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Live working — Guidelines for the installation and maintenance of optical fibre cables on overhead power lines

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British Standards

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Live working – Guidelines for the installation and maintenance of optical fibre cables on overhead power lines

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CONTENTS

INTRODUCTION

This Technical Report has been prepared in accordance with the requirements of IEC 61477 where applicable.

LIVE WORKING – GUIDELINES FOR THE INSTALLATION AND MAINTENANCE OF OPTICAL FIBRE CABLES ON OVERHEAD POWER LINES

1 Scope

The present Technical Report covers procedures for the installation and maintenance of optical fibre cables on overhead power lines. This includes:

– optical ground wire (OPGW) fibre cable;

– optical phase conductor (OPPC) fibre cable;

– optical attached fibre cable (OPAC);

– all dielectric self supporting (ADSS) optical fibre cable.

Optical fibre cables are considered for single and multi-circuit constructions in common use within some countries.

The primary concern is the necessary precautions to ensure the safety of personnel and equipment when installing or maintaining these types of optical fibre cable on overhead power lines.

2 Terms and definitions

For the purposes of this document the following terms and definitions apply.

2.1
all dielectric self supporting cable
ADSS
non-metallic all dielectric optical fibre cable which is physically and operationally separate from the power conductors and which can generally support itself over spans approaching 1 km, with the strength and resilience to withstand the most severe climates

2.2
aeolian vibration
periodic motion of a conductor induced by the wind predominantly in a vertical plane, of relatively high frequency of the order of ten or more Hz and small amplitude, of the order of the conductor diameter

[IEV 466-01-17, modified]

2.3
anti-twist running board (see Figure 1)
anti-twist headboard
pulling device designed to resist the torque generated by a change in tension of the OPGW cable thus preventing rotation in order to maintain optical fibre strain margin

2.4
blow-out
cable swing caused by the wind

2.5
conductor
phase conductor

2.6
conductor galloping
periodic motion of a conductor, or bundle, predominantly in a vertical plane of low frequency of the order of a fraction of one Hz and high amplitude, whose maximum value can be of the same order as the original sag

[IEV 466-01-19]

2.7
cradle block stringing (see Figures 2, 3, 4)
system of cradle stringing blocks, spacer rope, pulling rope, a brake unit, and a radio controlled motorized tug, which use the existing earthwire as support when installing the new optical fibre cable

2.8
de-energized
dead
at a potential equal to or not significantly different from that of the earth at the worksite

[IEV 651-01-15, modified]

2.9
earthwire
ground wire, shield wire, skywire, static wire
conductor connected to earth at some or all supports, which is suspended usually but not necessarily above the line conductors to provide a degree of protection against lightning strokes

[IEV 466-10-25, modified]

2.10
energized
alive, current-carrying, hot, live
at a potential significantly different from that of the earth at the worksite and which presents an electrical hazard

NOTE A part is energized when it is electrically connected to a source of electric energy. It can also be energized when it is electrically charged under the influence of an electric or magnetic field.

[IEV 651-01-14, modified]

2.11
fault current
current flowing at a given point of a network resulting from a fault at another point of this network

NOTE A fault current flowing to earth may be called an earth fault current.

2.12
fault-rating
combination of fault current and duration that the OPGW cable can accept without exceeding a specified maximum temperature

NOTE This is usually specified by the action integral, i^2t, where i is the maximum fault current in amperes and t is the duration in seconds.

2.13
induced current
current flowing as a result of induced voltage

NOTE An unwanted induced current along an insulating surface is a leakage current.

2.14
optical attached cable
OPAC
ground wire wrapped optical (GWWOP) cable
non-metallic optical fibre cable designed to be wrapped or lashed onto the existing earthwire or phase conductor

NOTE One of the following three attachment methods is used:

– wrapped: all dielectric (wrap); using special machinery, a lightweight flexible non-metallic optical fibre cable can be wrapped helically around either the earthwire or the phase conductor;
– lashed: non-metallic cables that are installed longitudinally alongside the earthwire, the phase conductor or on a separate catenary (on a pole route) and are held in position with a binder or adhesive cord;
– preform attached: similar to the lashed cables except that the method of attachment involves the use of special preformed spiral attachment clips.

2.15
optical phase conductor cable
OPPC
stranded metallic cable incorporating optical fibres which has the dual performance function of a phase conductor with telecommunication capabilities

2.16
optical ground wire cable
OPGW
stranded metallic cable incorporating optical fibres which has the dual performance function of a conventional earthwire with telecommunication capabilities

2.17
optical time domain reflectometer
OTDR
instrument which is used to measure and locate point and distributed losses along the length of an optical fibre

2.18
pull section
pull setting, stringing section
section of line where the optical fibre cable is being pulled into place

2.19
sagging
process of pulling the optical fibre cable up to its final sag where applicable

2.20
sealing end
assembly through which optical fibres pass providing sufficient insulation and voltage withstand capacity to maintain system integrity

2.21
stringing
process of pulling pilot ropes, pulling ropes, optical fibre cables, earthwire and conductors over stringing blocks supported on structures of overhead lines

2.22
vibration damper
device attached to a conductor or an earthwire in order to suppress or minimize vibrations due to wind

[IEV 466-11-16]

3 Understanding the hazard – Basic theory

The protection of personnel from injury during the process of installing, or during maintenance of optical fibre cables on overhead lines is most important. The personnel at the work site shall be protected against induced voltages and currents caused by energized adjacent lines. Personnel protection can be achieved by properly applying adequate protective earthing systems at the work area, by the use of correct work methods and specialized training, and by the use of equipment, which incorporates devices to protect against these types of hazards.

Electrical charges or voltage may appear on an optical fibre cable being installed, or on the other equipment and components such as the ropes involved in the cable stringing process, due to one or more of the following factors:

a) electromagnetic induction (i.e., capacitive and/or inductive coupling) from adjacent energized lines, or when crossing energized lines;
b) accidental contact of the optical fibre cable or ropes being installed, with an existing adjacent energized line;
c) electrostatic charging (i.e., conductive coupling) of the optical fibre cable or ropes by atmospheric conditions or by an adjacent high voltage direct current (HVDC) transmission line;
d) lightning strikes in the vicinity, or a lightning strike to the cable being installed or other equipment and components such as the ropes involved in the stringing process.

The hazards caused by lightning strikes, accidental contact with a live conductor, and switching errors are generally understood. However, the hazards caused by induced voltages and currents are probably less understood and are therefore explained in some detail here. It is important to note that the basic difference between the hazard caused by induction, and the other sources given above is that the induction is continuous as long as the source line is energized, rather than instantaneous or transient in the case of lightning or a fault current.

NOTE In the following examples, induction is shown as occurring on an optical fibre cable; however, the same result and hazard will occur for other components used in the stringing process such as conducting (metallic) pulling or pilot ropes, or earthwires.

3.1 Electric field induction from nearby circuits

There are two common types of induction problems caused by nearby energized a.c. lines: electric field and magnetic field. Each has both voltage and current implications.

3.1.1 Induced voltage

The electric field around an energized conductor produces a voltage on an isolated and unearthed conducting object nearby (see Figure 5).

The voltage produced depends on the source voltage magnitude and the geometry of the system but not on the length of the parallel between the energized line and the new optical fibre cable being installed.

If the circuit is unearthed, the induced voltage may be as much as 30 % of the energized line voltage. This induced voltage can be calculated, but it is generally not necessary to do so. If the new optical fibre cable being installed is earthed at any point, the charge is reduced to a much lower steady state value, depending on the resistance to earth of the earth path.

NOTE If the nearby line is an energized d.c. transmission line, electrostatic charging will result from ion drift and can produce even higher voltages than if the nearby line was an a.c. line.

3.1.2 Induced current

With an a.c. system, the energized lines and the earthed conductor being installed act like the plates of a condenser or capacitor, and a charging current flows across the air gap between them (see Figure 6).

The two following aspects should be considered.

a) A current flows through the temporary earth connection between the optical fibre cable and earth. It is proportional to the length of parallel between the energized conductor and the cable being installed. This current may amount to several amperes.

b) If the temporary earth connection becomes defective, is dislodged, or removed, the capacitive voltage is immediately re-established. Thus, if a worker is in fairly solid contact with the system and the only earth connection is dislodged, the worker can be exposed to a dangerous voltage and current. If the worker attempts to contact the optical fibre cable or connected parts, he will receive a dangerous discharge current, followed by a steady-state current. Thus, the worker shall avoid coming in close proximity to the optical fibre cable or connected parts since the induced voltage may be high enough to cause arc-over. Also, it should be noted that the steady-state capacitive current occurring after the contact may reach a dangerous level.

3.2 Magnetic field induction from nearby circuits

3.2.1 Induced current

In addition to the electric field caused by the voltage of the adjacent energized line, another effect is caused by the current flowing in the energized line.

The energized, current-carrying conductor and the nearby optical fibre cable being installed may be looked upon as the primary and secondary windings of an air-core transformer.

If the optical fibre cable is earthed at two places, it acts like the secondary of an air-core transformer, short-circuited through the earth. A circulating current will flow along the cable, through one earth connection, back through the earth and up the other earth connection to complete the loop (see Figure 7a). This induced current is proportional to the current in the energized line and is dependent on the geometry and impedance of the loop.

If a series of earth connections are applied, a series of loops are formed, each carrying current (see Figure 7b).

It would appear that the currents would cancel in the intermediate earth connections.

If there is a great difference in impedances of the earth connections in adjacent loops, for example a lake in the earth return of one, and rock in the other, the intermediate earth connection can carry almost the full circulating current.

If there are transpositions in the energized circuit, the phase angle of the induced current will be different along the line and can also create large circulating currents in the earthing system.

When work is being done in the vicinity of a heavily loaded energized line, or a fault occurs on the adjacent energized line, the current induced in the optical fibre cable being installed can be very large and can affect the choice of earthing assemblies.

NOTE If the nearby line is an energized d.c. transmission line, magnetic induction would only be related to the ripple effect and is therefore much less than would be the case if the nearby line was an a.c. line.

3.2.2 Induced voltage

Continuing the analogy of an air-core transformer, if the optical fibre cable being installed becomes earthed at one point only, for example by the removal of the last but one temporary earth connection, an open circuit secondary voltage to earth appears on the cable. This voltage is essentially zero at the location of the remaining earth, and increases in proportion to the length of the parallel (Figure 8a).

At the moment of removing the last but one earth connection, the circulating induced current is broken and a voltage appears across the gap. This voltage can become dangerously high, in the case of a long parallel between the energized line and the optical fibre cable being installed. It may have to be limited by a technique of sequential earthing, in which the optical fibre cable is subdivided by intermediate earth connections. The sections are then short enough to limit the open circuit voltage because the earth connections are sequentially removed (Figure 8b).

4 General considerations

This covers considerations which are common to multi-circuit lines with at least one circuit live, and live single-circuit lines.

NOTE A large proportion of optical fibre cable installation work, including safety and work method requirements, is very similar to that which is used to install new phase conductors or conventional earthwires in an environment where induction or electrical contact is possible. See IEC 61328.

The present Technical Report points out the specialized additional requirements as they apply to the installation and maintenance of optical fibre cables.

A typical multi-circuit line used in some countries comprises multiple circuits on one structure with phases of each circuit arranged vertically, the circuits displaced horizontally and the earthwire positioned centrally between the circuits. At least one circuit is assumed to be energized at any one time. Installation of optical fibre cables can be achieved with multiple circuits or one circuit live, depending on electrical safety clearances which can be maintained between energized phase conductors and the personnel and construction tools used to install the optical fibre cable. However, it becomes progressively more difficult to ensure that safety clearances are maintained as system voltages fall and clearances reduce. An energized single-circuit line may be suitable for the installation of OPAC, ADSS or OPGW optical fibre cable, but the configuration of the phase conductors should be taken into account before the feasibility of an application is finally established.

4.1 Engineering considerations

4.1.1 General

Helical fittings with a reinforcing layer are preferred for maximum optical and mechanical protection of the optical cable. They will ensure that mechanical loads are evenly spread and the cables are not crushed, thereby affecting the optical performance.

Splice closures should be resistant to damage, and be located where possible, out of public reach.

Minimum bend radii, as specified by the optical fibre cable manufacturer, should be observed during all installation processes in order to preserve the integrity of the optical fibres. This will dictate the minimum diameters of tensioner bullwheels, stringing blocks, sagging/tensioning devices, and clamps which are to be used.

The optical fibre cable manufacturer may require that the stringing blocks have an elastomer lined sheave. In this case, a stringing block earth connection will be necessary to provide the required earthing path.

To ensure maximum reliability and avoid cable damage, it is important to ensure that all fittings chosen are compatible with the optical cable system selected.

The optical fibre cable should be installed smoothly with no sudden changes in stringing speed or tension. Maximum stringing speed recommended by the cable manufacturer should be followed. If the cable manufacturer does not specify a maximum stringing speed, a conservative value is 40 m/min.

The tension on the optical fibre cable during stringing should be measured at the tensioner. This tension should not exceed the manufacturer’s maximum tension recommendations which are normally 15 % of the ultimate tensile strength of the cable. Some utility specifications require that a strip chart recorder be incorporated into the tensioner such that a printed or electronic record of actual tension on the cable is provided.

Under certain circumstances, to maintain clearance from energized conductors, it may be necessary to increase the stringing tension above 15% of the ultimate tensile strength of the OPGW fibre optic cable. This increase in stringing tension should be approved by the manufacturer before installation begins. Also, the length of the woven wire mesh grip may have to be increased from the typical 1,7 m up to 3,0 m to accommodate the increase in stringing tension.

The optical fibre cable should be allowed to initially settle after pulling into place and before clamping in. However, this should not exceed 24 h. Typically cable manufacturers require a minimum time for this to be done.

The continuity of all fibres for each reel of optical fibre cable should be checked when the reel arrives at the work site, and before it is installed on the structures. After completion of this test, the cable ends should be re-sealed against moisture entry.

Continuity should also be checked after the optical fibre cable has been installed on the transmission line to ensure continuity remains.

Continuity should be checked once again after any splices are made.

It is also recommended that the cable be checked for attenuation loss when the repeater section has been completed.

4.1.2 Specific

The completed system should be capable of working within a specified temperature range with the optical fibres remaining strain-free under heavily loaded conditions, such as wind and icing.

4.2 Safety issues

4.2.1 Choosing the correct equipment

For the cable installation process it is important to choose equipment with sufficient capacity to perform the work to be done. This should ensure a margin of safety beyond the actual requirements of the work.

4.2.2 Pre-work check of equipment

When installing new optical fibre cable near existing energized circuits where electrical contact or induction may occur, it is especially important that the equipment used such as pullers, tensioners, and tugs be thoroughly checked beforehand by competent trained persons to ensure they are functioning properly. In particular, braking systems should be checked to ensure correct operation and maximum load holding capability.

The puller and the tensioner should have controls which will allow the operator to preset the maximum linepull or tension which will not be exceeded. This will prevent overstressing of the optical fibre cable as it is being installed.

Pulling ropes should be examined for possible damage that may severely reduce their strength. It is recommended that a sample of synthetic ropes used as pulling or pilot ropes be tested for ultimate strength at least once each year. Weak or damaged ropes should be replaced.

Where synthetic ropes are used as pulling or pilot ropes, they should not be considered as insulating. They may initially present a high resistance electrical path, but experience has shown that over time and with use, the surface of the synthetic rope becomes sufficiently contaminated to be conductive, particularly in wet or humid conditions.

It is also important to choose a pulling rope which has low elasticity or stretch when under load. The rope should also match the weight per metre of the optical fibre cable or be even lighter so the rope will not sag lower than the optical fibre cable thus ensuring electrical clearance is maintained.

Where an existing earthwire is to be replaced with an optical fibre cable, often the existing earthwire is used as a pulling rope to pull in the new optical fibre cable. Since the mechanical strength of the existing earthwire, and particularly the compression joints, may be very questionable, this procedure should require extra caution. It is highly recommended that the existing earthwire be examined beforehand to determine if wire breakage, or other deterioration has occurred. If such significant damage is detected, the existing earthwire should not be used as a pulling rope.

If the existing earthwire is used as a pulling rope, **extra caution is needed**. The passing of old earthwire joints or splices around the bullwheels of a double bullwheel or multi-groove puller, can cause sudden failure of the joints. This failure normally occurs when the joints are bent and then straightened a number of times as they pass from groove to groove on the bullwheels. The existing earthwire and the optical fibre cable may drop, causing damage to the cable or the line structures, and may cause dangerous electrical contact.

A preferred procedure is to cut out the compression joint when it arrives in front of the puller, and to fit a woven wire grip on both ends of the severed earthwire. This grip is passed through the puller bullwheels, and can be removed before the earthwire is wound on the reel winder. Also this problem can be eliminated without cutting out the compression joint by the use of a single V-groove bullwheel puller.

Running earths, earth cables, earth clamps, and stringing block earths should be checked to ensure they are operating correctly and have no broken or damaged parts that would negatively affect the desired low resistance earth path.

4.2.3 Pre-work conference

It is especially important where the possibility of the optical fibre cable being installed can become energized through induction, or when working near existing energized conductors, that all members of the work crew understand the hazards involved. They should have the work procedures and their duties clearly explained immediately before work begins. They should be aware of the necessity of using the earthing and bonding systems described herein, and in IEC 61328, and they should know how to install and use these earthing and bonding systems properly.

If the scope of the job changes, or if job personnel changes, work procedures and duties shall be explained once again to all personnel affected.

Before work begins, the project supervisor should travel the work site from puller site to tensioner site. This is done to ensure that all potential contact points with existing energized equipment or conductors are adequately protected from contact with the optical fibre cable being installed by clearance, by insulating covers or by rider poles and nets.

4.2.4 Trained operators

The specialized equipment used in the stringing of optical fibre cable requires that operators be given special training beforehand in its safe and proper use. This is particularly important when they will be working on projects where maximum earthing procedures are required, due to the possibility of the cable or equipment becoming energized.

4.2.5 Communications

The ability of the equipment operators, supervisory personnel and observers at critical points in the pull section (such as at energized line crossings) to communicate clearly and quickly with one another is extremely important when installing optical fibre cables.

These personnel shall each have a radio system with a channel that is free from outside signal and noise interference, and is located at their operating position. Included in this communication channel should be the puller operator, the tensioner operator, the supervisor(s) and, if applicable, the person following the anti-twist running board as it moves from tower to tower, and persons at intermediate check points.

Failure of any radio in the system shall be cause for immediate stoppage of the pulling operation.

The radio or telecommunication system used by the puller operator and the tensioner operator shall be a portable set with earphones and microphone, but with no conductive wire connection between the operator and the machine. Such a connection could create a dangerous electrical path to the operator if electrical contact is made during stringing and if the operator were to leave the bonded area with his radio still attached to his person.

To ensure that there are no undetected problems due to machinery becoming jammed or ropes snagged, it is recommended that observers are placed at regular intervals along the section so that they have a continuous view of the work being conducted.

4.2.6 Other safety requirements

The minimum safety clearance as specified in the applicable local safety rules shall be maintained at all times. This is often most critical at angle/terminal towers.

Throughout the installation process, if the minimum optical fibre bending radius can be maintained, ropes and cables at the puller and tensioner ends of the pull section should be routed through the body of the tower from the tower peak to the tensioner or puller at ground level. Equipment shall be hauled up the centre of the tower, or on a face perpendicular to the earthwire, or by helicopter, particularly when both circuits of a double circuit tower are live. Control of ropes and equipment is critical in the vicinity of any live circuit. Where one circuit can be de-energized on a double circuit tower, all work is restricted to the de-energized side of all towers.

All towers, components and equipment shall be protected from mechanical overloading by appropriate methods of working. The method of working should ensure that, in the case of a mechanical failure of a component, the necessary restraint is provided to prevent the optical fibre cable moving towards a live circuit.

Emergency procedures shall be in place in case of unforeseen events which could result in minimum safety clearance being infringed or personnel being endangered in any other way.

Work should proceed only if weather conditions permit. Wind, humidity, lightning storms, and visibility are all important considerations in this regard.

During interruption of the work period, the optical fibre cable section should be secured in a safe and appropriate manner.

It is recommended that water-blocked and sheathed ropes are used when working near live circuits in order to avoid induced currents in wet ropes which can cause burning as they dry out. Where synthetic ropes are used as pulling or pilot ropes, they should not be considered as insulating. They may initially present a high resistance electrical path, but experience has shown that over time and with use, the surface of the synthetic rope becomes sufficiently contaminated to be conductive, particularly in wet or humid conditions.

When working on the installation of optical fibre cable which is close to a line carrying high electrical loads, or to an adjacent live circuit, care should be taken to accommodate by means of earthing and bonding the high induced currents and voltage which can occur in the optical fibre cable.

In the case of live single- or multi-circuit lines, work can be undertaken on OPAC and ADSS systems if sufficient electrical safety clearance to the live circuit is obtained. Work can be undertaken on OPGW systems with the circuit or circuits live if sufficient electrical clearances are achieved.

For single-circuit and multi-circuit lines which are de-energized, all types of optical fibre cable may be installed and maintained as they would be for dead circuit conditions depending on the positioning of the earthwire(s), but induction from adjacent live lines or live lines crossing the optical fibre circuit may still be an important consideration.

Work on live lines shall be conducted with the delayed auto recloser (DAR) switched out, and it should be tagged with a note to indicate that the DAR is in fact switched out.

Work on lines which have either one or more circuits energized should only be undertaken where it is unreasonable for all circuits to be de-energized, for the time period essential for carrying out the work. The system network management control should confirm that fact in writing, giving reasons if any network circuit outages would be available for a shorter period and under what conditions.

4.3 Earthing

The degree of earthing protection required for a given optical fibre cable installation project depends upon the exposure to electrical hazards which exist within the particular work area on the project.

When new optical fibre cable is installed in an area remote from energized lines, or when adjacent lines on the same tower are de-energized, and with no thunderstorm activity present, the **minimum** earthing requirements, at least, shall be used. These minimum requirements include bonding and earthing of all equipment involved at pull and tension sites. In addition, running earths should be installed on all metallic pulling ropes, on the optical fibre cable, and on the existing earthwire (if it is to be used as a pulling rope), in front of the pulling and tensioning equipment. When **minimum** earthing requirements are used, it should be noted that protection of workers from step and touch potential does not exist.

In contrast to the above, for a project located in a congested area involving exposure to numerous energized parallel lines, or when working adjacent to existing energized lines on the same tower, or if the project calls for the crossing of existing energized lines, and if there is a high probability of thunderstorm activity and adverse weather conditions, then **maximum** earthing requirements shall be used.

Such maximum earthing requirements include bonding and earthing of equipment, the use of running earths, earth mats at work sites, and stringing block earths on each stringing block. These earths and mats shall be sized and designed for a fault current where direct contact with an energized line is possible.

Sizing of the individual earth clamps, earth cable, or earth rods are not detailed here, but some general guidelines can be found in Annex A.

In addition to making sure the appropriate switches on the line where the new optical fibre cable is being installed are open and disabled, earthing and other protective measures shall be employed to ensure adequate and reasonable protection to all personnel. The best safety precaution is to consider all equipment, and the optical fibre cable, as if it could become energized at any time. The degree of protection provided for a specific project shall be a decision made by the project supervisor, subject only to the applicable regulations in force for that situation, and based on a clear understanding of the potential hazards.

When working in populated areas where onlookers could inadvertently wander into work site areas, additional measures for isolating the work site, such as safety observers and warning signs, are required. Work sites shall be surrounded with fence and warning signs prominently posted to alert onlookers to the danger.

Where a puller, tensioner and other associated equipment are required for the optical fibre cable installation, a fenced equipotential zone or earth mat should be created (as detailed in IEC 61328) to provide electrical protection to the personnel operating the equipment.

A running earth should be used adjacent to both the tensioner and the puller to guard against the effects of induced voltages in the earthwire or cable, during the installation process (see IEC 61328).

It is recommended that the integrity of the earth bonding between the tower peak and the earthwire be verified before commencing work.

Where earth rods are used, the resistance of the earth rods shall be electrically tested (meggered) to ensure the resistance of the earth rod is less than 25 Ω.

NOTE It is important to check that the protection on any energized line which could contact the optical fibre cable being installed is designed to clear the fault current if the impedance of the earth rod is as high as 25 Ω.

If an earth rod resistance of less than 25 Ω cannot be obtained, an earth mat at the work site (see IEC 61328) shall be used if the work site is at ground level, or an equipotential earthing system used in elevated work sites.

In order to ensure that the different earth rods at each work site have the same potential, they shall be bonded together with full sized earth clamps and earth cables.

When installing earth rods, caution should be taken to avoid all underground utilities such as existing energized underground electric lines, gas, sewer, and water pipes, communications cables, etc. A check of underground utility services in the area may be needed before earth rods are installed.

5 Optical ground wire (OPGW) cable

OPGW is acknowledged as the most secure of the four alternatives (see Clause 1), due to the mechanical protection being afforded to the communication fibres by the outer strands of the ground wire. This system can be installed on new lines and on existing lines during refurbishment.

5.1 Engineering considerations

There are two methods used to install OPGW optical fibre cables:

– the conventional tension method,

– the cradle block stringing method.

5.1.1 Conventional stringing method

The conventional method of OPGW installation, i.e. continuous tension stringing, is generally considered the preferable method if the required electrical clearances can be achieved. It requires less equipment and installation can be achieved faster.

The conventional tension stringing method will require the use of an anti-twist running board (see Figure 1) for a single layer OPGW, and may require an anti-twisting running board for two layer OPGW, to keep the OPGW from rotating during installation. This running board keeps the optical fibres strain-free during installation which is a fundamental feature of the cable design. This running board should have a fixed/solid connection to the OPGW so no relative rotation between the OPGW and the running board takes place. If a woven wire mesh grip is used at the front end of the OPGW to connect it to the running board, care should be taken to ensure this grip has sufficient capability to withstand the potential twisting force imparted from the OPGW as it is being pulled. This running board should have an appropriate swivel at the front end for connection to the pulling rope. This swivel will not allow any twist which occurs in the pulling rope to be transferred to the OPGW. This anti-twist running board should be designed such that it passes through the stringing blocks with minimum effort, especially those on line angle support structures. The running board normally has two weighted tails to offset the twisting tendency of the OPGW. In some cases, where a larger diameter of OPGW is being installed, it has been found necessary to add a third tail to completely offset the OPGW twist.

During the planning of an OPGW installation, to avoid possible electrical contact, consideration should be given to the differential sag between the OPGW and the conductors, particularly when the OPGW and conductors are operating at different temperatures.

Using the correct stringing block sheave and tensioner bullwheel diameter is important to protect the OPGW cable.

If the specific stringing block sheave recommendations are not available from the cable manufacturer, a conservative sheave diameter is 40 times the diameter of the OPGW.

If a specific tensioner bullwheel diameter is not available from the cable manufacturer, a conservative bullwheel diameter is 70 times the diameter of the OPGW.

5.1.2 Cradle block stringing method

Cradle block stringing is generally used for those applications where the required electrical clearance for conventional stringing methods cannot be achieved.

Cradle block methods of installation require unrestricted travel of a radio controlled motorised tug along the existing earthwire. Before an installation commences, the existing earthwire should be inspected to ensure that it is not damaged and that there are no loose or damaged wires. If any damage to the earthwire is found, it should be repaired before the installation commences, or consideration should be given to not using it as a support member for the cradle blocks.

There are two cradle block stringing methods used, depending on the project being worked on.

– Where new OPGW is replacing existing earthwire, and is to be installed for a number of spans, the multi-span cradle block system is normally used.
– Where an existing OPGW is to be replaced in one span only due to damage, the single span cradle block system is normally used.

5.1.2.1 The multi-span cradle block system

The forces required to pull and maintain sag in the new OPGW over many spans – up to 5 km, require that a larger motorized tug, a puller and a tensioner be used during the installation of the new OPGW. Tensions used during the cradle block stringing installation process are however low compared to the normal installation of phase conductor and accurate control is required. Puller and tensioner equipment used for tension stringing of phase conductors will not generally offer the fine control required at the low levels of tension which therefore may require specifically designed equipment giving excellent low tension control of linepull and speed. General requirements for pullers and tensioners are described in IEC 61328.

The lower tensions used for pulling the earthwire and the OPGW in cradle block stringing reduce the likelihood of failure of the pulling rope, the connectors and the earthwire. However, because the circuit or circuits on the line being worked on are live and road and rail crossings are not usually scaffolded, any failure of the existing earthwire, the OPGW, or the pulling or tensioning system could potentially have serious consequences. High integrity connections should be used between the pulling rope and the existing earthwire, or to connect to the OPGW.

Since it is difficult to determine the condition of the pulling rope, the nominal breaking load of the pulling rope should be rated at least 10 times the expected pulling force when used in the cradle block method. The rope should be inspected regularly.

The multi-span tug must have the tractive capability to install the pulling rope and cradle blocks over many spans up to 5 km.

As part of the cradle block stringing procedure, it is necessary to transfer the tug around the tower peak from one span to the next. To secure the tug during transfer, the tug should be first attached to the tower peak by a safety tether, before lifting it from the installed span into the next span.

5.1.2.2 The single span cradle block system

Where the new OPGW is to be installed in one span only as a replacement for the existing damaged OPGW, the force required to pull the cradle blocks and pulling rope is quite small and can be accomplished by using a battery powered single span tug.

Removal of the damaged OPGW and installing of the new OPGW can be accomplished with a small winch, or even by hand.

It should be noted that this system can be used to install new OPGW to replace existing earthwire in more than one span, but doing so one span at a time. It is however not as cost effective as using the multi-span cradle block system.

5.2 Installation procedures

5.2.1 Conventional stringing method

Tension stringing techniques, as described in IEC 61328 can be used to install the OPGW. It is recommended that fully hydraulic systems on the puller, tensioner and reel stands be used. If sufficient clearance from existing live circuits on the structure cannot be obtained, a circuit outage may have to be obtained.

5.2.2 Multi-span cradle block stringing method

Techniques exist which allow replacement of the existing earthwire without switching out the power circuit or circuits on the structure, or on any lower voltage circuits crossing underneath.

One such scheme makes use of the cradle block stringing system for multi-span installation of OPGW (see Figures 2, 3, 9, 10 and 11). This is a system consisting of a puller, a tensioner, an earthwire take up stand, and an OPGW let off stand. This system also includes cradle stringing blocks, spacer rope, pulling rope, a brake unit, and a motorized tug, all of which use the existing earthwire as support when installing the new optical fibre cable.

The advantages of using the cradle block system are that circuit outages are not necessary, and full-fault current rated, low-resistance earth continuity is maintained throughout the operation. The need to protect roads, railways, low voltage lines and other obstructions is minimised.

Initially the sag of the existing earthwire is measured which enables the sagging tension of the OPGW to be calculated and matched to the existing earthwire. The existing earthwire is then transferred to temporary anchor points on the tower, ensuring that the continuity of earth bonding is maintained. All cable block installation equipment is raised within the body of the structure.

In a typical multi-span cradle block stringing procedure, the motorized tug unit (see Figure 9) is used to pull two ropes across the span to the next tower. The first rope is used as a pulling rope for the OPGW, while the second, a spacer rope, is also attached to the tug unit to allow cradle blocks to be pulled out along the existing earthwire. The cradle block (see Figure 10) has a pulley in each of four corners and an opening gate on each side. One of the top pulleys of the cradle block runs along the existing earthwire and the bottom pulley supports the pulling rope.

The cradle blocks are clipped onto the spacer rope at approximately 10 m intervals as the motorized tug progresses across the span. The exact spacing is determined by ensuring that, if the cradle blocks move towards each other due to a loss of control of the spacer rope during installation, the loops formed by the ropes do not infringe the electrical safety clearance required.

The pulling rope is installed as a continuous length over the pull section of earthwire to be replaced, with stringing blocks to carry it through the intermediate towers. The pull section length will depend on the line route, but lengths of 3 km to 5 km are most practical to handle.

Once the pulling rope has been installed over the pull section, it is used to pull in the new OPGW, at a low tension, using a puller located at the puller end of the section. The OPGW is tensioned during installation by a tensioner located at the tensioner end of the section, and then sagged, clipped to its anchors, and bonded electrically to every tower, thus maintaining the earth continuity. The tensioner end of the old earthwire is then connected to a light pulling rope, and while the old earthwire is being pulled through the cradle blocks by the puller, it is tensioned out by the tensioner using a light pulling rope to provide back tension.

During final operation the end of the light pulling rope is connected to a brake unit (see Figure 11) which is pulled along the OPGW and this brake unit provides back tension to maintain cradle block spacing. The cradle blocks are recovered from the OPGW at each tower as the light pulling rope is being wound up at the puller.

5.2.3 Single span cradle block stringing method

The cradle block stringing system is also used for single span installation of OPGW to replace an existing damaged OPGW (see Figures 4, 11, 12 and 13). This is a system consisting of a radio controlled single span battery powered tug, a hydraulic braked OPGW let off stand, plus cradle stringing blocks, spacer rope, pulling rope, and a brake unit, all of which use the existing damaged OPGW as support when installing the new OPGW in a single span.

Many of the installation procedures are the same as described for the multi-span cradle block system.

5.3 Safety issues

There are considerable benefits which will accrue from the improved safety of cradle block stringing. This procedure uses greatly reduced pulling tensions, the OPGW and the existing earthwire are supported at regular intervals and the earth continuity is fully fault-rated. Thus, both the risk and the consequences of live line contact are reduced.

5.4 Earthing

The cradle block installation procedure can provide a fully fault-rated earth connection at all times, if properly implemented. In order to achieve this, it is necessary to provide two earth connections at each tower such that the new OPGW and old earthwire can both be attached simultaneously. It is very important that the new OPGW and the existing earthwire are properly bonded at each tower before the existing earthwire is removed. This may involve modifying or replacing the fittings for the existing earthwire before pulling in the new OPGW.

6 Optical phase conductor (OPPC) cable

OPPC is a stranded metallic cable incorporating optical fibres and is specifically designed to be used as a phase conductor as well as having telecommunications capabilities. The mechanical and electrical characteristics of OPPC are matched to those of the other conductors in the circuit. While the fittings for this type of conductor are similar to those used with OPGW, special phase-to-earth arrangements are required. An insulator assembly is used to allow the optical fibres to be taken from line voltage to earth potential at terminations. The optical fibres are fully protected and a sealing end system prevents water ingress at the point where the optical fibres are separated from the conductor. To date, the use of OPPC has been limited to distribution voltages within some countries, due to limitations imposed by the special phase-to-earth arrangements and therefore is not covered in greater detail in this technical report.

7 Optical attached cable (OPAC)

OPAC cable is a non-metallic fibre optic cable lashed or attached to an existing earthwire or a phase conductor.

OPAC cable systems (see Figure 14) have been installed on existing earthwires and also on conductors at lower system voltages, where similar phase to earth optical arrangements to OPPC will be needed. The techniques to allow installation on earthwires without a power system outage have been available for some time and OPAC cable has been widely selected for post-fit applications.

Helical wrap OPAC cable is designed to be helically wrapped around the existing conductor or existing earthwire.

Lashed OPAC cable is designed to be placed longitudinally beside the host existing conductor or existing earthwire, and a tape or tapes are wrapped around the pair to hold the lashed optical fibre cable in place.

Preform attached cable is similar to the lashed cables except that the method of attachment involves the use of special preformed spiral attachment clips.

7.1 Engineering considerations

Normally, helical wrapping or lashing is carried out on existing earthwires, but on system voltages below 150 kV, conductors of a de-energized circuit may be helically wrapped or lashed. The installation requires unrestricted travel of the tug and wrapping/lashing machine along the existing earthwire or conductor, since any loose strands could unravel and foul the tug or wrapping/lashing machine as they pass (see Figure 15). Therefore, prior to installation, it is recommended that the existing earthwire or conductor is inspected and any damage, such as loose strands, is repaired before installation commences. The normal recovery procedure cannot be used where a tug or wrapping machine is entangled with broken earthwire or conductor strands. In this situation, a single-circuit outage should be arranged if necessary and a crane used to effect the recovery.

Detailed design of the tug and wrapping/lashing machine should be to a high standard to ensure they cannot fall from the earthwire/conductor by using gates that fully close around the earthwire/conductor. Removable parts of the tug and wrapping/lashing machine, such as counter-balance weights and cable drums, should be secured to the main body of the machine using fixings with locking pins to provide a high degree of integrity.

To ensure that safety clearance is maintained, the equipment ropes should be carefully controlled during lifting to ensure that they cannot blow out into the conductors. This can be best achieved by lifting all the equipment inside the tower body if there is sufficient space. The other method of lifting is on the tower face perpendicular to the line. When using this method, control slings should be used to maintain the rope and equipment on the tower centre line.

When machinery is being moved around the tower peak, it should be tethered to the tower to prevent it from falling if mishandled.

The success of the wrapping/lashing technique is critically dependant on the installed tension of the optical fibre cable, since, once tension is lost, it cannot be restored and loose loops will form. Adequate tension is required to ensure that, under all environmental conditions, the wrapped/lashed cable remains tight to the existing earthwire or conductor. The wrapping/lashing of the cable around the earthwire or conductor is to be undertaken in a controlled manner at constant tension, speed, and lay length, to avoid loops forming at a later stage. The tug and wrapping/lashing machine design should ensure that, while it is stationary, the cable or lashing tension can be maintained for a prolonged period.

7.2 Installation procedures

OPAC cables are cost effective when they are installed onto an existing earthwire or conductor which is judged to have sufficient remaining serviceable life. No heavy equipment or vehicles are needed, installation is quick and requires no earthing protection. OPAC cables are especially suited to existing lines where induced voltage gradients prevent the installation of self-supporting aerial cables such as OPGW. OPAC cables may be the only viable solution where ground clearances or tower loading prevent the use of ADSS cables and difficult terrain or limited access may prevent the use of alternative systems.

OPAC cable is installed on an earthwire or a de-energized conductor with specially developed machinery normally provided by the cable supplier and matched to the cable to be installed. With an installation on the earthwire, the circuits can remain live, depending on local working regulations. Obviously, installation onto conductors is not feasible for a double-circuit line with both circuits energized. Nor can OPAC cables be wrapped or lashed onto bundled conductors. The installation machinery consists of a counter-balanced wrapping/lashing machine pulled by a radio-controlled motorised tug, or pulled manually from the ground for lower OPAC cables.

Machines have also been developed to remove wrapped cable and it is recommended that these be considered as an integral part of the wrapping system.

Warning devices, such as aircraft warning spheres, bird flight diverters and vibration dampers etc., should be removed immediately prior to installation of the OPAC cable. At the designated start point (known as a spinning tower) the tower is rigged to raise the installation machinery to the appropriate position on the tower. The first items to be raised and placed onto the existing earthwire or conductor are the motorised tugs. OPAC wrapped cable is normally supplied on drums, wound back to back as a cassette, which ensures maximum distance between splices. However, in some circumstances, a single drum may be used. The cable drums are then installed on the wrapping machine, the whole assembly raised up the tower, transferred onto the existing earthwire or conductor and coupled to the tugs.

When the wrapping/lashing machine and tug are positioned on the conductor or earthwire, safety locks which prevent the machines from leaving the conductor, are engaged. The optical fibre cable, which has been designed for earthwire or conductor installations, is secured around the tower and on both span ends before the wrapping/lashing installation starts. This is done at every tower by using a cable clamp and a mechanical bridging device around the tower. Similar devices are used to bridge conductor fittings such as vibration dampers. Wrapping or lashing then proceeds in either one or both directions from the tower.

From the spinning tower, one span is usually completed before starting the other which ensures that there will be no interaction between the radio control units of each tug. A helicopter can also be used to tow the machine in certain applications. The use of helicopters to move machines and people from structure to structure speeds up the installation significantly.

On completion of a span, it is essential to secure the optical cable to the conductor to prevent loss of tension during transfer of the machinery to the next span. Due to its weight, the machinery is transferred around the tower using a small jib and hand winch.

When the wrapping/lashing machine reaches a designated splice point or terminal tower, the remaining cable is unwound from the drum. The cable is then passed through a conduit which had previously been secured down the tower leg.

7.3 Safety issues

The wrapping/lashing machinery should control the cable such that, should a failure occur, long loops of cable cannot form, possibly infringing the safety clearance. This is particularly relevant to cable removal machines.

Before an installation commences, the condition of the existing earthwire or conductor and fittings should be assessed to ensure that they can safely support the load of the tug, and the wrapping/lashing machine, a full payload of cable and recovery equipment which will be used if a breakdown occurs. Adequate factors of safety should be allowed when considering the load on the earthwire or conductor.

The approval process of a wrapping/lashing system should include a full risk analysis of the machinery and procedures to ensure that it is safe for use under live line conditions. There should be an appropriate emergency plan within the procedures which adequately describes the actions to be taken if, during installation, there is a danger of the safety clearance being infringed.

Motorised tugs should be equipped with an emergency stop facility to allow line crews to halt the tug at the span end if radio control is lost.

8 All dielectric self supporting (ADSS) cable

ADSS cables are non-metallic optical fibre cables which are physically and operationally separate from the conductors. The cables are self-supporting on spans up to 1 km and have the strength and resilience to withstand the most severe climates. ADSS cable has many of the advantages of OPAC cable with the added benefit of being independent of the earthwire and the conductors. However, there is concern that electrical degradation may sometimes occur on these cables in higher voltage environments, typically on lines with a system voltage above 150 kV. Heavily polluted environments can create further problems below this system voltage.

8.1 Engineering considerations

All dielectric cables, particularly when installed on lines with phase voltages greater than 110 kV, are prone to sheath degradation. In some circumstances, degradation may be mitigated by the use of special sheathing compounds, specially designed fittings and by placing the cable between the phases where the space potential is a minimum. The cable supplier/installer, together with the utility, should assess the voltage stress applicable to the particular line. The supplier should provide evidence of the withstand performance of the cable system.

There are a variety of computer models which illustrate the level of capacitively induced voltage on the surface of an ADSS cable. Space potential plots of double-circuit lines with alternate phasing show a null point at the diagonal intersection of the bottom two phases from each circuit. Selecting a cable support point in this region will ensure that, when both circuits are live, degradation of the cable sheath will be minimised or eradicated. There is also a similar null point between the phases of the top two cross arms, however this position on the tower is not advantageous and will give rise to increased bending moments on the tower. Any significant periods of single-circuit working will reduce any phase cancelling benefits, and so this situation must be considered in the risk assessment.

Certain phase arrangements do not provide a null point. However, the computer models are able to indicate the most advantageous landing point for reduced induced voltage levels.

When the optimum cable support point has been chosen, installation begins with the fitting of the attachment points and any necessary reinforcing steelwork to each of the towers along the section. The drilling of steel tower members to provide a cable support point is to be avoided and this should only be carried out when absolutely necessary.

The design of the puller and the tensioner should allow fine control to ensure that the pulling force is always maintained within a reasonable margin. The puller and the tensioner should incorporate safety systems and redundancy in critical components to ensure that the rope and ADSS cable are never over-pulled and that tension is maintained if there is a failure of the machinery, thus preventing the ADSS cable clashing with live circuits.

The attachment of the pulling rope to the ADSS cable should be via a high integrity connection and a swivel. The pulling attachment should be secured to the strength member of the ADSS cable. If the pulling attachment is to be fixed to the strength member with an adhesive, this is best carried out under factory conditions. The cable is then supplied with the pulling attachment fitted.

A significant factor in determining clashing conditions is the weight of the ADSS cable relative to the conductor. The ADSS cable is usually much lighter and will tend to blow out further than the conductor. For lateral wind conditions, the blow-out for the ADSS cable can be calculated. However, the situation is more complex for longitudinal wind conditions. Wind along the line route will tend to shift the cable sag towards the leeward tower and this effect will be greater for lighter ADSS cables on long spans. If the ADSS cable is above, or level with a conductor, this effect makes it difficult to calculate the clearances and ensure that clashing is avoided. Where sufficient ground clearance exists, a possible solution is to attach the ADSS cable below the lowest conductor. ADSS cable has a relatively high strength to weight ratio, therefore the sag is very small, which helps to maintain the mid-span clearance.

Various computer models exist to show the sag performance and relative movements of different cables under a range of climatic conditions.

8.2 Installation procedures

A prime concern during installation should be to preserve the integrity of the cable sheath. All dielectric cables should be installed using the tension stringing method (see IEC 61328), thus ensuring that the cable is held high enough between structures so it is not snagged or abraded along the ground. The pulling rope is raised in a controlled manner so that it cannot blow into the phase before it is fully tensioned. Adequate tension should be maintained at all times such that the pulling rope and cable are pulled through tower to tower, keeping them well clear of the conductors and other hazards along the route.

Control of the pilot rope and the pulling rope is essential as they are raised and brought up to tension. Traditionally this has been done by having linesmen at mid-span using a control rope to contain blow-out until the required pulling force has been established. The linesman then slides the control rope along the ADSS to the tower and the rope is removed. A more reliable way of controlling the pulling rope is to use tensioning weights at the span ends. It is recommended that ground-level protection is provided, as required, over obstacles such as low voltage lines, roads and railway lines.

Using the correct stringing block sheave and tensioner bullwheel diameter is important to protect the ADSS cable.

If the specific stringing block sheave recommendations are not available from the cable manufacturer, a conservative sheave diameter is 30 times the diameter of the ADSS cable.

If a specific tensioner bullwheel diameter is not available from the cable manufacturer, a conservative bullwheel diameter is 35 times the diameter of the ADSS cable.

Installation and maintenance may be carried out, subject to correct safety procedures, without interference with the power system. In this respect, self-supporting cables offer a minimal Mean Time to Repair (MTTR).

The basic principles and techniques used in the installation of these cables are very similar to those used in the installation of the conductors. Conventional tension stringing techniques are adopted wherever possible utilising standard installation machinery and accessories, although in some cases, special machinery may be needed. Therefore it is important to follow the advice of the cable manufacturer in all aspects of the installation process.

8.3 Safety issues

ADSS cable has usually been strung at bottom cross arm level with circuits live, emphasising its independence from the power system. The procedure for stringing with one circuit live on a multi-circuit system may be more hazardous because of higher induced voltages on the cable sheath.

When tension stringing installation of the optical fibre cable is used, it is recommended that the pulling ropes be made of new polyester or polypropylene material, to prevent either mechanical or optical damage to the cable. At the highest system voltages, the use of water-blocked and sheathed ropes is recommended to prevent electrical degradation. Where synthetic ropes are used as pulling or pilot ropes, they should not be considered as insulating. They may initially present a high resistance electrical path, but experience has shown that over time and with use, the surface of the synthetic rope becomes sufficiently contaminated to be conductive, particularly in wet or humid conditions.

It is also important to choose a pulling rope which has low elasticity or stretch when under load. The rope should also match the weight per metre of the optical fibre cable or be even lighter so the rope will not sag lower than the optical fibre cable, thus ensuring electrical clearance is maintained.

8.4 Earthing

Although ADSS cables are manufactured from insulating material, there is still a possibility that leakage currents will occur. Therefore, as with metallic conductors, a running earth should also be employed on the ADSS cable adjacent to both the tensioner and the puller to ensure that any induced voltages or leakage currents do not present a hazard to the operators.

Temporary earthing clamps should be installed on the fittings at towers during stringing to prevent any leakage current which could be harmful to personnel, particularly in wet, humid and/or polluted conditions.

9 Maintenance

Maintenance of the optical cable systems is essential to ensure that communication is uninterrupted. Work on the power system should not interfere with the operation of the optical cable system. This applies to all voltage networks up to and including 400 kV. Maintenance falls into two main categories: routine maintenance and corrective maintenance as a result of failure.

The following recommendations are applicable to all four optical fibre cable systems, that is: OPGW cable, OPAC cable, ADSS cable and OPPC cable, and are all also dependent on national/local legislation and the overhead line company policy.

9.1 Safety issues

Routine replacement of damaged fittings and splice closures should only be undertaken with the circuit(s) energized if the comprehensive risk analysis that has been carried out on safety issues indicates that such operation can be performed safely. This analysis should include earthing, infringement of working clearances and training of line personnel on similar systems. The risks and hazards considered should include items such as the nature of the defect and its likelihood of premature failure, earth bonding, contact with energized conductors, danger to line personnel and the general public, switching out of the DAR, access to towers and security of communications and power systems during repairs.

Where repairs are required on an OPGW, OPAC or OPPC somewhere in mid span, these can be accomplished using live line working procedures, by suspending linesmen in a basket from a helicopter. Repairs from the tower can be accomplished on OPGW, OPPC, OPAC and ADSS by using helical or other repair fittings, temporary slipover heat shrinkable sleeves, two-part crimped repair sleeves or an approved sheath welding system, as applicable. Trials have shown that it is possible to use a standard repair sleeve under wrapped cable applied by using a hydraulic crimping tool.

ADSS cable should be repaired by lowering of the cable, using similar techniques as for installation. It is also recommended that subsequent repair be carried out as described above.

Seriously damaged OPGW or OPPC and OPAC cable should be replaced. As a temporary measure, either a section of ground deployed cable, or self-supporting cable should be used until a permanent replacement can safely be installed. If a prior risk analysis allows normal installation procedures, the temporary link should be installed with circuit(s) energized.

Where mechanical damage has occurred only to the sheath of OPAC or ADSS cables, a repair using a heat shrink or other sleeve to restore the integrity of the cable may be suitable. If heat shrink sleeves are used, a suitable heat shield should be employed to protect the cable during the process.

A controlled hand-over between the operator and repairer is recommended to ensure that no optical safety hazard exists to the repair personnel. Before commencing a repair to individual fibres, it is recommended that a fibre identifier be used to ensure that the fibre is unlit.

9.2 Routine maintenance periods

All overhead line systems are surveyed at regular intervals, either by ground patrol or helicopter. This allows remote identification of any obvious problems on the electrical power system with all circuit(s) energized. During this survey, the optical cable system should be routinely inspected in the same manner.

9.3 Detailed inspection

Routine maintenance should consist of visual inspections of the cable and fittings during normal line patrols.

A more thorough inspection of the power network is normally carried out on each circuit less frequently, often with circuit(s) de-energized. During these periods, the optical cable should also be subject to a detailed inspection, particularly of fittings, cable sheath, OPGW, OPAC and OPPC strands.

Splice closures should be inspected externally to look for weather or other related damage, including that from excessive mechanical vibration (galloping and aeolian) and vandalism. Invasive inspections, for example opening and inspecting splices, should not be performed unless there is evidence of a closure failure.

In order to check for any optical attenuation or continuity problems, optical measurements can be taken at any time with the power system energized. In the case of ADSS cable systems, a close inspection of the cable sheath should only be carried out with circuit(s) energized if the safety clearance is not infringed.

9.4 Corrective maintenance

Repair strategies should be formulated to determine the best course of action for various failure scenarios. Repairs may be permanent or temporary depending on the type of failure and the need for the urgent restoration of service. As a means of temporary repair, ground deployed cables can offer the fastest return to service.

Repair will normally be required as a result of mechanical damage to the optical fibre cable. For this reason, maintenance requirements for OPGW will be significantly lower than for either OPAC or ADSS cables. Splice closures will also require maintenance from time to time and the incidence for each cable type will be similar.

It is not practical to have a splice in the span on any of the cable designs. Repair will normally be accomplished by replacing at least two spans of cable as it is improbable that sufficient cable, either side of the damage, will be available to be brought down each tower to a splice box. When deciding on the repair strategy, consideration should be given to determining the new optical budget if additional splices are added. If the margin is too small, replacement of the optical section is recommended.

The first indication of a fibre fault will normally be an alarm raised by the transmission equipment when the fibre fails. However, there are systems, which can monitor the characteristics of a lit fibre and give an early warning of the need for a closer inspection if the fibre deviates from its defined operational parameters. Real-time monitoring may be considered necessary for critical circuits where alternate routing is not possible.

When a fault is detected, an optical time domain reflectometer (OTDR) should be used to determine the location of the fault. Initially, a measurement is made from the terminal end to determine the approximate location of the fault and a survey of the line is made to determine the exact location of the fault. If there is no physical indication of damage to the optical fibre cable, a second OTDR measurement may be made at the end of the optical section nearest to the fault. The exact location of the fault should be determined before taking repair action so that the span or spans affected can be identified.

A short term solution to failure of an individual fibre may be to route a service on to an alternative fibre within the cable. Fibre failure is usually associated with mechanical damage to the cable and it is recommended that every incidence of failure be followed by a full inspection of the cable.

Working procedures should be developed for the replacement of damaged fittings and/or the removal and replacement of damaged OPAC, ADSS, OPGW, or OPPC cable.

Following completion of both temporary and permanent repairs, a full series of optical tests should be carried out to ensure that the repair has been effective and has not introduced high attenuation due to micro-bending.

10 Summary of considerations

Several different types of optical fibre cable are being routinely installed on electrical power lines at all voltage levels under conditions which may be hazardous.

Optical fibre cables are frequently installed with power circuits energized. Guidance is given on how to ensure that such installations are carried out safely in conjunction with local safety rules.

Methods of working safely are very dependent on system voltage level and type of construction.

Major factors affecting safety include:

– the use of properly trained, competent staff, certified in installation procedures;
– adequate survey of conditions before work commences;
– the pre-planning of procedures to be adopted in the event of an emergency;
– the use of risk analysis techniques to identify and minimise risk;
– minimising the risk of loss of control of cables or conductors;
– earthing practice to prevent dangerous induced current or voltages, or electrical contact;
– maintaining an adequate electrical safety clearance at all times;
– continuous monitoring of weather conditions;
– the use, where appropriate, of equipotential zones or earth mats;
– the use, where appropriate, of sheathed and water-blocked ropes;
– delayed auto-reclose facilities to be disabled during optical fibre cable installation.

The installation and maintenance of optical cabling on energized power lines can be achieved with acceptable levels of safety. Work on the power or optical systems shall not affect the operational security of either system.

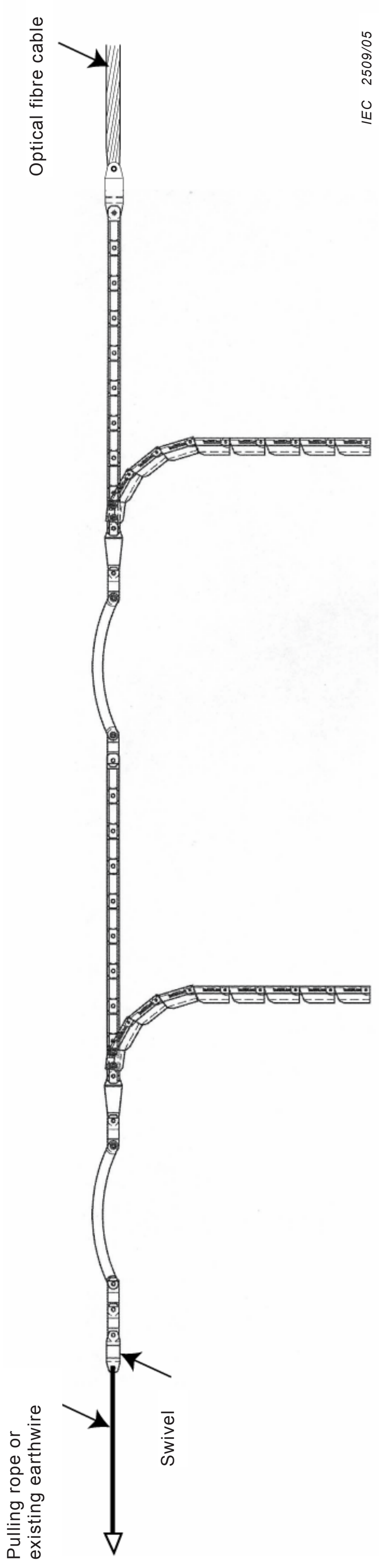


Figure 1 – Typical anti-twist running board (see 2.3 and 5.1.1)

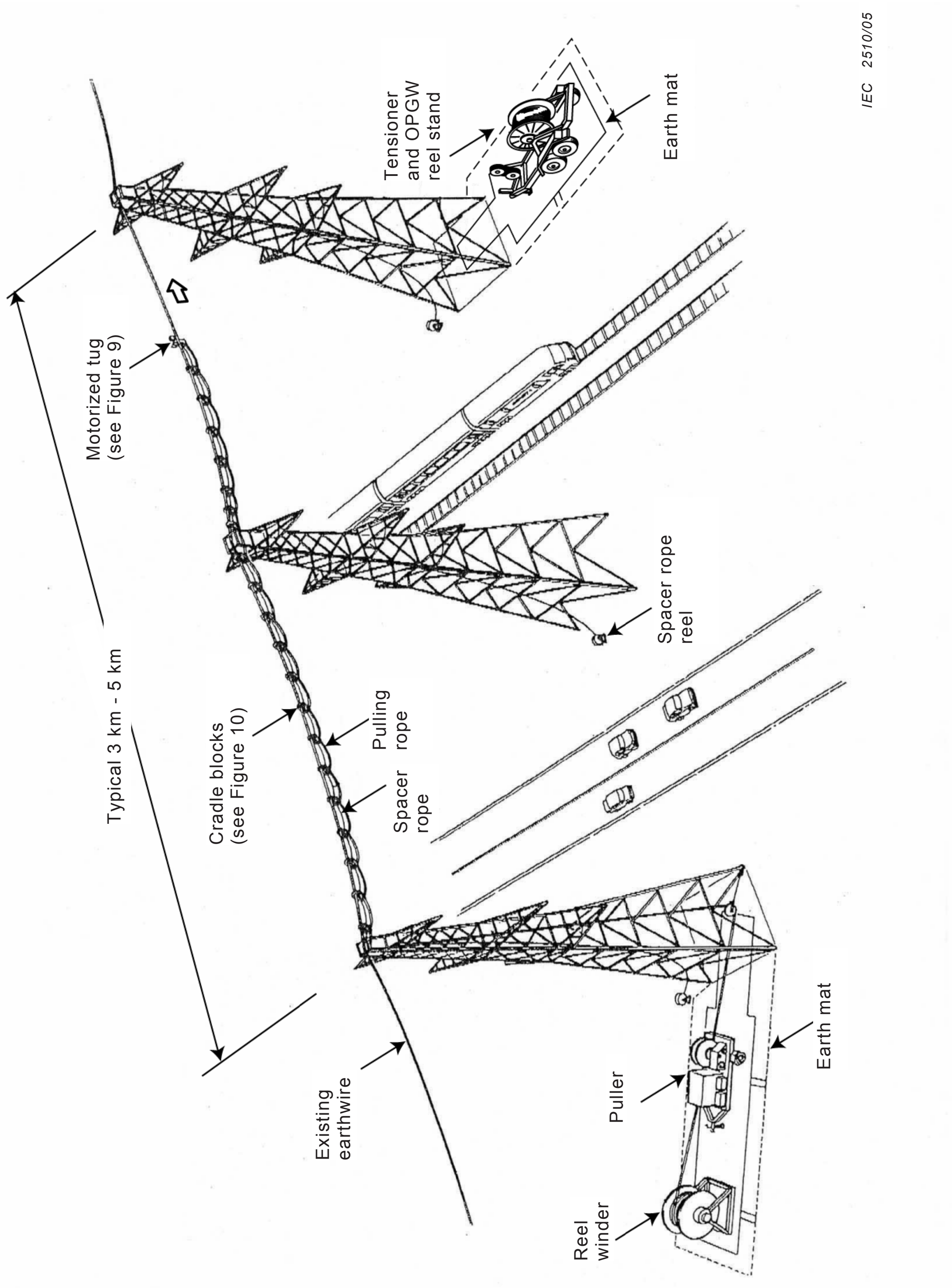
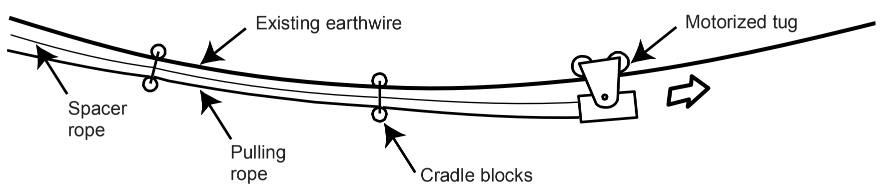
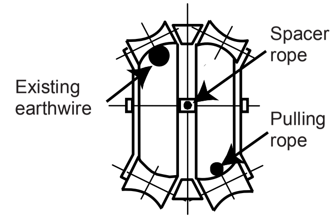
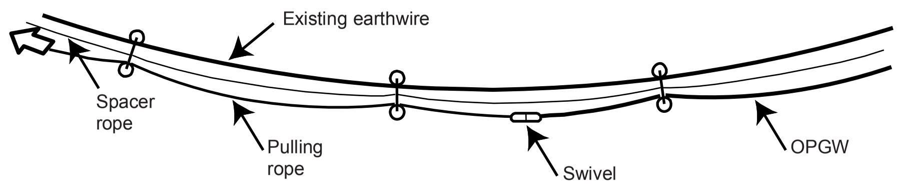
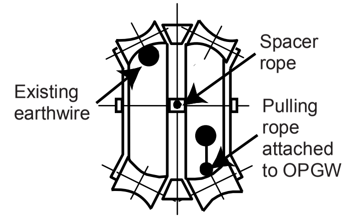
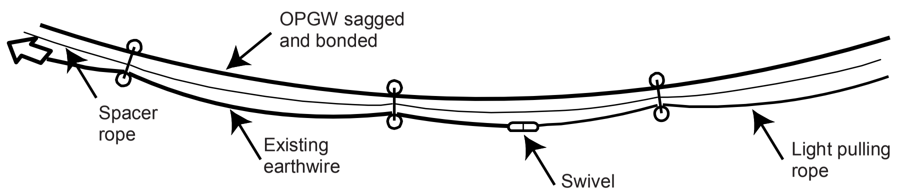
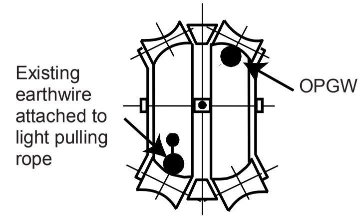
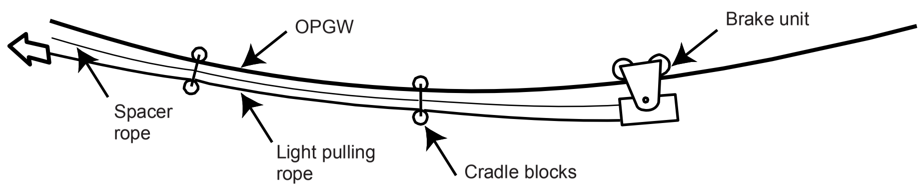
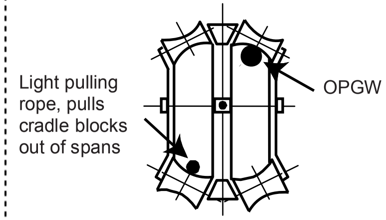


Figure 2 – Multi-span cradle block system – General layout (see 2.7 and 5.2.2)

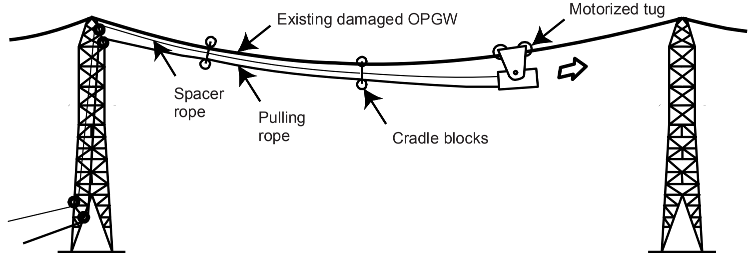
Description of process	Puller end / Method / Tensioner end	Cradle block function
1. The motorized tug, supported by the existing earthwire, pulls the spacer rope and the pulling rope into place in each span from the puller to the tensioner end. The spacer rope places the cradle blocks in each span.		
2. The puller pulls the new OPGW optical fibre earthwire into place with the pulling rope. The OPGW is tensioned out by the tensioner.		
3. The OPGW is sagged and bonded at each structure. Then the existing earthwire is disconnected from its support at each structure, and is pulled out with the puller, and tensioned out by the tensioner and a light rope.		
4. A brake unit is attached to the tensioner end of the spacer rope and the light pulling rope. The puller pulls the cradle blocks out of each span from the tensioner end to the puller end.		

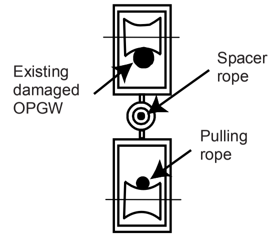
IEC 2511/05

Figure 3 – The multi-span cradle block system work procedure (see 2.7 and 5.2.2)

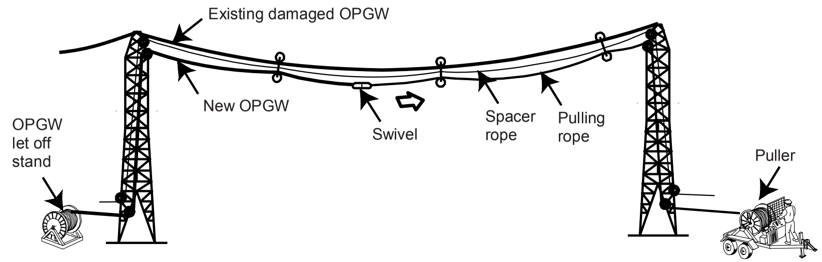
Description of process	Tensioner end — Method — Puller end	Cradle block function

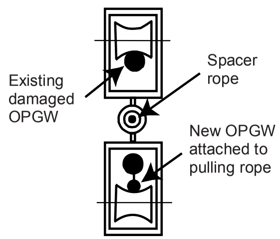
1. The motorized tug, supported by the existing damaged OPGW, pulls the spacer rope and the pulling rope into place in the span. The spacer rope places the cradle blocks in the span and is anchored at both towers.



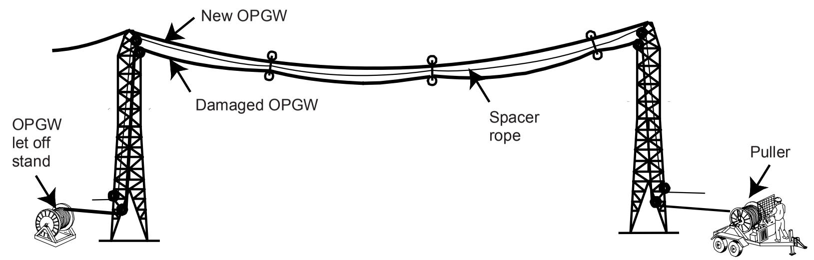


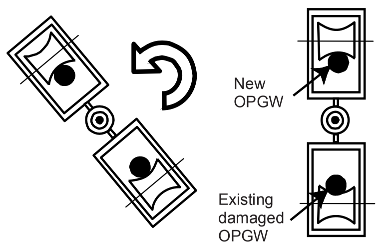
2. The puller pulls the new OPGW optical fibre earthwire into place with the pulling rope. The OPGW is tensioned out by the OPGW Let off Stand.



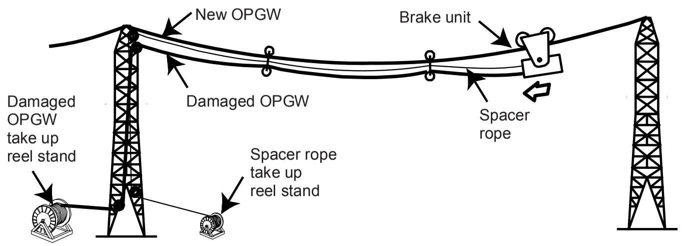


3. The OPGW is sagged and bonded at each structure. Then the existing damaged OPGW is disconnected from its support at each structure, and is pulled out with the puller, and tensioned out by the Let off Stand and a light rope.





4. A brake unit is attached to the tensioner end of the spacer rope and the light pulling rope. The puller pulls the cradle blocks out of the span from the tensioner end to the puller end.



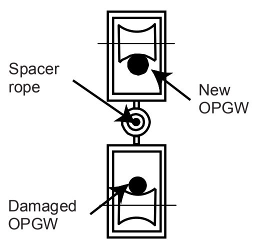


Figure 4 – The single span cradle block system work procedure (see 2.7 and 5.2.3)

IEC 2512/05

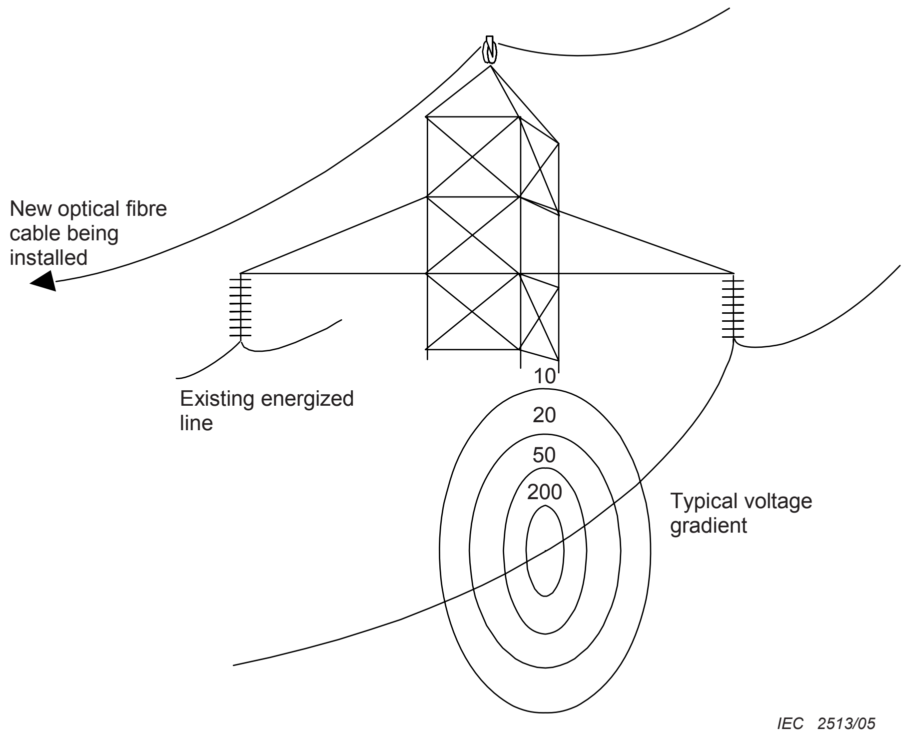


Figure 5a – Pictorial view

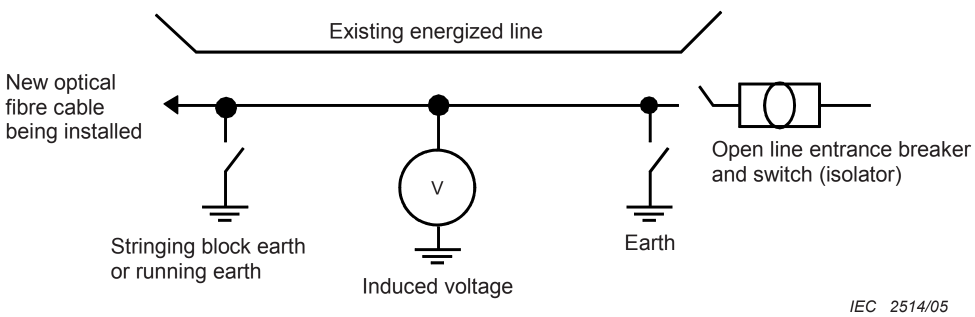


Figure 5b – Diagrammatic view

NOTE This figure is simplified. The three phases of the existing energized line are involved in the induction.

Figure 5 – Electric field induced voltage on a parallel optical fibre cable being installed (see 3.1.1)

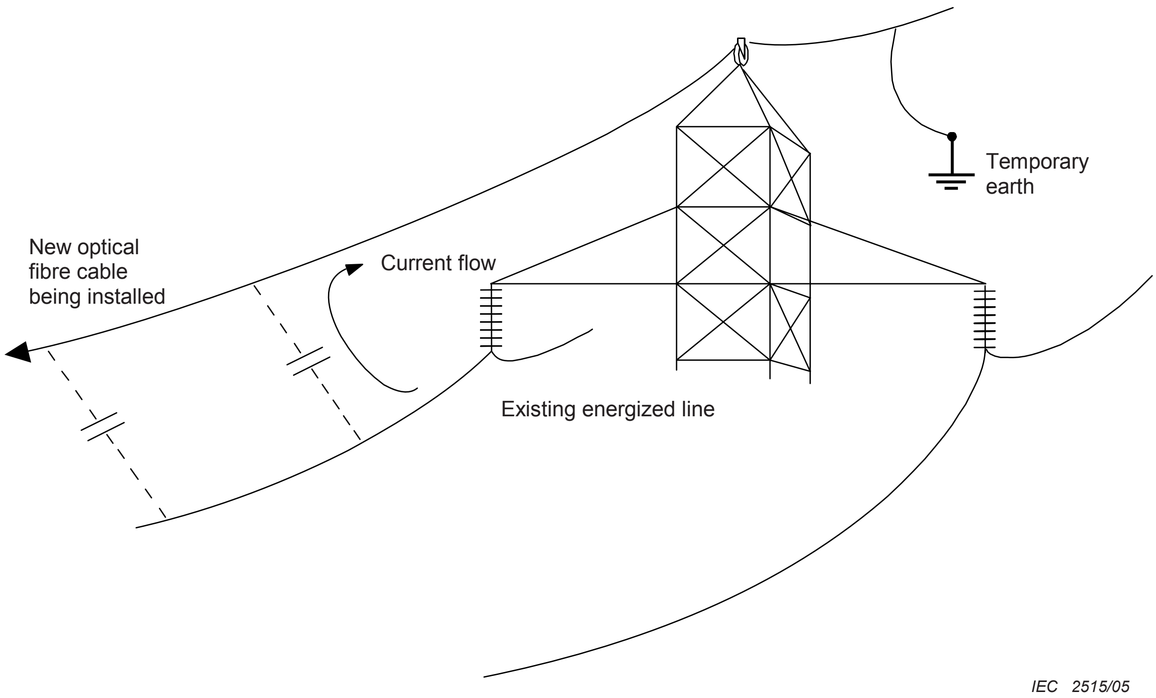


Figure 6a – Pictorial view

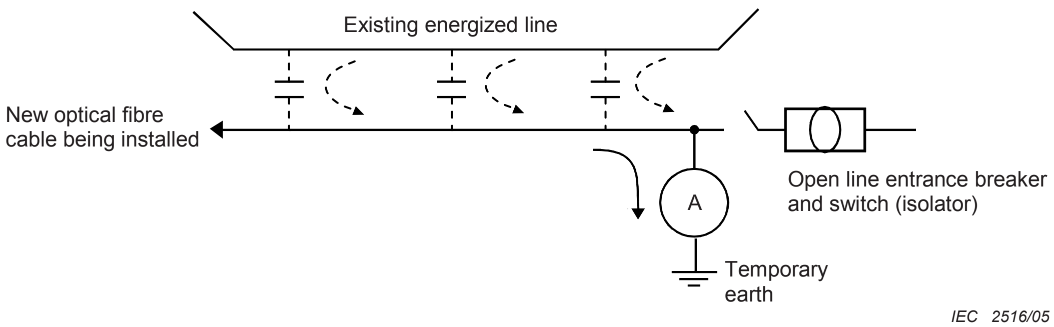


Figure 6b – Diagrammatic view

NOTE This figure is simplified. The three phases of the existing energized line are involved in the induction.

Figure 6 – Electric field induced current on a parallel optical fibre cable
(see 3.1.2)

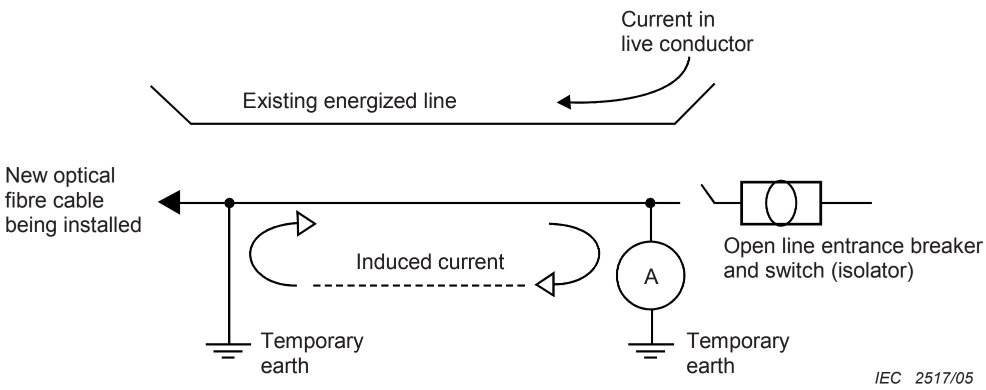


Figure 7a – Two earths on optical fibre cable allow circulating current to flow

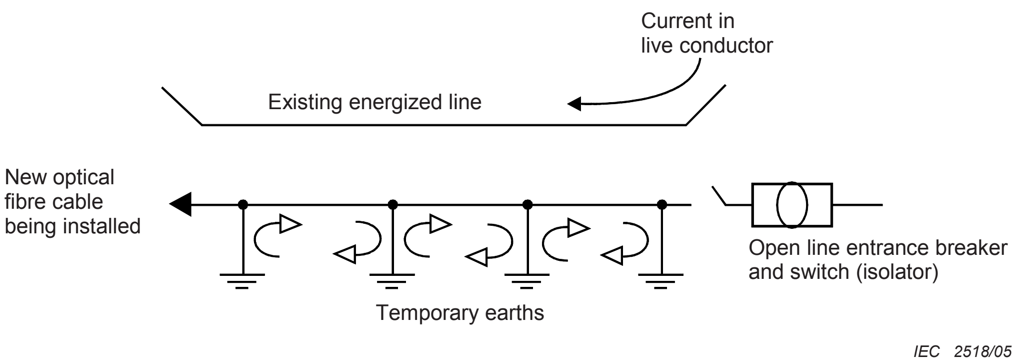


Figure 7b – Circulating currents with multiple earths

NOTE This figure is simplified. The three phases of the existing energized line are involved in the induction.

Figure 7 – Magnetic field induced current on a parallel optical fibre cable
(see 3.2.1)

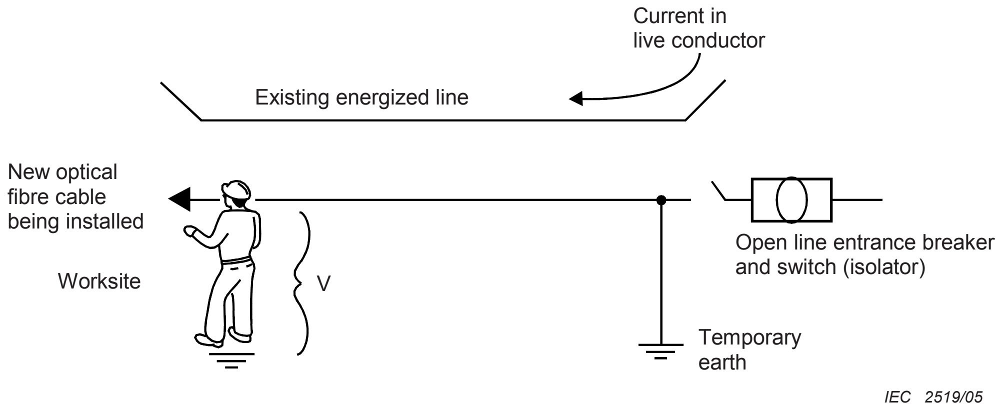
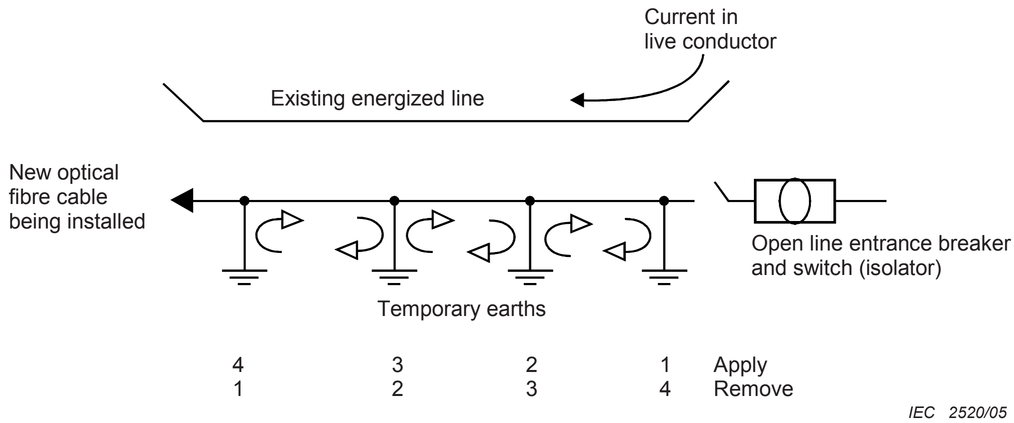


Figure 8a – Open circuit voltage with one earth only



NOTE In area of high induction, the last earth removed should be done so with a portable earth interrupter tool.

Figure 8b – Temporary earths to be applied and removed sequentially

Figure 8 – Magnetic field induced voltage on a parallel optical fibre cable
(see 3.2.2)

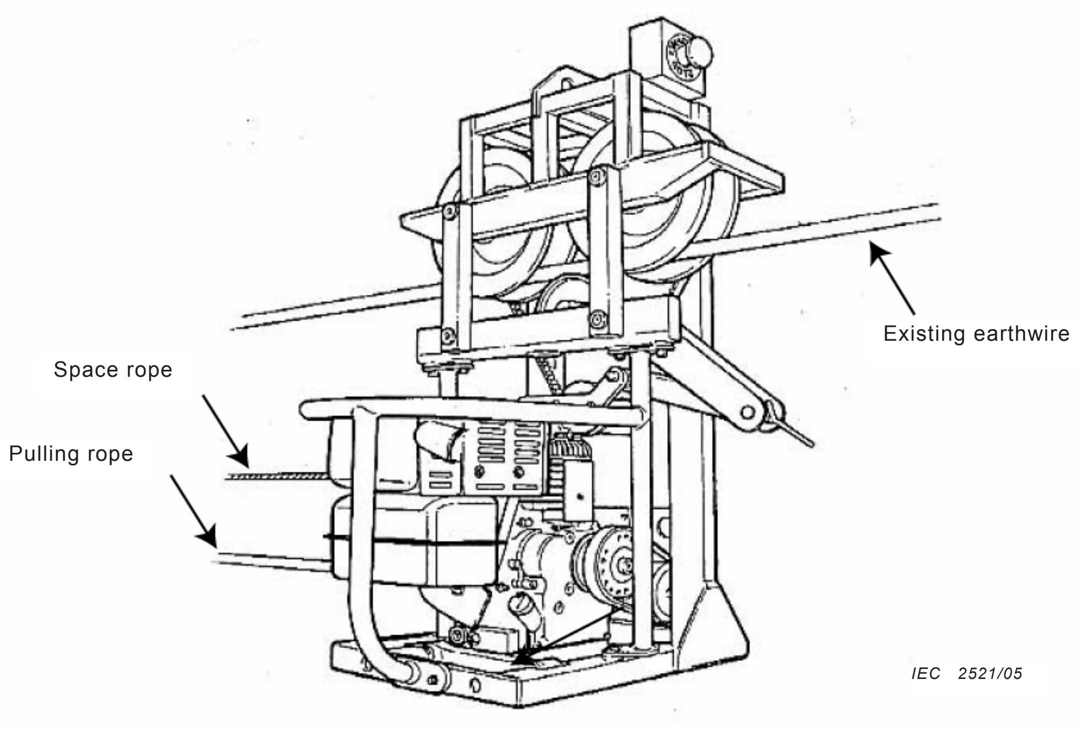


Figure 9 – Typical multi-span motorized cradle block tug, radio controlled
(see 5.2.2)

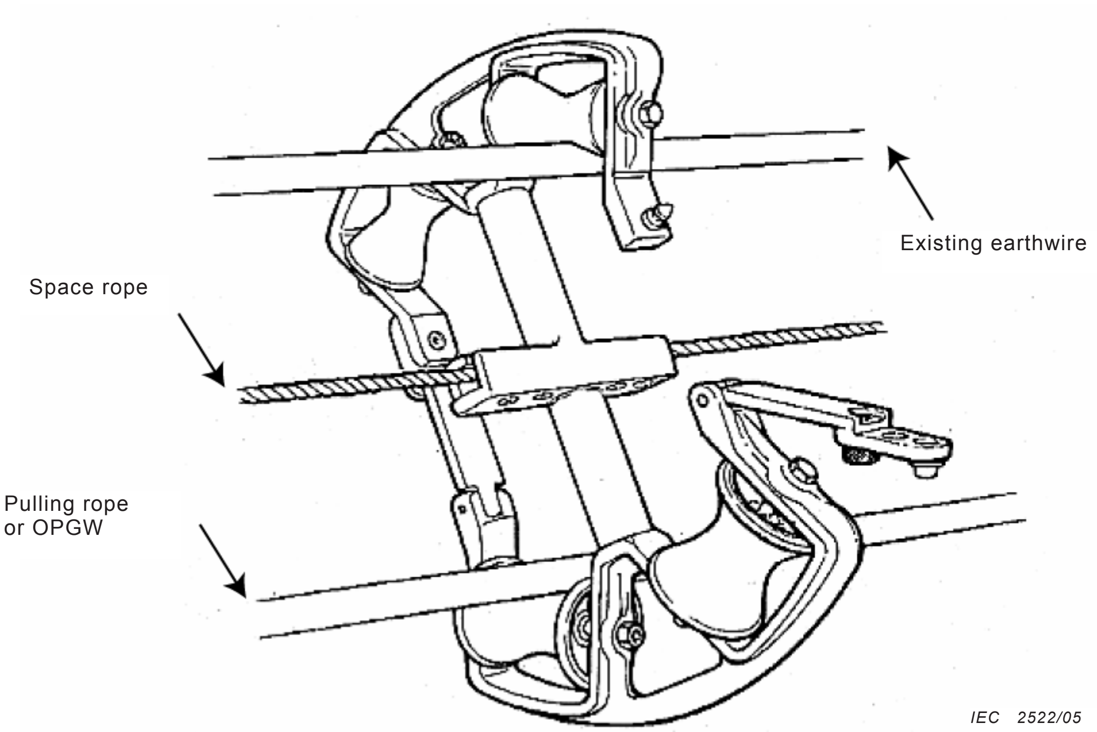


Figure 10 – Typical multi-span cradle block (see 5.2.2)

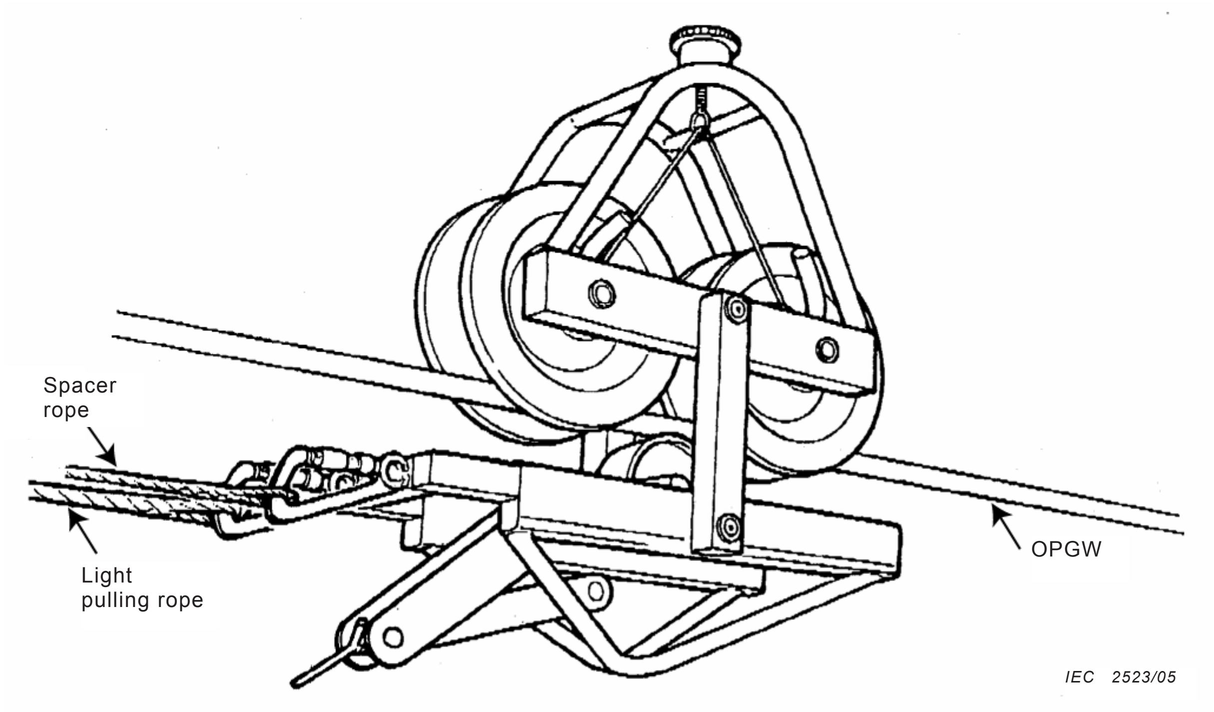


Figure 11 – Brake unit (see 5.2.2 and 5.2.3)

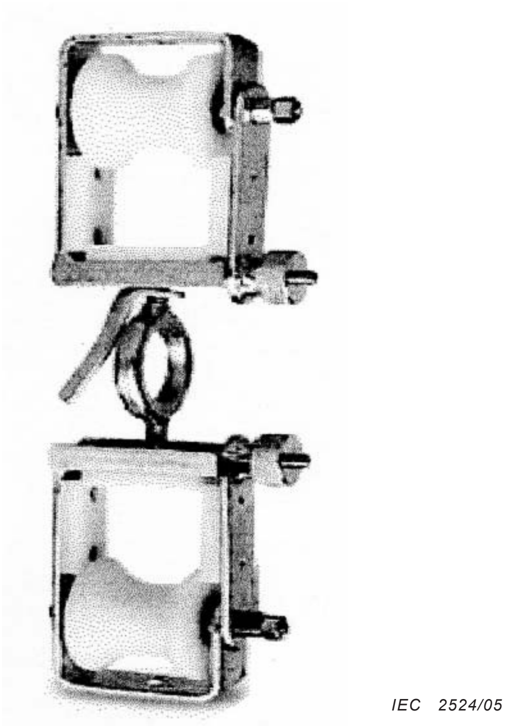


Figure 12 – Typical single span cradle block (see 5.2.3)

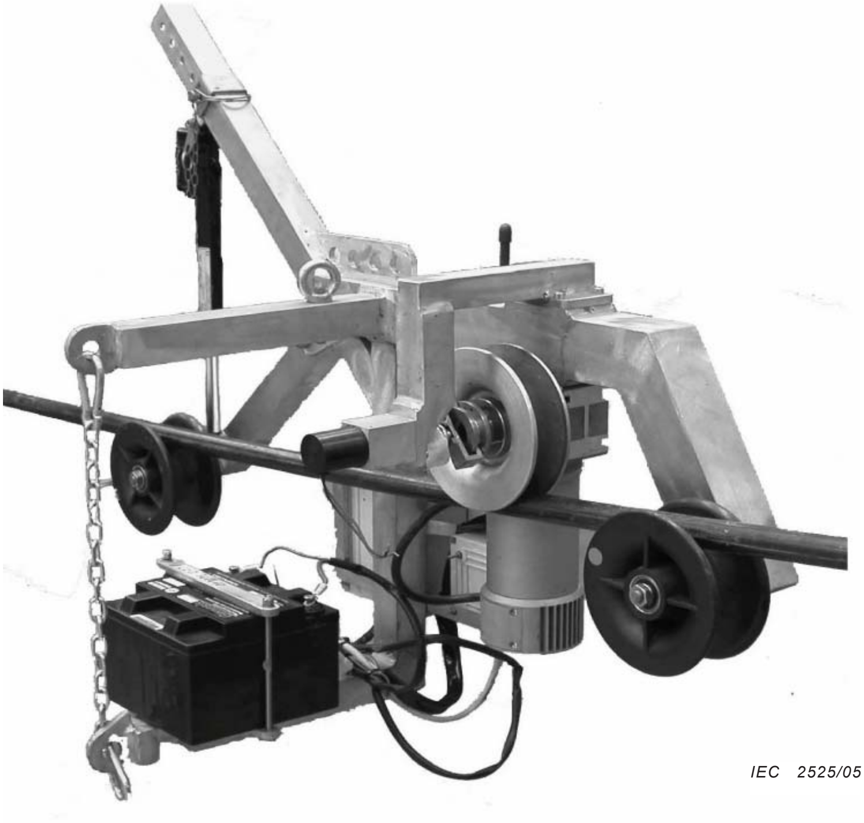


Figure 13 – Typical single span battery powered cradle block tug, radio controlled
(see 5.2.3)

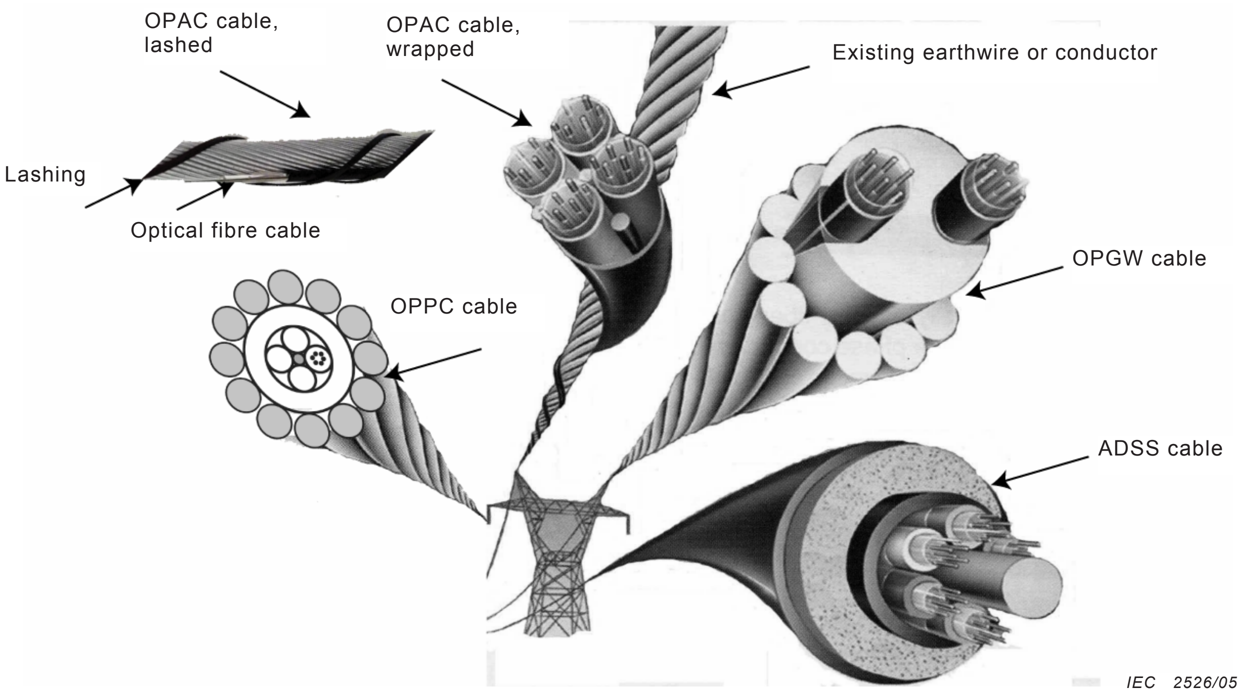


Figure 14 – Typical types of optical fibre cable (see 7)

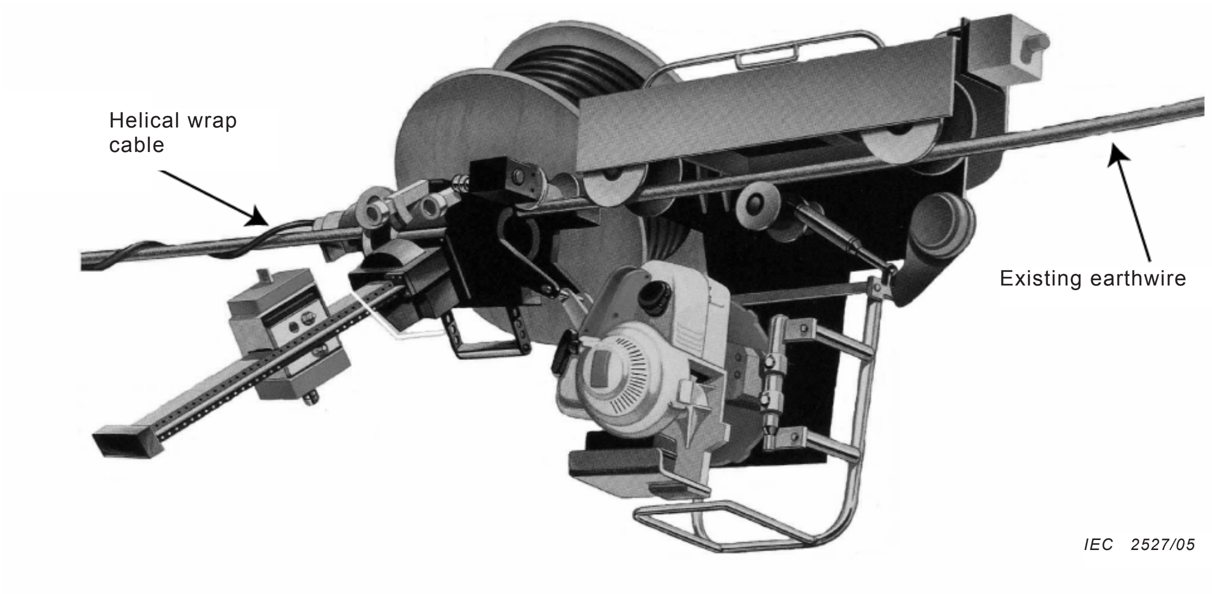


Figure 15 – Typical optical fibre cable motorized tug and wrapping machine (see 7.1)

Annex A
(informative)

Choosing the size of earths, earth cables and bonds

It is important that the size of earth cables and clamps for bonding and earthing be adequate for the maximum steady-state induced currents as well as the largest fault currents to which they are likely to be exposed.

This annex recommends requirements when selecting or specifying the dimensions of earths, earth cables and bonds (see also IEC 61230).

The three categories of possible current exposure are as follow:

– lightning current;
– fault current;
– induced current.

Where a fault current is a possibility, the earthing equipment shall carry this current long enough to allow the line protection system to operate. After the earthing equipment has carried a fault current, all components of the earthing system so exposed shall be immediately replaced.

All components of the earthing system shall be sized to carry a current of 20 000 A symmetrical for 20 cycles and still continue to pass the steady-state current induced without interruption. This will protect against most instances of the above possibilities of current exposure. However, the possibility of a larger fault current occurring deserves special consideration.

When the possibility exists of the optical fibre cable coming into contact with an existing live conductor, during the new cable installation process, the earthing system shall be capable of carrying the maximum expected phase-to-earth or phase-to-phase fault current which the live circuit may deliver.

Such possibilities of contact occur when the new cable passes over an existing transmission or distribution line, and it is not feasible to de-energize the existing line, or where blowout of the cable could cause live conductor contact.

NOTE In cases of severe or maximum induction, the above current rating may not be adequate, and the magnitude of the induced current should be determined by measurement or calculation and appropriately sized earthing and bonding cables selected.

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IEC 61477:2001, *Live working – Minimum requirements for the utilization of tools, devices and equipment*
Amendment 1 (2002)
Amendment 1 (2004) [2]

[1] Edition 2 in preparation.

[2] There exists a consolidated edition 1.2 (2005) that includes edition 1 and its two amendments.

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