

Annex: Coatings

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A1.0 Introduction

Although coatings have been applied to busbars for several perceived reasons, there are in reality few genuine engineering needs to do so. Since coatings are expensive to apply and may require additional maintenance, they should be applied only when truly necessary.

A2.0 Reasons for Coating

A2.1 Coating to Provide Electrical Insulation

The primary reason to insulate busbars is to provide protection against electric shock in the event of direct contact.

Two significant problems arise. Firstly, the electrical insulating material is also a thermal insulator, so the bars will run at a higher temperature or will be limited to a lower working current. As a result, bars with a larger cross-sectional area will be needed. Although coating can reduce the current-carrying capacity, the short circuit capacity is not affected because the SCC is always calculated assuming that no heat is lost. Secondly, it is difficult to apply insulation to the required degree of integrity during installation. Even when using pre-insulated bars, additional insulation has to be applied at joints and connections, requiring clean working conditions and skilled operatives.

It is preferable to avoid the need for direct insulation, ensuring safety by mounting non-insulated bars out of reach or behind appropriate barriers, together with the provision of the appropriate fixed safety warning labels.

A2.2 Coating to Inhibit Corrosion

In most circumstances, copper is highly resistant to corrosion and does not normally need additional protection. However, in environments containing ammonia, sulphur and chlorine compounds, especially where the humidity may be high, protection is required.

A2.2.1 Metal Coatings

Historically, tin, tin-lead alloys, nickel or silver coatings have been used.

- Tin and tin-lead alloys: Pure tin coatings should be avoided because they tend to form whiskers, which can cause transient short circuits. Tin-lead alloys are rarely used now due to environmental concerns. Tin-containing coatings are relatively expensive.
- Nickel is the preferred material since it is relatively cheap, is durable (except at high humidity) and provides a harder surface than the alternatives. Nickel oxide is tough, so high pressure is required at joints to ensure reliability. Nickel may corrode significantly in contact with more noble metals such as gold.
- Silver is expensive but is very effective, except where sulphur compounds are present.

Protection will only be effective if it is continuous over the whole surface, including joints and connections. This means that metal coatings, which are always relatively thin (2 to 5 μm), are free of pinholes and other defects which would allow corrosion of the conductor material. Plated bars must be carefully protected before and during installation to avoid damage.

Metal coatings will not significantly affect the current rating or working temperature of the busbars.

A2.2.2 Non-Metallic Coatings

In very corrosive environments, busbars may need additional protection, using similar materials and techniques as would be used for electrical insulation. Obviously, the current rating of the busbars will be reduced due to the additional thermal insulation.

A2.3 Coating to Increase Current Rating

Matt black surfaces have higher emissivity than light-coloured polished surfaces, so it has often been suggested that matt black paint should be applied to busbars to improve cooling by radiation.

In practice, the potential improvement is small and sometimes negative. The natural emissivity of a copper bar that has been in use for even a short time will be above 0.5 and will rise over time to 0.7 or above, while a well applied matt black paint will have an emissivity of 0.9 to 0.95. As a result, an increase of about 30-35% in cooling by radiation may be expected. Even at a temperature rise of 60°C, this corresponds to an overall

increase in cooling of barely 12% and an increase in current-carrying capacity of less than 6%. At lower temperature rises, or where bars are facing each other, the radiation loss is lower and the 'gain' due to painting is much lower.

On the negative side, the paint layer acts as an insulator, reducing the efficiency of the convection process, perhaps by as much or more than the increase in radiation efficiency. In general, painting will give little increase, and quite possibly a reduction, in the current-carrying capacity of a busbar for a given working temperature.

Painting may be worthwhile for very wide bars (where convection is less effective) operating with high temperature rises (where radiation is more effective).

A2.4 Coating for Cosmetic Purposes

It is inevitable that fingermarks will occur on busbars during assembly and, in the first few weeks of operation, the natural grease in the marks darkens much more quickly than the surrounding copper. In some countries this is thought to be unsightly and the busbars are painted in order to hide the marks. There is no technical merit in painting busbars – it is an additional cost, increases the working temperature and makes maintenance more difficult. On the other hand, painting may be required to meet the demands of the local market.

A2.5 Coating to Improve Joint Performance

Plating of the contact area of joints is not recommended unless it is really necessary to combat corrosion.

As described in Section 6.0 'Jointing of Copper Busbars', a contact is formed by a large number of cold welds between the surfaces of the two conductors. If plated conductors are used, these cold welds cannot form and the softer plating material tends to flow, reducing contact pressure and reducing joint reliability.

A3.0 Methods of Coating

Coating of high conductivity copper is normally limited to the application of insulation to conductors in very long lengths, a method not well suited to the relatively short lengths used for busbars. In other, non-electrical applications, protection is usually achieved by the choice of a copper alloy with intrinsic resistance to the application environment, so there is a limited requirement for other types of coating. As a result, most direct experience with local coatings is with steel, primarily in the oil, gas and chemical industries. For use with HC copper, it is important to establish that the chosen coating will be compatible in the long-term. Many coatings methods will require some form of pre-treatment to ensure good adhesion and this should also be included in the compatibility assessment.

Whatever type of coating is used, it is important that the coating is continuous and free of pinholes and voids. To avoid thinning of coatings at edges, conductors with rounded, rather than sharp, edges should be used to reduce mechanical and electrical stresses.

Coatings can be applied either during manufacture of the conductors or during on-site assembly. In practice, there will probably always be a need to apply at least some coating on-site at joints and connection points, requiring an assessment of the mutual compatibility with the factory-applied coating. The following sections give some examples, but many other techniques are available.

A3.1 Factory Application Methods

Factory application of coatings during manufacture of the conductor allows a much greater choice of materials and processes and should ensure a more consistent quality of coating at lower cost than on-site coating. However, it is necessary to locally coat the busbar joints in a compatible manner during on-site installation.

A3.1.1 Extrusion

Extrusion is viable only for bars supplied in very long lengths, typically relatively small diameter round rods or tubes. It is cost-effective and is compatible with traditional electrical insulation materials such as PVC and XLPE.

A3.1.2 Powder Coating

As the name suggests, these coatings are applied in powder form, by electrostatic spraying or in a fluidised bed, and then cured either by heat, UV light or some other means. Nylon and epoxy powders are often used. For many materials, the heat curing temperature and time requirements will not result in the annealing of the copper conductor and will tolerate temperatures of 150°C.

A3.2 On-Site Application Methods

A3.2.1 Heat-Shrinkable Sleeve

Heat-shrinkable sleeve is normally made from cross-linked polyolefin. It will shrink to about 50% of the supplied perimeter temperatures above about 70°C, with a consequent increase in thickness. It is easy to apply on-site using an adequately powered hot air gun but can be time consuming. It can typically tolerate working temperatures up to 90°C.

A3.2.2 Painting

Painting, by brush or spray usually requires a primer coat. Note that paint cannot be expected to provide adequate shock protection because the integrity of the coating cannot be guaranteed.

A3.2.2.1 Alkyd Paints

Alkyd paints are traditional oil-based paints and are suitable for use at temperatures up to about 120°C. They have a limited lifetime of a few years.

A3.2.2.2 Two-Part Epoxy

Two-part epoxy paints are applied immediately after mixing and cure at normal ambient temperatures. The cured paint has good abrasion resistance with a lifetime of over ten years but it is not resistant to UV. It is typically suitable for use at temperatures up to about 150°C.

A4.0 Inspection and Maintenance

As with uncoated bars, routine inspection and maintenance is required. The biggest potential problem is the loosening of joints, which is normally detected as a local rise in temperature, detected during regular inspection with a thermal imaging camera.

In the case of coated bars, the presence of a coating on the nuts and bolts may initially prevent loosening but, once loosening has occurred, will certainly make it more difficult for the joint to be correctly re-tensioned. Because the coating thicknesses may vary, especially in the areas of the joints, it is important to establish the temperature profile in the early life of the installation for future comparison.

It is also necessary to visually inspect the coating for integrity, looking for cracking, especially at joints where different coatings meet or the size changes, and for disturbance of the surface that might indicate underlying corrosion.