Comparative study for cables and busbars

Preliminary considerations

To compare the prices of two categories of product as different as traditional cables and busbars, it is necessary to make some preliminary considerations based on actual cases, particularly as regards calculating the actual cost of installation.

Clearly the price of cable depends on the price of the raw materials. Here we have taken the price of copper as 4700 lire per kilo.

Busbars are quoted as if they refer to an offer for an end user of average importance for building a medium-size system.

Installation prices for busbars, cables and cable ducts are calculated as the average of prices provided by several major companies dealing in wiring installations.

Busbars

A busbar is defined by CEI EN 60439-2 as "a type-tested assembly (TTA) comprising a system of conductors with one or more bars separated and supported by insulating material and contained in a conduit or similar casing".

Zucchini busbars are assemblies that have been type-tested (TTA) and comply with IEC 439/1 and IEC 439/2 product standards and the corresponding harmonised Italian standards CEI EN 60439-1 and CEI EN 60439-2.

Here, from among the vast range of Zucchini busbars we have selected the series of Armoured Ventilated Bars (AVB) for places not requiring a high short-circuit current and where there are no major problems of space, and the Super Compact (SC) line where a high short-circuit current, compact size and a high degree of protection (IP55) are required.

Power cables

The sizing of power cables must be done very carefully. They must be built according to CEI 20-14, CEI 20-22/2 and CEI 20-37 product standards.

The capacity of the cables is greatly affected by the type of installation, which determines the effectiveness of heat dissipation, and reactance depends on their reciprocal position.

Application factors for the different types of installation, particularly for close grouping as in our example, are taken from Table C, CEI 64-8, part 5, 4th edition.

This comparison only takes into account cables laid in perforated ducts, which ensure good ventilation and hence good heat dissipation.

Note that CEI 64-8 considers cables as laid "in the air" if at least 30% of the surface of the tray supporting them is perforated. At present the only tray on the market meeting these requirements are the wire type.

The cables used in this comparison are PVC insulated, which means the copper they contain can withstand temperatures of up to 70°C.

For reasons of cost, ease in procuring materials and assembly, we decided not to use multi-pole cables greater than 185 mm^2 or single-pole cables greater than 240 mm^2.

Comparison of power supply costs for a medium-size metal working company. Transformer – low-voltage switchboard connection

The cost of connecting the transformer and switchboard depends mainly on two factors:

1. the rated power of the transformer
2. the wiring layout

To make a reliable cost estimate, it is necessary to consider actual routing.

Let us examine two typical situations:

In the first case we have a connection between a transformer and a low-voltage switchboard that is short and straight (see Figure 1).

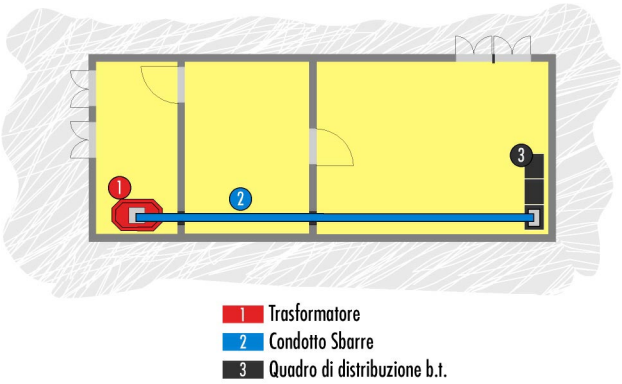

Figure 1: Straight connection between transformer and low-voltage switchboard.
1) accumulator room; 2) low-voltage switchboard;
3) high-voltage switchboard; 4) transformer; 5) busbar.

Sizing of the wiring system starts by calculating the power required to run the factory in question. When calculating installed power, it is necessary to consider the contemporary load coefficient, the utilisation coefficient, the average cosφ of loads, and a convenient upscale coefficient taking into account possible extension to the system. When the installed power has been calculated, you can select the most suitable size of transformer for the factory.

Now, presuming that the link between the transformer and low-voltage switchboard is short and straight, we can prove that the cost depends only on the power of the transformer.

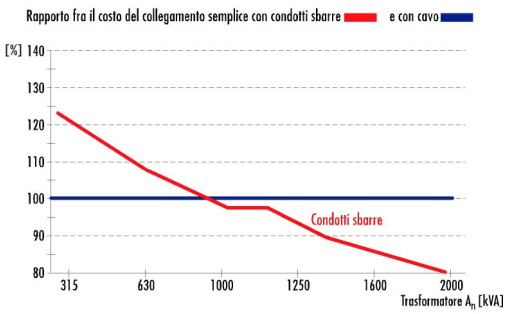

Figure 2. Ratio for busbar and cable connection costs.

The graph in figure 2 shows the cost ratio between connections busbars and the traditional – but often obsolete – method using power cables.
Taking the cost for cable connection as 100, we can see for each size of transformer that the cost of a cable connection increases with the size of transformer, and cost parity (materials plus installation) is reached for a 1000 kVA transformer.

In the second example, let us suppose that for reasons of system reliability and flexibility the factory has decided to install three transformers and the connection between transformers and switchboard has at least two horizontal, rather than straight, angles.

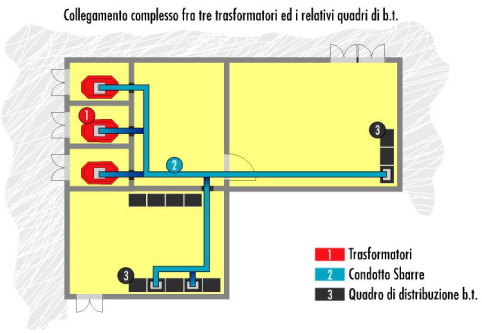

Figure 3. Complex connection between three transformers and low-voltage switchboard.
1) transformers; 2) busbar; 3) low-voltage switchboard.

In the second example here, the cost ratio between connecting with busbars and cables has a similar trend to the previous example, but cost parity is reached for smaller transformers (see Figure 5).

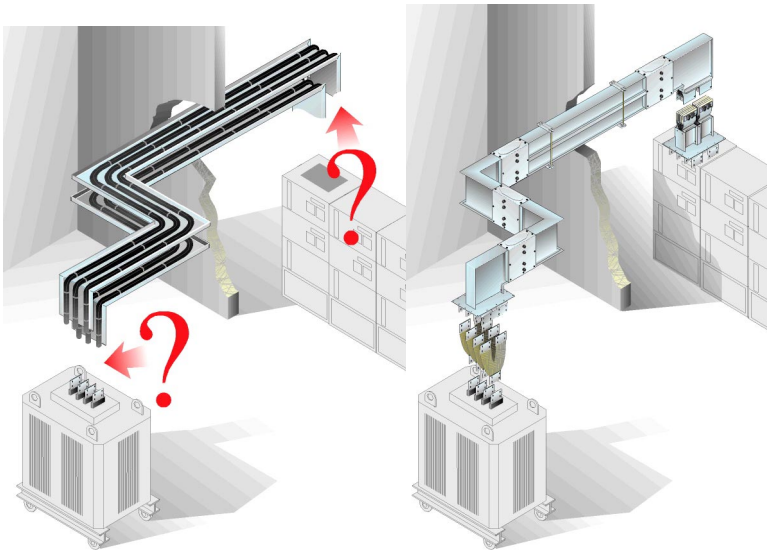

Figure 4. Transformer- switchboard connection. The problems in connecting a bundle of cables and the transformer terminal and switch are highlighted.

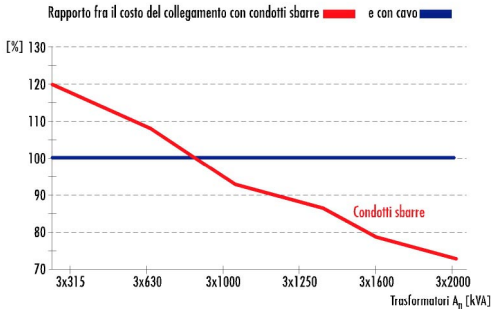

Figure 5. Ratio between the cost of a complex transformer- switchboard connection using busbars and cables.

Designing a wiring system in a 15-storey office block

Let us suppose we have to design a wiring system in a 15-storey office block and we need to power utilities rated at 45kW.

All the floors are supplied via a single shaft. Each floor needs a control panel with a knife switch and fuse holder (or a thermalmagnetic circuit breaker) to protect and cut off the system for the entire floor. In our example, the switchboard supplying the various floors via the shaft is not in the immediate vicinity of the shaft, it is about 30 metres from the base of it.

This means three different systems can be considered:

1. The entire system can use busbars, i.e. link the switchboard-shaft and the 15-floor riser using a prefabricated system of busbars.

2. Alternatively, the low-voltage switchboard and the riser power supply box can be connected using busbars with a bundle of suitably sized cables, and the riser alone using busbars.

3. Lastly, the entire system can be laid with power cables. This means that the same number of bundles of cables as floors in the building will have to run from the switchboard and each bundle will have to run up the shaft vertically, stopping at its own floor, so the number of bundles decreases the further up you go.

Now let us examine the advantages and disadvantages of these three solutions.

1. Busbars

A study of the power for each floor shows that the capacity of the busbar must be 1000 A. Where the busbar leaves the low-voltage switchboard, it is protected by a thermalmagnetic circuit breaker. As the busbar runs the 30 metres to the shaft, it passes through the boiler and air-conditioning rooms and then runs up the shaft vertically to the top floor (see Figure 6).

There is a tap-off at each floor to supply the utilities on that floor. Flame barriers can be situated along the shaft at the various floor levels to prevent the spread of fire, smoke and heat if a fire should break out on a lower floor.

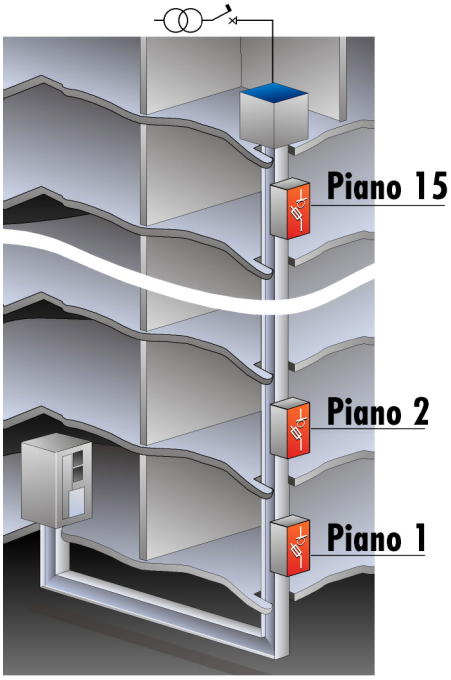

Figure 6. Switchboard-transformer link using 1000 A busbars powered at both ends.

2. Mixed cable/busbar layout

Figure 7 shows a mixed layout for the system supplying power to the various floors in the building. It takes four 3 x 185/95 mm^2 multi-pole cables in parallel to supply the 1000 A busbar riser with a cable link. This bundle of cables connects with the busbar via the switchboard at the front end. To supply the riser, the cables too need to pass through the heating, cooling and ventilation rooms, so steps must be taken to prevent toxic and corrosive gases from spreading through the building from the air conditioning plant in the event of a fire. Alternatively, cables with a low emission of gas and toxic agents must be used.

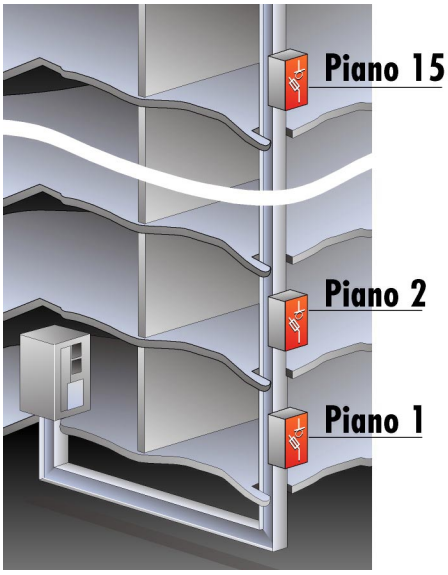

Figure 7. Mixed cable/busbar link

3. Cable layout

Figure 8 shows the power supply to the various floors of the building with a bundle of cables each from the switchboard to its own substation at each floor. The cables used are multi-pole, section 3 x 50/25 mm^2. The switchboard needs to have as many circuit breakers as the outputs (15), or alternatively the individual cables can be fused.

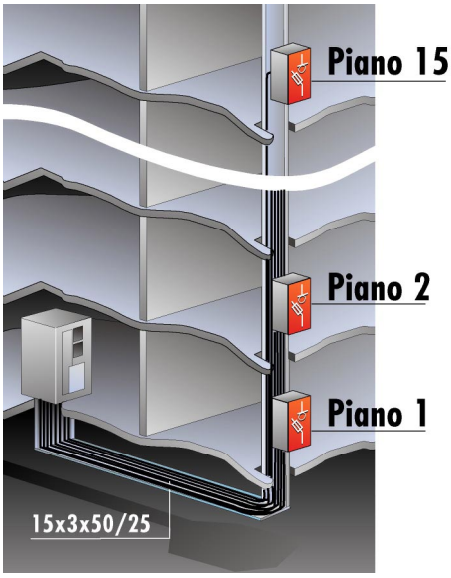

Figure 8. Switchboard–floor substation link with 3 x 50/25 mm2 cables

Flexibility of the different types of system

When calculating ratings, designers generally take into consideration a convenient upscale coefficient for future extensions to the building. So with cables it will be necessary to oversize all the system's cables at the outset. For obvious economic reasons, this coefficient will only take into account the probability of a slight increase in load power. If the power increases excessively, the transformer supplying the building will have to be replaced or paired with another transformer.

With the use of busbars, later extensions do not involve many technical problems.

If we suppose that the absorbed power at each floor in the building increases by about 10%, the power of the main transformer is no longer enough to meet demands, so in this case the best technical and economic solution is to install another transformer of a suitable capacity. The new transformer will only have to be connected to the busbar from the top of the riser (top floor). Thus in this case it will only be necessary to pass one cable along the shaft to supply the busbar on the other side. This solves the problem easily and economically.

Let us now consider the more common case in which total power required by the building is constant, but division between the floors varies. In the cable solution it is necessary to check that the various cables supplying the floors of the building can withstand the new load and if necessary add another cable in parallel if the power exceeds the capacity of the cable. With the busbar solution, this will not be necessary thanks to the flexibility of the system. At most, it will be necessary to change the protection device of the cable from the switchboard to the floor substation - only a few metres of conductor.

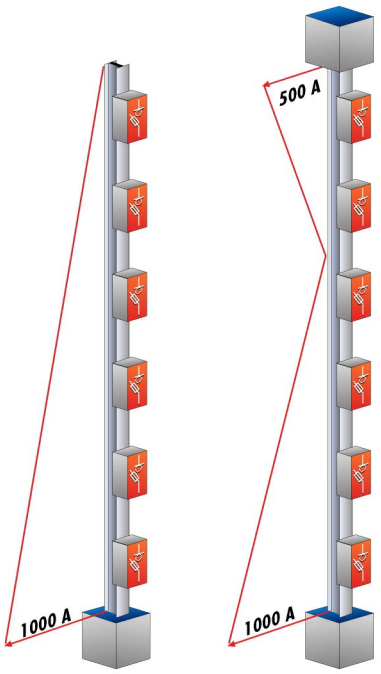

Figure 9. Distribution of the loads of the riser in busbars with power supply from one or both ends.

Result of the system cost comparison

When considering all the above factors and taking the cost of a system made entirely of busbars as **100**, the cost for a mixed cable/busbar set-up is equal to **125**, whereas if the system is made entirely with cables the overall cost is **108**.

Technical comparison between cables and busbars

Apart from strictly economic reasons that increasingly favour the prefabricated solution as against the one to be wired up, there are various advantages of the busbar version in technical terms.

The rated current that a cable can carry refers to the average daily temperature of +30°C, whereas busbars - according to CEI 60439/2 - are sized to work at an average ambient temperature of +35°C, peaking at 40°C.

Historically speaking, Zucchini S.p.A. made a choice that was highly committing and not always appreciated for its fundamental importance in the sizing of wiring systems. In actual fact Zucchini S.p.A. busbars are sized, tested and guaranteed fully operational at average daily temperatures of 40°C up to 45°C. This gives a 5% advantage over the competition and a 10% factor over cable.

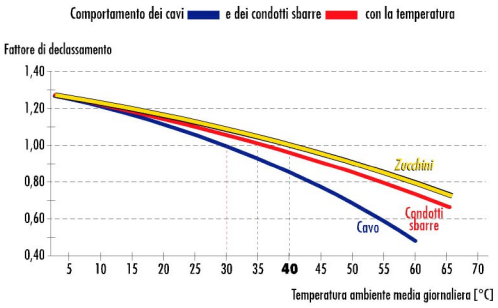

Figure 10. Comparison of the behaviour of cables and busbars according to temperature.

Another advantage is the fact that cables are generally installed in bundles and with such a cross-section that they cannot be bent tightly. Busbars, on the other hand, have a highly compact structure and can achieve angles of up to 90° (see Figure 11).

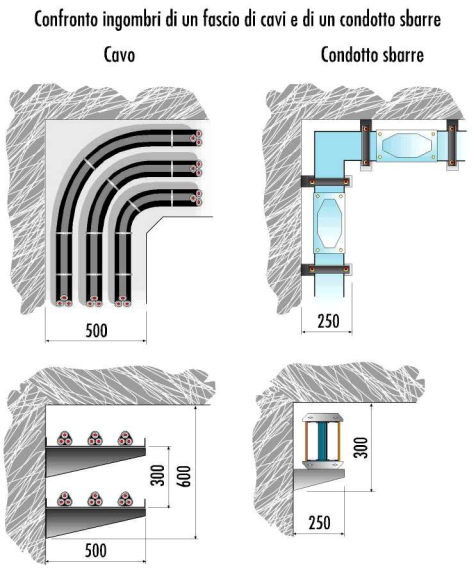

Figure 11. Comparison of the overall dimensions of a bundle of cables and a busbar.

Fire load is the energy generated by the complete combustion of the flammable materials in a room. The use of busbars involves a very low fire load which makes them ideal for areas where this factor is of extreme importance. The graph in Figure 12 shows how an increase in current means a virtually exponential increase in the fire load of the cables. In high capacity busbars, the weight of plastic materials used is up to 1/10 that of cables of a similar capacity.

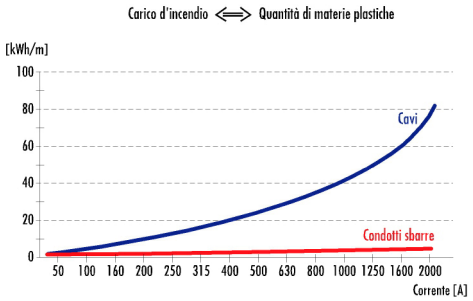

Figure 12. Fire load factor according to the rated current IB for a busbar and a bundle of cables having the same capacity.

Another problem that designers have to tackle is that making a high power connection requires several cables in parallel. Three conditions must be met to ensure that the current is divided equally between the cables - all the cables must be the same type, the same length and laid in the same way. If any of these conditions is not met, the cables cannot be considered the same and thus protected by a single device. It is necessary to protect each cable individually, for example by means of a fuse. Furthermore, when laying a bundle of cables it is necessary to anchor them properly so that they can withstand the electrodynamic forces that are generated in the event of a short circuit.

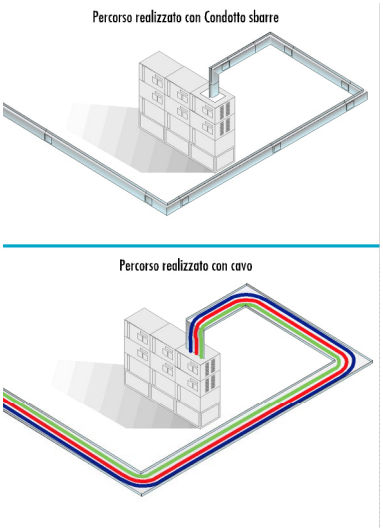

Figure 13. When there are several curves in the same direction, the length of the outer cables differs considerably, so the installer needs to make the length the same before connecting to the substation.

Lastly, when designing cable risers, it is important to size each cable separately (15 in our example) by suitably protecting them against overloads and short circuits, calculating the voltage drop for each and checking the earth fault conditions.
When sizing busbar risers, the designer only needs to make calculations on a single riser, which reduces design times and costs.

Busbars are the ideal way of connecting the transformer and the switchboard. In this type of connection the decisive factor is the short-circuit current that the busbar can withstand. Zucchini busbars series SC withstand short-circuit currents (Icw) up to 176 kA for one 1 second and 387 kA peak current without getting damaged. Due to the compact structure and the fact that the conductors are sandwich assembled, short-circuit currents in the Super Compact can be withstood mechanically and thermally without damage.

Unlike cable connections, it is often not necessary to install additional protection due to the short link between transformer and the low-voltage switchboard. The medium-voltage on the primary circuit of the transformer also protects against short-circuiting and overloads on the low-voltage side, so it is often suitable for protecting the short link between transformer and switchboard.

When laying large cables, their weight is often a problem and a hazard. It takes 4 to 8 men to pull them through the galleries and fix them in such a way that they can withstand the dynamic stress of short circuiting. In vertical installations in particular, where there is a shaft, the cables need to be winched up to the relevant floor. Under these conditions, the cable has to bear its own weight and the insulation can get damaged by scratches, cuts and micro-cracks that are not visible to the naked eye but may become visible later when the system is powered on, most likely affecting reliability. The installation of busbar risers, on the other hand, does not require more than two workers. As they are modular and rigid, the work can easily be carried out in a limited space.

A further advantage of busbars with respect to cables is their huge operating flexibility. For example, once the power required by the various floor distribution boards has been calculated, it is not possible in a cable system to re-distribute loads with the same total installed power, whereas busbars are equivalent to having a distribution unit extending the entire length of the building, which means it is easy to re-distribute the loads.

Conclusions

As busbars are compact and extremely versatile, they open up new horizons in the design and installation of industrial, commercial and tertiary wiring systems.
There are huge economic and technical advantages in situations where there is a high fire risk, since busbars are highly heat resistant and feature a much lower fire load than cables of equivalent capacity.
All the features described above should be taken into consideration when designing an actual plant. Considering the enormous difference in technical and installation cost terms, a mere comparison between the cost of cables and busbars per metre is not technically or economically significant.
Last but not least, a busbar system has an intrinsic value that will never depreciate. If necessary it can easily be dismantled and re-installed in another building or part of the investment can be recovered at the end of the system's working life since busbars are mainly made of copper and steel, which maintain their value through time.

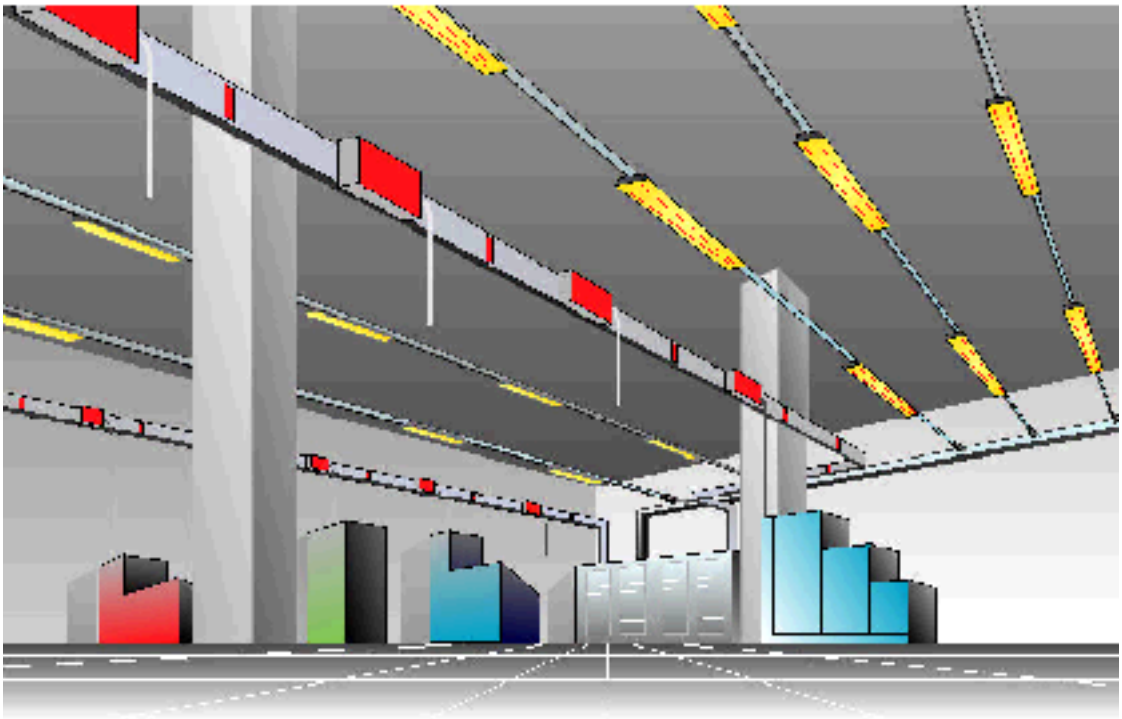

Figure 14: Typical factory with power distribution and a lighting system comprised entirely of busbars.