SIEMENS

White Paper

Considerations For Application Of Stranded Cable and Mechanical Lugs

For Use With Circuit Breakers

Introduction

When installing a circuit breaker to protect a circuit, many installation factors must be considered. One of these decisions is to choose the best suited means of connecting the circuit breaker to the load. For molded-case circuit breakers, the most common connection means are solid and stranded wire conductors.

When cable connections are made to the circuit breaker, it is important to select the proper wire and wire connector (commonly refered to as a "lug" or "mechanical lug") to work in concert to provide power to the electrical load. The lug must be matched to the wire that the user is installing. The wire material (aluminum or copper), size, and insulation temperature rating are most often stated, but one other parameter can be just as important – the number of strands that make up that wire.

Stranded Wire Considerations

Stranded wire types are defined by ASTM B231 / B231M. The most common type of conductor used with molded-case circuit breakers is described as Class B, which covers stranded conductors coated with insulating materials such as rubber, paper products, and varnished cloths. Additionally, Class C wiring is very common. Class C is similar to Class B, but offering greater wire bending flexibility afforded by the increased number of smaller diameter wire strands.

Fine stranded cable (wire), commonly called "welding cable" or "locomotive cable" is very flexible and easy to install. These characteristics make it desireable for applications where wire bending space is limited, and routing of cables may be challenging. However, most mechanical lugs intended to be used with molded case circuit breakers, including those sold by Siemens, are not listed (UL, CSA, or otherwise third-party or manufacturer certified) for use with this wire.

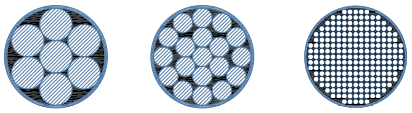

Figure 1 Class B stranded conductors, Class C stranded conductors, and fine stranded cable

The number of strands used to assemble a particular wire can affect the ability of a pressure wire connector to be properly tightened, and to maintain a firm grip on the wire throughout the life of the product.

- If the wire is not firmly secured in the connector, the magnetic forces present during a short circuit could pull the wire out of the connector, causing a series or even phase-to-phase arcing fault.
- The cycling on and off of downstream loads results in thermal cycling (periods of heating, following by periods of cooling) of the conductors. The thermal cycling may result in the loosing of the connection. The resultant overheating may manifest itself in nuisance tripping, series arcing, or fire.
- During the tightening process, strands from the ductile fine stranded cable may splay out throughout the barrel of the lug. Because of this, the loose strands can flow into unintended areas, and become bound up in the clamping mechanism or threads of the mechanical lug. Strands binding in the mechanism could lead to breakage, and/or false torque measurements of the mechanical lug's clamp force, resulting in a loose joint, or a joint that might loosen with thermal cycling, leading to pull-out, overheating, series arcing, phase-to-phase arcing, or fire.

Class B and Class C are identified in Table 14 of UL 486A–486B–2013. The following is an excerpt from that table:

Conductor Size	Number of Strands	
	Class B	Class C
14 – 2 AWG	7	19
1 AWG – 4/0	19	37
250 – 500 kcmil	37	61
600 – 1000 kcmil	61	91
1250 – 1500 kcmil	91	127
1750 – 2000 kcmil	127	271

Manufacturers offer a wide range of conductor options, as well as wire connectors to suit a large range of commerical, industrial, and utility applications. Ultimately, the installer is responsible for making sure that the lug ordered with the circuit breaker is approved for the type cable intended for installation

Choosing the Right Mechanical Lug

Molded-case and insulated-case circuit breakers are designed, tested, and third-party certified to meet Underwriters Laboratories Inc (UL) Standard UL 489[1]. UL 489 requires that all lugs intended for use with these types of circuit breakers comply with UL Standard 486A–486B, which specifically addresses requirements for wire connectors, including design and design verification requirements.

It is always imparitive to observe the markings on the lugs to ensure that they are being properly applied. Lugs, and or their instruction leaflets are required to provide the following types of information:

- Manufacturer's name, or trademark
- The connector's catalog number
- The conductor wire material intended for use with. Typical markings are "CU" (copper-only), "AL" (aluminum only) or "AL-CU" (both aluminum and copper).
- Range of wire size permissible for use in the lug. If intended to use with only one wire size, then that specific wire size is listed.
- Number of conductors permissible per terminal point. If more than one conductor may be inserted for a single clamping mechanism (i.e. barrel and set screw), then the lug must be marked with that information. Typically, this information preceeds the range of wire size information.

[1]UL Standards are available from Comm-2000, 151 Eastern Ave, Bensenville, IL 60106, USA (http://www.comm-2000.com)

Additionally, the wire connector is required to be marked with the conductor class when types other than Class B and Class C have been proven acceptable for use with the connector.

Compression Sleeving

In order to control/limit the fraying or splaying of stranded and fine stranded conductors, some third-parties have developed compression sleeves. The intention is to keep the individual strands of a conductor bound tightly together, prior to, or after installation into the mechanical lug.

These compression sleeves are thin strips of copper intended to wrap around and fit snuggly over the conductors. Some designs are round barrel type, while others are strips intended to be wrapped around the conductors.

The use of compression sleeves can affect the ability of a pressure wire connector to be properly tightened, and to maintain a firm grip on the wire throughout the life of the product.

- The torque designation of the lug is based on use with solid or Class B/C stranded wire. The additional sleeving can alter the required torque to compress the sleeve and wire combination. If the wire is not firmly secured in the sleeve, or the sleeve is not firmly secured to the lug, the magnetic forces present during a short circuit could pull the wire out of the sleeve and/or connector, causing a series or even phase-to-phase arcing fault.
- The presence of a sleeve adds an additional component within the current path. Further complicating the problem, crimped sleeves have flat-spots and other deformations to the inner and outer surfaces. In all cases, the sleeve must be evaluated to make sure that it does not cause the circuit breaker to overheat under load current conditions.
- The cycling on and off of downstream loads results in thermal cycling (periods of heating, following by periods of cooling) of the conductors. The thermal cycling may result in the loosing of the connection. The resultant overheating may manifest itself in nuisance tripping, series arcing, or fire.
- Additionally, the presence of a sleeve may alter the calibration of thermal-magnetic trip units, and therefore result in nuisance tripping.

While this solution may appear attractive on the surface, be aware that this solution is subject to the same design testing and third-party certification with the intended circuit breaker(s), mechanical lugs, and conductors in accordance with UL 489 and UL 486A–486B.

Additional Resources

Many specific types of wire such as MTW, THHN, THW, and USE are mentioned in both UL 486A–486B and UL 489 that meet these Class B and Class C stranding requirements. NFPA 70-2014 Article 310 of the National Electric Code (NEC)[2] also covers requirements for conductors for general wiring. Several tables such as Table 310.15(B)(16), 310.15(B)(17), and others list the standard conductor types and their ampacities for general use.

Technical Support

If any doubt still exists as to the appropriateness of a cable and connector combination, contact Siemens Technical Support. The Siemens Technical Support Hotline team can be reached at 1- 800-333-7421, or by submitting a request through Online Support Request: http://support.automation.siemens.com/US

[2] The National Electrical Code is published by the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269,

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