Session Four:

**Technical Solutions for the Installation of High Voltage Cables**

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**Innovation in action**

**Abstract**

Each Turn key project presents a different set of technical issues that require technical innovation to resolve. On most projects the need for innovation is identified well in advance of construction commencement and hence there is plenty of time to develop and trial a solution or solutions. Other projects with tight time constraints may dictate that innovative solutions are developed on the run. Both scenarios require the right people with the right skill set to be proactively involved. Olex has now gained significant expertise in innovation from completing several turnkey projects both locally and internationally. These projects have each enabled Olex to develop specific tools, materials and skill sets to enable successful completion of the project.

**Introduction**

Olex as an organisation has been undertaking turnkey installation projects for underground Extra High Voltage and certain submarine projects since 1991. This service has been offered as a means of supporting the core business of cable sales but is now regarded as a critical component of Olex business. Each project brings its own technical challenges and as a direct result Olex has developed people, hardware software and systems that enable the greater majority of these challenges to be dealt with prior to construction commencing. Each project, however, is unique and will have a technical challenge that is very much specific to itself and as such a specific solution to deal with that challenge needs to be developed. Generally such a solution can be developed prior to construction but on every project there are challenges that must be dealt with during construction.

Every technical challenge requires a level of innovation to be able to develop a solution that meets the criteria of:

a) will this solution integrate with all the other technical aspects and requirements of this project?  

b) will this solution meet the lifetime requirements of the project?  

c) does this solution fit within the time and budget constraints of the project?
d) Does this solution add value to the project, the customer and Olex?

For innovation to occur the right people with the correct skill set must be motivated to proactively seek a solution that meets the above criteria. Some key questions that must be asked prior to a solution being developed are;

a) do we have the right people to develop a solution in house and if not,
b) where can we source the expertise to develop a solution and do they have the people and equipment to develop a solution on Olex behalf and finally,
c) will any solution developed stand up to an independent third party scrutiny.

Olex has undertaken multiple recent turnkey projects that have successfully demonstrated a high level of technical innovation and this paper will be highlighting the challenges faced and the technical innovations developed to overcome these challenges.

**The Tamar River 22 kV kV Submarine Project**

To enable reinforcement of its distribution network in Northern Tasmania Aurora Energy in Tasmania determined that a 22 kV feeder be installed that would cross the Tamar River near Georgetown. The project was a combination of underground and submarine cable and necessitated some specialised solutions to manufacture and install the cable. Submarine cable is a specialised product that is purpose designed to be installed in a submerged environment (either fresh or salt water). The timeline for the project was extremely tight with the contract awarded in February of 2007 and completion required prior to November of the same year due to the Shark migration season.

**Design of the cable**

Typically the basic construction of a submarine cable is similar to underground (distribution) cable in that three individually screened cores are laid up together and oversheathed with PVC, HDPE or a combination of both. Submarine cables are comprised of the same basic building blocks as underground cables but have the additional criteria that they must be completely waterblocked to prevent water penetration to the cores of the cable.

This water blocking is generally achieved by;

a) the extrusion of a thick layer of lead over the cores, the lead sheath makes the cable impenetrable to water as also provides mechanical protection to the cores underneath.
b) one or two layers of Galvanized steel wire armour and layers of bitumen are helically wound and poured over the lead sheath to provide mechanical protection to the cable during and after installation of the cable.

c) the extrusion of a thick layer of HDPE. The HDPE provides mechanical protection to the layers underneath and also additional water protection by ensuring that salt water cannot penetrate to these layers. This is as a result of the process of osmosis whereby the salt water changes to fresh water under pressure.

In addition the cable was provided as a totally waterblocked solution. This was achieved by not only waterblocking the cable in a radial direction through the layers described above but also by longitudinally waterblocking the cable such that if the cables outer layers are damaged and the water is able to penetrate to the cores then the water penetration is localised to the point of entry. This was achieved by:

a) water blocking of the conductor through the inclusion of waterswellable strings and tapes
b) decreasing the risk of water trees forming by extruding water tree retardant XLPE over the conductors. A tree retardant additive is added to the XLPE by the supplier.
c) Filling the interstices between the cores of the cables with foamed EPR rubber fillers and water swellable yarns
d) Applying waterswellable tapes over the laid up assembly.

Figure 1. Design of Cable Interstices fillers
The water swellable tapes and strings are impregnated with a powder that reacts with and then turns into a jelly on contact with either salt or fresh water. This reaction ensures that any penetration of water is limited to less than 1m either side of the cable damage.

Whilst radial waterblocking of the cable outer layers and waterblocking of conductors has been established and accepted for some time. An effective means of waterblocking the interstices of a three core cable previously had not been established. Given Olex expertise in cable design a solution was developed in house. Olex own research and development team was commissioned to undertake research and experimentation to design, develop and then prove a means by which longitudinal waterblocking of the interstices could be achieved with materials that;

a) would ensure that the budget for the cable would not be exceeded and
b) that could be incorporated in Olex standard manufacturing processes.
c) Ensured that the weight of the cable would not be increased as a result of changing the materials used in the cable interstices

Several materials were sourced and different configurations trialled to establish the most effective and efficient means of achieving this waterblocking method. The samples tested were hand made but with materials that were specifically selected as they could be incorporated into Olex standard manufacturing processes.

The optimal and final solution selected was as described above and is depicted in figure 1. The test method chosen (figure 2) to establish the effectiveness of the water blocking method was to place a length of clear plastic tube over the end of the sample, seal the tube to the sample using self amalgamating tapes, suspend the tube vertically, fill the tube with water and then track the progress of the waterflow into the cable. The solution chosen was the most effective at blocking the penetration of water into the cable.
Once the solution was established and approved the materials required to fill the cable interstices were sourced for production of the submarine cable. Given the very strict timeline for the project completion there was no opportunity to prepare and run a trial of the solution on the production machine. As such considerable preparation was undertaken in ensuring that the laying up machine selected would successfully complete the process. This preparation involved informing the suppliers of Olex requirements and providing them with information and equipment to enable a successful process.

The cable cores were then manufactured in accordance with Olex standard processes and the cores, EPR foamed filler, water swellable tapes and yarns were set up on Olex laying up machine (figure 3). The cores were successfully layed up over the course of a weekend under the supervision of Olex design team and then sent for further processing to complete the cable.
Design of the submarine cable hauling eye

The next issue in the cable design was ensuring that when being hauled water could not penetrate the cores of the cable. To ensure that this could event could not occur the cores of the cable had be completely sealed, this was achieved by placing a copper cap over and then soldering it to the lead sheath, over this a standard cable cap was crimped onto the cable sheath to provide mechanical protection to the copper cap underneath and additional sealing. A pulling stocking with additional length was then placed over this assembly, the stocking acts as a sleeve over the sheath and when tension is applied it locks onto the cable armour wires and the cable can be pulled (See figure 4). The cable hauling assembly was fitted on site prior to the cable being pulled and the basic assembly of the hauling eye arrangement is as shown below. The solution was developed in house and was fitted when the cable arrived at site by an experienced cable jointer.
Anchoring of the submarine system and Testing of the installed submarine/land cable system

The testing undertaken on the installed cable was as per the requirements of AS/NZS 1429.1 with a high voltage test and sheath voltage test. The issue for the submarine cable when it joins to the underground cable is that the armouring wires are attached to an anchoring mechanism to ensure that any movement of the submarine cable is not transmitted into the submarine to underground cable joint. Olex calculations showed that with tidal movement the cable joint could be subjected to as much as 5 tonne of additional weight. A single point suspension clamp as used in the mining industry with a 10 Tonne capacity was chosen to anchor the cable. In doing this it was identified that the metallic sheathing layer would be earthed potentially compromising the overall sheath integrity of the submarine cable and an end to end test of sheath integrity would not be possible.

To deal with this issue Olex designed an anchoring mechanism (See figure 5) during the construction phase of the project that still enabled the integrity of the sheath to be maintained for the entire length of the circuit whilst ensuring that no movement of the cable could be transmitted. The submarine to underground cable joint bay end wall was constructed of a thick layer of reinforced concrete, the armour wires were extracted and installed in the single point suspension clamp with the same methods used in the mining industry. The clamped submarine cable was then installed in a box that was fastened to the joint bay end wall, the box was then filled with a resin that set hard and was an insulating medium. Care had to taken to ensure that the resin selected that did
not raise to a temperature that would damage the cable core when the resin was setting (going off). A resin that did not rise above 70 °C was found and when assembly was completed the entire system was tested the sheath integrity was sound.

**Figure 5. Submarine Cable Anchoring design**

![Submarine Cable Anchoring design](image)

**Installation**

Given the size of the drums to be installed, the remoteness of the location where the submarine cables were being installed and that the cable would need to be removed from the drum on a barge it was determined during the construction phase by Daly’s Constructions (the cable installer) that a traditional drum stand would not be sufficient or safe to pull cable from. Daly’s designed and built a hydraulically spindle driven drum stand that could be installed and operated on flat surfaces that could be subject to movement (such as a barge) during installation. The drum stand was designed with a 45 Tonne capacity, can hold drums that are 4.5m high and up to 3m wide (See figure 6). Bearing in mind the potential for cable runaway during submarine cable installations the drum stand also has the capability to lift/recover up to 3 Tonne of cable weight.
Energex CityGrid Reinforcement project

Energex commissioned Olex to design and install a double circuit 110 kV system to deliver 220MVA using 132 kV cable and accessories. The system was part of the overall reinforcement of the Brisbane CBD supply grid and delivered power from Carindale terminal point to Charlotte Street substation in Brisbane via the Wellington Road substation. The contract for the design phase of the project was awarded in September 2005 and completed in December 2005. Manufacturing of the cable and construction of the system commenced in 2006 and all works were completed in March 2007.

Design of the cable

The cable design used was typical in that it comprised a copper conductor that is XLPE insulated, has a metallic sheath and a plastic jacket (See Figure 7). The conductor design was a 4 sector waterblocked 1600 mm² milliken conductor. A conductor of this size and construction with waterblocking had not been manufactured previously by Olex. In waterblocking a conductor of this size Olex had to take into account that an increase in diameter of the conductor was simply not acceptable as the conductor had to fit within standard accessory components. Waterswellable strings and yards were sourced and purchased and samples were manufactured and tested. The final solution chosen had no additional increase in diameter. This allowed the standard accessory
fittings to be used and means that where water blocked conductor is joined to non water blocked conductor special equipment and tooling to join the different conductor types (waterblocked to non waterblocked) were not required.

Figure 7. CityGrid Cable Design

Design of the Captain Cook bridge bow spring

The cables installed between the Charlotte Street substation and the Wellington Road substation had to cross over the Captain Cook Bridge, the bridge is designed in such away that it can flex and move due to temperature and load variation. The bridge flexing and movement would actually occur at a rate that could potentially damage the cable. To accommodate this Olex worked in conjunction with both Energex and the Victorian University of Technology to design, test and build a bow spring support frame (See figure 8). The support frame was constructed in Olex mechanical test laboratory using the exact materials that were used on the bridge. The frame was
subjected to loads that simulated the movement of the bridge over a prolonged period of time as the design must last the lifetime of the cable. The designed Bow Spring support was installed at the bridge expansion points to allow the cable to move with the bridge without the cable being damaged.

Figure 8. Bow Spring Test rig

Verification of the conduit status.

The CityGrid cable was completely installed in conduit, this method is preferred in highly trafficked areas whereby a short circuit of trench can be dug, the conduits installed and the trench backfilled within a short period of time. Once all the sections of conduit are installed the cable can be pulled through the conduit with minimal disruption to traffic and the associated safety and security risks of having an open trench. During installation of the conduits there is a possibility that foreign materials may enter the conduit that may dame the cable sheath during installation. The typical method of dealing with this was to pull a cleaner through the conduits prior to the cable being pulled through it. This, however still did not provide a guarantee that the conduit was both clean and undamaged. To deal with this issue Olex developed Roboxle (See Figure 9), Roboxle is a conduit inspection unit that was developed by Olex through a local engineering and research firm. The purpose of Roboxle is to provide a visual record of the inspection thus ensuring that no water or foreign objects are left behind after conduit installation and that the conduits themselves are not damaged.

Roboxle:

a) has a lightweight robust construction
b) has a Water resistant sealed design
c) operates in a variety of conduit sizes up to and including 300mm conduit.
d) its operating range is only limited by the recording medium.
e) has capability to playback footage on robot for integrity validation.
f) has active illumination including structured lighting system. (White Light)
g) has video recording capability on board
h) can display the distance travelled.
i) has a simple user interface (Power button + small joystick)
j) has a resolution camera with small focal length (fisheye) lens.

Robolex has been used extensively on recent Olex projects and is becoming a crucial tool in ensuring that a cable installation proceeds without damage to the cable.

**Figure 9. Design sketch of Robolex and photograph**
Conclusion

The need for innovation in any project environment is paramount, without innovation many projects simply would not be started or once started would not be completed on time and under budget. Generally this innovation is an effective means of risk management whereby a risk is identified prior to or during construction. To facilitate this innovation the correct people must be involved and be motivated and led to achieve the optimum outcome for the project. This means that there are effectively sub-projects within the main project and whilst these sub-projects are critical to the completion of the main project the innovation that is developed either as a collective or as an individual still must be completed within a timeframe and budget to ensure that the overall goal of the main project is achieved.

References:

“VERIFICATION OF MECHANICAL SUPPORT FOR CABLES USED ON BRIDGE STRUCTURES AT DILATION POINTS” by Vincent Roulliard (VUT), Ken Barber (Olex), Roman Piechota (Olex) and Graeme Barnewall (Olex)

Bibliography

Mark Jansen has been employed as an Electrical Engineer with Olex Australia since 1997. Mark’s roles have included systems design engineer, logistics project manager, Electrical test engineer and Cable applications engineer. Some key achievements in this time have been the condition monitoring of the Liverpool to Roskill 110 kV underground line in New Zealand, Commissioning the current Medium Voltage partial discharge test Laboratory in Olex Tottenham and more recently having a direct involvement is several key projects that Olex is undertaking on behalf of critical customers.

Mark is dedicated to his family and is actively involved in the community.