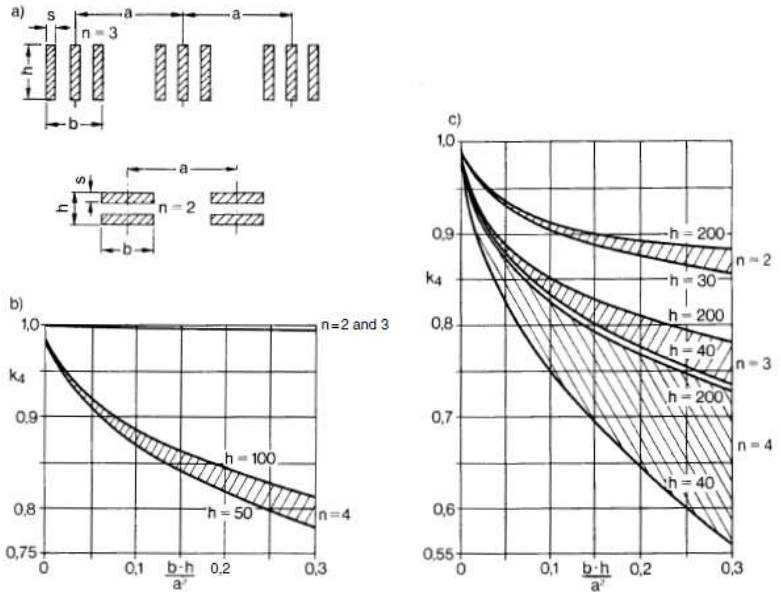

Figure 3. Select coefficient for copper conductance.

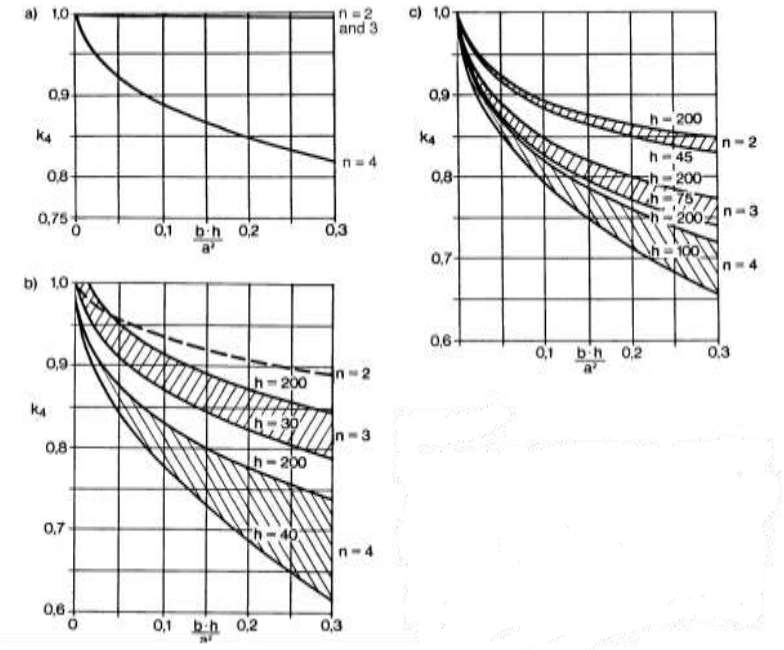

Figure 4. Select coefficient for aluminum conductance.

For combination of copper and aluminum this coefficient is applied when the 2 meter bar does not jumper

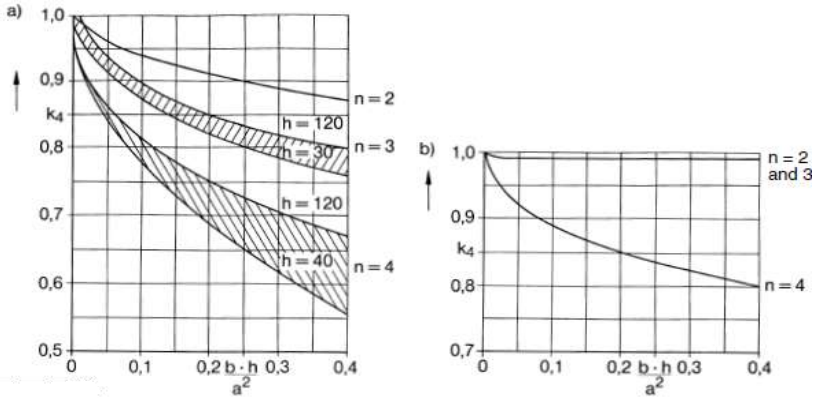

Figure 5. Select coefficient for combination of copper and aluminum conductance.

The sixth factor: for changes in conductor resistivity a factor is applied that depends on the semiconductor material.

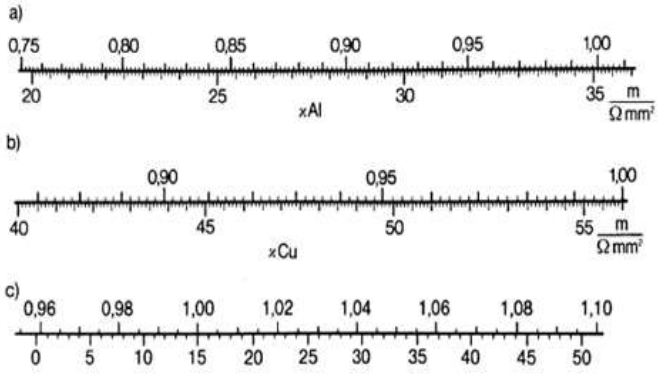

Figure 6. Chart of resistivity coefficient of conductor.

a) For conductors of aluminum

b) For conductors of copper

c) For load capacity variation with copper-clad aluminium conductors having other than 15% copper

After selecting coefficients from above tables, calculated amount of current should divide into selected coefficient, based on final value cross-bar can be selectedThe most important parameters in the selection of bar are Short curcuit and subsequent results. Strong mechanical force at the moment of short circuit apply to bars and If the bar is not selected correctly it will be destroyed. according to standards minimum cross-sectional area of the phase bar must be larger from earth bar. Now the question is, if the calculation phase and earth in such a way that phase is equal to earth, In this situation, what should we do?

The answer is that If the cross section of the bar phase is equal to bar earth,in calculations, Phase bars should be choose a higher level at the time of purchase and installation. The part that color of the bar carved for conection to prevent corrosion and oxidation, must be use grease. Earth bars should be installed reliably until at the moment short circuit between phase and earth or between two phases and earth that current passes through earth bar, it remain constant. for earthing particularly withdrawable switchgear and moving equipment is better to use Straw flexible cable.

Earth busbar standard IEC 364_5

$$A=If\times \left(\sqrt{(tf)}/K\right) \quad (2)$$

$$K=226*\sqrt{Ln\ \times 1+(\theta f-\theta i)}\ /\ 234.5\ ^\circ c+\theta i \quad (3)$$

A:The earth cross-section busbar (mm^2)

If:Maximum single-phase short-circuit current

tf:Duration of short curcuit

K:The coefficient of the conductor is used

θi:Maximum ambient temperature

θf:The maximum temperature during short circuit can tolerate

In a similar cross area Bars that are coated with Silver Plating and similar ways has higher temperature tolerance than bars are without electroplate Also, this type electroplate is economical in large project and prevent phosphate of conductor dramatically even in a very long time and increase bar lifetime particularly if also connectors are plated. for environments that have high moisture and high corrosion,due to higher resistance of tin than silver it is better to be tin-plated connectors. In connection bars should Bolts Have a same electroplate. And also galvanize should be uniform and have at least 4 micron thickness and not remove easily. used screws is better that select from 8.8 gread or greater. for clamping screw is better that a torque meter is used In accordance with the following standards or technical documents by manufacturer. DIN43673: Standards relating to the use of screws and fittings

Table 5. Table of determine force of torquemeter to close screw.

Tolerance: -0% + 20 %
Screw type: 8.8 G M6 M8 M10 M12 M16 M18
Tightening torque (Nm) 9 22 45 75 185 260

Because of the high current and available vibration, spring washer should be used to close bars. in MV & HV systems should be noted that bars do not have sharp corners because every time there is a possibility of arc. distance between bars and energized parts and body is depending on the voltage level and the height above sea level. In choose the section in a limited space, care must be taken that the insulation distances well respected, This distance should not be less than the value in the following table, if this distance is not possible to regard, Then a good insulation such as fiberglass, etc should be used

Table 6. Allowed distance between Phase to phase and phase to earth at different voltage levels.

Un kv	**Um** kv	**Power frequency** kv	**Impulse Voltage** 1.2/50 ms Urb kv	**In Door mm**	**Installation**	**Out Door mm**
3	3.6	10	20	60		120
			40	60		120
6	7.2	20	40	60		120
			60	90		120
10	12	28	60	90		150
			75	120		150
15	17.5	38	75	120		160
			95	160		160
20	24	50	95		160	
			125		220	
30	36	70	145		270	
			170		320	
36	41.5	80	170		320	
			200		360	

Note that this table to an height of 1000 meters above sea level and humidity 11gr / m^3 is considered, and for other moisture should use the graph below

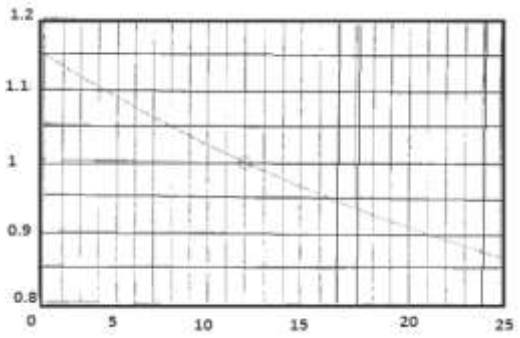

Figure 7. Curve of correction factor versus humidity change.

For example, moisture 11g / m^3 by a factor of 1 is shown for more moisture is better with a heater and thermostat decrease humidity.

Table 7. Select effective voltage in isolation distance with respect to the test(DIN0670 part1000/IEC 60694).

Reated Voltage (rms)	Reated short-time power frequency withstand voltage		Reated lightning impulse withstand voltage	
	For isolating Between fases & Distances to earth		For isolating Between distances fases& to earth	
Kv	kv	kv	kv	kv
7.2	23	20	70	60
12	32	28	85	75
15	39	36	105	95
17.5	45	38	110	95
24	60	50	145	125

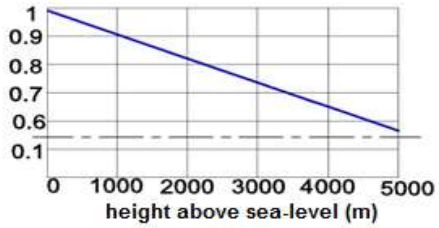

Figure 8. Select proportional coefficient with height from sea level from above group

For example:

The system has a nominal voltage of 7.2 kV and it s bars have been installed in the 4,000 meters above sea level, what is allowed distance phase to phase and phase to ground ?

The two forms are possible:

1- $\text{reated short} - \text{time power frequency withstand voltage to be sellected} \geq \frac{\text{reated short–time power frequency voltage}}{\text{Selected coefficient of Figure 8×1.1}} = \frac{20}{1.1\times0.65} = 27{,}97 \text{ Kv}$

In this example for select insulation distance between two phases and one phase to earth 27,97Kv obtained from the above formula, from that row Should consider the voltage is greater than the number obtained that Based on table is 28kv. This means that insulation distance between two phases and phase to earth Should be equal to the rated voltage 12Kv

2-

$$\textit{reated lightning impulse withstand voltage to be sellected} \geq \frac{\text{reated lightning impulse withstand voltage}}{\text{Selected coefficient of Figure 8×1.1}}$$

During installation busbar and bar particularly in the switchgear wash them with special chemicals for one to two minutes,with this action copper layer on a bar is removed And the color bar seems silver, this action increase current rate twenty percent approximately.Punch-size busbars for connections must be in accordance with the cable size.

3. CONCLUSION

In designing a power system for selecting bars should factors such as ambient temperature, operating temperature, height from sea level, voltage level, short circuit current, type of bar coverage, number of busbar in each phase,considered. also busbars connected to each other while has a different tolerance for temperature and short-circuit current, conductor type, coverage,connectors and it s location, and Other points that are listed in the standard should be considered.

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