A SIFCO White Paper

SIFCO®
SELECTIVE PLATING
DIVISION OF SIFCO INDUSTRIES, INC.
ISO 9002 Registered Quality System

A Look at Bus Connections: Why a Localized Silver Deposit Makes Sense

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Executive Overview

In the electric power industry, optimizing power flow is a primary concern. Unplated bus bars, like those installed as far back as 1910, can result in significantly inefficient joints. The effects of bus bar surface irregularities, the formation of non-conductive surface films caused by the local environment and temperature, and the formation of copper oxides can lead to bus joints that have a high joint resistance and voltage drop, leading to hot spots, and possible catastrophic failure.

The use of powders and greases can help, but only for a short period of time. The use of electroplated silver on bus joints results in an improved joint, with as much as a 30% improvement in the joint efficiency over its life. The SIFCO Process of Selective Plating allows this silver plating to be safely done on-site with minimal bus tear-down, and no transportation to off-site facilities.

TVA utilized the SIFCO Process on the upgrade of its bus duct system at the Fontana Dam. TVA realized substantial savings by choosing to plate existing bare connections.

SIFCO Selective Plating, based in Cleveland, OH, has six service shops located throughout the U.S., making it very convenient for them to travel to plant locations for on-site silver plating of bus joints.

Overview

In the electric power industry, optimizing power flow is a primary concern, in the generation, transmission and distribution process. One key ingredient is providing and maintaining low resistance conductive joints.

Field experience and laboratory studies have shown that this is especially true in the case of bus bars and bolted high current connections. Specifically, plated bus bars out-perform unplated bus bars by providing stable contact resistance and a low maximum operating temperature that increases the service life of the bus joint. More importantly, stable contact resistance joints will reduce the need for frequent maintenance, decrease overall downtime of equipment and maintenance costs and greatly reduce the risk of catastrophic failures.

Good industry practices recommend that all bus contacts be plated. Most government, IEEE and insurance provider specifications require that all bolted bus connections be plated in accordance with applicable specifications.

One of the key elements to effective bus bar contact plating is applying a uniform deposit of sufficient thickness to provide corrosion protection and a “leveling effect” to increase the surface area of the bus joint. Some conductive “wipe-on” coatings such as Cool Amp® may be quick and inexpensive, but the actual silver deposits are very thin and yield only temporary results due to degradation by heat and environmental factors over much shorter periods of time. Other processes may not provide the thickness and durability required to ensure adequate “compression” of the joint and long term corrosion protection required to mitigate the affects of oxidation.

Brush plating using pure silver provides a simple, cost effective solution for in-place plating of bus systems during routine maintenance and can also be of value in upgrading bus, rather than replacing existing bus, when generator or system capacity increases are desired.

The Early Years

In most early power plants, the aluminum or copper bus bars were installed uncoated and left that way. While the performance of an uncoated bus joint may have been sufficient years ago, today's increasing demands for power, given the limited capacity and economies of the marketplace, are forcing the producers to improve the efficiency and performance of the entire system.

Many early bus connections have not been unbolted since first being installed as far back as 1910. A new bus connection, then as today, has several inherent factors that limit its ultimate lifetime performance. They are:

- Irregularities in the mating surfaces
- Particulate contamination prior to installation
- Oxidation.

All of which, when combined, have an escalating effect of increasing contact resistance and temperature and thereby decreasing the efficiency of the joint over time and can cause catastrophic failures.

Even when new, imperfections in the bus bar's copper surface result in only a fraction of that surface coming into direct contact with its connection. By some estimates, that fraction can be as low as ten percent. Although increasing the contact force may flatten out the high areas, the effects are minimal and may even place undesired stress on the fastening system.

The formation of non-conductive surface films due to harmful ambient atmospheric contaminants is also a limiting factor of joint reliability – even in bolted contacts. Fritting will reduce the contact resistance of thin surface films, but thicker, more tenacious films may still present a problem that will be magnified by increasing temperature at the joint due to increased resistance. Fritting is the occurrence of the dielectric breakdown of a contact film. A potential gradient of 100V/μm could be sufficient to cause this dielectric breakdown.

The oxidation of the bus material is an ever-present occurrence unless steps are taken to prevent it with a barrier coating. The formation of oxidation layers on the bus material within joints leads to increased resistance, and thereby increased voltage drops and increased local temperatures. It has been reported that the joint resistance across uncoated bus can increase more than 20% due to oxidation formation. Studies have shown that silver plating bus joints significantly reduces bus material oxidation in service.

The combined effects of irregular surfaces, contamination and the formation of non-conductive surface films, and oxidation can create "hot spots" that will further deteriorate the reliability and performance of the joint. Some plants have operated for decades with severely overheated, inefficient bus connections that by today's standards are economically unacceptable.

A Better Joint

Testing and field experience has shown that one simple step can be taken to minimize the effects of irregular mating surfaces and the formation of oxides and other surface films on joint performance. That step is plating the joint area with a soft, conductive and corrosion resistant material. The application of a 0.0002" to 0.0005" thick deposit such as silver, nickel or tin can improve the lifetime performance of the joint by as much as 30% and reduce maintenance substantially.

Coating with a soft material such as silver or tin effectively forms a compressive gasket on the surfaces to be connected. The force applied when bolting the surfaces together squeezes the conductive material into the low areas, effectively increasing the contact area and decreasing the overall joint resistance.

Tests have demonstrated that these materials greatly slow down the formation of copper oxide and other surface films, maximizing conductivity and minimizing heat. According to TVA's Dale Harris, Principal Electrical Engineer, Power Systems Engineering River Operations, "Although the initial contact resistance of a silver plated joint and a bare copper joint may be equivalent, over time the contact resistance can be as much as 100% less for a silver plated connection than for a bare copper connection." A silver plated joint allows operation at a higher temperature without joint degradation over the life of the joint. The end result, over time, is significantly increased performance, efficiency, economy and reduced maintenance.

Because of silver's softness it can be formed more precisely to the contours and crevices of the original piece increasing the actual contact areas. Silver provides a good electrical connection preventing the formation of copper oxide at the mating faces. A nickel coating has shown some cost advantages, but silver displays greater operating performance and efficiencies, exhibiting less resistance and maintaining lower temperatures while in service.

Tank plating the connection using a cyanide silver bath solves the problem of providing a sufficient thickness, but it is costly and time consuming. In the case of bus bars, they must be completely removed from the system and sent offsite for plating. While the performance is substantially better than wipe-on coating, the increased outage time required for this method can be unattractive.

Electroplating, as performed using the SIFCO Process of Selective Plating, can be completed on-site with minimal disassembly, during any planned outage without removing the equipment from its location. To ensure safety for the operators and those in the surrounding areas, SIFCO uses non-cyanide silver in its plating process. This portable plating process accurately applies the non-cyanide silver at a rate of 0.020" per hour, producing a smooth even finish. Two mating faces of a 4" x 4" copper bus joint can very easily be masked and plated with 0.0003" of silver in less than 15 minutes.

The desired thickness for each particular application and/or part is calculated prior to plating. SIFCO uses digital ampere-hour meters to accurately control plating thickness to ensure smooth finishes and uniform plating.

A smooth finish and a uniform deposit of sufficient thickness will significantly enhance the reliability and the performance of the electrical joint.

What Is Selective Plating?

Selective plating is an electrochemical process in which metal ions are deposited on a metallic surface. This process is the answer to the situations described above. Selective plating can be used to repair shafts, housings, and journals with low buildup requirements in a much faster and cost-effective way than traditional welding or spraying methods. On-site selective plating provides a much improved method for plating bus bars and other electrical connections.

Selective plating involves bringing chemical cleaning and plating solutions in small volumes to the part that needs plating, isolating the area on the part that requires the buildup, and applying the deposit metal with the use of electricity. It is all based on simple electrochemical principles. Using Faraday’s law, it is possible with this process to control the thickness of the deposit to within 0.0002”, thereby eliminating post-machining requirements in many cases.

Selective plating is best suited economically for applications where the required buildup is <0.010” overall dimensional change. In these situations the need for post-machining is usually eliminated. However, selective plating can also be used economically in situations where the buildup requirement is up to 0.060”, but minimal mid- and post-process grinding or finishing may be required.

Upgrading the Bus Duct System at TVA's Fontana Dam

As part of the TVA's comprehensive hydro modernization program, electrical bus duct systems are sometimes replaced with new systems sufficiently rated for the new higher unit output capacities. This occurs when a generating unit's output rating is increased beyond the capabilities of its corresponding bus duct system or when the plant's physical arrangement must change to accommodate other new equipment. TVA has, however, successfully demonstrated that many older bus systems can be re-rated to higher ampacities by using in-place brush plating to increase the current carrying capabilities of the bus. Success is highly dependent upon the modified bolted joints because they must be stable, reliable, and operate at a reduced contact resistance for a wider operating range. All of this can be accomplished at much less cost than bus replacement.

TVA has realized substantial savings by choosing to plate existing bare connections rather than upgrading to a new bus system. Bolted connections were silver plated in-situ during scheduled outages.

Steps in the operation:

- Mechanically clean the contact surfaces to remove heavy oxides.
- Solvent clean the contact and adjacent surface to remove any traces of oil or other residue.
- Mask to define the area to be plated.
- Electrochemical preparation
- Plate the part
- Remove the masking

Conclusion

The performance of contact joints is dependent on maintaining low resistance. The conductivity of the joint will naturally deteriorate over time due to the rigors of service as well as natural forces such as oxidation and moisture. The very thin wipe-on coatings do not provide any lasting benefits once the joint has been put into service.

Testing has shown that plating bus joints with 0.0003" – 0.0005" thickness of silver greatly improves their lifetime performance. On-site selective plating with non-cyanide silver may be the most economical approach because it eliminates the need for component disassembly and transportation to an off-site plating facility, while quickly providing a superior quality, uniformly thick deposit that will stand the test of time.

The SIFCO Process®

SIFCO Selective Plating has provided this high quality process of selective plating to industry for over 40 years. Known worldwide as the SIFCO Process, it is a true electro-deposition capable of providing sound metallurgical deposits on components. With over twenty metals that can be deposited, the SIFCO Process can find many uses throughout various industries, including the power distribution market.

The SIFCO Process meets many specifications, including AMS 2451, MIL STD 865c and MIL STD 2197. In addition, many companies such as Siemens Westinghouse Power Corporation, Alstom Power, and GE Power Systems have used and specify the SIFCO Process.

With six service shops in North America, SIFCO Selective Plating can be on-site at your location within a few hours to selectively plate your bus joints. Its technical sales staff, spread throughout the U.S., and the SIFCO R&D and Technical Support staff at its headquarters in Cleveland, OH, are ready to help analyze the technical and economical aspects of your bus joint requirements to evaluate whether selective plating is viable for your specific application.

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DIVISION OF SIFCO INDUSTRIES, INC.
ISO 9002 Registered Quality System

World Headquarters
5708 Schaaf Road
Cleveland, OH 44131, USA
Ph: (216) 524-0099
(800) 765-4131
Fax: (216) 524-6331
Email: info@brushplating.com
Website: www.brushplating.com/landingpage.html
FAA Repair Station #SOXR680K