
# Study On The Most Feasible Method For 33kV Underground Cable Installation In Urban Area Of TNB Distribution (Selangor)

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**ABSTRACT**

Underground distribution cable is a vital part of TNB Distribution system in delivering the required power. Selecting the most suitable cable installation method is important and it has become more difficult nowadays due to stringent requirement imposed by the passage caretaker. TNB Distribution will have to deliberately consider both requirements from TNB and the passage caretaker. This study analysed and compared various cable installation methods to select the most suitable method to fit the location criteria. The independent variables of the research consists of three major criteria that influence the cable installation methods, which are the technical effect, the practicality and the cost effectiveness. The research used a multi-model approach where the effect of the independent variables on the dependent variable, which is the method of cable installation were evaluated by a developed matrix model. The technical effect of the various cable installation method was examined using CymCap Simulation programme. The field data was used to analyse the practicality of the cable installation method to determine the best solution with respect to the aesthetic value and the strict requirement imposed by the passage caretaker. The research also studied the cost effectiveness of the cable installation methods to be adopted. The combined results determined which installation method is most feasible in the urban area of TNB Distribution (Selangor) in Malaysia.

***Keywords:*** underground cable, installation method, criteria, cost, urban.

## 1. INTRODUCTION

Underground distribution cables are a vital part of any power distribution system. Correct installation of cables will ensure a reliable electrical system with a long operational lifetime and improved system security. To ensure a reliable underground cable network, care must be taken during the installation of the cables.

Distribution of electricity is one of the core businesses of TNB, hence high efficiency and optimum use of cable properties in delivering electricity for powering the desired load is of upmost interest. The selected method of installation shall optimize the current carrying capacity or known as ampacity (Abu Zarim, 2010). Other than that, the bending radius (TNB, 2002 ), pulling tension (Smith, 1981) and maximum pulling length (Seman, Silver, Bush, & Kendrew, 1984) must also be considered in choosing the installation method.

There are two mainly costs associated in choosing the right method of installation which are (SJHT, 2012) the initial cost and long-term cost. Initial cost consists of planning constructing and commissioning of the cable. Long-term cost includes any works that require direct access to the cable.

The selection of cable installation method shall meet the committed project duration. Short duration of project will require a less time consuming but reliable method of cable installation (Barber, 2004). Suitability and readiness of the installation methods for further works that require fast access to the cable during its operation and maintenance period shall also be deliberately weighed (Beament & Ford, 1993).

The decision in choosing which method of installation is very much influenced by the regulation imposed by the caretaker of the passage or locality where the work is to be carried out. The caretaker includes LLM, JKR (JKR, 2002) (TNB, 2002 ), KTMB and local authorities. Some of them impose more stringent requirement which may incur higher cost. They prefer the no-digging activity due to certain reasons, which limits to trenchless method. Nevertheless, the site condition shall further determine which method is more appropriate, practical and applicable. Space limitation, for instance may restrict the possibility to enable the Horizontal Direct Drilling (HDD) machine to be placed permanently until the installation work is completed. In addition, the number of cables or circuits to be laid together will also play a role in determining the most effective method (Wang, Chen, & Li, 2011).

If TNB were to follow fully the requirement of the caretaker of the passage, it will jeopardize the interest of TNB which are the technical properties of the cable and the cost of installation. Therefore, it is very important to determine the most suitable and practical cable installation method to meet the requirements of both TNB and the caretaker.

The research objectives are to carry out technical analysis, to compare the practicality of installation method in accordance to site condition and to study cost effectiveness of various installation methods for medium voltage underground cables adopted by TNB. This study aims to enhance knowledge and competency of TNB in choosing the appropriate method in laying cable based on area where the work is to be carried out.

The research questions for this study are; Does the installation method significantly related to the ampacity of the cable?; Which installation method allows for easy and fast access to the cable when required?; and Which installation method is economical but yet practical throughout the lifecycle of the cable?

This research is very significant in today's condition where the requirement for safe and efficient on installation of underground cables on distribution system is very crucial to not only TNB but also the caretaker of the passage. The policies and specifications normally being practiced by utilities are no longer applicable in the eyes of the caretaker of the passage. Hence, the caretaker tends to impose no digging policies or trenchless method in order to safeguard the topmost important criteria which are public safety and also aesthetic value of the said area. But in the other hand, the utilities are feeling bullied by the caretaker of the passage and the more important is the hike of cost during installation.

The philosophy adopted for this study is positivist epistemology. As mentioned above, the study is about engineering sciences where we discuss the installation method of power cables as well as its effects on cable technical properties; the practicality of the method in accordance to the site and the cost effectiveness of each method. The research output is derived from scientific, mathematical and observable facts which are related to positivism.

## 2. Literature Review

This research is a study on criteria for choosing underground cable installation method in Distribution Division, Tenaga Nasional Berhad. The study will focus on installation of cable on the paved road or along the road, which include the highway; and crossing the railway. Installation and any further works that require accessing to the cables on these routes would normally involves the process of getting approval from the caretaker of the particular area. The process could sometimes take a long time or even difficult or complicated before the sanction or approval is issued. Typical location factors that need to be considered when selecting type of installation (Heinemann & Scheid, 2013) include whether the location is in a wet or dry environment, if it will be used in a cable tray, direct buried, and the temperature rise that the conductor will experience including ambient temperature. The electrical factors that need to be considered include the amount of current that the circuit will carry, the length of the circuit run for voltage drop, and voltage of the circuit. Methods vastly used to install cable at this area include direct buried in trench and laying in pipes or ducts. This research will also explore the method of installing cable on tray in the utility tunnel.

### 2.1 Direct Buried Cable In Trench

This is the widely used method in installing the underground cables throughout Peninsular Malaysia by Distribution Division, Tenaga Nasional Berhad.

Cables will be installed in trenches excavated at site to the dimension in accordance to the cable laying practices by Distribution Division, Tenaga Nasional Berhad. The sizes of the trench must be appropriate to the number of cables to be installed.

According to Schlabbach, (2003) in order to fulfil the technical requirement when laying the cable; we can design the trench in a suitable way. Nevertheless, it must oblige the standards and norms, maximal current loading that the cable can carry as the most important criteria. He also found that the cost reduction when reducing the trench is in the range of 17% to 20% compared to standard practice.

It is also mentioned by Dudas & Rodges, (1999) that direct buried method are 80.3% used rather than cable installed in ducts. This was found from their survey in various rural utility co-operations. According to Dudas & Rodges, (1999), installation of cable in ducts is uneconomical but normally used in rocky soil or where direct buried method is impractical or not possible.

Obviously direct buried method of installation for underground cable is the best option because of its advantages; ie lower cost during installation and it gives the highest ampacity as compared to cable installed in ducts as concluded by Abu Zarim, (2010). Nevertheless, these types of installation are the main contributor for cable breakdown since it is prone to third party digging. Furthermore, nowadays the local authorities are not keen for the utilities to use this method. They are likely to impose trenchless method as an installation method.

Hanna, Salama, & Chikhani, (1993) found that it is important to keep ample spacing between the cables to avoid de-rating when cable laid using direct buried method. The uniformity of temperature distribution inside the trench increases the total ampacity of the system.

Direct buried method is only permitted for single conductors from Underground Service Entrance (Type USE) Underground Feeder (Type UF) as stated by Daly, (1999).

Furthermore the spaces between cables and the number of cables lay in the same trench give empirical affects to the cable ampacity based from analysis concluded by Wang, Chen, & Li, (2011). The cable ampacity increases as the space between cables and the number of cables reduces. Thus, the spaces between cables play a very important role but this condition can only be satisfied if the right of way provided are enough to cater this condition.

Direct buried is found as the most common method for installing underground cable whilst laying in ducts are the most often method used in urban area as explained by Bascom & Antoniello, (2011). Direct buried method is where the trench will remain opened until cable laying is performed.

Local conditions will dictate whether cables can be either installed using ducts or directly in the trench. In open trenches cable sand or surrounding soils were used for cooling purposes (Ton & Kam, 2013).

Direct buried underground cable is the second cheapest technology after overhead line, for any given route length or circuit capacity as conclude by (Sterling, 2012). It also represents the least expensive underground technology in term of Lifetime Cost.

### 2.2 Cables Laid In Pipes Or Ducts

Although direct buried method is preferred by TNB but sometimes cable needs to be laid in pipes or ducts especially in situation where direct buried method is not suitable and to ease maintenance work. Situations where pipes/ducts are required includes crossing of road, highway, railways, monsoon drain, culvert and river. This method is also chosen when the duration permitted for excavation and reinstatement works is very short and limited.

The most common methods used by TNB for cables laying in pipes or ducts are installation of cables in pipes in trenches via open cut; in duct banks with concrete encased and Horizontal Directional Drilling (HDD) or trenchless installation. TNB has also embarked on installing cables in tunnel or multi-service tunnel. This is especially implemented in Putrajaya and Kuala Lumpur.

According to finding by Abu Zarim, (2010), even though the cost of cable laying in pipes or ducts is higher than direct buried method, the option to choose the method depends on the local authority requirement. Most local authorities have strictly imposed of cable laying in pipes and ducts using trenchless method especially for urban and suburban areas. These are due to no-digging policies and aesthetic value of the particular area.

Ross (1974) also mentioned that use of cable ducts offers effective alternative for difficult crossings of highways and rivers.

According to Watkins (1951), designing a practical and good conduit system shall pay attention to technical requirement of the cables as well as the street layouts. A good conduit system shall stress upon its suitability for installation, protection, operation and maintenance of the cables contained. Controversial items include maximum permissible length of the conduit section between manholes which is highly dependent upon permissible cable-pulling stresses and friction factors of the conduit; and various bending degree and radii. Street layouts are also important in designing the conduit system.

From the workshop of reviewing current cable practice and pertaining issues in ten countries; (Barber, 2004) summarized that direct buried is still the most widely and commonly use due to its low cost incurred. In some countries, they install PVC or HDPE pipes with open trenches during the night to avoid traffic disruption. This method is followed by trenchless technology. There is a great interest by all countries in the use of tunnels. Japan and Korea chooses this method to avoid damages by external forces. Multipurpose tunnel is widely used in Japan and undersea tunnel is used in Singapore.

The privatisation of electricity company has raised the expectations of customers not only on the reliable and economic provision of electricity but also increased awareness in environment. More mechanically robust cable installation method such as laying in duct banks will help to combat the damage by the third party digging. Alternatively, East Midlands Electricity has considered trenchless method using ‘thrust bore’ or ‘guided moles’ in preference to direct-bury through open-dig, (Barrlett, Attwood, & Gregory, 1997).

Beament & Ford (1993) stated that London Electricity Board (LEB) has effectively and vastly used the method of laying cables in ducts with permanent joint pit structure which reduces the needs of future excavation and public disturbance.

In some European countries, the increase numbers of sewer and water lines built in plastic has made the installing of the electricity underground cable into the same right of way or the same concrete ducts or service tunnel becoming more attractive and practical (Jeyapalan, 2005).

Chamberlin (1987) reported that designs of underground electric distribution systems installed in ducts and vaults can vary greatly in cost, reliability, space requirements, and equipment.

Invernizzi and Zendri, (2005) mentioned that Rome adopted various methods of cable laying which include trenching, microtunnelling and multifunction underground structure or tunnel; with every method has its pros and cons. They are considering more innovative techniques and standards to minimize costs and duration of the cable installation in trench.

In the past, trenchless method were commonly used for crossing an obstacle such as highway, railway or river. Nowadays, Malaysian Public Works Department has imposed the regulation which requires all utilities to install their underground asset through trenchless method to reduce damage to the infrastructure and minimize disturbance to the traffics; as well as to preserve the aesthetic value as mentioned earlier.

There are various trenchless technologies available in the market but the most common being adopted by TNB is horizontal direct drilling. (Kramer, Rodenbaugh, & Conroy, 1994) mentioned that the cost of using trenchless technology continues to decrease as better equipment, increased competition, higher equipment utilization, and greater contractor experience become more common. Trenchless installation method offers an attractive and cost-effective alternative to open cut. HDD technology is used to install water, gas, heating, drain, sewers pipes and cables under obstacles such as rivers, busy streets, highways, airport runways, areas congested with buildings or underground utilities, and environmentally sensitive areas (Gierczak, 2014).

Horizontal directional drilling method utilizes to minimize environmental (Heinemann & Scheid, 2013) or community impacts. Horizontal directional drilling is a form of trenchless technology that allows pipelines to be installed underground while minimizing surface disruption. Directional drilling is used when trenching or excavating is not practical, such as in sensitive environmental areas. Horizontal directional drilling technology can be utilized for short or great distances through gravel, cobble, glacial till and hard rock.

Horizontal directional drilling (HDD) is intended to minimize above and below ground surface damage, restoration requirements, and disruption to traffic, with little or no interruption of existing services. HDD (Slavin, 2009) typically used for longer distances, greater depths, and larger diameter pipes, such as major river crossings.

HDD cable installations (McDonnell, 2013) raise long term maintenance problem such as additional time to locate and repair cable failures. Once the fault is located and identified, the entire section of cable containing the fault would likely need to be replaced, since the majority of this installation is inaccessible. The process of replacing the cable would be very similar to the original installation process.

There are several criteria that can affect the decision-making regarding the use of HDD and this criteria includes economic attractiveness and project delivery time (Baik, Abraham, & Gokhale, 2003).

HDD has inherent capabilities and is used for installing utility lines, making massive river crossings, high profile locations and large diameter projects have been possible due to innovation (Booman, Kunert, & Otegui, 2013).

In whichever methods of installations, maximizing current carrying capacity or also known as cable ampacity is very important, to deliver the desired load. Economic constraints and limitation on space availability contribute to the importance of attaining higher cable ampacity.

Wang et al., (2010) revealed that the ampacity of duct laying cable is influenced by the installation properties and condition. Cable ampacity increases as soil thermal conductivity and distance from external heat source increases. It decreases linearly with increases of soil temperature.

Zhang et al., (2011) also found that optimal design of cables installed in ducts and appropriate reducing in number of cables laid in vicinity ducts can further improve cable ampacity.

In-service underground cable generates heat that dissipates through the surrounding soil and affects the soil thermal conductivity. Wang, Chen, Chen, Li, & Yang, (2010) analysed and discovered that the ampacity of underground cable laid in the duct, increased significantly with the increase of the soil thermal conductivity and the distance from the external heat sources.

In addition, Hashmi, Millar, & Lehtonen, (2011) found that high temperature of in-service cable gives rise to temperature in vicinity soil creating moisture migration phenomenon which results in the decrease of cable ampacity. The effect is lesser for cables laid in the ducts than direct-buried cables.

Engineers have to deal with the safe pulling length, pulling tension and pulling friction especially when laying cables in pipes or ducts. Seman, Silver, Bush, & Kendrew, (1984) recommended that maximum pulling tension of cable should be observed during implementation. The use of pre-lubrication and concrete encase at duct bends are advisable.

Smith, (1981) suggested that accurate prediction of cable pulling forces is essential for designing pipe cable system. This is essentially important when designing duct system in the city streets where routes are through congested areas which severely limiting the placement of pipes and manholes.

High pulling friction will cause external damage to the cable being installed in pipes or ducts hence it is essential to limit and control the pulling friction. The presence or use of lubrication and magnitude of normal force significantly reduces the pulling friction (Fee & Quist, 1991).

Laying in ducts in urban area will give advantages due to high density of utilities, rocky soil and also as an additional mechanical protection. Dudas & Fletcher, (2006) showed an incremental statistic on usage of cable installed in ducts for low voltage system in urban area. Even though the installation cost is relatively high but the replacement cost is low in the future.

Rudasill Jr & Ward, (1996) in their research provided a simple cost analysis but meaningful for engineer to choose the type of installation for underground cable which will benefit the provider in term of capital and operational expenditure. They also proved that underground cable laid in conduit or ducts is the most cost effective method of installation for underground cable based on the total present value as compared to direct buried method.

Any method of installation activities always causes some impact on environment (Ton & Kam, 2013). Operators objectives is to minimize and where necessary to reinstate as the original condition. In ducts installation specifically HDD method used special grout or bentonite (mud) to cool cables.

Another important point to be considered when laying cable in pipes or ducts is the durability and long term performance of the pipes. It is found that the long-term failure of both PE and uPVC ducts is dominated by slow brittle crack growth occurring as a result of internal pressure and / or external loads (Zohrabi, Fairfield, & Sibbald, 1998).

### 2.3 Laying On Tray

Cables installed in service tunnel are normally laid on trays. To have a reliable and trouble free service life of underground cable in trays, a proper guideline must be followed, as discussed by Finks & Ticker, (1995). We need to do pre-design cable tray and pre-determine suitable number of cables to be installed by using a calculation based on size, rating and location; which will produce a successful installation of cable in trays. This will result a reliable system and also will avoid the cable from any scratches at the outer jacket.

To choose service tunnel as utilities placement techniques in urban underground environment are very costly but yet a very reliable method to overcome intangible factors such as veritable maze in high density urban area. Curiel-Esparza and Canto-Perello, (2013) used Analytic Hierarchy Process (AHP) and Delphi technique to facilitate the decision making in choosing the utilities placement techniques for civil engineers. Laying cables in utility tunnels need to be aimed towards meeting future needs, not just to reduce economic expenses to the lowest possible level. This kind of method can minimize digging up the streets, less visual impact and more protection against adverse climate, vandalism and natural disasters (Canto-Perello & Curiel-Sesparza, 2012).

Urban utilities tunnel are used as an alternative for direct buried method. The cables are place on the tray along the tunnel. This method can avoid the trench digging activity, traffic interruptions, noise pollution, vibration and public resentment of this disruption continues to increase (Legrand, Blanpain, & Buyle-Bodin, 2003). The initial costs of constructing the tunnel in order to lay cables on tray are very high. Laying cables in tray will avoid “spaghetti subsurface problems” and the most important is attaining sustainable development of urban underground space. Utility tunnels initial costs might seem discouraging but helpful to users and utility company (Cano-Hurtado & Canto-Perello, 1999).

## 3. Methodology

### 3.1 Data Collection Method

This study employed a multi-method approach in data gathering to analyse and compare the practicality of cable installation method, the technical aspect and the cost involved for each methods. The first method of data gathering is by interviewing staff of TNB Distribution with the background of construction and maintenance. An interview was carried out to explore and gain information based on the work implemented at site. The second method of data gathering involves simulation process of technical data from various cable installation ways using CymCAP. The third method is cost analysis of initial installation and long term costs.

### 3.2 Data Analyzing Method

The data collected for each criteria in terms of practicality, technical and cost was analysed using a developed matrix model. The results of the analysis will determine the suitable methods of cable installation for urban area. The following table shows in general the list of criteria and sub-criteria to be analysed.

**Table 1 – Criteria and Sub-Criteria for Analysis**

| No | Criteria | Sub-criteria |
|---|---|---|
| 1 | Practicality | • Ease of installation<br>• Maintenance<br>• Aesthetic value<br>• Public safety/disturbance |
| 2 | Technical | • Ampacity of cable<br>• Ease of bending<br>• Pulling tension/maximum pulling length |
| 3 | Cost | • Initial cost (installation cost)<br>• Long term cost (maintenance and others) |

## 4. Results And Discussion

### 4.1 Practicality

This study focused on cable installation method using open cut (Figure 1) and HDD (Figure 2). Figure 3 illustrates the top view of cable laid in pipes through open cut (on tarmac road) and HDD. Utilities would normally choose the easiest installation method in laying cables whether by laying in pipes (on tarmac road) or using trenchless method such as HDD HDD as well as other installation method. Open cut installation method on tarmac road will normally result in a shorter time in project duration, easy to plan and route arrangement of the cable. This method also will help much on avoiding the damaging or digging in-service other utilities in ground. Trenchless or HDD installation method normally takes a longer period due to the processes involved. Accurate utility mappings also play an important role in regardless method of installation we use.

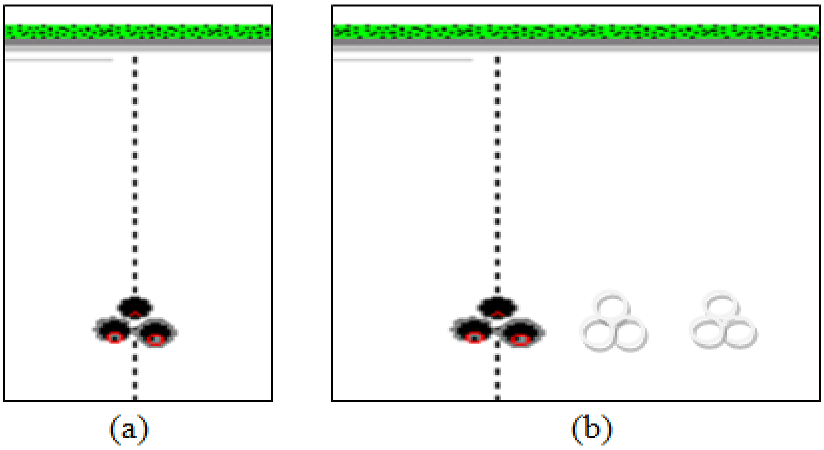


Figure 1 : Typical cross-section of cable laid in pipes through open cut (on tarmac road), a) One circuit of 630mmp XLPE cables. b) One circuit of 630mmp XLPE cables and 2 circuit spare ducts.

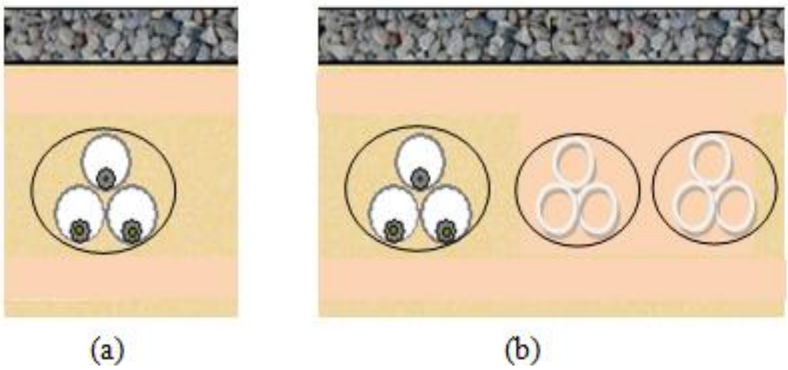


Figure 2 : Typical cross-section of cable laid in pipes through HDD method, a) One circuit of 630mmp XLPE cables. b) One circuit of 630mmp XLPE cables and 2 circuit spare ducts.

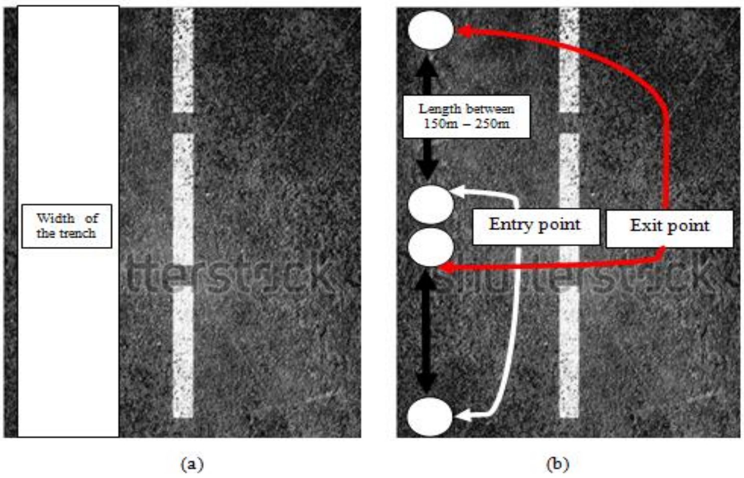


Figure 3: a) Top view of cable laid in pipes through open cut (on tarmac road). b) Top view of cable laid in pipes through HDD.

Laying cables on tarmac road usually will cause poor eyesores to the road user and caretaker during the excavation process. Signboards, blinker, barricades and cone need to be placed in accordance to traffic management requirement to minimize hazards and to ensure safety to the public. A non-standard tarmac will affect the quality of the excavated existing road thus will result a bad road condition for the road user. Trenchless or HDD method will usually obstruct the road user in certain spot since the drilling machine need to place statically at entry and exit point. The project duration will take longer time compared to open cut by using HDD method.

From the maintenance point of view, laying in HDD method is more difficult to maintain in the presence of breakdown due to cable failure. The detection of the failure portion is difficult because of the depth of cable which can be as deep as 15m underneath. The cables need to be pulled out around 150m – 250m and replaced the affected stretch involving from entry to exit point. This will incur higher cost compared to open cut installation method where repairing will only involve the affected failure portion around 10m – 20m only. Open cut installation method will give more advantages in term of costing and repairing techniques. Spare pipes for open cut installation method will help on minimizing disturbance to the road user where utilities will only apply minimum excavation to the road during maintenance. Apart from that, the condition of the spare pipes needs to be checked before pulling through cable.

Trenchless or HDD method is normally safer to the public user since there will be less road settlement to the existing road. A good resurfacing after open cut installation method will ensure safety to the public user and posted a good impression to the public thus will improve the utilities image to the road caretaker.

### 4.2 Technical Analysis

The cable ampacity calculation commercial software, CymCap, was used to calculate the cable ampacity for cable laid in pipes through open-cut installation method and horizontal direct drilling installation method. Figures 4 and 5 show the simulation parameters and arrangement.

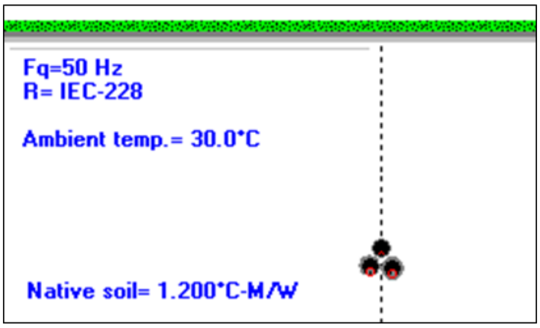

Figure 4 : Simulation for cable laid through HDD

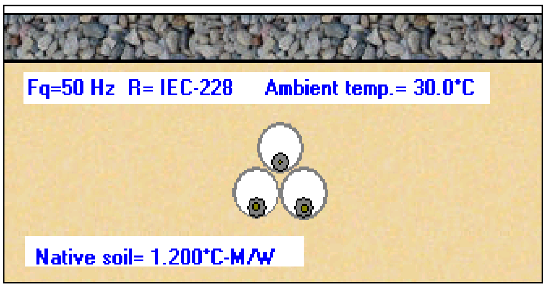


Figure 5: Simulation for cable laid in pipes through open-cut

The results are as in table 2

**Table 2 – Results of Ampacity**

| Installation method | Depth | Ampacity |
|---|---|---|
| Laid in pipes (open-cut) | 1.5 m | 587A |
| Laid through HDD (trenchless) | 5 m | 545A |

Cable laid through HDD has lower ampacity, in comparison with the cable laid in pipes through open-cut, due to the depth of the installation. Nevertheless, the ampacity of both installation methods meet the standard of TNB (TNB, 2002 ), where the minimum ampacity required is 525A.

Cable laid in pipes through open-cut trench is more flexible and manageable for routes that require certain degree of horizontal bending, especially when more flexible pipe such as HDPE pipe is being used. Nevertheless, the manufacturer's maximum bending radii shall not be exceeded.

Figure 6 shows the vertical cross-section of cable laying through HDD. Due to its vertical profile, horizontal bending for cable laying using HDD method is very limited and can be impractical and impossible based on the site conditions and requirement. For routes that require certain degree of bending, for example a route turning at the road T-juntion, cable laying through HDD method will require longer and diverted path to overcome the bending requirement without encroaching the third party's parcel.

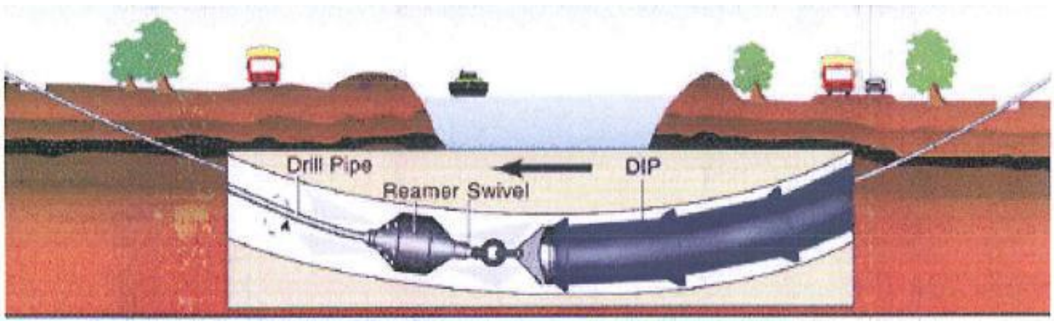


Figure 6 : Pull-back of the pipe and cable through the reamed hole

Cables are usually pulled into position during laying in the trench or duct. However if the cable is handled with a pulling tension above its maximum permissible pulling force, this can damage the electrical and mechanical properties of the cable. It is easier to pull cable through pipes laid in trench due to its flat or minimum gradient. The pulling operation in HDD pipe is harder due to its vertical profile.

**4.3 Cost**

The cost for each type of installation method, with spare pipes of 2 circuits and without spare pipe, was calculated with reference to TNB's List of Schedule Rate, 2012 (SJHT, 2012). The work components involved in the cost calculation include the following.

**Table 3 - Laying of 500m x 3 x 1 Core 650mmp**

| | |
|---|---|
| Initial Cost (A) | Installation work based on method of laying (tracing, excavation, sand-bedding, pipe laying, cable pulling, backfill and reinstatement for open-cut trench *OR* pilot hole drilling, pre-reaming, pipe and cable pulling for HDD method of installation) |
| | Resurfacing of the road (for open-cut) |
| | Milling and Paving of the Road (for open-cut) |
| Long-Term Cost (B) | Laying a new circuit of 3 x 1 Core 650mmp (for system improvement work) |
| | Repair and replacement of cable due to cable breakdown (maintenance work) |

The calculated cost is as scheduled in the following table.

**Table 4 – Calculated Cost for Each Installation Method**

| Cost | Cable laid in pipes through open cut without spare pipes | Cable laid in pipes through open cut with spare pipes of 2 circuit | Cable laid through HDD without spare pipes | Cable laid through HDD with spare pipes of 2 circuit |
|---|---|---|---|---|
| Initial Cost (A) | RM433,500.00 | RM533,500.00 | RM611,000.00 | RM1,436,000.00 |
| Long-Term Cost (B) | RM867,000.00 | RM52,000.00 | RM1,222,000.00 | RM52,000.00 |
| Total cost (A+B) | RM1,300,500.00 | RM585,500.00 | RM1,833,000.00 | RM1,488,000.00 |

The cost for laying cable through HDD or trenchless method without spare pipes is exorbitantly high in comparison with the others. In most maintenance cases, the existing

HDD pipe is damaged and cannot be re-used, hence new pipes have to be laid. The lowest installation cost is by laying cable in pipes through open cut.

It is observed that although the initial cost of laying with spare pipes incurs higher cost for both installation method, the long-term cost and hence the total cost is significantly reduced. The reduction is 55% for installation of cable in pipes through open cut, and 19% for trenchless installation method.

**4.4 Selection of Installation Method**

The following matrix model summarized the results of each installation method and the selection of the most feasible of cable installation method in the urban area is done by comparing the overall criteria.

**Table 5 – Summary of Results**

| No | Criteria | Sub-criteria | Laid in pipes through open-cut (on tarmac road) | | Laid in pipes through Horizontal Direct Drilling (HDD) | |
|---|---|---|---|---|---|---|
| | | | without spare pipes | with spare pipes (2 circuits) | without spare pipes | with spare pipes (2 circuits) |
| 1 | Practicality | Ease of installation | Need for excavation (smaller trench), mill & pave and resurface. | Need for excavation of wider area, but resurface and mill & pave for the same width of road passage. Facilitate future cable laying works. | Minor excavation required (only entry and exit points); no resurface and mill & pave required. Longer duration to complete. | Minor excavation required (only entry and exit points); no resurface and mill & pave required. Longer duration to complete. |
| | | | Moderate | Easy | Difficult | Moderate |
| | | Maintenance | Difficult | Easy | Difficult | Moderate |
| | | Aesthetic value | Poor | Poor | Fair | Good |
| | | Public safety / disturbance | Poor | Fair | Fair | Good |
| 2 | Technical | Ampacity of cable | Good (587A) | Good (587A) | Fair (545A) | Fair (545A) |
| | | Ease of bending | Good | Good | Fair | Fair |
| | | Ease of pulling | Good | Good | Fair | Fair |
| 3 | Cost | Total cost (Initial and long term cost) | 1,300,500.00 | 585,500.00 | 1,833,000.00 | 1,488,000.00 |

The scoring of each sub-criteria above is based on the following scales :-

**Table 6 – Level of Scoring**

| Level | Score |
|---|---|
| Good | 3 |
| Fair | 2 |
| Poor | 1 |

| Level | Score |
|---|---|
| Easy | 3 |
| Moderate | 2 |
| Difficult | 1 |

The most expensive cost scores the least and the least will score the highest. In the interest of TNB, higher weightage is given to two main criteria which are the cost and ampacity. The scoring for these two criteria is as follows:-

**Table 7 – Score for Cost**

| Level | Rank | Score |
|---|---|---|
| Least expensive | 4 | 10 |
| Slightly higher | 3 | 7 |
| Higher | 2 | 5 |
| Most expensive | 1 | 3 |

**Table 8 – Score for Ampacity**

| Level | Rank | Score |
|---|---|---|
| Good | 3 | 10 |
| Fair | 2 | 7 |
| Poor | 1 | 5 |

The score for each method is depicted in the matrix-model as follows:-

**Table 9 – Overall Score Matrix Model**

| No | Criteria | Sub-criteria | Laid in pipes through open-cut (on tarmac road) | | Laid in pipes through Horizontal Direct Drilling (HDD) | |
|---|---|---|---|---|---|---|
| | | | without spare pipes | with spare pipes (2 circuits) | without spare pipes | with spare pipes (2 circuits) |
| 1 | Practicality | Ease of installation | 2 | 3 | 1 | 2 |
| | | Maintenance | 1 | 3 | 1 | 3 |
| | | Aesthetic value | 1 | 1 | 2 | 3 |
| | | Public safety / disturbance | 1 | 2 | 2 | 3 |
| 2 | Technical | Ampacity of cable | 10 | 10 | 7 | 7 |
| | | Ease of bending | 3 | 3 | 2 | 2 |
| | | Ease of pulling | 3 | 3 | 2 | 2 |
| 3 | Cost | Total cost (Initial and long term cost) | 7 | 10 | 3 | 5 |
| | TOTAL SCORE | | 28 | 35 | 20 | 27 |

## 5.0 Conclusion

This research focus on the most feasible method for 33kV underground cable installation method in urban area of TNB Distribution (Selangor). The comparison is made only between two methods of laying, considering TNB's practice and the requirement from the road caretaker. Based on the matrix-model above, it can be concluded that laying in pipes with spare pipes is the most feasible method to install the 33kV underground cable. The advantage of having spare pipes is to minimize future digging which is in-line with the requirement of road caretaker and putting both TNB and the road caretaker on the win-win condition. Nevertheless, HDPE pipes have been found may be damaged when exposed to external mechanical pressure sourced from the heavy vehicle.

Further studies shall explore on more durable pipes to be used and other method of cable installation such as utility tunnel or concrete encased ducts.

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