

29

Recommended practices for mounting buses and making bus joints

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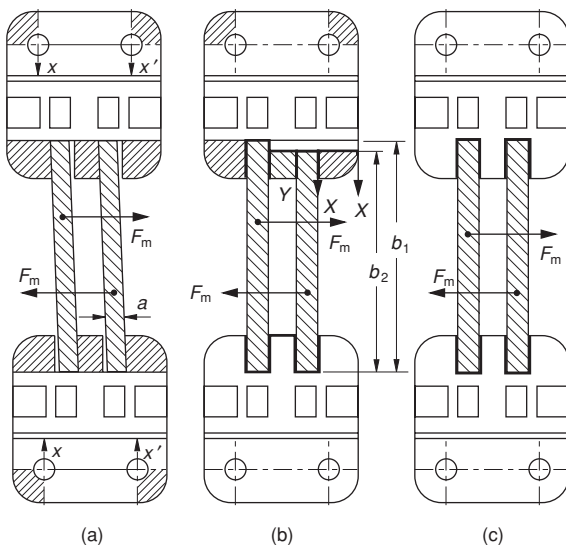
29.1 Precautions in mounting insulators and conductors

Often a failure on a fault may be due not to the inadequate size of busbars, fasteners or insulators but to poor alignment of the insulators or to too large a gap between the busbar and the insulator slots. It may be a consequence of an inappropriate mounting or unequal width of the busbars or insulator slots. In such cases, load sharing will be uneven and the weakest section may fail. This can be illustrated as follows:

- As shown in Figure 29.1(a) as a result of loose fit of busbars with an unequal gap, the insulators (shaded in the figure) may fail for the following reasons:
 - Misalignment of insulators may cause an unequal distribution of forces.
 - A loose fit of busbars inside the slots may cause excessive vibrations on a fault and may lead to loosening of the fasteners and shearing of the wedges and/or the edges and the fingers of the insulators. Even the insulator mounting section $X - X'$ may become vulnerable to failure.
- When one or all of the busbars are shorter in width as shown in Figure 29.1(b) the upper insulator may fail at the shaded parts through the wedges or the edges, as they will now encounter relatively higher cantilever forces.

Conclusion

- Loose busbars within the slots give rise to vibrations and a humming noise due to magnetic inductance.



- (a) Smaller thickness of busbars 'a'
It may cause vibrations within the insulator slots during a fault and magnify forces acting on the insulators and fasteners
- (b) Unequal width of busbars 'b' (b_1, b_2)
The insulator may shear off at Section $X - X'$ or yoke y
- (c) Proper mounting

Figure 29.1 Mountings of insulators and busbars

This may lead to loosening of fasteners and be detrimental to the performance of the busbar system in the long run. To lessen the effect of this, the busbars should be only marginally loose inside the slot for easy movement during expansion or contraction. This requires accurate size of insulators and their correct mounting and alignment as shown in Figure 29.1(c). In this case all the load-bearing members are equally involved in sharing the force and make the system stable and strong.

- One may consider a factor of safety of 50–100%, depending upon the criticality of the installation in all the forces that may arise on an actual fault to ensure a foolproof system.

29.2 Making a joint

This requires special precautions for both aluminium and copper, as both metals are highly susceptible to oxidation and corrosion (at ordinary temperatures aluminium being more susceptible than copper). Oxides of aluminium and copper are poor conductors of heat and electricity and must be avoided, particularly at joints rather than in the straight lengths, to ensure proper transmission of current from one section of the bus to another. Also, aluminium is soft. Making a perfect joint to achieve a longer durability is therefore essential. It involves attaining the least contact resistance by ensuring proper contact pressure to eliminate any localized heat. A slightly faulty joint may yield to faster erosion of the metal and relaxation of the contact pressure. Loose contact pressure will lead to high contact resistance and cause a high localized heat, which may result in ultimate failure of the joint. For instance, if the outer diameter, thickness or the hole of the washer is not commensurate with the diameter of the hole in the busbar then the washer may gradually sag into the hole, in normal service, through pressure by the bolt and heat of the buses. Gradually it may loosen its grip at the joint, release the contact pressure and lead to failure of the joint.

The contact resistance can be minimized by increasing the pull of the fasteners. Increasing the area of overlap may not reduce the contact resistance, unless the number of fasteners is also increased. It is mandatory to maintain a certain minimum contact pressure per unit area of the joint overlap. An average contact pressure at around 40–55 kg/cm² for aluminium and roughly 150–200% of this for copper joints is considered adequate to provide a reasonable low contact resistance. Too much pressure is also not advisable as it may result into a cold flowing of metal and loosen the contact pressure with passage of time. For the purpose of easy application, it is expressed in terms of bolt torque, depending upon the area of overlap and the number of fasteners, as specified in Table 29.1.

The following are more precautions that are considered mandatory for making a good joint:

- Before making the joint, clean the surface and apply the contact grease to avoid oxidation, as discussed in Section 13.6.1(iv).
- Make the joint immediately after the above process.

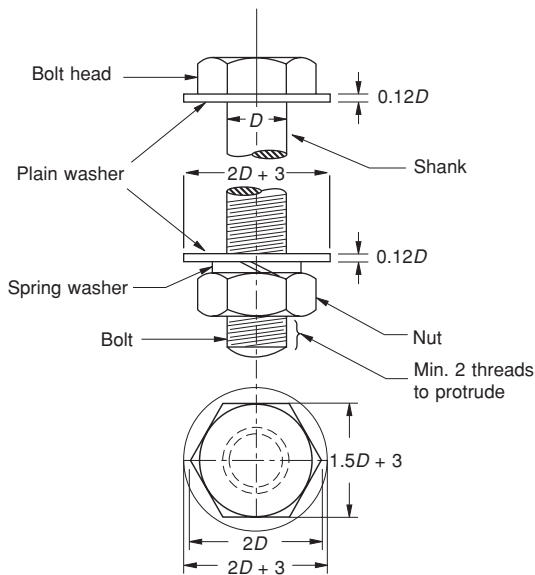


Figure 29.2(a) Correct procedure for using a bolt and nut assembly

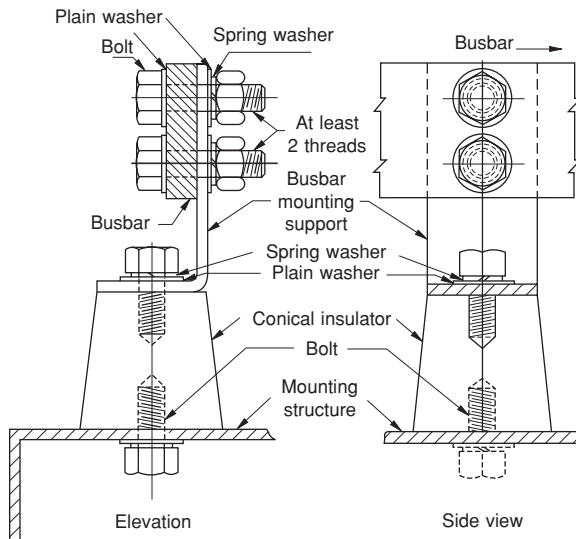


Figure 29.2(b) A typical mounting and fixing arrangement of a conical insulator and a flat busbar

- 3 Make the joint by using the correct size of bolts, nuts and washers. Refer to Table 29.1 for the recommended number and size of fasteners for different widths of bus sections and Table 29.2 for the recommended size of washers for different sizes of bolts. See also Figures 29.2(a) and (b) for a correct fastening method.
- 4 For jointing large bus sections it may be advisable to use pressure plates to avoid excessive local pressure as illustrated in Figure 29.4.
- 5 Use a torque wrench (preferably motorised) to tighten the fasteners to ensure correct surface-to-surface

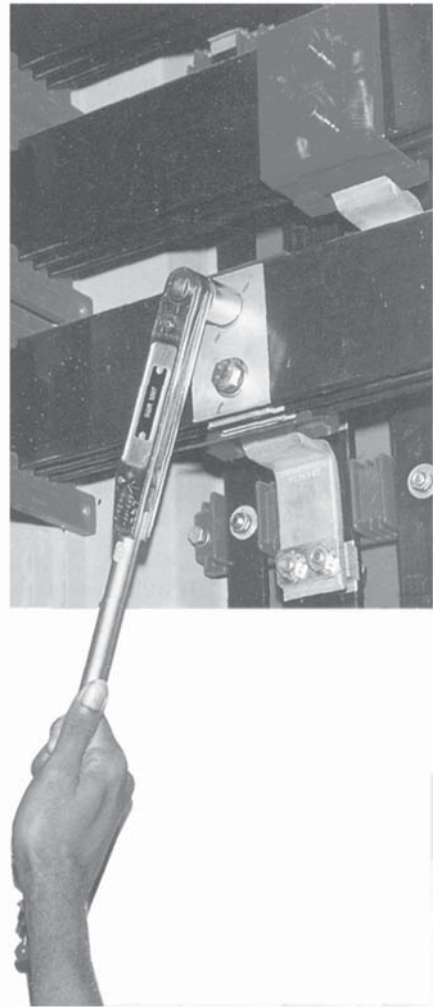


Figure 29.2(c) Use of manual torque wrench to tighten the fasteners (motorised spanners are employed for faster production)

contact of the current-carrying parts (Figure 29.2(c)). The recommended values of bolt torque are given in Table 29.1. A pressure that is too high may cause relaxation of the joint by cold flow and must be avoided.

See also Section 28.5.1 on sealing of bus joints.

29.2.1 Straight-through joints

To join two sections of a bus, fishplates are used as illustrated in Figure 29.5. Slotted holes are usually provided in the fishplate to allow for fixing adjustments. They are not meant to absorb the thermal expansion of the busbars on load, for they are supposed to make a rigid joint, hence there is no scope for surface movement. For typical sizes of slots, refer to Table 29.1, and for washers, Table 29.3. Smaller sections and single busbars can also be joined by simple overlapping as shown in Figure 29.6. Same procedure and technical requirements would apply for aluminium and copper busbars. See also

Table 29.1 Recommended busbar overlaps for different sizes and torques of fasteners

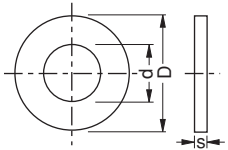
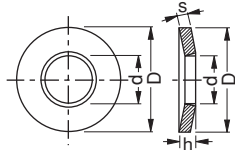
Bar width	Length of overlap	Bolt arrangement as indicated in Figure 29.3	Dimensions (Figure 29.3)			Bolt size	Hole diameter	Minimum recommended bolt torque	Typical size of slots for fishplates or straight through joints (Figure 29.4)
1	2	3	4			5	6	7	8
mm	mm		A mm	B mm	C mm		mm	kgm ^a	mm
25.4	50 ^b	1	12.5	12.5	—	M6/M8	6.6/9	1.5/2.5	—
38.1	76 ^b	1	19	19	—	M10	11	3.5	11 × 16
50.8	76 ^b	1	25	25	—	M12	14	5.5	14 × 18
76.2	76	2	19	19	—	M10	11	3.5	11 × 16
101.6	102	2	27	27	—	M12	14	5.5	14 × 18
152.4	152	3	32	29	48	M12	14	5.5	14 × 18
203.2	203	4	32	29	48	M12	14	5.5	14 × 18

^aThese torque values will normally require high tensile fasteners.

For copper busbars the torque may be raised by 150–200% of this.

^bOverlap for tee joints even up to the width of bar will be adequate. Such as, for a tee joint of 50.8 mm wide bar, with a 101.6 mm straight bar, 50.8 mm overlap will be adequate, refer to Figure 29.7.

Table 29.2 Recommended sizes of punched washers for hexagonal bolts and screws as in IS 2016 to make a good joint

Bolts size	d mm (max)	D mm (min.)	S mm (min)	Conical Bellville washers h ^a (max.) mm
				
M 6	6.6	12.5	1.6	2.0
M 8	9	17	1.6	2.6
M 10	11	21	2.0	3.2
M 12	14	24	2.5	3.95

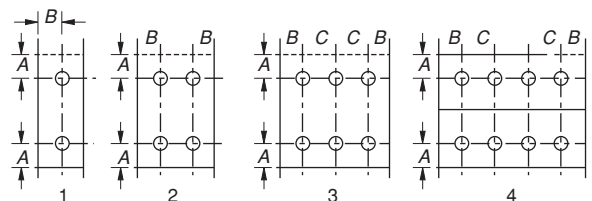
^aBased on DIN 6796 for conical spring washers for bolt/nut assemblies.

Notes

- The above are the sizes of washers when the hole in the busbar is circular. If the hole is in the shape of a slot, as recommended in Table 29.1, column 8, to facilitate easy jointing of the fishplates or straight-through joints, then the bulk of the washer should span the slot as illustrated in Figure 29.4. A normal size of washer as noted above may lose its efficacy and sag into it (by setting), loosen its grip in the course of time, and lead to failure. In such cases it may be recommended to use either pressure plates or heavy washers as per 'S' of Table 29.3 or normal washers may be chosen corresponding to the larger width of the slot, considering this as its hole size *d*, as noted in Table 29.3, to achieve a good rigidity and stability of washers to maintain the required contact pressure over long periods of service.
- Where the contact pressure is of utmost importance, it is recommended to use conical washers (some call them Bellville washers) to counteract the loosening of a bolt and nut assembly, caused by setting or indentation. The last column of Table 29.2 indicates the vital dimension *h* for such washers as in DIN-6796.

Table 29.3 Recommended sizes of washers for slots

Slot size	Recommended size of washer for slot <i>d</i>	Sizes of normal washers as in IS 2016		
		<i>d</i> mm	<i>D</i> mm	<i>S</i> mm
11 × 16	16	11	21	2.5
14 × 18	18	14	24	3.15

**Figure 29.3** Busbar bolting for Table 29.1

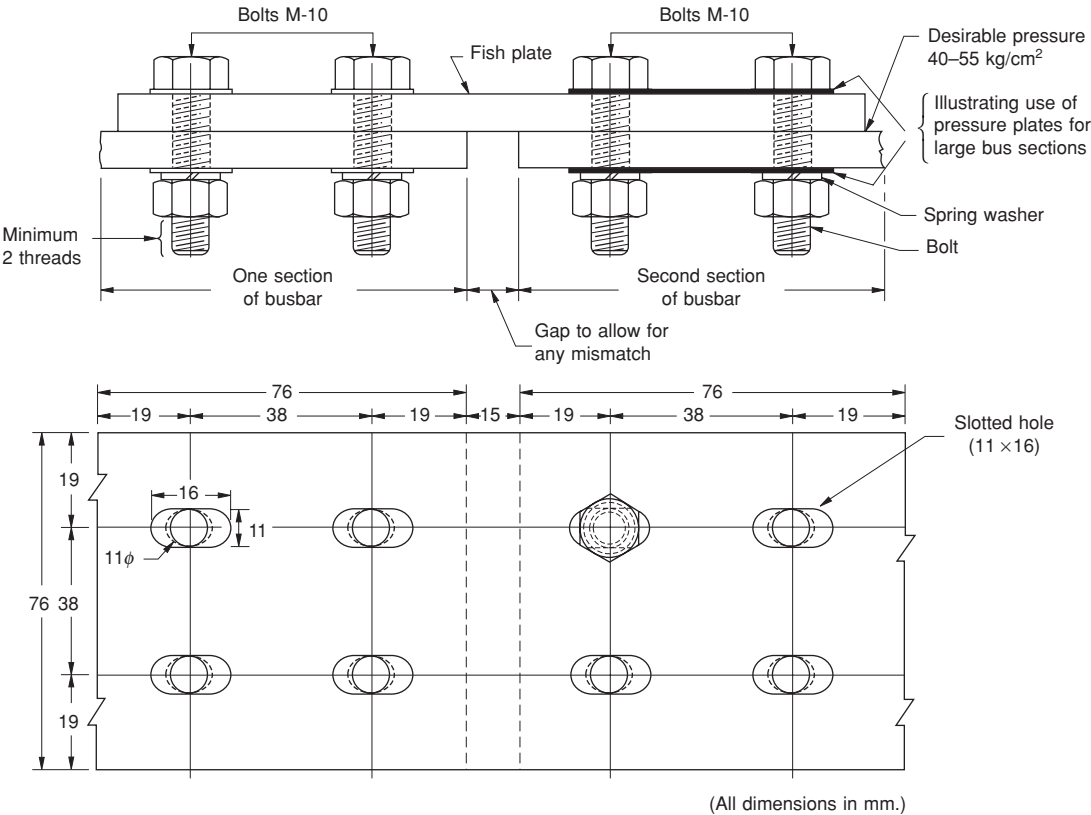


Figure 29.4 A typical arrangement for jointing two sections of a busbar through a fish plate

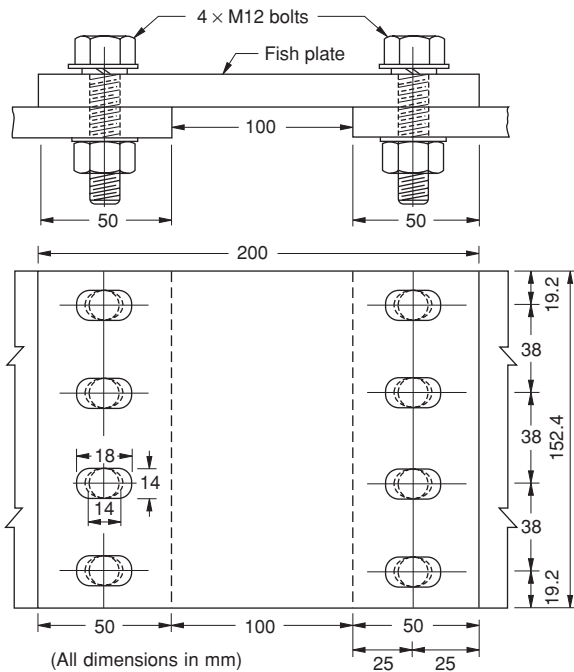


Figure 29.5 Another arrangement for jointing two sections of a busbar through a fish plate

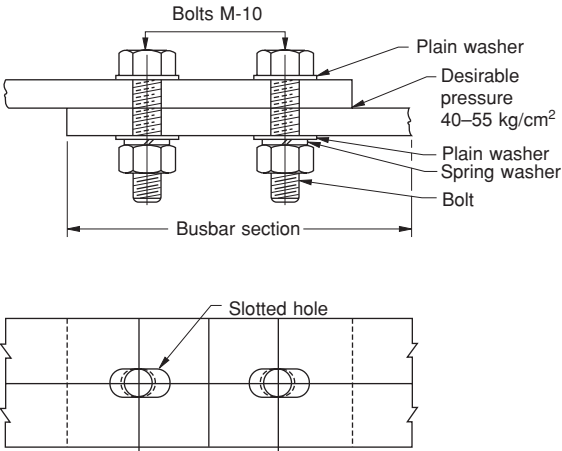


Figure 29.6 Jointing of two single busbar sections

Publication 22 of CDA (Copper Development Association, UK).

Overlapping of joints

Correct-overlapping of joint is an important parameter to make a good joint, as well as to allow no excessive heat at the joints. Based on the recommendations of the leading aluminium section manufacturers, the desired overlaps are shown in Table 29.1, and two such joints are illustrated in Figures 29.4 and 29.6. Laboratory tests and site experience have revealed that a larger overlap is of no additional benefit. For larger sections also, only one row of fasteners, as illustrated in Figure 29.5, is adequate to provide a reasonably good joint, so long as the recommended contact pressure per unit area, of 40–55 kg/cm² for aluminium joints (roughly 150–200% of this for copper) is maintained, as indicated earlier.

29.2.2 Tee joints

Refer to Figure 29.7 when making a tee joint with a larger section of bus to tap for the outgoing feeders in a PCC or MCC. A smaller overlap up to the width of the feeder bus section will be sufficient to provide an adequate contact area and bolting surface.

29.2.3 Expansion joints

During normal operation busbars undergo elongation as a result of heating. When the busbars are short, as in a PCC or MCC, and have free ends, no provision to account for expansion of busbars will be necessary. Expansion of the structure on which the busbars are mounted and

the free ends will absorb the small expansion. But for longer lengths and when the end of the bus is to be bolted at a rigid end, as at a transformer, expansion joints must be provided at suitable locations to absorb the linear expansion of the busbars. For the normal grade of aluminium in use, the linear temperature coefficient of expansion can be considered to be 0.000023 mm/°C (Table 30.1). A busbar 25 m long and operating at a temperature of 85°C having a temperature rise of 40°C above an ambient of 45°C will have an expansion of $25 \times 1000 \times 40 \times 0.000023$ mm, i.e. 23 mm. In such cases, the busbars must have free longitudinal movement and must be provided with suitable expansion joints at reasonable intervals, say, at every 7.5/10 m. Busbars supported on bolted clamps as shown in Figure 29.2(b) are not recommended as they block the linear expansion of the busbars, which may deform the busbars and result in damage to the insulators and the supports and cause a fault. Finger-type busbar supports, as shown in Figure 13.31(b) must be preferred to clamp type supports.

The expansion joints may be of aluminium or copper thin sheets (foils 32 gauge and thinner) or even copper-braided wires to allow easy flexibility on expansion. Figure 29.8 illustrates one such flexible joint. The normal procedure to make a flexible joint is to fold these sheets together and press clamp at the ends, as shown in Figure 29.9, where it is to be bolted with the bus sections. It is riveted at convenient locations to hold the foils in position. To avoid oxidation at the contact area, when it is open to atmospheric conditions, it is recommended to braze or weld them at the edges (as noted in Section 28.4.1) where they are to make the joint, as shown in Figures 29.8. Fusion welding, inert gas, metal or tungsten arc welding processes are recommended for joints shown in Figure 29.9.

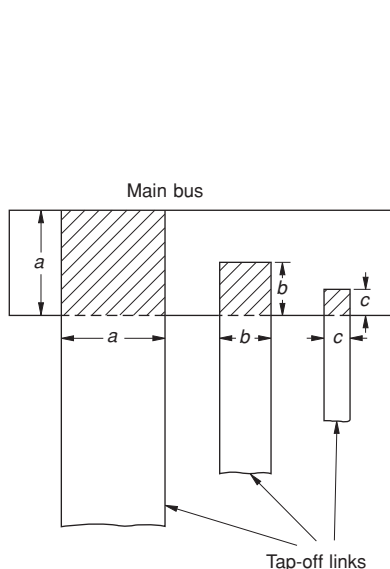


Figure 29.7 Tap-off connections from a large section of busbar showing the overlap as equal to the width of the smaller section tap-off links

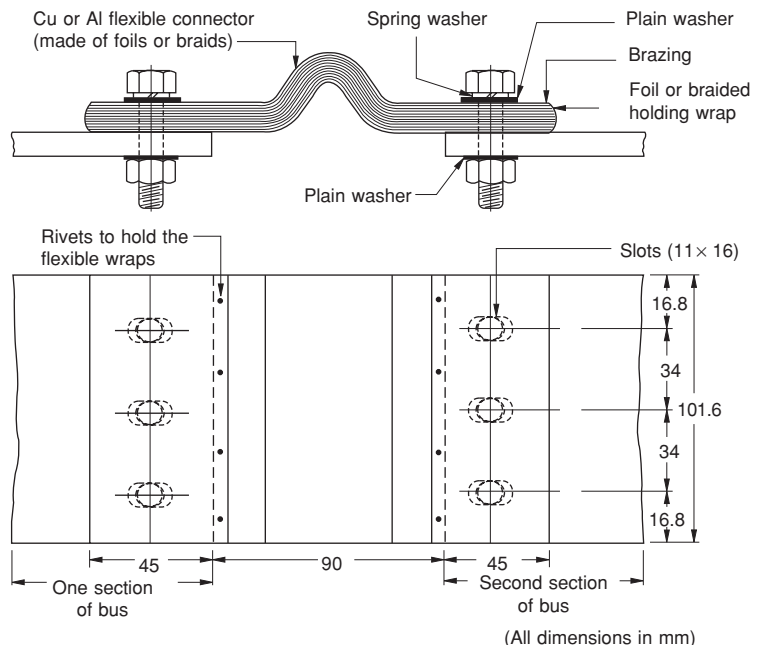


Figure 29.8 A typical flexible expansion joint

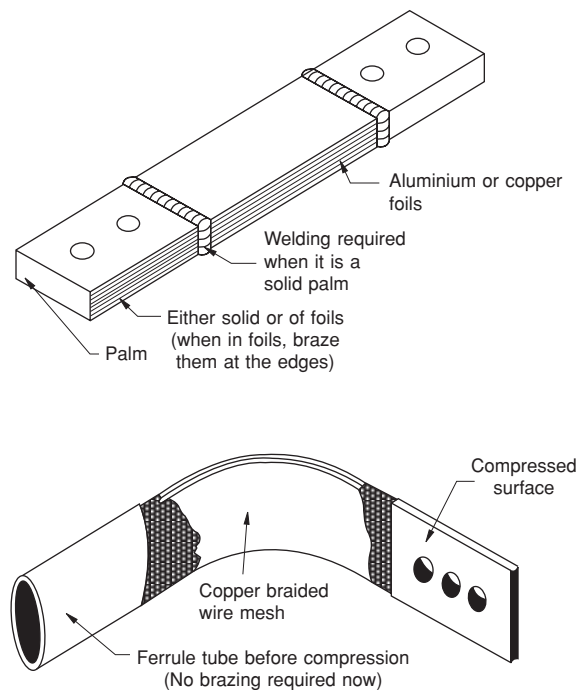


Figure 29.9 Making a flexible connector

29.2.4 Flexible joints

- This is a synonym for an expansion joint.
- A flexible-end joint connects a generator or transformer to a bus system or a bus system to a power panel.
- An expansion joint connects two straight, normally aligned sections of the same run of busbars.
- A flexible joint may also have to connect two nonaligned sections of current-carrying conductors, which may also be different in configuration and size (Figure 29.10). They may therefore be longer than an expansion joint to suit the site requirement and help connect the two ends.

The purpose of a flexible joint is thus besides making an electrical connection, adjust small mismatch at the two ends, absorb the busbar's expansion and vibrations of the generator or the transformer and prevent transmission of the same to the bus system and mounting structure. Another very important function of flexible joints is to protect insulators and mounting supports of the busbars and the terminal supports of the end equipment (transformer, generator or power panel) from the dynamic stresses developing during a switching operation or a fault condition.

Depending on the rating and length of the bus system, a flexible-end joint may be necessary at the panel end also to absorb expansion of the busbars and also to assist in making the end connections when the configurations of the bus sections in the equipment are different or have a mismatch, although there are no vibrations at the panel end.

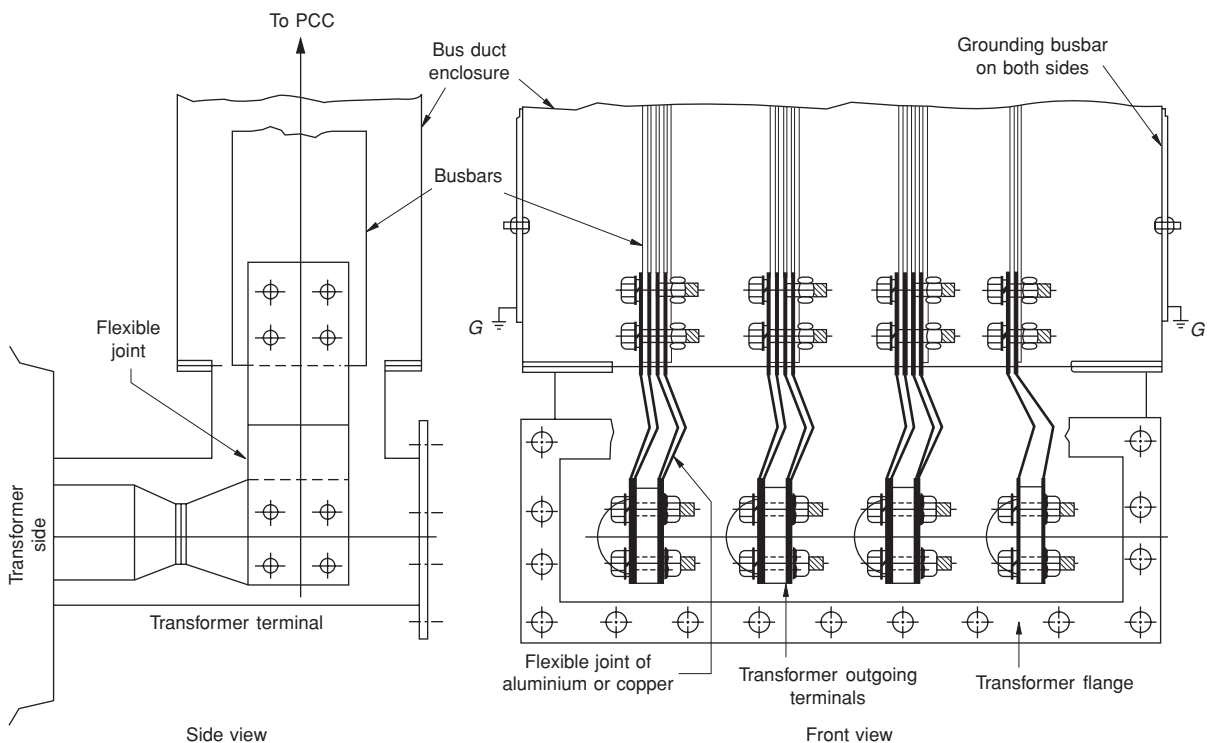


Figure 29.10 Typical arrangement of a flexible connection between a bus duct and a transformer

It is normal practice to provide a copper flexible joint at the generator or the transformer end as the terminals are also of copper and usually have a smaller spacing between them, where termination of aluminium flexibles may present a problem (although the use of aluminium flexible is not forbidden).

29.2.5 Bimetallic joints

Electric current passing through a metal joint having a moisture content causes electrolysis of water vapour. Copper, being a galvanic metal, forms an electrolytic circuit with other metals and decomposes the joint. Decomposition is corroding and erodes the aluminium metal if the other metal is aluminium. For galvanic effect refer to Table 22.3.

For making joints between aluminium and copper, care should be taken that both surfaces are properly cleaned and dried and applied with a thin layer of grease, before jointing, to eliminate electrolysis between the two metals in the presence of moisture. It is recommended that such a surface (particularly of copper) be tin or silver plated to avoid electrolysis, which may take place with the passage of time. Such a situation is predominant when making aluminium connections to the main switchgear devices and components such as breakers, switches, fuses, contactors, relays and all other current-carrying and switching devices. The connecting terminals of all these components are invariably of copper or bronze alloy. As standard practice, these terminals, are either silver plated or tin plated by the component manufacturers to facilitate a direct jointing or connection with aluminium links. However, use of grease at every joint and precautions, to eliminate the presence of moisture at the joints is mandatory to ensure a good joint.

Some application engineers may, however, prefer a bimetallic joint (e.g. a Cupal joint) for jointing between copper and aluminium. A bimetallic (Cupal) joint has copper foil on one side and aluminium on the other. The basic purpose of such a joint is to eliminate electrolysis during normal operation. It becomes superfluous, when proper care is taken in making the joint as noted above. It is a misconception that such a joint can deal with differential expansions of the two metals.

Checking a joint

It is important to check the fitness of a bus joint made in a factory or at site. This can be done with the aid of a d.c. millivolt drop or measurement of the joint resistance ($m\Omega$) test. Such measurements are taken on a number of similar joints and the results tabulated and compared. Values in the same range may be considered good joints, while those with wide variations (higher drops) will be

indicative of a poor joint. Such joints may then be investigated and improved.

29.2.6 Silver plating of joints

It is sometimes preferred to silver plate aluminium joints to eliminate any possibility of contact oxidation and to ensure an almost uniform current distribution through the contact area without an excessive heating as discussed in Section 28.5.1. Such a practice may, however, be of little advantage to smaller ratings in view of cost. It will be worthwhile only for higher currents, say, 2500 A and above and also for higher operating temperatures. At higher ratings it is recommended either to weld the edges of the joints (straight-through or flexibles) to seal the openings and prevent any oxidation during operation, or to silver plate the joints. Silver oxide is a good conductor of heat and electricity. With the use of silver joints or welded joints, a higher operating temperature of the busbars and the joints is permissible up to 105°C as against 70°C as in Table 28.2 or 85–90°C as in Table 14.5 (IEC- 60439-2) for ordinary joints. With the use of silver plated joints therefore, the rating of a bus system may be improved and the use of metal optimized. See also Section 28.5.1.

Note

Silver and copper do not make a chemical bonding with aluminium through the electrolytic process. Aluminium therefore cannot be silver coated directly. The recommended procedure is to first apply a Zn coating (1–2 microns), then a coating of Cu (1–2 microns) and then a coating of Ag (5–6 microns). Also see note under Section 28.2.6(1).

Silver plating being cumbersome, welding is a more preferred method.

29.3 Bending of busbars

Bending a busbar also requires utmost care. Smaller sections may not matter as much as larger and thicker sections. The metals (particularly aluminium), being brittle, may show up cracks, particularly on the outer surfaces, when bent, as a result of excessive tensile force at this surface. The cracks may reduce the current-carrying capacity of the busbar at this section, besides rendering it mechanically weak, to withstand the electrodynamic forces on a fault. Sharp bends are therefore not recommended. When it becomes necessary to have sharp bends to meet locational requirements, it is recommended that the particular area of the bus section be heated first, to make the metal somewhat soft and then to bend it gently while the metal is still hot. A more appropriate method will be to use a hydraulic bending machine which can exert pressure evenly and more gently to prevent cracks.

Relevant Standards

<i>IEC</i>	<i>Title</i>	<i>IS</i>	<i>BS</i>	<i>ISO</i>
–	Electroplated coatings of silver for decorative and protective purposes.	1067/2001	–	–
–	Technical supply conditions for threaded steel fasteners – Phosphate coating on threaded fasteners.	1367-12/2003	–	–
–	Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm.	1367-20/2001	BS EN 20898-7/1995	898-7/1992
–	Electroplated coatings of silver and silver alloys for general engineering purposes.	1771/1999	–	–
–	Plain washers.	2016/2001	–	–
–	Recommended practice for plating on aluminium and its alloys.	2450/2001	–	–
–	Specification for spring washers for general engineering and automobile purposes. Metric series.	3063/1999	BS 4464/1998	–

Relevant German Standards

DIN 6796/1987	Conical spring washers for bolt/nut assemblies.
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Notes

- 1 In the table of relevant Standards while the latest editions of the Standards are provided, it is possible that revised editions have become available or some of them are even withdrawn. With the advances in technology and/or its application, the upgrading of Standards is a continuous process by different Standards organizations. It is therefore advisable that for more authentic references, one may consult the relevant organizations for the latest version of a Standard.
- 2 Some of the BS or IS Standards mentioned against IEC may not be identical.
- 3 The year noted against each Standard may also refer to the year it was last reaffirmed and not necessarily the year of publication.

Further Reading

- 1 Copper Development Association, *Copper Busbar* (available in FPS and MKS systems), Pub. No. 22, U.K.