The ultimate question – Are ferrules necessary?

The current market for industrial electrical connection technology includes numerous innovative connection technologies that provide users with many advantages. However, many users still struggle with a minor detail – is a ferrule sensible or even necessary for conductor connections? (Figure 1 lead image)

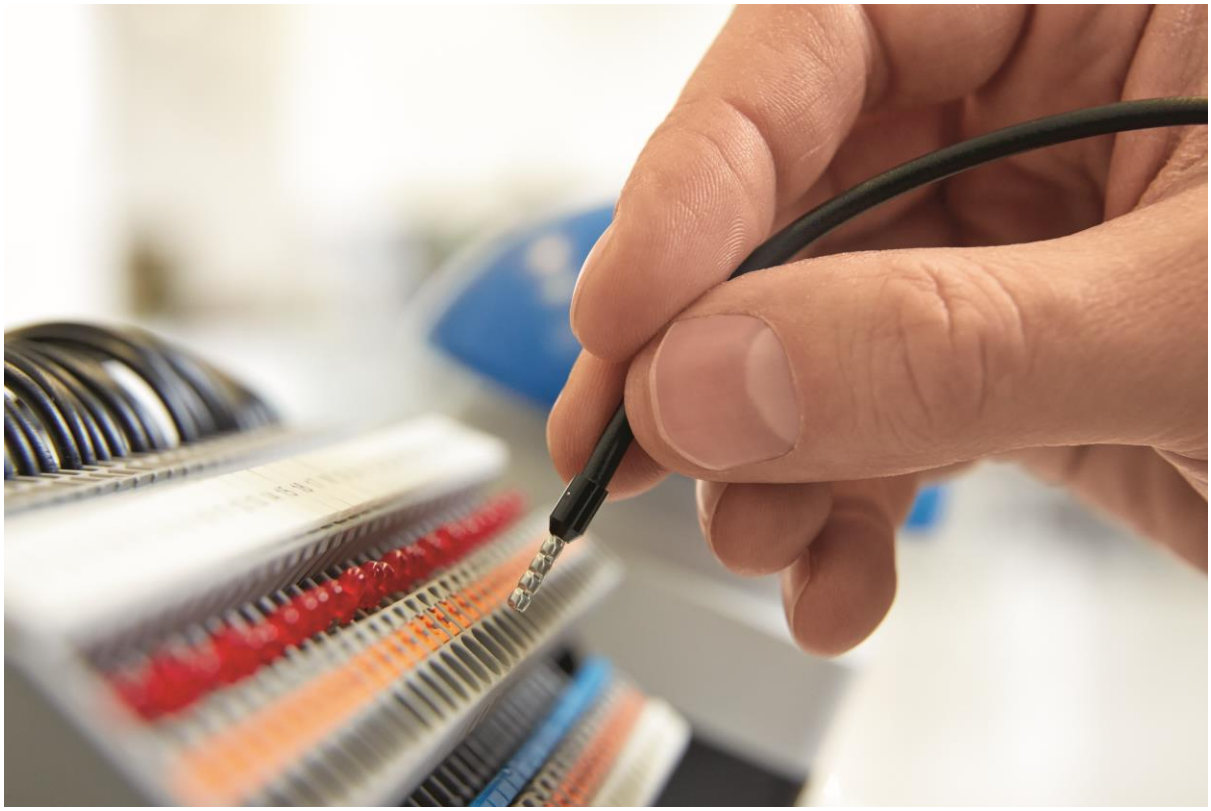

Figure 1, Lead Image - In many control cabinet components, conductors are connected using ferrules – with Push-in connection technology from Phoenix Contact they are wired directly without using any tools

Ferrules were invented in the 1960s. Back then, they were primarily used as mechanical protection for the copper wire in the terminal connection. The terminal screw often made direct contact with the conductor – causing damage or even resulting in an open circuit. It is here that the sleeve provides mechanical protection. Alternatively, the litz wire ends were soldered – however, when subjected to pressure and temperature influences, tin-lead solder becomes highly viscous. This often resulted in contact problems, ultimately leading to the use of this method being prohibited by standards.

Even in modern innovative connection technologies, pre-assembled litz wire ends are commonly used. This is because ferrules still offer certain advantages. Moreover, the process of conductor pre-treatment – cutting to length, stripping, and crimping – offers significant potential for optimisation and possible savings.

What is required by standards?

A flexible copper wire does *not* have to be assembled with a ferrule. All screw-type and screw less type terminal connections are subject to standard EN 60999-1/VDE 0609. This standard clearly states that a mechanical conductor terminal point – irrespective of the clamping principle – must be designed so that all unprepared types of conductor can be connected reliably: rigid solid, rigid multi-stranded and flexible conductors can be connected directly without any pre-treatment. The standard applies exclusively to copper wires.

In normative terms, the ferrule only exists as a possible option for conductor pre-treatment – it simply represents a form of splice protection that facilitates the connection of flexible conductors. In a screw-type or screw less type terminal connection as per EN 60999-1, the use of ferrules is neither prescribed nor ruled out. Users have to make their own decision here. Terminal block standard IEC 60947-7-1 also states that a manufacturer must specify conductor pre-treatment if this is relevant for reliable conductor connection. At Phoenix Contact, all terminal points are more than qualified to meet the normative requirements for the connection of all conductor types – whether with or without ferrules (Figure 2).

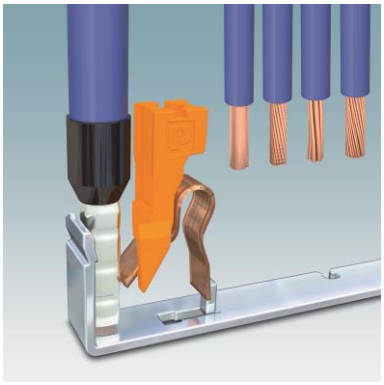

Figure 2 - Universal use: the terminal blocks from the CLIPLINE complete product range from Phoenix Contact are qualified and approved for all common conductor types

Advantages of ferrules

In addition to providing protection against damage, ferrules offer mechanical advantages during wiring by preventing the splaying and over bending of individual litz wire ends. This is particularly beneficial when performing multiple rewiring operations in the control cabinet – not least from a safety point of view. The sleeve bundles together all the individual litz wires, and the crimping process joins the conductor and sleeve permanently and inextricably together.

In confusing installation situations, individual litz wires are often not contacted cleanly, which can for example change air clearances and creepage distances or even trigger spark-overs. Ferrules with plastic collars offer the additional advantage of the conductor insulation being completely immersed in the sleeve body and overlapped, thereby providing bend protection. The colour of the plastic collar denotes the cross section range.

Ferrules also offer advantages from an electrical point of view. Standard ferrules on the market are made from highly conductive copper materials. The surface is usually coated with tin to protect against corrosion. From an electro-technical point of view, the friction-locked and form-fit crimped ferrule is a transition point in the flow of current, and is therefore best avoided. After all, every transition point also implies contact resistance.

Test results

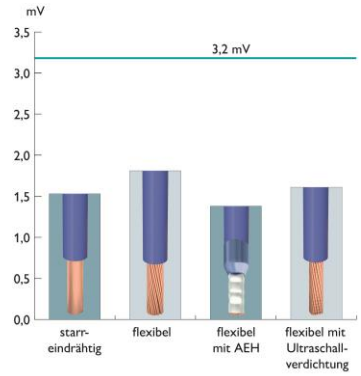

Figure 3 - Comparison of conductors: for 2.5 mm² copper wires, the analysis shows that a correctly pre-assembled conductor offers advantages even in the case of a voltage drop and contact resistance, and is significantly below the nominal value

Phoenix Contact examined and compared the common conductor pre-treatment methods with regard to their electrical voltage drop and contact resistance based on the example of a 2.5 mm² cross section range. It became clear that even one conductor pre-assembled with a ferrule offered some advantages. This is because the contact resistance values of an untreated flexible conductor are slightly higher than those of a conductor pre-assembled with a ferrule. (Figure 3)

The reason for this is that copper oxidizes. Soon after the production process, an almost invisible permanent and durable protective layer that is only around 2 to 4 µm thick forms on the bare metal surface. Depending on the humidity and temperature, as well as the substances in the air, this oxide layer grows – making copper last for centuries.

However, what appears to be visually appealing and desirable in the construction industry is actually a hindrance in electrical engineering, as flexible copper wires also oxidize. A microscopically thin oxide layer forms on the surface of each individual litz wire, severely inhibiting conductivity and acting as an isolator. Shunts occur between litz wires, affecting the total contact resistance of the conductor.

When ferrules are crimped correctly, the hard oxide layers are broken open mechanically and the individual litz wires are compressed together with a gas-tight fit (Figure 4). As a result, shunts are minimised. The crimping shape – whether rectangular, hexagonal or trapezoidal – makes hardly any difference here.

Along with the high-quality materials of the individual components, the interplay between the conductor, ferrule, and crimping tool is also a basic prerequisite of this analysis. A permanently reliable electrical connection can only be created if all contributing factors are properly coordinated. Flat-nose pliers or diagonal cutters are not suitable crimping tools.

The quality of the conductor pre-treatment plays an important role, especially in the case of screw less type connections such as spring-cage terminal blocks. A screw connection would certainly be able to “squeeze” a poor crimp connection selectively with a high tightening torque in the terminal point. However, this process would be incorrect – even if there were no electrical consequences.

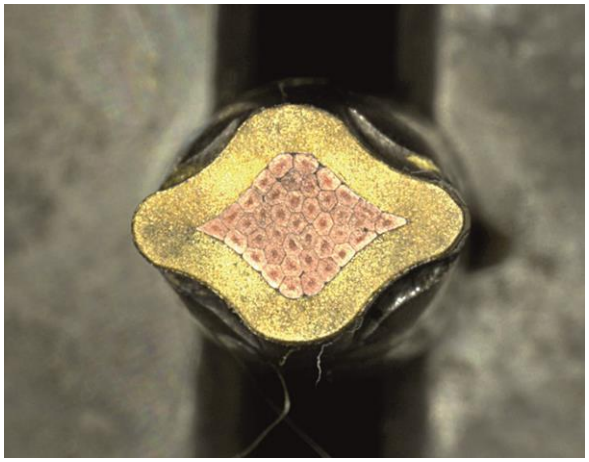

Figure 4 - Correct crimp connection: the section shows a firm fit with maximum packing density – crimping tools from Phoenix Contact feature forced guidance that does not rely on the user; thanks to the high crimping force, the litz wires are plastically deformed without trapping any air

Crimping tools from Phoenix Contact feature an integrated pressure lock, which ensures that the crimping cycle is always completed. It remains locked until the necessary crimping pressure is reached; thereby ensuring that sufficient pressure is applied. The required gas-tightness and required sleeve withdrawal force in accordance with DIN 46228 Part 4 are therefore consistently satisfied. Consistent high-quality results are achieved with long-term stability, regardless of the force applied by the user and the deviations in the diameter tolerance of the sleeve and conductor (Figure 4).

In control cabinet manufacturing, the process costs represent a large proportion of the total costs – these days the costs are calculated per connection point. To optimise processes and increase efficiency, many users therefore choose spring connection technologies. Here too, conductor pre-treatment has a considerable influence on the process chain. Push-in technology from Phoenix Contact is based on the pressure spring principle. Rigid or pre-assembled conductors are inserted directly without using any tools. This provides a consistent and tool-free solution for quick, effortless, and convenient wiring from the field through to the controller. Electrical installations can therefore be built easily and cost-effectively.

Summary

In electro-technical systems, ferrules offer many advantages – both mechanically and electrically. Along with high-quality materials and tools, precise processing is a basic prerequisite for optimum and cost-effective results. With these requirements in mind, ferrules – combined for example with Push-in connection technology from Phoenix Contact – improve wiring efficiency significantly.

More information
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Crimphandy – Portable and automated

The trend toward greater flexibility and mobility also includes tools. Phoenix Contact presents an interesting tool in the form of the “Crimphandy”: simply insert the trimmed conductor into the Crimphandy and the device handles the rest. The conductor is stripped, fitted with a ferrule, and reliably crimped in under two seconds. The functions in detail:

- Portable use, thanks to the compact, battery-powered design
- Effortless use, thanks to automated processes
- Automatic cross section monitoring prevents faulty crimping
- High quality, thanks to precise quadratic crimping