Field trial of carbon composite core covered conductor system

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SUMMARY

Bare Single Wire Earth Return (SWER) conductors have been associated with a number of fire starts which have resulted in a large loss of life and property. This paper presents a field trial demonstration of an alternative to traditional bare conductors aimed at reducing the potential fire start risk.

The electrification of remote and rural areas via the SWER system was possible due to the low capital cost (primarily due to long spans and simple pole top infrastructure), ease of installation (simple stringing techniques) and relatively simple support infrastructure required (transformers, fuses, insulators). The system initially developed in New Zealand[1] found early acceptance in Australia where there is now over 200,000km installed. The 22 and 33kV SWER systems are also located in the Americas, Africa, and Asia. Typically the networks utilise traditional galvanised or Alclad steel wire constructions such as SC/AC 3/2.75mm. With such conductors, long spans (400 to 800m) through remotely populated, farming, forest, and scrub vegetation are not uncommon for the SWER network.

The wide variety of vegetation, wildlife and weather interactions across the remote and rural network pose a number and variety of risks. The potential for fire starts is one such risk. The main identified risks associated with bare conductors are from broken energised conductors falling into combustible vegetation; trees coming into contact with energised conductors and wildlife electrocutions at pole tops. Increasing the strength of the conductor and applying a covering address these possibilities. The ability to utilise the strength to weight properties of composite materials coupled with an abrasion resistant covering allows the opportunity to utilise the existing pole infrastructure and maintain sag clearances.

Pole top fittings and connections designed for the conductor, environment and interconnection with the existing infrastructure are required for the transition from bare to covered conductor systems. The conductor, fittings, and installation experience gained from a field trial in a high fire danger region of Victoria Australia are outlined in more detail in this paper.

KEYWORDS

Bushfire - Single Wire Earth Return - Covered Conductor – Installation – Fittings

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BACKGROUND

A problem that many Australian Utilities encounter is the ignition of ground fires by the emission of incandescent particles following such events as conductor clashing, the operation of expulsion fuses and unconfined arcing faults[2 3]. Fire starts categorised as electrical failure have been quoted as being the source of 1.59% of all vegetation fires[4]. Bushfires caused by electrical infrastructure have also been reported to be involved with a disproportionate number of bushfire-related fatalities (in Victoria, Australia)[5] in part due to a higher proportion of electrical infrastructure related fire starts occurring on days of high winds and higher Grassland Fire Danger Index (GFDI) values where an arc can be fanned by winds in an abundance of dry vegetation – such fire starts, particularly in remote locations, can quickly become large dangerous fires.

In early 2009 the large-scale bushfires in Victoria, Australia resulted in a large loss of life and a widespread community trauma[6]. A significant focus of attention was the cause of a number of the largest fires and Single Wire Earth Return (SWER) power lines were associated with a number of the tragic fires. SWER power lines are commonly 22/12.7kV and 33/19kV systems. SWER power lines are widely used in Australian rural environments servicing remote and dispersed customers[7]. SWER systems are also located in the Americas, Africa and Asia.

The two most common conductor designs used for SWER are simple bare overhead line constructions: SC/GZ 3/2.75mm and SC/AC 3/2.75mm. The galvanised version was used extensively prior to the aluminium clad version entering the market and is hence to be found widely in the field. The galvanised version is still used but is utilised more frequently in corrosive coastal environments while the aluminium clad version predominates new installations.

In order to improve the bushfire start risk associated with the network in the highest fire danger regions, a Utility can replace the conductor with an underground cable or a covered conductor[8]. The undergrounding option is particularly expensive. A conventional covered conductor system will typically require a greater number of poles to support the heavier/ larger diameter conductor (compared to SC/AC 3/2.75mm). The inclusion of additional poles to the existing network, particularly across valleys and in National Forests, is often not practical. The community expectation of a safer network at an affordable cost required a solution to utilising existing pole infrastructure while maintaining sag clearances and pole top loadings.

CABLE DESIGN

A covered carbon composite core conductor and fittings system suitable for the 22kV SWER network in Australia has been developed and field trialled in a high fire risk environment. The use of a carbon composite core strength member with an aluminium tube conductor and a protective sheath covering is a dramatic alteration of the existing stranded Alclad or galvanised steel wire construction. The high-strength to weight ratio of carbon composite materials compared to the steel SWER conductors allows a covered conductor to be installed on the existing infrastructure of poles.

The incorporation of a sheath or covering over the conductor provides a much greater level of safety compared to existing bare conductors. Safety is improved in a number of ways. The principle manner of improving the bushfire safety is by reducing the risk of an arc from the conductor to a tree rubbing on an overhead conductor or when a broken conductor impacts the ground and dry/ flammable vegetation. The sheath barrier also offers improved protection against accidental electrocution from such instances as contact from farm machinery.

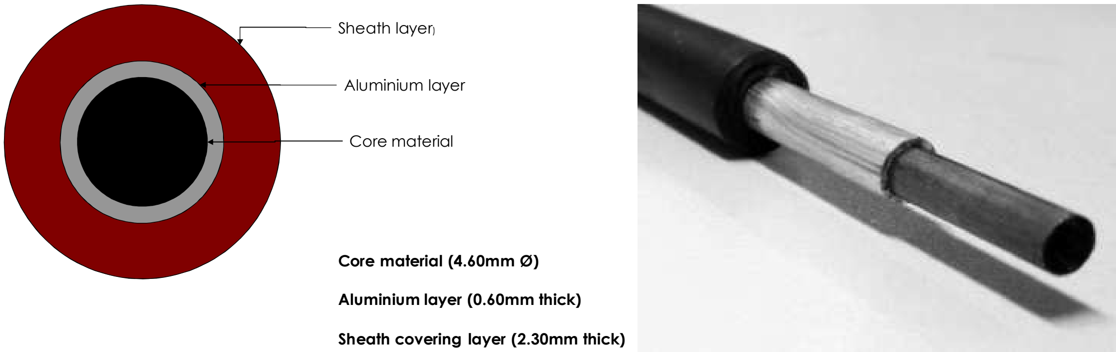

Figure 1 : Carbon Composite Core Covered Conductor Construction

Table I: Carbon Composite Core Covered Conductor 10 product comparison

Carbon Composite Core Covered Conductor 10 product comparison chart			
Product	**CCCC10**	**Alclad 3/2.75**	**Gal steel 3/2.75**
Description	**CCCC10 4.60/0.60/2.30**	**SC AC 3/2.75**	**SC GZ 3/2.75**
Diameter, mm	**10.40**	5.9	5.9
Breaking Load, kN	**34.1**	22.7	22.2
Mass, kg/km	**109**	118	140
DC Resistance, Ω/km	**2.89**	4.80	11
Thermal expansion	**9.79 E-6***	12.9 E-6	11.5 E-6
Young's Modulus, GPa	**133***	159	189
Ampacity, Amps (summer noon, still air)	**50**	38	25

*: measured on load bearing components (carbon core and aluminium)

FITTING DESIGN

The novel design of the conductor requires specialised fittings. However, the form, appearance and installation techniques required are familiar to Utility field crews. The use of insulation piercing electrical connectors, spiral vibration dampers, armour rods, insulator ties, compression dead ends and mid-span joints have all been developed and deployed.

The insulation piercing connectors were specially designed for the covered carbon composite core conductor. The design had to ensure that the teeth did not pierce through the aluminium layer thus damaging the carbon core yet still made a good electrical connection. The final design was fully type tested in accordance with Australian Standards for IPC connectors[9]. The cable with IPC connectors fitted was also mechanically tested to ensure that the connectors did not affect the strength of the cable.

Since these IPCs are required to operate at voltages well above 1 kV the design also had to ensure that metallic bolt did not act as a virtual earth and initiate tracking issues within the connector. The connector is fitted internally with a patented system to ensure that the bolt is kept at line potential.

The other aspect that had to be considered and fully tested is the water tightness of the seals around the teeth to ensure that moisture does not get into the aluminium or the core. The production versions of the connectors were subjected to water immersion and dielectric tests in accordance with Australian standards to ensure a water tight seal.

Of concern to the Utilities is the potential for these connectors to be mixed up with low voltage insulation piercing connectors. To avoid confusion, the bolts were made bright orange so that they stand out. A view of the IPC connector can be seen in Figure 2.

Also, a great challenge was the tension terminations fittings and mid-span joints. These have to compress the carbon core through the aluminium layer without damaging either of them. They also have to ensure complete water tightness to protect the core and the aluminium layer.

Originally it was envisaged to use termination fittings that would go over the top of the outer insulation similar to what is used on conventional Covered Conductors. However, given the stringing tensions required it was impossible to apply enough force through the covering to firmly grip the aluminium layer and carbon core without damaging the covering. It was then decided that the terminations similar, to the mid-span joints, would require removal of the covering and the compression fittings applied over the bare aluminium layer.

Extensive mechanical and vibration tests were carried out to ensure the adequacy of the design as well as the suitability of production versions. A view of a Compression Dead End can be seen in Figure 3.

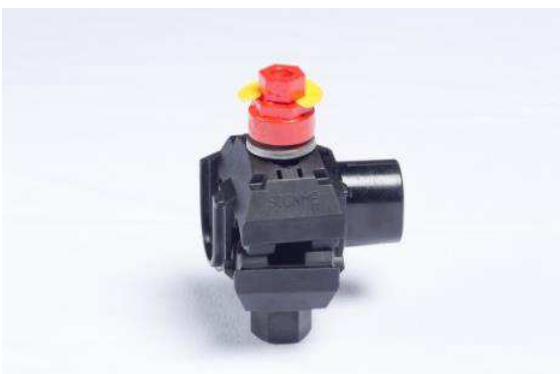

Figure 2: Insulation Piercing Connector.

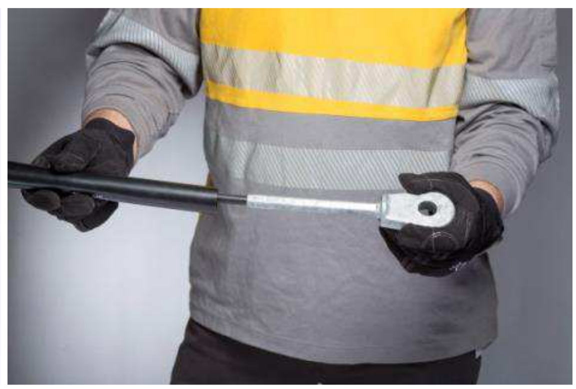

Figure 3: Compression Dead End.

The covered carbon composite core conductor has a greater minimum bending radius than the bare cables currently being used. Therefore, to protect the cable aluminium armour rods were used at every support pole. Preformed metallic top and side ties were then used to hold everything in place and to grip the cable to prevent slipping. To protect against wildlife the ties and armour rods are fitted with polymeric covers.

A development project is currently underway to develop a polymeric system to replace the armour rods and metallic tie tops. For these early installations, the fully metallic system with polymeric covers is being used.

Earthing of the line during maintenance work is important. However, any earthing bail directly attached to the line may remain energised if the line falls to the ground. To protect against this, the earthing bails are fitted on to clamp top insulators which are attached to the pole. A 16 mm^2 insulated copper cable crimped to the bail is then connected to the cable via an insulation piercing connector similar to the attachment of a surge arrester as seen in Figure 6.

LIGHTNING PROTECTION

The protection of any insulated conductor against lightning induced damage is very important. Numerous studies have shown that lightning impulses travelling along the line will flash over at terminations and support structures[10]. The flashover may cause a pin hole through the insulation that will allow moisture in and eventually causes corrosion issues. Alternatively, the flash over initiates a power follow that will potentially result in the line burning down. Although the trial installation area chosen does not have a high isokeraunic level, it was decided to be prudent and adopt a similar strategy to Northern Queensland and install surge arresters every 300m[11]. The surge arresters used were the standard surge arresters that the utility currently purchases under contract. The surge arresters are connected to the line via a 16 mm^2 insulated copper cable using the insulation piercing connector previously discussed. A view of an attached surge arrester can be seen in Figure 6.

To further protect against pin holing and burn down at support structures, the aluminium armour rods and metallic ties are connected to the line via an insulation piercing connector attached to the top or side tie. This then forces the flash over from either the tie or the armour rod thus protecting the cable.

FIELD INSTALLATION

The novel construction and properties were trialled in a high fire risk environment in the Otway region of Victoria, Australia, where the SWER system was converted to an underground supply; the pole infrastructure was utilised to string the new design. The section chosen for the field trial incorporated a number of modest span lengths with the longest being 380m. The elevation difference was modest with a 50m differential, however, there were a number of large angle deviations (30-35°) at the suspension poles requiring insulator side ties in addition to pole top ties with minor deviations (0 to 5°). The installation site was 25km from the coast with some low hill sheltering and plantation forest surrounding the majority of the installation length. Pole top ties and suspension clamp geometries were trialled. Compression dead end and mid-span joints were included in the trial. Electrical connections were achieved via insulation piercing connectors (IPC's). Connections to the existing network (surge arrestors, transformers etc.) and the customer were via conventional conductors.

Figure 4: Field installation site – Otway's Region, Victoria, Australia.

This installation allowed for installation procedures to be examined for both the conductor and fittings in a typical field environment without interrupting supply to customers. The conductor was installed via a pull through via the existing SC/AC conductor with readily accessible equipment. A conventional pulling sock with a swivel connector was utilised. As with any conductor design, special attention is required to the type of installation equipment and the procedures required, this is particularly important for managing the bend radii encountered during the installation of carbon composite core conductors.

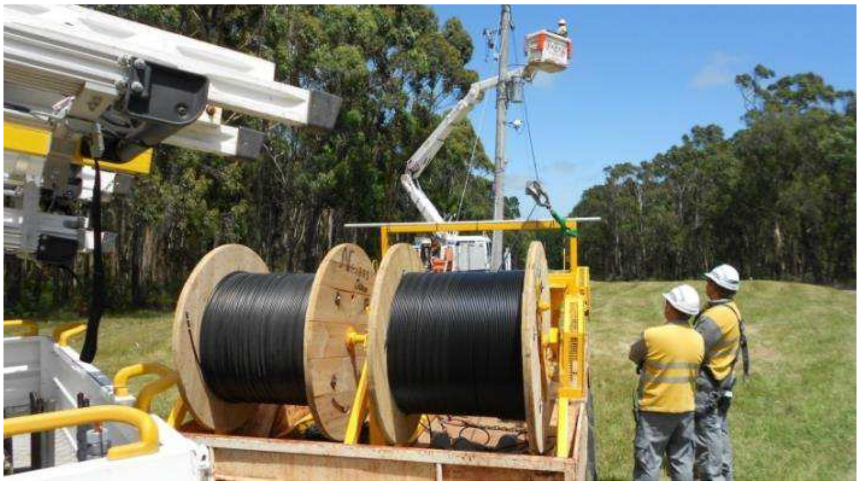

Figure 5: Field installation site – Otway's Region, Victoria, Australia

Examination and testing of the installed system over nine months were carried out. The temperature range that the field installation experienced was from a minimum of 1.6°C to 40.2°C; a maximum wind gust of 100km/hr and 433mm of rainfall.

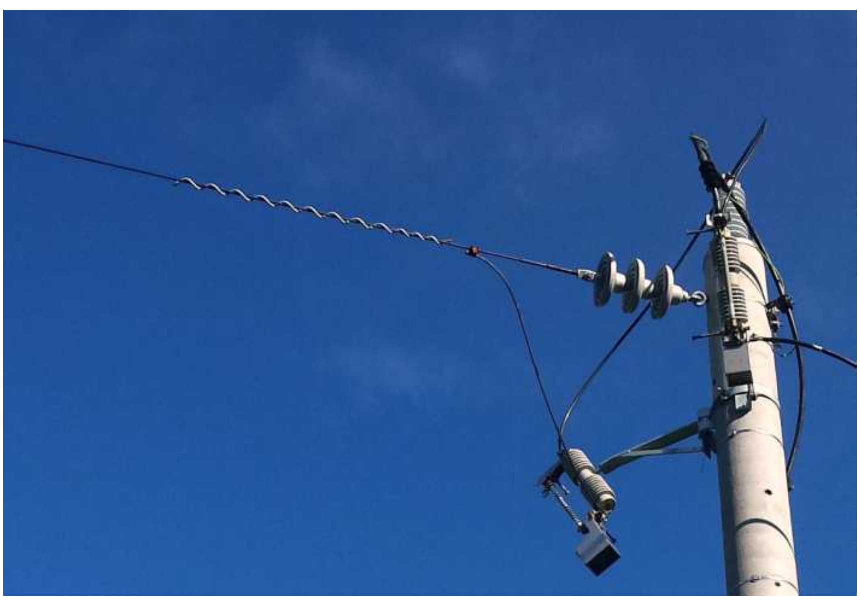

Figure 6: Covered Carbon Composite Conductor, Compression Dead End, Insulation Piercing Connector (connected to existing downstream electrical infrastructure via insulated 25mm^2 stranded plain hard drawn copper), and Spiral Vibration Damper.

CONCLUSIONS

The development of a covered carbon composite core conductor and fittings suitable for high bushfire risk regions allows Governments and Utilities more options to improve the safety of networks currently serviced by bare overhead conductors.

A covered carbon composite core conductor was successfully installed with conventional, common and readily available equipment. Care and attention are required when handling the covered conductor with particular emphasis on maintaining minimum bend radius during the installation.

The mechanical and electrical fittings are tailored to the conductor. These fittings are installed in a standard manner. The use of compression tooling for the dead ends and mid-span joints although familiar to transmission installation field crews may require specific training for distribution field crews who typically work only on 22kV and 33kV networks.

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