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Performance Evaluation of Crimped Terminations

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Abstract

There are several acceptable ways to connect cables and there are varieties of termination methods for cable. The termination method utilized depends basically on the system installed, type of cable used and type of connector. Using the proper termination method results into good mechanical and electrical integrity of the distribution system. Key ingredient in the termination process is to use the proper tools and materials required for the type of termination. Crimped and bolted aluminum and copper lugs are commonly used for termination of power cables. This paper describes and compares performance of different combination of copper/aluminum lugs with copper/aluminum cables.

Index terms: Inhibitor, termination, cable, lug, crimping, conductor, contact resistance.

Introduction

For industrial and commercial applications, crimped and mechanically bolted aluminum and copper connectors are commonly used for terminating power cables. Copper connectors are available for use with copper conductor, and aluminum connectors are available for use with copper and aluminum conductor. Sometimes copper conductor with aluminum connector or aluminum conductor with copper connector is also used. There are significant differences in the material and electrical properties of aluminum and copper and their oxides, which may affect their long-term performance.

High-resistance oxides form very quickly on aluminum and copper conductors expose to air. Once the oxides are stabilized, they prevent further oxidation of the parent metal; however, due to this high electrical resistance, these oxides must be broken or removed before making up connections. Oxidation-inhibiting compounds are used to prevent re-oxidation of the metals in the connections. Copper oxide is generally broken down by reasonably low values of contact pressure. Unless the copper is very badly oxidized, good contact can be obtained with minimum cleaning. Aluminum oxide is a hard, high-resistance film that forms immediately on the surface of aluminum exposed to air. This tough film gives aluminum its good corrosion resistance. After a few hours, the oxide film formed is too thick to permit a low-resistance contact with cleaning. The film is so transparent that the bright and clean appearance of an aluminum conductor does not give assurance of a good contact. After cleaning the oxide film from aluminum, a compound must immediately be applied to prevent the oxide from reforming. Aluminum and copper have vastly different coefficients of expansion and allowances for expansion must be considered when connecting cables with connectors. The greater hardness of copper compared with aluminum gives it better resistance to mechanical damage. It is also less likely to develop problems in clamped joints due to cold metal flow under the prolonged application of a high contact pressure. Its higher modulus of elasticity gives it greater beam stiffness compared with an aluminum conductor of the same dimensions. The temperature variations encountered under service conditions require a certain amount of flexibility to be allowed for in the design. The lower coefficient of linear expansion of copper reduces the degree of flexibility required. Because copper is less prone to the formation of high resistance surface oxide films than aluminum, good quality mechanical joints are easier to produce in copper conductors. Al has an amperage capability that is approximately 1.85 times that of Cu. In other words, one kg of Al has the same electrical capability as 1.85 kg of Cu. Cu has a greater conductivity on an equal volume, cross sectional area, basis. The ability of copper to absorb the heavy electromagnetic and thermal stresses generated by overload conditions also gives a considerable factor of safety. High conductivity aluminum exhibits evidence of significant creep at ambient temperature if heavily stressed. At the same stress, a similar rate of creep is only shown by high conductivity copper at a temperature of 150°C, which is above the usual operating temperature.

Good quality Crimped or Compression Jointing

For cable size 6 mm2 and above, two/three crimps are recommended. The lug should be positioned so as to have the first crimp on the straight portion of the barrel towards the pan handle (the crimp should not be made on the curved shlolder between the pan handle and the barrel of the lug). The second crimp should be made inwards along the barrel about 3-4 mm away from the first crimp. This is shown in fig-1

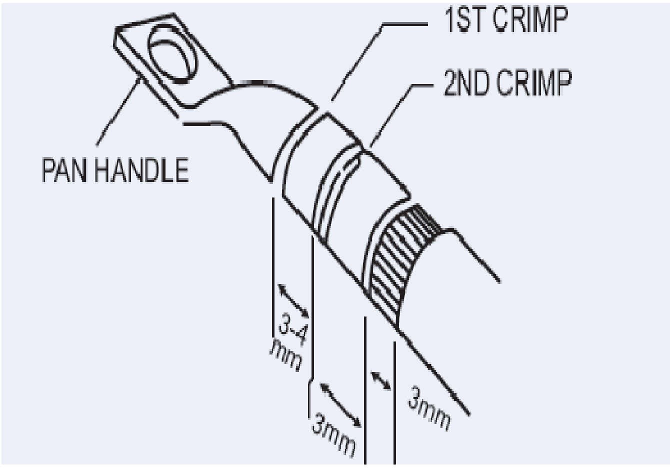

Figure 1: Crimped lug

Precautions should be taken for compression jointing/crimping

Normal length of insulation to be stripped from the cable/wire should be equal to barrel length plus 1 to 3 mm.

Crimping should be carried out with a good quality battery operated crimping tool. For correct crimped joints proper die and tool is essential to ensure matching between conductor and lug as well as between lug and die.

It is advisable to fill the lug barrel with inhibiting compound. In addition, the compound should also be applied on the exposed cable strands.

Measurement of millivolt drop, a method to identify quality of termination:

In this method test current is allowed to flow through the bus bar joints. Lesser the milli-volt drop across a joint better will be the joint, as there will be lesser contact resistance, lower temperature rise and lesser power loss. Chart-1 gives upper limit of allowable mV drop against different load current.

Millivolt Drop Mesurement Chart			
Joints	**Test Current**	**mV Drop Upper Limit**	**mV Drop in labortory condition for good terminal joints**
Links to terminal	100 Ampere ac/dc	2.5 mV	0.5 to 1.1 mV
Cable lug to terminal upto 50 Amp	50 Ampere ac/dc	8.0 mV	1.0 to 2.0 mV
Cable lug to terminal upto 50 - 100 Amp	50 Ampere ac / 100 Ampere dc	5.0 mV	2.0 mV
Cable lug to terminal beyond 100 Amp	100 A ac/ dc	2.5 mV	0.5 to 1.5 mV

Chart 1: Millivolt drop measurement chart

Problem formulation

Following cable and lug combinations are considered in this paper for measuring millivolt drop

a. Copper cable and Copper lug.
b. Copper cable and Aluminium lug.
c. Aluminum cable and aluminum lug
d. Aluminum cable and copper lug.

In each case milli-volt drop across the lug and cable at different loads will be measured. Lower the voltage drop lower will be the contact resistance for the same load.

Results based on practical experiments

In the chart and graph given below we are trying to compare results of the following combination of lug and cables at different loads varying from 27 Ampere to 151 Ampere. Here we are measuring voltage drop across the lug. Lower the voltage drop lower will be the contact resistance.

a. Copper cable and Copper lug.
b. Copper cable and Aluminium lug.
c. Aluminum cable and aluminum lug
d. Aluminum cable and copper lug.

Single core 95 sq mm cable manufactured by reputed company was used in all the four cases.

Lugs used in all the four cases were manufactured by reputed company.

Good quality battery operated crimping tool with suitable die was used all the four cases.

Good quality corrosion inhibiting compound was used in all the four cases.

In fig—2, curve is showing current flowing through the bus bar joints and Y axis is showing milli-volt drop taking place in the termination. Lesser the milli-volt drop across a joint better will be the termination, as there will be lesser contact resistance, lower temperature rise and lesser power loss.

Fig, 3 is showing a typical photograph of Aluminum cable with copper lug and aluminum cable with aluminum lug.

From the results shown in chart-2 we can see that termination of copper cable with copper lug is having minimum milli volt drop. This is followed by Copper cable with aluminum lug and Aluminium cable with aluminum lug. The millivot drop across aluminum cable with copper lug was found to be highest.

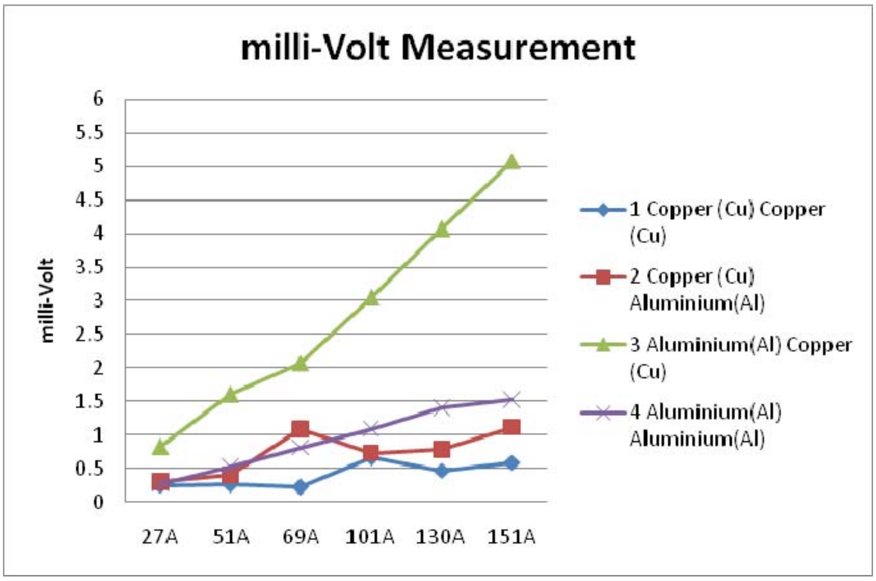

Figure 2: Curve showing milivolt vs Current in amper

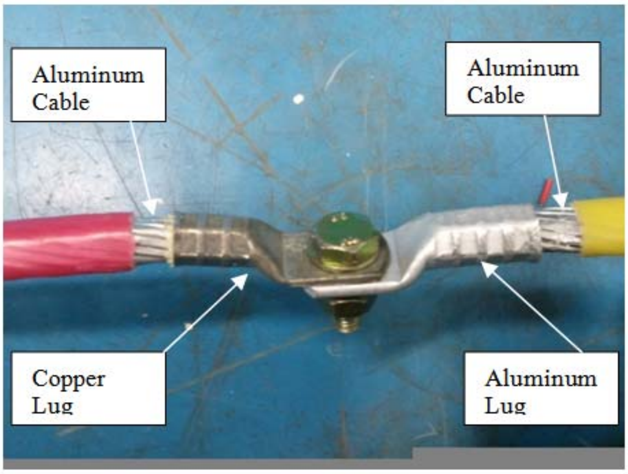

Figure 3: Al cable with Cu lug & Al cable with Al lug

Sr. No.	Type of Cable	Type Of Lug	milli Volt drop readings at different current readings					
			27A	51A	69A	101A	130A	151A
1	Copper (Cu)	Copper (Cu)	0.3	0.3	0.2	0.66	0.47	0.59
2	Copper (Cu)	Aluminium(Al)	0.3	0.4	1.1	0.73	0.78	1.11
3	Aluminium(Al)	Copper (Cu)	0.8	1.6	2.1	3.05	4.06	5.08
4	Aluminium(Al)	Aluminium(Al)	0.3	0.5	0.8	1.09	1.4	1.52

Chart 2: Mili volt drop found during experiment

Conclusion

The performance of crimped termination is dependent on maintaining low resistance. It is evident from the experimental results that copper cable with copper lug is having minimum resistance. Resistance of Crimped termination of copper cable with aluminum lug and aluminum cable with aluminum lug are also more. However resistance of aluminum cable with copper lug is highest and hence such crimped termination should be avoided as far as possible.

Stable and minimum contact resistance of crimped terminations will reduce the need for frequent maintenance, decrease overall downtime of equipment and maintenance costs and greatly reduce the risk of catastrophic failures.

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