SELECTING THE RIGHT CABLE FOR THE NETWORK

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ABSTRACT

With the ever increasing cost of fossil fuels, the pressure on individuals and power utilities to cut down fuel consumption is mounting and seems to be becoming one of the biggest challenges in recent years. Most of the articles and papers explain different ways to cut down on the direct fuel consumption but very few do so on indirect ways. By selecting the right size underground cables for the network, the transmission/distribution losses can be reduced by up to 25%, which relates to the reduction of 1% in fuel consumption to generate electricity. Underground cables not only need to be designed and installed properly, but also appropriate maintenance procedure and practice should be carried out periodically to increase the life of the cable and asset.

1 INTRODUCTION

Fuel saving is an increasingly important topic. The price of energy, in particular fossil fuels, is historically high and seems set to increase. Fuel bills, whether for home, car, power generation, or for power utility, take up an ever increasing proportion of people’s budgets. Equally, while there is still some debate about the details, the evidence for man-made climate change effects (global warming), becomes stronger every year. And even if global warming is not a reality, it is absolutely certain that there is only a finite amount of oil in the world - the more we use, the sooner prices will soar as the easily-extracted reserves are used up. So whether it is for environmental reasons, or just perfectly reasonable self-interest, most people want to cut down on their use of oil-based fuel - be it petrol (gasoline), diesel, fuel for the home or for power generation. There are a number of papers and research articles available within the industry which focus on a number of ways to save fuel by one method or another.

The driving force of the electricity distribution industry is the transportation or the delivery of power between two points, requiring all parts of the system to perform to perfection over a very long period of time.

An integral part of this link between the points is the method of transportation, either overhead or underground. The reliability and lifetime of this link is influenced by a number of different factors, some of which the network controls and some, which it doesn’t. The overhead to underground conversion has benefits for both the utility and its customers, as well as for the wider community. Using the Lifetime Cost Ratio, it has been proven that underground networks can be economic.

The very rapid growth of underground power distribution in residential areas has led to extensive usage of polymeric insulated cables for medium voltage applications.

The underground residential distribution (URD) cable, because of its lower overall manufacturing and installation costs, has been well utilised. The two main advantages of underground versus overhead distribution are; the improvement in the appearance of the residential environment, and security from ice, wind and other natural hazards (supply reliability).

Underground cables need to be properly installed. The engineer must possess sufficient background knowledge in cable construction, installation design, actual installation, testing, and maintenance of the underground cables.

2 INVEST IN CABLE SIZE

The selection of the cable is governed by a number of factors, i.e.

- Sustained / Steady current rating capacity of the cable
- Emergency or short circuit current rating capacity of the cable
- Voltage drop
- Conductor temperature

The steady or sustained current rating capacity of the cable is governed by a number of installation factors, i.e. whether the cables are directly buried in ground or in duct in the ground or installed in free air, soil or air temperature, soil thermal resistivity, depth of burial, etc.

The factors mentioned above are the minimum factors to be considered while selecting the appropriate conductor for a particular application. However, as per our best knowledge and information, at the moment no installation
code around the world has a specific requirement for energy efficiency. Not only is conserving energy good for the environment but also it makes good economic sense.

With the deregulation of the electrical energy supply industry in most countries, it is speculated that the cost of energy will increase significantly over time.

Power losses in low and medium voltage cables consist of the following [1], [2], [4]:

- **Conductor losses or 1R losses**
- **Dielectric losses**
- **Metallic screen losses**

Out of the three above losses, the contribution by conductor losses is significant towards the total losses. Dielectric losses for cables up to 36 kV can be neglected because of technological advancements in insulating materials like XLPE or TR-XLPE. All medium voltage cables (3.6/6.6 kV and above) have the requirement of a non magnetic metallic layer over the core (an assembly comprising the conductor, semiconductive conductor screen, insulation and semiconductive insulation screen). The main purpose of the metallic screen is to carry asymmetrical fault current and/or 3-phase unbalanced current. Generally the metallic screens are bonded either at one or both ends or in some cases cross bonded. The losses in the metallic screen depend upon the type of bonding adopted, along with the size of metallic screen. Generally for the same screen size, the losses will be higher if the screens are bonded at both ends of an electrical section compared to single point or cross bonding.

Significant energy saving can be achieved by increasing the cable conductor size over the required size based on factors explained above as per the application. This will increase the initial cable and installation cost but the payout period can be quite short. This is due to the energy savings obtained through reduced 1R losses in the conductors. These savings will continue for the life of the cable, which could be fifty years or more.

In the following example, we will see by increasing the conductor size we can reduce the running cost by reducing the losses and hence increasing the efficiency or saving in cost of fuel to generate electricity. Also, we will see the payout period can be as small as a few years. The payout period is basically derived by the cost difference between the cable sizes and the cost of energy saved per year. The information and data used in the exercise is based on typical New Zealand units.

In the example the cost of power is assumed to be $0.06 per kWh. The payout period will change accordingly if the power rate changes, i.e. the payout period will be less if the cost of energy is more and vice versa.

<table>
<thead>
<tr>
<th>Cable Type</th>
<th>MVA Req'd</th>
<th>Cable Rating*</th>
<th>Cond Temp at req'd MVA</th>
<th>Losses @ req'd MVA</th>
<th>Power Saved by using larger cond</th>
<th>Energy Saved Per Year**</th>
<th>Cost of Energy Saved Per Year**</th>
<th>Cable Cost Difference***</th>
<th>Payback Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x 240 mm² Cu, 11 kV</td>
<td>9.5</td>
<td>458</td>
<td>90°C</td>
<td>50.2</td>
<td>14.2</td>
<td>6121.5</td>
<td>3727.3</td>
<td>8480</td>
<td>2.3</td>
</tr>
<tr>
<td>[1 x 300 mm² Cu, 11 kV</td>
<td>9.5</td>
<td>560</td>
<td>67°C</td>
<td>56.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 250 mm² Cu, 15 kV-133 kV</td>
<td>9.5</td>
<td>371</td>
<td>88.3</td>
<td>77.2</td>
<td>20.0</td>
<td>87512.4</td>
<td>5256.7</td>
<td>8550</td>
<td>1.6</td>
</tr>
<tr>
<td>1 x 350 mm² Cu, 15 kV-133 kV</td>
<td>9.5</td>
<td>441</td>
<td>66°C</td>
<td>57.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 240 mm² Al, 11 kV</td>
<td>7.5</td>
<td>396</td>
<td>88.5</td>
<td>81.2</td>
<td>15.2</td>
<td>66514.7</td>
<td>3990.9</td>
<td>900</td>
<td>0.2</td>
</tr>
<tr>
<td>1 x 300 mm² Al, 11 kV</td>
<td>7.5</td>
<td>448</td>
<td>97°C</td>
<td>56.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 250 mm² Al, 15 kV-133 kV</td>
<td>7.5</td>
<td>293</td>
<td>88.5</td>
<td>77.5</td>
<td>21.4</td>
<td>93857.5</td>
<td>5619.5</td>
<td>2970</td>
<td>0.5</td>
</tr>
<tr>
<td>1 x 350 mm² Al, 15 kV-133 kV</td>
<td>7.5</td>
<td>349</td>
<td>66°C</td>
<td>56.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Based on following installation conditions
Max continues conductor temperature = 90°C
Soil thermal resistivity = 1.2 K.m/W
Metallic screens (10kA for 1 second) bonded at both ends of an electrical section.

<table>
<thead>
<tr>
<th>Conductor Type &amp; Network Voltage</th>
<th>MVA Req'd</th>
<th>Cond Rating*</th>
<th>Losses @ req'd MVA</th>
<th>Power Saved by using larger cond</th>
<th>Energy Saved Per Year**</th>
<th>Cost of Energy Saved Per Year**</th>
<th>Cable Cost Difference***</th>
<th>Payback Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krypton (158 mm²), AAAC, 11 kV</td>
<td>7.5</td>
<td>446</td>
<td>107.1</td>
<td>26.5</td>
<td>116070.0</td>
<td>6964.2</td>
<td>1000</td>
<td>0.1</td>
</tr>
<tr>
<td>Neon (210 mm²), AAAC, 11 kV</td>
<td>7.5</td>
<td>530</td>
<td>80.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Based on 50% operating time per year (4380 hrs/year)
***For illustrate purposes only

Figure 01

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Thus we have seen in the above examples that by using a larger conductor size than what would traditionally be selected, up to 25% of the ongoing losses can be reduced. Internationally, on the average, 3-4% of the energy is believed to be lost in 11 kV distribution networks. This means that by using just one larger standard conductor size, up to 1% of the distribution losses can be saved, and hence the fuel to generate these losses.

Another benefit of using a larger cable size than traditionally required is that the voltage drop is less. Consequently the equipment can operate more efficiently, therefore requiring less current. This will further reduce the payback period. The cost of power saved per year in the above table, is a continuous saving for the operating life of the cable and will increase if the cost of power increases and hence the payback time reduces.

There are, of course, some practical limits on how far you can go on conductor sizes. Equipment at both ends must be designed for the cable size. There may be some installation issues along the cable route length. There may be some initial or upfront cost considerations. All of these must be taken into account but as we have already seen, by increasing the cable size by one standard conductor size, the savings can be quite significant.

3 OVERHEAD LINES VS. UNDERGROUND CABLES

We have learnt that the ongoing savings can be achieved by investing in a larger cable size on both types of installations, i.e. underground cable or overhead lines. The next question is the choice between overhead lines and underground cables. The Overhead systems are out in the open, so it is easy to detect and fix the design, installation or weather problems. Underground cables, however, are out of sight and out of mind, at least until the circuit starts failing. The question to overhead or underground the utility network has been around for a very long time. In the past this would have been driven by installation costs. Currently what is seen as the general ruling, within cities is mostly underground and in the rural area’s overhead, but within the suburbs a mixture of both overhead and underground. Due to changes within today’s society, we have become more reliant on power supplies, and this is placing higher demands on the reliability of power systems and weather conditions are no longer an acceptable reason for power outages. The public is becoming more concerned about the environment along with the visual appearance and appear to be happy to pay a little bit more for underground networks.

There have been many studies done in the past with regards to the economics of the above methods. The preferences and economics depend upon the infrastructure and individual country’s requirements. Some of the factors are:

- **Lifetime Cost**
  - Capital cost or installation cost
  - Operating and Maintenance cost
    - Vegetation management cost
    - System O&M cost, i.e. Losses
- **System Reliability**
- **Ecology**
  - Visual impact, space required & site ownership
  - Electric and Magnetic Fields
  - Installation Processes
  - Service experience

The above factors are well explained in the technical paper “Fuel Savings By Selecting The Right Cable For The Network” presented during 17th PPA Annual Conference and Trade Exhibition by the author [4].

4 LOSSES IN UNDERGROUND CABLE [1], [2]

The sources of electrical losses in the underground cables are:

4.1 Conductor losses or I²R losses

AC. Resistance hence the conductor losses are the predominant factor towards the total losses, which consist of:

- **Skin effect (\textit{Ys})**: is attributed to the variation of conductor self inductance which is greater to the centre of the conductor than to its surface or periphery, hence the concentration of current flows at the surface causes the increase in the AC Resistance.

- **Proximity effect (\textit{Yp})**: is generated by the magnetic field produced by current flowing in the parallel current carrying conductor. Here the current densities on the inner area, side facing each other, are smaller than the current densities flowing in the outer area due to the differences in the magnetic flux densities cutting the conductors cross sectional area.

4.2 Dielectric and charging current losses

In a simple analogy, power cables can be considered as a lumped capacitor, the capacitance of which is determined by the dielectric constant of the insulating
material and the physical dimensions of the cable. These parameters along with the supply frequency determine the charging current and dielectric losses, which are voltage dependent losses. The leakage current flowing across the insulation is very much influenced by the quality & cleanliness of the insulating material. The leakage current is an ionic conduction due to the presence of free electrons in the direction of the electric field. For HV and EHV cables, generally above 66 kV, the dielectric losses can significantly reduce the cable rating; however dielectric losses of 33 kV and below, XLPE insulated cables are negligible and are ignored for final rating calculations.

4.3 Metallic Sheath (screen) losses

Metallic screen losses are current dependent losses and are generated by the induced current when the load current flows through the conductor. The screen current in single core cables are induced by the induction (transformer) effect. The screen induced electromotive forces (emf) generate two types of losses:

Circulating current losses: are generated in the metallic screens if the screens form a closed loop by being bonded at both ends or intermediate points along the cable route. These losses are the function of, load current, supply frequency, mean cable diameter, the resistance of the metallic screen and the spacing between the conductors.

Eddy current losses: consists of current circulating radially and longitudinally in the cable metallic screen generated on the principal of skin effect and proximity effect explained above. They are generated in the cable metallic screen irrespective of the bonding method adopted and are generally very much smaller in magnitude.

5 CABLE DESIGN

The purpose of a cable system is to convey power from the source of energy to the load. The amount of power is proportional to the product of the circuit voltage and conductor current (under given conditions of circuit length and load impedance). The designer must consider both the current rating (ampacity) as well as the voltage rating for any given circuit problem. The ampacity is determined largely by the service environment or installation conditions. Design requirements quite logically depend upon cable application. Low voltage cables do not require low-loss, high dielectric strength insulations because much of the insulation wall is there simply for physical robustness. Portable cables require special considerations for good flexibility and the physical protection of cut-resistant and impact-resistant coverings. Extra high voltage cables can employ only those insulations having low dielectric losses. The medium voltage cable used in modern distribution systems requires a reasonable balance of physical and electrical characteristics.

5.1 Electric Stress

The electric stress for any given insulation thickness is always the maximum at the conductor. It might be thought that a maximum stress value for a given insulation would be determined and the insulation thickness for each conductor size determined from this value. This method would permit quite large variations in the average stress throughout the insulation wall that cannot be disregarded. In practice, solid type insulated cables are usually restricted to a minimum conductor diameter in industry standards and usually has the same wall thickness for the full range of conductor sizes. The maximum stresses at the conductor for XLPE cables are about 3.3 kV/mm and 4.3 kV/mm for the small conductor sizes of 22 kV and 33 kV cables respectively.

5.2 Temperature Ratings

XLPE insulations perform well at elevated temperatures so that a continuous conductor rating of 90°C has been established with emergency and short-circuit ratings of up to 130°C and 250°C respectively.

5.3 Metallic Screens

The design of the metallic screen has received much attention recently; with reference to short-circuit currents during a ground fault. The cross-sectional area of these screens should be such that the short circuit temperature rating is not exceeded during a ground fault and should not be greater than the conductor short circuit capability.

5.4 Non-metallic sheath

In New Zealand it has been standard practice to use PVC non-metallic sheaths often over steel wire or aluminium armours. Over the last decade there has been a strong trend away from steel wire armour and PVC non-metallic sheaths towards unarmoured cables with non-metallic sheaths of High Density Polyethylene over PVC bedding. In the last few years a trend is starting to move away from the dual PVC/HDPE to either a single layer of LLDPE or a dual PVC/MDPE with a much thicker MDPE layer due to installation issues with the dual PVC/HDPE sheath. The following points are a summary of some current world practices:

♦ 92% of USA utilities specify encapsulated LLDPE non-metallic sheaths based on cost effectiveness;
♦ LLDPE has superior water and ion migration resistance, which reduces neutral corrosion and the growth of insulation water trees;
♦ 90% of failures in direct buried cables are the result of mechanical damage or jointing faults;
Polyethylene non-metallic sheaths have superior mechanical properties, which result in improved resistance to the rigours of installation practices;

- Polyethylene materials incorporating suitable levels of carbon black exhibit UV degradation resistance properties equal to that of PVC;

- The use of semi conducting LLDPE non-metallic sheaths is increasing, in order to negate neutral-to-ground impulse voltages. Such materials still exhibit the same physical and mechanical attributes as standard LLDPE.

6 INSTALLATION DESIGN

In the installation design, the engineer must look at the factors that affect the cable performance, the environment in which the cable is to be installed and select the correct type of installation either direct buried or direct buried in ducts over the lifetime of the asset. Underground problems, however, are out of sight and out of mind, at least until the circuit start failing. Although utilities design their underground circuits for a 40+ year life, improper installations often can lead to premature field failures. Unless you lay your cables to rest properly, they may come back to haunt you. There are few factors which are to be considered to determine the current rating of the cable without compromising with the integrity of the cable insulation properties.

- Depth of Burial
- Proximity of Other Cables
- Ground Temperature
- Duct Sizes
- Method of screen bonding
- Ground Thermal Resistivity.

The ground thermal resistivity has a significant effect on the maximum continuous current rating of a cable. Cables under continuous heavy loadings can slowly dry out the surrounding ground and cause the ground thermal resistivity to increase. In the summer time, long hot dry spells can also cause drying out of the ground; hence heavy summer-time loads can have a more pronounced effect than may be expected.

Other factors that have to be considered during the installation design and the actual installation phase are, Cable Support, Minimum Bending Radius, Duct Sizes, Pulling Tensions, etc.

The utility must also be aware of the changing environment over the life time of the asset due to the changes which effect the underground performance similar items such as tree pruning for overhead lines e.g. the council plants a row of trees along side the underground cable circuit, these will dry out the ground much more.

To prevent premature failures, you must ensure you place your cable system within a hospitable environment. Too few utilities have stringent specifications or quality-assurance programs for the installing of the underground cable when compared to the requirements they place on the manufacturer. The effects of poorly installed cables from jointing, installation damage, thermal backfills and soils may not be evident for many years.

7 INSTALLATION

7.1 Moisture

Cables are manufactured in conditions that exclude moisture and it is important that precautions are taken during installation to ensure that moisture is not permitted to enter the cable.

- Cut ends or opened areas must be protected from moisture at all times, including during pulling in;
- Cables, after cutting must be re-sealed for storage, by an effective method such as a heat shrinkable cable cap;
- When using a pulling stocking, any cable end seal must be checked for integrity before and after the pull, and replaced when broken, torn, or the seal is broken;
- When using pulling eyes attached to the conductor, the pulling eye must be sealed to the cable non-metallic sheath to prevent the entry of moisture;
- Cable with cut ends, damaged end caps or opened non-metallic sheath must never be dropped into water.

7.2 General Drum Handling

Before commencing installation, the cable drums should be checked to determine that they have been received in good order and condition. The end caps should also be checked for integrity to ensure that moisture has not entered the cable.

- The arrow painted on the side of the drum indicates the direction for rolling. If the drum is rolled in the opposite direction then the layers of cable will become loose;
- Rolling of the cable drum should be avoided as much as possible;
Lifting of cable drums should be carried out carefully by cranes or forklifts;
- Cable drums should not be dropped as damage can occur to the cable and/or the drum.

7.3 Drum Positioning

All drum moving or lifting should be carried out in a safe manner in accordance with the requirements of the Occupational Safety and Health regulations. Drum pay off stands must be capable of carrying the full weight of the drum of cable and withstand the additional forces when the cable is being pulled off.

- Drums are normally mounted so that the cable is pulled from the top of the drum;
- When paying off the drum rotates in the opposite direction to the arrow on the side of the drum;
- During paying off, the cable inner end moves backwards and slack turns can develop within the cable drum. Unless the cable end is checked and re-secured at frequent intervals during the paying off, the slack may develop into kinks in the cable;
- Drums should preferably be mounted at the start of a reasonably long straight section of the cable trench;
- A method of braking the cable drum during paying off must be provided to control the pay off and prevent over running.

7.4 Trench Preparation

All trench excavation must be carried out in accordance with the local authority regulations and Occupational Safety and Health regulations.

- The cable trench should be prepared with cable rollers spaced every 2 to 3 metres in the straight sections;
- The spacing of the rollers should be frequent enough to prevent the cable touching the ground during pulling;
- Any corners should be made as large as practical and corner rollers provided at any bend in the route. Spacing of the rollers on corners or bends will need to be more frequent than for the straight sections;
- Long rollers may be required between the drum payoff position and the start of the trench to allow for the cable reeling off across the width of the drum.

7.5 Duct Preparation

- Ducts should be clean and smooth and fitted with a bellmouth at the entry point;
- The duct exit point should also be fitted with a bellmouth if the end of the duct is followed by a bend;
- There should be a depression in the bottom of the trench at the entry to a duct to allow gravel and other objects to fall off the cable and not get dragged into the duct with the cable.

7.6 Cable Laying and Pulling

When installing any cable, irrespective of the type of insulation (i.e. paper, EPR, XLPE, etc), it should be handled with due care otherwise damage may occur to the non-metallic sheath. All cable laying and pulling cable off drums should be carried out in a safe manner in accordance with the requirements of the Occupational Safety and Health regulations.

- To attach the pulling rope to the leading end of the cable, a cable pulling stocking is normally used, but cable pulling eyes are available that can be fitted to the conductor(s);
- A swivel should be fitted between the pulling eye and the winch cable to prevent torsional loads being transferred to the cable during pulling;
- It must be emphasised to staff laying the cable that the cable is a high-value commodity and is very sensitive to damage;
- In order to prevent damage to the corrosion protection and insulation properties of the cable non-metallic sheath, the cable must not be dragged over sharp objects and must not be bent too sharply;
- Attention is drawn to the fact that as the temperature decreases PVC compounds become increasingly stiff and brittle, with the result that if the cable is bent too quickly to too small a radius or is struck sharply at temperatures in the region of 0°C or lower, there is a risk of shattering the PVC components;
- Cables with PVC components should not be laid when the cable temperature or the ambient temperature has been below 5°C during the previous 24 hours;
- The cable should preferably be pulled into position in one continuous pull;
- When pulled by winch, the winch operator must observe the dynamometer or tension measuring device to avoid the cable pulling tension from being exceeded;
- After each length of cable is placed in position, the end caps should be checked for damage to ensure that moisture can not enter the cable. Any suspect end caps should be replaced;
- When lengths of cable are being cut from a drum or when the drum is not emptied completely, the ends of any cut length should be sealed with an end cap, such as a heat shrink end cap, to prevent the ingress of moisture;
- When installing heat shrink end caps, the surface of the cable non-metallic sheath where the end cap is to fit should be cleaned and roughened by sanding with coarse sandpaper to provide a key;
- If a length of cable is being left on a drum for use in the future, the cable ends must be sealed and the tail tied off. The tying off of the tail may be
carried out by attaching a heavy cord to the cable behind the end cap, pulling up any slack cable, and then anchoring the cord to the drum flange with a staple. The bottom end should also be checked as it may also need to be secured, particularly if the cable has “worked back”;

- Care must be taken to ensure that the end cap is secure and not likely to be stripped off by the cord. It is also important to ensure that the cord is not likely to slip off the cable and allow the cable end to flick back and cause injury;
- Nails should not be driven through the non-metallic sheath to secure the cable, as this will allow moisture to penetrate into the cable.

7.7 Backfilling and Reinstatement

Prior to backfilling, a visual inspection should be carried out and the following checked.

- The cables have a proper bedding;
- The spacing is correct if there is more than one cable in the trench;
- Pulling equipment is removed;
- Cables are suitably supported at duct entries and the ducts sealed to prevent entry of moisture and vermin;
- The cable is free of obvious damage caused by installation;
- The end caps should be checked for integrity to ensure that moisture can not enter the cable;
- The bedding and initial backfill must be stone free sand or soil to prevent damage to the cable non-metallic sheath.
- The reinstatement should be carried out to comply with the local authority requirements.

8 JOINTS AND TERMINATIONS

All jointing and terminating should be carried out as per the manufacturer’s detailed requirements and instruction manual. It should be noted that when the cable is prepared for this operation, it will be the first time anybody has seen the insulation/insulation screen interface, therefore great care should be taken with the cleanliness compared to the manufacture. Jointing is a skilled specialist trade and should be treated as such. Care must be given to the environment where these terminations are taking place.

Poor site management

- Joint pit of insufficient size
- No access into the joint pit
- Muddy pit floor
- No covers for the pit

Jointer Expertise

- Lack of jointer experience
- Poor tools

- Instructions not read or even understood
- Bad habits for cable preparation

What should we expect?

- Jointer trained to International standards
- Jointers competent for their employment task
- All the necessary equipment for the task

9 TESTING

If a test after installation is carried out, it should be noted that:

- The test is to detect defects caused during installation.
- The test is applied to the cable and accessories.

The D.C. testing of the primary insulation is not recommended. There are two important reasons for not using a High Voltage DC Test:

1) The DC field in the cable and accessories applies different electric stresses (both in magnitude and in physical location) to an AC field, so much so that it is considered to be a poor process to find faults.

2) The application of HV DC leads to premature failure of aged and “wet” primary insulation. This has been proven in the laboratory and has been proven repeatedly in the field.

These tests considered to be the minimum that should be carried out for commissioning and maintenance purposes on Polymeric Medium Voltage Cables, Non-metallic Sheath Integrity, Insulation Resistance after Installation and High Voltage A.C. after Installation

10 OPERATION

Cable management systems are now in operation for XLPE cables that ensure the efficiency and reliability of electrical power systems. It is very important to monitor and supervise the operating conditions within the network.

It is possible to integrate optical fibres into the power cable. Perhaps the most convenient place is in the copper wire screen, where a tube of the same diameter, containing a number of optical fibres can be placed. A distributed fibre optic measurement allows the monitoring of temperature along the entire length of the power cable.

An example of this is that they can measure the temperature distribution up to 10 km within ± 1°C and 1 metre resolution.

This technology is used in New Zealand in the new Vector CBD Tunnel; this technology can also be integrated into a three core Medium Voltage XLPE cable.
ACKNOWLEDGEMENTS

The writers would like to acknowledge the contribution of a number of individuals to the paper. Also, we would like to acknowledge the help and information provided by WEL Network, Hamilton, NZ for conducting the impartial case study and cost evaluations.

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[4] Fuel savings by selecting the right cable for the network, By - Griffiths D & Jassal R

For the utility transmission sub transmission feeders, main network backbone, or all 33 kV feeders should have this optional cable installed with the cables. The additional cost is very minimal to the project cost and will allow the network planner in the future to integrate this information into the system control and the asset planners to plan future upgrade based on real time actual cable loading.

11 MAINTENANCE

The end user of the cables must determine whether these tests are relevant for them, the frequency, and the additional associated costs to perform them.

If any of the tests are envisaged as being used as Maintenance Tests, then they should also be performed as a Commissioning Test and the measurements recorded for later comparison. The methods of performing the tests on each installation should also be recorded so that the tests are performed in exactly the same way in the future. These test can be as follows, Insulation Resistance, Conductor Resistance and Screen Resistance, 5 Minute Step Voltage, Tan Delta Measurement using a VLF AC Voltage Test Set, Partial Discharge. All the values obtained in the above tests should be recorded in a cable log so that they are available for comparison purposes in the future.