Return to Session

CHALLENGES AND OPPORTUNITIES WHEN INSTALLING HV CABLE IN AUSTRALIA AND SRI LANKA

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ABSTRACT

Those involved in the cable installation field know only full well, every installation project has unique challenges, with no two installations being exactly the same. Having just completed two significant 132kV cable contracts in two completely different cities, we believe there are however, some valuable lessons learnt for future projects.

This paper looks at the design and construction of two projects, one in the city of Colombo, Sri Lanka and the other in the city of Brisbane, Australia. Both are the most significant cable projects for each country and in both cases the objective was to extend the 132kV power supply system and optical fibre communication system together with the construction of new substations. The paper describes some of the key aspects of each project and compares similarities and differences.

KEYWORDS

Turnkey projects, design, cross bonded systems, ducted installation, traffic conditions, cable installation, construction works.

INTRODUCTION

To meet the increasing demand for electricity in the highly populated growing capital of Sri Lanka, Ceylon Electricity Board (CEB) decided to upgrade the existing 132 kV network in Greater Colombo area. There are two main load centers in Colombo naming Kolonnawa and Pannipitiya substations, which are connected to the National Grid by overhead transmission lines. These substations are also connected together by an overhead 132 kV transmission line. The new link comprised the establishment of four 132 kV underground cable circuits and the associated optical fiber circuits between the above substations via three new grid substations at Maradana, Havelock Town and Dehiwala forming a ring connection to increase the reliability of the power supply in the Greater Colombo area. Never before has an underground cable project of this magnitude been undertaken in Sri Lanka.
Olex Australia won the contract for Design, Supply and Installation of approx 80 km's of 132 kV power cables and associated optical fiber cables on turnkey basis.

Energex, a supplier of electricity in State of Queensland, Australia, had identified a major infrastructure project to reinforce and ensure reliability of electricity supply to Brisbane Central Business District. The City Grid project brief was to design & install and commission approx 75 km's of 110 kV power cables and associated optical fiber cables. Unlike Greater Colombo Project, the City Grid project consisted of three separate contracts, i.e. design, supply and construction and all three contracts were awarded to Olex Australia Pty Ltd. The objective of this project was to extend the 110 kV power supply system and optical fibre communication system in the Brisbane area, by constructing two 110kV cable circuits and Optical Fibre communication links between the existing Charlotte Street Substation and the new Carindale Termination Point via Wellington Road Substation.

Being two large EHV underground cable installation projects of similar size one in South East Asia and the other in Australia there are similarities as well as differences both in design and construction aspects of each project. The Greater Colombo Grid substation project was to be constructed in a densely populated South East Asian city where as the latter was in a developed city in Australia. However the challenges were somehow similar as in both projects the cable route passed through the main CBD districts of Colombo and Brisbane, design approvals from the clients were required, construction permissions/permits were needed prior to start of construction activities etc. The Colombo project was funded by a German loan and the payment process was more complicated and time consuming when compared to the project in Brisbane. The rules, regulations and formalities imposed by different regulatory bodies in both countries were very challenging causing difficulties and there were delays in completing both projects due to third parties works.

DESIGN SIMILARITIES

Preliminary designs for both projects were done by the Client's independent consultants and the detailed designs for the cable circuits were finalized after the award of contract.

Both projects comprised of cross bonded systems to optimize cable circuit ratings. On both projects similar cable accessories were utilized. Temperature monitoring was also one of the key design features on both projects and most importantly the cables were installed in a fully underground ducted system to minimize traffic disruptions.

Water blocked Milliken sector plain annealed copper conductors with semiconductive conductor screen, superclean XLPE insulation, semiconductive insulation screen, and semiconductive swellable tapes are some of the similarities in cable designs.

The native soil thermal resistivity, practicality of the joint bay locations, identifying existing underground services and selection of correct backfill materials were key inputs in finalizing detailed designs for projects.

Return to Session

DIFFERENCES IN DESIGN

Cable Design

For the Colombo project, 1000mm^2 and 800mm^2 copper cables with lead sheath, including copper wire screen and HDPE sheath were utilized. Optical fibres were incorporated within the construction of power cables for temperature monitoring.

For the Brisbane project 1600mm^2 copper cables with copper sheath and a dual layer of outer sheath consisting of PVC and HDPE were utilized. A separate optical fibre cable was installed for temperature monitoring and communications.

System Design

The Colombo project system design constituted of 3x 110 kV power cables spaced and laid in flat formation with transposition of cables at joint locations. The Brisbane project system design was based on 3x 110 kV cables laid in trefoil formation.

Duct Installation

The ducts used for the two projects were different in type, size and the jointing methods.

For the Colombo project 250mm HDPE pipes were utilized. The method used for jointing the HDPE ducts was Butt Fusion.

In the Brisbane project, low cost PVC pipes were used and jointed with adhesives. To ensure that there were no irregularities at joint locations; Olex developed a special purpose camera with onboard recording facilities and structural light source for the inspection of ducts installed in Brisbane Project.

DTS Unit

A long range 30 km using single mode fibres was installed in Colombo as the optical fibres were incorporated in the cable, whereas in Brisbane because the optical fibres were not in the cable a DTS unit utilizing multimode fibres was installed which gave a better spatial resolution.

132 KV COLOMBO PROJECT

Civil Works

Trench excavation, duct installation and backfilling the trench with selected backfill was the first phase of the civil construction works for both projects. Construction works in Colombo differed in many ways from the project in Brisbane even though the two projects had similarities in design, cable and accessories requirement etc. This was mainly due to the differences in the conditions of the two cities. Colombo is a typical South Asian city where the population density is very high and traffic conditions are congested due to under developed road systems. The roads are very narrow, (in many cases only two lanes) and poorly maintained. When compared to Brisbane, Colombo is not a planned city and there are hardly any alternative routes for the movement of traffic so that diversion of traffic is not an option for the construction works. It was a big challenge to carry out the construction works with minimal traffic disruptions.

Photo 1: Busy Roads in Colombo

Permission from the City Traffic Police department was mandatory before commencement of any construction works. Obtaining permits was perhaps the biggest problem as the department was reluctant to grant permission due to the traffic disruption that would be caused by the construction works. It was with great difficulty that the weekly permissions were issued, and when issued, only allowed works during the night for most sections, resulting in a very difficult situation. In most cases the works could be started only after 9pm and had to be finished before 6am. In some instances it was required that the trench be backfilled and reinstated before dawn. It should be noted that the amount of night works allowed in the tender documentation was far less than the actual night works required on site, resulting in a significant increase in costs.

HDPE ducts were installed for the cable installation in Colombo. A training program for jointing HDPE ducts was organized by the European supplier of ducts in Colombo.

Advantages of using HDPE ducts for power cable installation

HDPE ducts are flexible/elastic and therefore are suitable for installing ducts in bends. The material is not brittle and is suitable for rough handling. The material is very strong and gives more protection to the cable.

An HDPE pipe when joined properly gives adequate protection to the cable outer sheath during installation. Angle joints are also available for bends.

There are two main methods used for HDPE duct jointing,

1. Butt Fusion – Time consuming, cheap
2. Electro Fusion – Fast, Expensive

Butt Fusion Method was used in Colombo project.


Photo 2: Jointing HDPE pipes

The existing underground services in Colombo roads made the construction works very difficult. The narrow roads are full of clustered underground services leaving hardly any space for new services. Proper records of the existing underground services were not available before the start of the construction works. The preliminary investigations (trial hole excavations) carried out at the design stage were not sufficient to locate the existing services. The lack of records resulted in many damages to the existing services during excavations costing more money and time. Since the proposed 132kV cable circuit required specified clearance from the existing services to maintain the current rating of the circuit, increase in depth was required in many instances resulting in wider trench widths as per the depth spacing charts. The design chosen for the majority of the route was to have the ducts 'unfilled', this meant that it was possible to have Bentonite mixture pumped into the ducts after cable installation to compensate for the lack of axial spacing between ducts where increase of the trench width was not a practical option.

<u>Special Constructions - Colombo project</u>

There were several sections of the cable circuits in the Colombo project where the construction of the cable circuits was extremely challenging.

1) 500 meter long marshy land crossing in the Dehiwala to Pannipitiya circuit.

The original design of the marshy land crossing consisted of installing cable ducts inside a concrete channel constructed above the ground level. This channel was to be supported by concrete piles driven down to the bedrock; however, the construction of the concrete channel was to be carried out parallel to and away from the existing road along the marshy land. The marshy land was declared as a bird sanctuary and therefore it was a concern from the environmental authorities to build a concreted channel above ground in marshy land. As an alternate proposal a low cost alternative method was recommended by digging a deeper trench of 3m and to improve the ground under the cables by filling the trench with quarry dust up to 1.5 meters level.


Photo 3: Installation in Marshy land

2) Baseline road crossing

Baseline road was a major newly built 9km long road in Colombo. Initially there were ducts installed for the proposed 132kV cables during the construction of the road but they were not in the correct location and not usable. It took six months to get the permission from Road Development Authority for installing new ducts across this road.

3) Under bed canal crossings

There were three under bed canal crossings in Colombo project. The requirement of the local authorities is that the cables should be installed at least 1.5 meters below the canal bed.

4) Bridge crossings

There were three main bridge crossings along the cable route with no provisions to install any services. Independent cable support structures were designed and constructed. The designs had to be without any support columns in the middle of the canal as this would obstruct the flow of the canal.

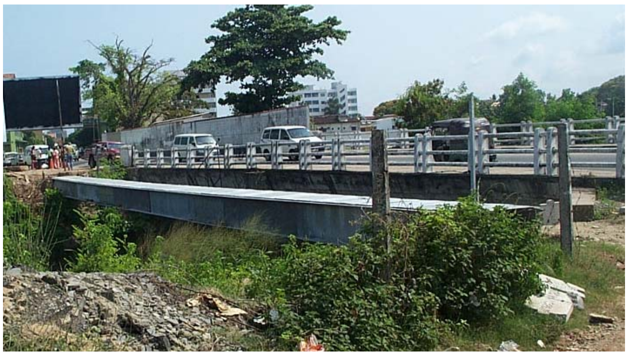
Photo 4: Bridge Crossing

5) Construction of cable trench along the Galle road.

Galle road is one of the busiest roads in Sri Lanka. The construction works could only be carried out between 9 PM with the trench to be backfilled and reinstated by 5 AM to allow traffic movement during the day.

6) Culvert crossings

There were many culvert crossings along the cable route. Most of these culverts are designed as box culverts. Drilling through the culverts was not accepted due to the concerns that this may affect the strength of the culvert and obstruct the flow of water. Given the restrictions we had to cross the canal under the box culverts. Some of these box culverts were more than 2.5 meters deep resulting in a 3 meter deep trench.

Photo 5: Culvert crossing

Cable installation

The cable installation works were carried out during weekends except for the Galle Rd sections which were done at night time.

The cable drums were transported to site on low bed trailers during the night time and then lifted one by one on to the drum stands using hydraulic jacks. Steel ropes, caterpillar pushers and a hydraulic winch were used to pull the cables. During pulling the bends were kept open and corner rollers were installed to facilitate cable pulling. Cable lubricants were applied to the cable over sheath at each pipe duct entry and removed before the caterpillar pushers to improve grip.

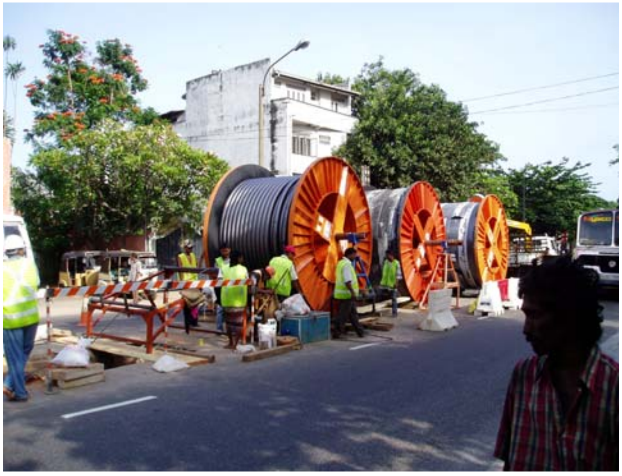

Photo 6: Cable drums in position, ready for cable installation.

Photo 7: Cable installation in Colombo.

Local community acceptance of construction works

To overcome the public frustration due to traffic disruptions, the local project engineers developed an innovative solution by colorfully decorating the jointing huts to display an image of an operating room and slogans that the work of installation of cables and jointing was providing a community benefit.

Photo 8: Specially designed enclosure over joint bay for HV cable jointing in controlled environment.

BRISBANE PROJECT

Civil Work

In Brisbane, project signed agreements from major service providers were obtained during design phase. The design scope included geotechnical, acoustic, dilapidation, earth resistance survey, earth potential rise report, low frequency induction report and to carry out thermal survey of the entire route. The biggest challenge we faced was to obtain the necessary permits/approvals from major stakeholders in both projects. In both projects, pre-mould joints were used and special joint bay arrangements were made. In this respect Brisbane being a more developed/planned city, construction of underground cable circuits was easier than Colombo. Since the roads are wider with multiple lanes traffic could be managed easily when compared to Colombo. Also there were options for the alternative routes allowing the contractors to completely close the roads if required. The night works and weekend works was required only in the exceptional cases like major road crossings. Use of mechanical equipment, FTB as backfill material, fewer obstructions from the existing services made the construction works in Brisbane much faster than Colombo.

Because of the easier conditions previous practice was to install the cables in trenches without ducts. However we felt that despite the additional costs of pipes overall project cost savings could be made by adopting a conduit system approach. Low cost PVC pipes were used and joined with adhesives. With this system there is a requirement to thoroughly clean and inspect the ducts before cable pulling to ensure that the cables can be pulled through these ducts without any damage to the outer sheath. The specification called for CCTV inspection of all conduits prior to cable installation.

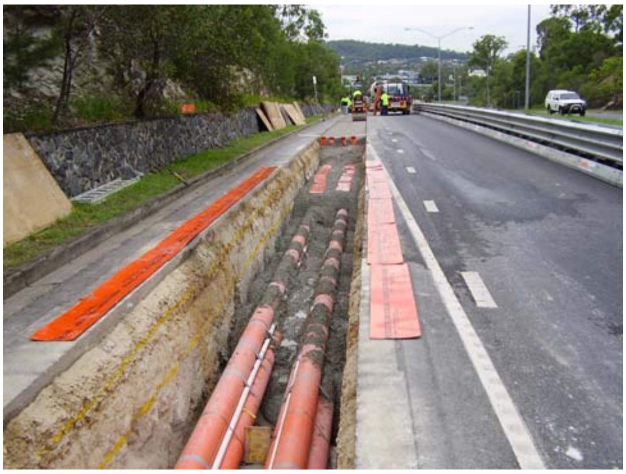

Photo 9: Backfilling of cable trenches.

A special purpose built camera sled with on board recording capabilities and structured light source unit was used. It was attached behind the pigging assembly for cleaning ducts to ensure that the cables can be pulled through the ducts safely and without any damage to the outer sheath. The pigging assembly is attached to the hauling rope connected to a winch located in the joint bay and the camera unit is attached to the last foam pig. The pigging assembly, camera and haul rope are pulled through the conduit. On completion of cleaning activity the camera is removed and the footage viewed on site to verify the suitability of conduits for cable installation. The camera is capable of being operated for up to four hours. Considerable savings in cost and man-hours were achieved with this innovative approach when compared with conventional CCTV approach for monitoring.

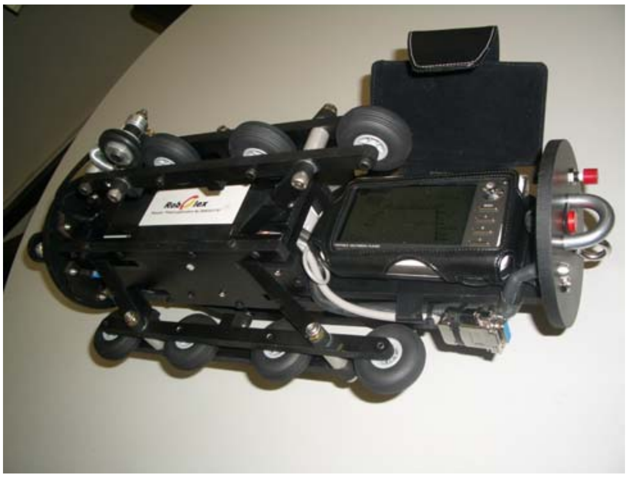

Photo 10: Robotic cable inspection system with digital camera and laser scanning

Special Constructions - Brisbane project

Design features included directional boring under major roads, railway lines and waterways to install the ducts prior to cable installation and cable installation along the Captain Cook Bridge in Brisbane. A special gantry had to be constructed attached to the under side of the 550m long bridge with appropriate cable support structures inside. The captain Cook Bridge has two structural joints along the bridge where the concrete structures move vertically with the load of traffic and horizontally with the expansion due to changes in the ambient temperature. A special cable support device had to be designed for the gantry at these locations to absorb the movement of the structure.

Photo 11: Installation of cables on Captain Cook Bridge

Cable Pulling

Use of motorized mobile drum stand and high capacity caterpillar pushers in Brisbane substantially reduced the tension on the nose of the cable even for longer sections. The maximum pulling tension applied on the cable during cable installation was around 20 kN with the use of above mechanized pulling equipments. Cable drums were transported to site using a specialized design low bed truck with a motorized drum stand.

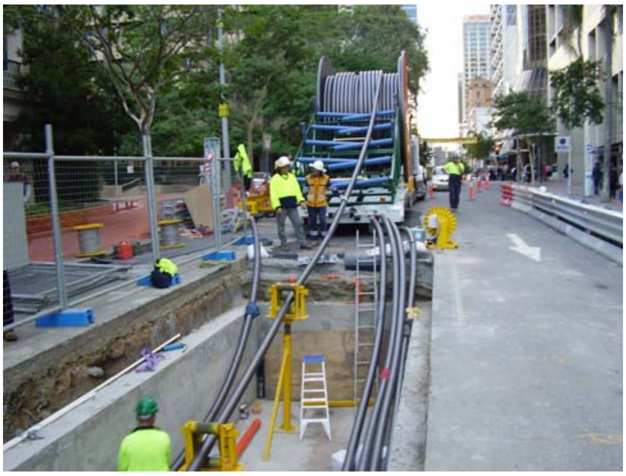

Photo 12: Cable Installation in Brisbane

For most of the sections only one caterpillar pusher was used with the winch and motorized drum stand. The caterpillar pusher was located close to the drum and cable lubricant was applied to the outer sheath prior to cable entering the ducts. Using the caterpillar pushers at the beginning (close to the drum) brings several advantageous. The pushing forces applied on the cable by caterpillar pushers at the beginning, reduces the sidewall pressure on the cable at the bends resulting in a reduction of overall pulling force. Removal of lubricant is not required as lubricant is applied after the caterpillar pusher. It is not possible to remove the lubricant completely from a moving cable before it comes to the caterpillar pusher which makes the grip between the cable and caterpillar pusher in affective.

CONCLUSION – LESSONS LEARNT

Greater Colombo Grid Substation Project

From the experience gained in Colombo during the 30 months project period; we learnt that one of the significant factors affecting the progress of projects in south East Asia is the approvals from third parties. Most of the utility authorities in these countries are still operated as government organizations governed by strict rules and regulations. Contractors should carefully examine the extent of the principle approvals obtained by the client for the project. It takes more time to get the approvals for designs and hence more time should be allocated for the design stage for these projects.

A major obstacle for the construction works on the roads of a developing country is the very difficult traffic conditions due to under developed road systems. Also the clustered arrangement of existing underground services makes the construction much more difficult. Slow progress is expected on site due to above reasons. Also the contractors should carefully analyze requirement of night works.

Most of the projects in the third world counties are funded by foreign funding agents as per loan agreements between two countries. This can cause delays in the payments due to lengthy approval process before the money is released.

City Grid Project - Brisbane

Each State in Australia has different rules and regulations and it is very important to obtain the appropriate licenses from the regulatory bodies prior to the start of project works. The safety regulations to be followed and the legal requirements to be fulfilled by the contractors can also vary from one state to another.

Experience on these projects proves that the use of HDPE pipes rather than PVC pipes is better for cable installation projects. Use of HDPE pipes has several advantages as described above. Most importantly the availability of proper jointing methods of HDPE pipes reduces the risk of damaging the cable inside the duct during cable pulling. Duct proving is not required in case of HDPE pipes. However the cost difference of two options has to be considered depending on the size of the project.

A feature of the City Grid project was cable installation along the Captain Cook Bridge. The cable gantry had to be designed in a way to absorb the vertical movement with traffic and the horizontal expansion with temperature. This design protected the gantry itself and the HV cables from the mechanical stresses during such movements. The important part of the design was the two cable support structures on the gantry which were designed to absorb above mentioned movements. Valuable information was obtained by carrying out a full scale tests in the cable dynamics laboratory at Olex. The cost of this testing could be easily justified by the data obtained for use in developing cable installation methodologies.

PVC sheathed cables were used for the bridge section as the specification required fire protection (all cables of the other sections have HDPE outer sheath). It was noted during installation that the pulling tension of PVC sheathed cables was much higher than the calculated pulling tension values. This is because the outer PVC sheath of the cable is softened when the cable is exposed to sunlight resulting in a higher friction coefficient between the PVC sheath and PVC ducts.

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