Introduction

With the increase in copper prices, copper theft, which was once a nuisance factor, has now become a major problem for the telecommunications industry. Copper theft in the US alone has a cost impact in excess of US$1 billion dollars per annum. Copper theft in the telecommunications and power sector includes the theft of ground bars, cables and grounding conductors. It is a significant problem in Australia and now extend to all the states.

The Problem

The copper theft happens either during construction stages or later on when the sites are operational. If the theft occurs during construction then there is economic loss and an annoyance. However theft of copper in operational facilities is a larger concern because it brings about a serious safety problem not only for the copper thieves but the general public. There is serious impact on noise level at a telecommunications site when the ground grid is removed and this has operational ramifications.

Copper is used in grounding applications widely in bare and insulated forms. Conductors used in this application are often perceived to be “not live” and are a prime target for copper thieves.

The frequency of the copper thefts seems to follow the price of copper in the scrap metal trade, which naturally follows the market price of copper. With the demand of scrap copper and hence copper prices remaining high, it is envisaged that this problem will be on the rise in months and years to come, if this trend continues.

Solutions to Reduce Copper Theft

There are two types of solutions discussed here that are aimed at minimizing or eliminating theft of copper from grounding systems in telecommunications.

1) Alternative Conductors to Copper
2) Alternative Ground Bars to Copper

Clear signage stating that the conductors are not copper, can be used to compliment other measures at the sites.
Alternative Conductors to Copper

Copper is not substituted easily with other materials because of its unique properties in terms of its conductivity and corrosion. However there are a number of conductor solutions available that can retain the use of the copper properties but yet change the composition so that it is of little or no scrap value. The conductors discussed here are well suitable for grounding applications. These newer conductors are also suited for other non-grounding applications.

Theft Deterrent Composite Cable, TDCC

This is a bare concentric stranded conductor that consists of peripheral galvanized magnetic steel stranding, which protects and conceals the internal tinned copper stands. This conductor is ideal for exposed locations where copper theft may occur. The conductor is difficult to cut with hand tools, and the outer steel stranding is ferrous, which further deters thieves looking for copper. Copper stranding inside of conductor increases conductivity and conductor flexibility. Copper stranding is tinned for superior corrosion protection.

Theft Deterrent Composite Cable, or TDCC is not suitable for direct burial because of the risk of corrosion to the galvanized steel layer. The most suitable location for the use of this cable is between the ground bar and the ground electrode system. CADWELD is a suitable connection method for this conductor. It is recommended that the portion of the conductor that is buried be insulated.

Copper Bonded Steel Conductor CBCS

This is solid high carbon steel (1018 grade) core and molecularly bonded with a minimum of 250µm copper. These conductors cannot be removed from the grounding system using normal copper cutting hand tools and has a significantly lower scrap value than the equivalent solid copper conductor. This type of cable is usually a fraction of the cost of copper cables. It performs exceptionally well in terms of corrosion, both above and below ground levels. This conductor is suitable for above and below ground applications. It can be used as a ground lead between the ground bar and a traditional copper based ground electrode system or it can be used as the horizontal conductor in a ground electrode system.
Traditional connection methods like CADWELD are ideal for this conductor. It looks like copper from the outside and may still be prone to theft in some applications. However, they are difficult to cut and remove.

The technology behind the CBSC conductor is well proven. Essentially its construction is much like the construction of copper bonded ground rods. However, the steel center is slightly softer grade steel.
The CBCS conductor can be difficult to handle due to its stiffness. But this is the same property which makes it theft deterrent.

The conductor can be manufactured in straight lengths or as pre-bent lengths for connection between the ground bar and the earth electrode system.

**Galvanised Steel Strap Conductors**

One historical reason that galvanised steel has been used, is that buried grounds were close to telephone exchanges where there were lots of lead sheathed cables. Lead and copper buried together was perceived as a corrosion risk.

The snag with galvanised steel is its rapid corrosion in comparison with copper. Traditionally telecommunications carriers had procedures for annual ground resistance testing which would identify extensive corrosion. Some carriers still do regular ground testing but with the high number of sites in a cellular network it can be difficult to instil the discipline to carry these tests out.

Experience from site examinations and long-term studies have demonstrated that the rapid corrosion of galvanised steel is almost always a problem. The expected life of Galvanised Steel would be 10-15 years in comparison with 40 years for copper bonded steel conductors in the similar soil conditions.

The issue of copper theft is a worldwide problem and not many carriers and in that case utilities have opted for galvanised steel but rather looked at more modern solutions. The image below shows the corrosion on galvanised steel strap which was in the ground for 12 years.

For further reading on corrosion on copper bonded vs galvanised steel grounding systems please refer to technical paper “A Technical Report on The Service Life of Ground Rod Electrodes” Chris Rempe ERICO 2004 and “Experimental Evaluation of the Corrosion Performance of Copper-Bonded and Galvanized Grounding Electrodes” by Dr F. D'Alessandro (B.App.Sc., B.Ed. PhD, SMIEEE) and Dr. B. Baumgartner.
Case Study on Theft Deterrent Conductors

A large power utility in Australia was facing the problem of copper theft from earth conductors on pole mounted distribution transformers. This problem was both a safety risk and a nuisance that cost the utility lots of dollars. Copper was by far the most suitable material for this application. The first alternative considered was aluminum conductors. There were several snags identified with Aluminum. These included corrosion at top part due to wash down of copper oxides from upper conductors, Aluminum not suitable for underground use and continued theft as Aluminum is soft and easy to cut and has scrap value. The problem was far more pronounced in rural areas.

The solution utilized by the utility was the use of copper bonded steel conductor for the portion that was susceptible to theft. A copper pigtail which is pre-CADWELDED was used on the top for connection and for the connection to the earth electrode deeper in the ground. The exposed part of the copper bonded steel conductor was additionally provided with mechanical protection. The benefits of this solution were that it provided satisfactory conductivity on fault conditions, is resistant to corrosion, difficult to cut with common tools and has no scrap value. The solution was easy to implement using the same connection methods as previously used for copper conductors.

A similar solution has been implemented by a major utility in the USA but this time the application is earth risers at an electrical substation.

The copper bonded steel conductor is pre-bend and pre-fabricated with tails for underground connections. The portion of the conductor that is above ground copper bonded steel conductor.
Alternative to Ground Bars
The Theft Deterrent Ground Assembly (TDSGA) is an alternative to using conventional bus bars in a telecommunications grounding system. The system is designed to equalize the surge energy to the tower at the top, middle and bottom locations, while offering the electrical conductivity required during the surge event.

The theft deterrent ground assembly can be installed one of 3 methods.

Method 1. The TDSGA can be installed on to a 3” galvanised pipe which site beneath the feeder entry into the building. The pipe acts and a conductor between the TDSG and the ground electrode system. A connection is made between the 3” pipe and the ground electrode system via a 2/0 wire which is CADWELDED on to the pipe with a VS type connection.

Method 2: The TDSG can be installed on to a wall much like a traditional ground bar with the aid of suitable angle brackets.

Method 3: The TDSGA can be installed on the telecommunications mast directly using suitable clamps. Some mounting options are shown below for mounting to a circular mast and a traditional angle member of a larger mast.

In two of the mounting arrangements, no down lead is necessary to the earth ground ring, helping to eliminate the risk of copper theft. In the third method a
ground lead is required. The Deterrent Composite Cable for this application. This conductor is connected to the copper earth electrode system using CADWELDED connection. The copper bonded steel conductor is also a suitable conductor to act as the ground lead.

**Alternative Earth Bars**

A study was undertaken of the following alternative materials available for use as ground bars.

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<th>Materials</th>
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<tr>
<td>C11000 Copper</td>
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<tr>
<td>Copper Plated Steel (0.2 mil)</td>
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<tr>
<td>Copper Plated Steel (0.5 mil)</td>
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<tr>
<td>Galvanized Steel (3.9 mil)</td>
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<tr>
<td>Zinc-Nickel Alloy Plated Steel</td>
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<tr>
<td>Copper-clad Aluminum</td>
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<tr>
<td>Tin-Plated Aluminum (0.02 mil)</td>
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<tr>
<td>Stainless Steel, Type 304</td>
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<td>Aluminum</td>
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The investigation included corrosion simulation and testing electrical performance including the measurement of AC & DC Resistance.

The change of impedance and visual inspection was carried out after subjecting the earth bars to alkaline and acidic conditions to simulate long-term corrosion in soil. The simulation included salt mist treatment to Standard IEC 60068-2-52 and humid sulfurous atmosphere treatment to standard ISO 6988:1985.

- This investigation demonstrated that the earth bars that showed closest performance to solid copper earth bar are copper clad aluminum and tin plated aluminum. These are considered the best alternative to copper earth bars. These materials have the highest compatibility with the various lugs and connectors commonly used in the telecom and the power industry.

- Copper plated steel and galvanized steel showed similar characteristic to each other but had higher DC and AC resistance than copper and tin-plated aluminum even before the corrosion tests. Some of these bars can be considered as alternatives to copper earth bar under certain conditions.

- Zinc-Nickel Alloy Plated Steel and Stainless Steel either showed high DC or AC resistance or high corrosion and were deemed not suitable for use as earth bars. These are not good materials to use as alternative to copper earth bars.

- The aluminum bar under investigation showed that its DC and AC resistance is higher than tinned aluminum and it showed a higher inclination to corrode than tinned aluminum and tinned copper. Generally, bare aluminum is
not deemed an alternative to copper earth bars. It can be used if certain precautions are taken about cleaning prior to connections being made and it is not in direct contact with copper or the ground.

**Conclusion**

There is no simple answer to the problem of copper theft in the industry. It is not easy to find alternative materials to copper that will exhibit the same or better combination of electrical, mechanical and corrosion characteristics. Alternative composite conductors made of more than one material are emerging as a viable alternative in earthing. Alternative methods of installation are used to provide further disincentive for copper thieves.

**BIBLIOGRAPHY**


2. *Experimental Evaluation of the Corrosion Performance of Copper-Bonded and Galvanized Grounding Electrodes* by Dr F. D’Alessandro (B.App.Sc., B.Ed. PhD, SMIEEE) and Dr. B. Baumgartner


6. *Study on Alternative Ground Bars to Copper*, Dale Boling, ERICO.