A New Overhead Line (OHL) System

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Introduction

For over 100 years OHL has been the standard and near universal method of tramway and light rail electrification. In a few cities where the historic or architectural environments were considered to be special, alternate electrification systems were developed. These included a variety of surface contact systems, and the conduit, with underground conductors reached through a slot in the road surface. This last method was used in London, Washington, Paris, Brussels and other European capital cities. All the surface contact systems invented were short lived due to high costs, but more importantly, unreliability, including the electrocution of horses then used to pull carts. This has left OHL as the only practical and economic system for electrification until another surface contact system, which has recently been used for the new Bordeaux tramway, and high tech battery operation over short unelectrified parts of a tramway. As well as these, mechanical systems of compressed air, diesel engines and fly-wheels have also been used to avoid the need for OHL.

Electrical Functionality

An OHL system needs to perform several sometimes conflicting functions. It needs to convey electric current to the pick-up of the tram car or LRV via a trolley pole or pantograph. In the circuit between substation and tramcar, the OHL has a resistivity, an order of magnitude higher than the track return path. So the first function of the OHL is to have a minimum resistivity. Resistivity can be reduced by using better conductors, or larger cross sections, usually achieved by means of a catenary or a parallel feeder system. Stringing up a second cable or installing a parallel feeder have higher capital and maintenance costs than a single trolley system.

Mechanical Functionality

The OHL must be strong enough to carry the conductor weight and resist weather forces of wind and icing especially. Finally, the OHL must be able to accommodate the force exerted by the pantograph. Two main support systems have been developed:

- Span wires between poles or directly hung from buildings.
- Bracket arms from poles, carrying the OHL for one or two tracks.

Single wire trolley systems have been supported directly by insulated ears off either span or brackets. This, however produces hard spots in the OHL that cause the pantograph to bounce, a source of arcing and rubbing strip damage. Catenary OHL uses registration arms to achieve a horizontal zigzag to even pantograph head wear. A catenary however, achieves an equally soft interface for the pantograph, ensuring maximum pantograph and OHL life, and the best contact conditions.

In the UK of late, the size of foundations for OHL street poles has got to the stage where under footway plant and utilities must be diverted to provide the space for a nearly 1m cube concrete base. Such poles and foundations are appropriate for main line railways but excessively over designed for street tramways. The tension of a trolley wire system depends partly upon the design of the support system but is heavily temperature sensitive, being slack in hot weather and taut in the cold. On the other hand, catenary systems are pre-tensioned with weights and springs to maintain a constant tension in the contact wire. Ideally, street OHL systems should have the contact wire tensioned, but catenary style systems are inappropriately bulky and certainly aesthetically obtrusive.

Aesthetics

Many cities have spent considerable sums burying telephone and electric cables to reduce or remove entirely a clutter of wires along and across city streets. Tramway promoters who want to reintroduce a network of OHL to power their tramways need to produce elegant designs, comparable examples and persuasive arguments to convince planning authorities. When a world heritage location like The Vienna Opera House is not only framed by tramways OHL, but actually provides attachments to reduce the need for poles to support span wires, then almost anywhere could justify a new tramway, using elegant designs to address aesthetic issues?

Carnforth new OHL installation

As a result of the analysis above, a new approach to OHL design has been developed and a prototype 1200m system was installed in the last quarter of 2004 at the Carnforth Rail Centre in Lancashire UK. The starting point for the design of this installation was the fundamental equation describing the installation of wire simply supported. This allows the trade-off between support spacing, wire sag and OHL tension to be computed.

OHL conductor

The majority of tramways use a 12mm diameter grooved copper (alloy) conductor, which has a cross-sectional area of 120 mm^2. In order to reduce electrical resistivity, a larger diameter (14mm) conductor was selected with a cross section of 150 mm^2. Resistivity is about 25% lower, but diameter and therefore issued perception, only 14% bigger. However, the larger wire is also 25% heavier per unit length.

The Poles

The Carnforth site already had a variety of steel and wooden poles, all over 50 years in situ, and two steel over-bridges. Having considered the options from the above equation, a support spacing of 50m on straight track and 25m on curves was selected. The existing supports were augmented by 24 timber poles, 9m long, supplied and installed by United Utilities. These simple wooden poles are usually used in fields to support 3-phase agricultural supply lines. As for field installations, the poles were set 2m deep into compacted soil, the Carnforth site proved to have erratic soil conditions with quarry waste and steam locomotive ash forming the majority of the ground. Within an hour of erection, the poles were strong enough to allow an installer to climb up with spiked boots. 24 poles were erected in two days with a single team, auger and a mini-JCB.

OHL Supports

Most of the OHL is supported by bracket arms attached with stainless collars to the poles, and held horizontal by stainless steel ropes fixed to the top of the pole. A couple of span wires, using stainless steel ropes, were also used. The OHL is suspended off the bracket arms or span wire using self insulating ‘parafil’ strops, 2m long. These were tied around the bracket arms and then clamped into place with grub screwed rings. The ends of the parafil strops are attached to the OHL, into simple clamp line ears. The strops are inclined to the horizontal to pull the OHL off the track centre line, and thereby achieve a zigzag to even pantograph wear. On curves, the strops are inclined to the outside of the curve, and therefore allows the OHL to follow the pan head.

Installation

Once the poles were erected, the bracket arms or span wires were put in place. Then temporary pulleys were attached to alternate poles. The 1200m long OHL for the whole installation was pulled through using a pilot rope and winch. Starting at one end, the OHL was anchored and then progressively attached to further bracket arms or span wires over a 300m stretch, whilst a 30,000N tension was applied using a hand operated turfer winch. Thus the OHL was fixed into position and tensioned in 4 stages. The fixing of the OHL was undertaken from a mobile ‘cherry-picker’ work platform. For much of the installation, this work had to be undertaken over historic rail vehicles parked on the track, and sometimes also over an adjacent track.

Maintaining tension

Once the while 1200m OHL was up, the last part of this new system was applied, side tensions. These enable a continuous and single OHL, reducing costs by avoiding the need for overlaps to end tensions. The second advantage of side tensioning is that a line tension of 30,000N can be maintained by weights of between 50 and 100Kg, which can easily be accommodated inside tubular steel poles. The third advantage of side tensioning is that the tension up spacing can be flexible to suit the geometry of the OHL. At curves, side tensioners can also compensate for temperature variations to ensure that the OHL remains at the correct alignment, and within sag specification.

Conclusion

A new OHL using a low resistivity single conductor has been demonstrated. This reduces costs and visual impacts, whilst satisfying the mechanical and electrical performance needs. A month after the prototype installation was completed at

Carnforth, winter gales blew down 25% of the trees on the site, and some OHL on the WCML was damaged. The new OHL described here remained intact.