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TECHNICAL REPORT

colour inside

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

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

FOREWORD

IEC TR 62263 has been prepared by IEC technical committee 78: Live working. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2005. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) it incorporates some technical changes to update equipment work methods and procedures, bringing them in line with the state of the art;

b) the content of the previous edition is kept but without mandatory terms as required by IEC ISO Directives 2 for a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
78/1468/DTR	78/1481/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

Words in *italics* in the text are defined in Clause 3.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document discusses general procedures for the installation and maintenance of optical fibre *cables* on single and multi-circuit overhead power lines. Due to the hazards involved in *stringing* near *energized* lines, the general concepts of electric and magnetic induction are presented.

The overall intent of this document is to provide state of the art methods in an informative manner recognizing that there are several procedural variations within the industry. There are also multiple standards and regulatory jurisdictions which specify methods and requirements beyond the scope of this document.

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

1 Scope

This document covers procedures for the installation and maintenance of optical fibre *cables* on single and multi-circuit overhead power lines, including:

– *optical ground wire (OPGW)* fibre *cable*;
– *optical phase conductor* fibre *cable (OPPC)*;
– *optical attached fibre cable (OPAC);*
– *all dielectric self supporting (ADSS) optical* fibre *cable*.

Relevant electrical hazards are also discussed.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050–466:1990, *International Electrotechnical Vocabulary (IEV) – Part 466: Overhead lines* (available at www.electropedia.org)

IEC 60050-–651:1999, *International Electrotechnical Vocabulary (IEV) – Part 651: Live working* (available at www.electropedia.org)

IEC 60743, *Live working – Terminology for tools, devices and equipment*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-466, IEC 60050-651, IEC 60743 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Terminology for equipment and procedures associated with the installation of overhead *conductors* and *earth wire*s varies widely throughout the utility industry.

3.1
all dielectric self-supporting cable
ADSS cable
optical fibre *cable* which has no metallic supporting or messenger *cable*

3.2
anti-twist running board
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

3.3
bullwheel
wheel or wheels incorporated as an integral part of a puller or tensioner with multiple offset grooves allowing the continuous winding of a *conductor* or a rope to generate pulling or braking tension through friction

3.4
conductor
cable
wire
bare or insulated *wire* or combination of *wires*, suitable for carrying an electric current

3.5
cradle block stringing
system of *cradle stringing blocks*, spacer rope, pulling rope, a brake unit, and a remotely controlled motorized tug, which use the existing *earth wire* as support when installing the new optical fibre *cable*

3.6
de-energized, adj.
at an electric potential equal to or not significantly different from that of the earth

[SOURCE: IEC 60050-651:2014, 651-21-09, modified – the term “dead” has been removed, in the definition “at the worksite” has been removed and the note has been removed.]

3.7
earth wire
ground wire
conductor connected to earth at some or all supports, which is suspended usually but not necessarily above the line *conductor*s to provide a degree of protection against lightning strikes

[SOURCE: IEC 60050-466:1990, 466-10-25]

3.8
energized, adj.
current-carrying, adj.
live, adj.
at a potential significantly different from that of the earth at the work site and which presents an electrical hazard

[SOURCE: IEC 60050-651:2014, 651-21-08, modified – “current-carrying” has been added as a term, in the definition “electric” has been removed, “significanty” has been added, and the notes have been removed.]

3.9
fault current
current flowing at a given point of a network resulting from a fault at another point of this network

3.10
induced current
current flowing as a result of induced voltage

3.11
optical attached cable
OPAC
non-metallic optical fibre *cable* designed to be wrapped or lashed onto the existing *earth wire* or phase *conductor*

3.12
optical phase conductor cable
OPPC
stranded metallic *cable* incorporating optical fibres which has the dual function of a normal *conductor* with built-in telecommunication capabilities

3.13
optical ground wire cable
OPGW cable
stranded metallic *cable* incorporating optical fibres which has the dual function of a normal *earth wire* with built-in telecommunication capabilities

3.14
pull section
section of line where the *conductor* is being pulled into place by the puller and tensioner

3.15
sagging
process of pulling the optical fibre *cable* up to sag

3.16
sealing end
assembly through which optical fibres pass providing sufficient insulation and voltage withstand capacity to maintain system integrity

3.17
stringing
process of pulling pilot ropes, pulling ropes, optical fibre *cables*, *earth wire* and *conductors* over *stringing blocks* supported on structures of overhead lines

3.18
stringing block
block
sheave or pulley, complete with a frame used separately or in groups and suspended from *structures* to permit the *stringing* of *conductor*s

3.19

vibration damper
device attached to a *conductor* or an *earth wire* in order to suppress or minimize vibrations due to wind

[SOURCE: IEC 60050-466:1990, 466-11-16]

4 Understanding the hazard – Basic theory

4.1 General

The process of installing *conductor*s on transmission and distribution lines exposes personnel to both electrical and mechanical risk.

Electrical worksite hazards include induced voltages and currents from *energized* adjacent lines as well as accidental energization of the *conductors* being installed. Personnel protection can be achieved through correct work methods, specialized training and properly applying adequate protective earthing systems.

Electrical charges or voltage can appear on a *conductor* being installed, or on other equipment and components such as conducting (metallic) pulling rope, pilot rope or *earth wires* due to one or more of the following factors:

a) electromagnetic induction from adjacent *energized* lines/circuits, or when crossing over *energized* lines;
b) accidental contact of the *conductor* or ropes being installed, with an existing adjacent *energized* line; this is the most likely cause of electrical hazard when working on distribution lines in crowded urban areas where existing circuits cannot be shut down;
c) electrostatic charging (i.e., conductive coupling) of the *conductor*s or ropes by atmospheric conditions or by an adjacent high voltage direct current (HVDC) transmission line;
d) switching error in which the *conductor* being installed is accidentally *energized*;
e) lightning strikes in the vicinity, or a lightning strike to the *conductor* 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* line 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*.

Mechanical worksite hazards include unexpected breaking of the pulling line elements, movement of the equipment under load, handling of material, lifting of material and tools on the tower and working activity at height.

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

4.2 Electric field induction from nearby circuits

4.2.1 Overview

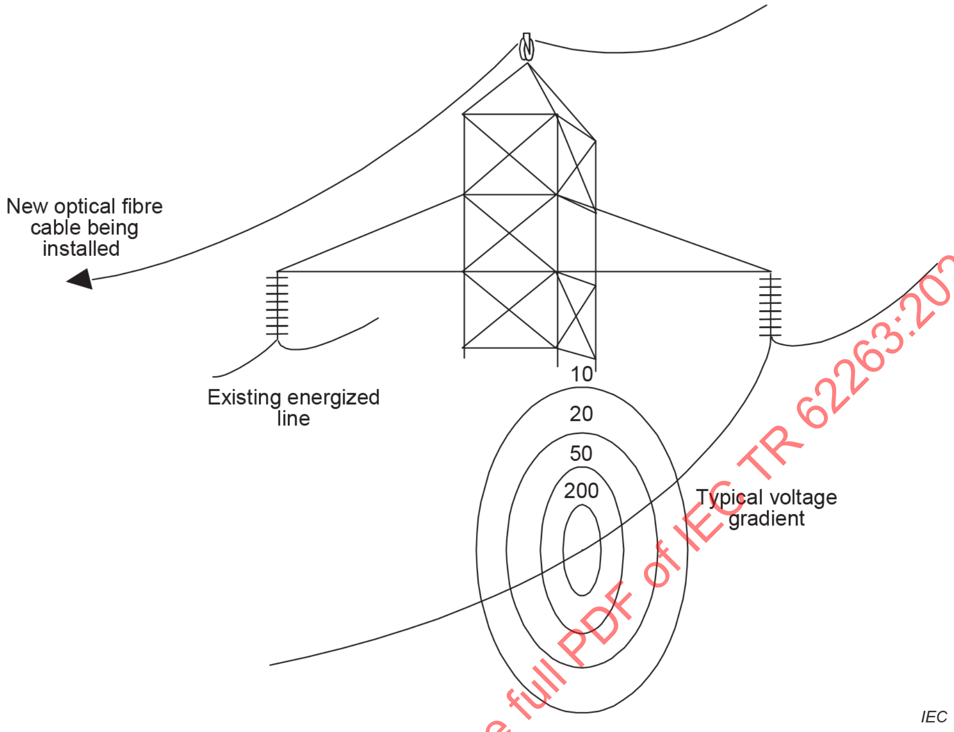
If the nearby line is an *energized* DC transmission line, the induced voltage is the result of switching transients or ion drift, and can result in even higher voltages than if the nearby line were an AC line.

4.2.2 Induced voltage

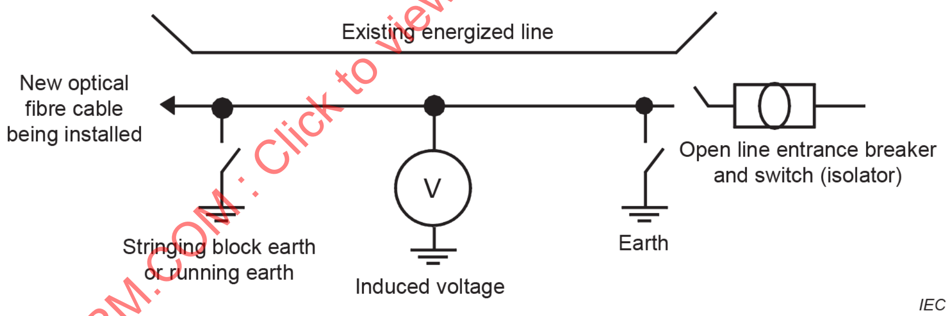
The electric field around an *energized conductor* produces a voltage on an isolated and unearthed conducting object nearby (see Figure 1).

The voltage produced depends on the source voltage magnitude and the geometry of the systems but not on the length of the parallel between the *energized* line and the new *conductor* being installed.

If the circuit is unearthed, the induced voltage can 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 *conductor* 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.



a) Pictorial view



b) Diagrammatic view

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

Figure 1 – Electric field induced voltage on a parallel optical fibre cable being installed

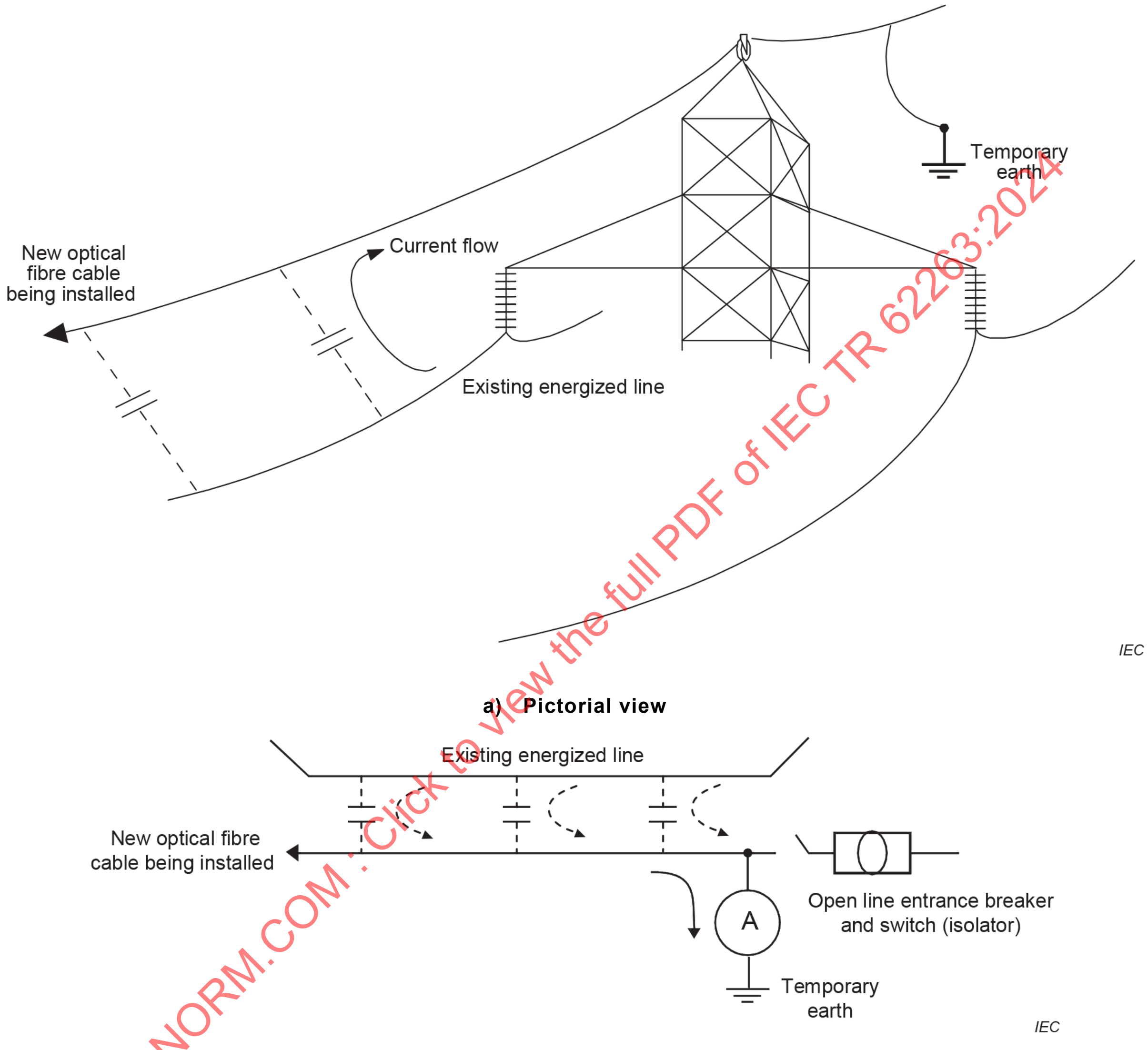
4.2.3 *Induced current*

With an AC 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 2).

The two following aspects will 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 can amount to several amperes.

b) If the temporary *earth* 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* is dislodged, the worker can be exposed to a dangerous voltage and current. If the workers attempt to contact the *conductor* or connected parts, they will receive a dangerous discharge current, since the induced voltage can be high enough to cause arc-over. Also, it will be noted that the steady-state capacitive current occurring after the contact can reach a dangerous level.



b) Diagrammatic view

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

Figure 2 – Electric field *induced current* on a parallel optical fibre cable

4.3 Magnetic field induction from nearby circuits

4.3.1 Overview

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.

If the nearby line is an *energized* DC transmission line, magnetic induction would only be related to the switching transients or ripple effect, and is therefore much less than would be the case if the nearby line were an AC line.

4.3.2 *Induced current*

The *energized*, *current-carrying conductor* and the nearby optical fibre *cable* being installed can 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 3a)).

This electromagnetic current is proportional to the current in the *energized* line and is dependent on the geometry and impedance of the system.

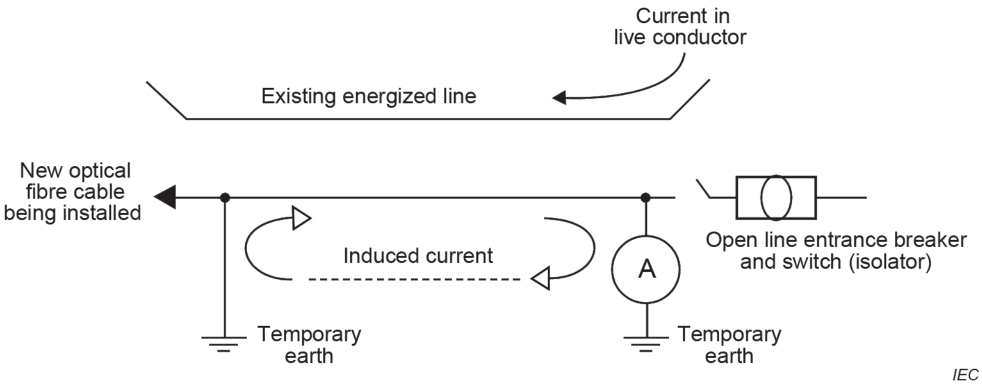
If multiple earth connections are applied, then multiple loops are formed, each carrying current (see Figure 3b)).

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

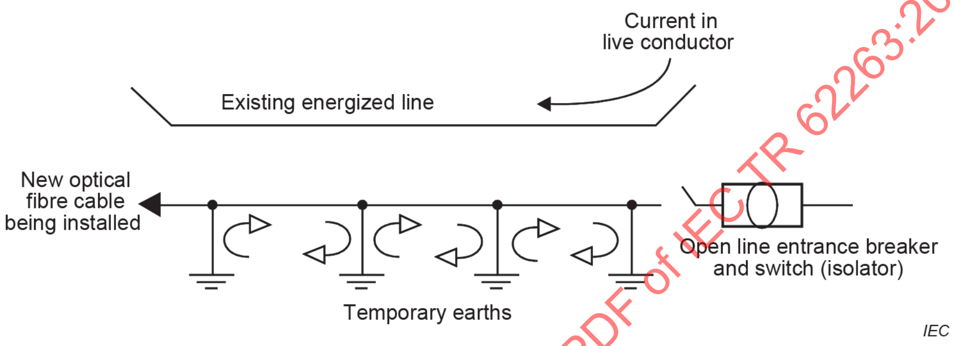
If there is a great difference in impedances of the earth connections in adjacent loops, for example a lake in the earth-return of one, and rock in the other, the intermediate earth connection can carry almost the full circulating current.

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.



a) Two earths on optical fibre cable allow circulating current to flow



b) Circulating currents with multiple earths

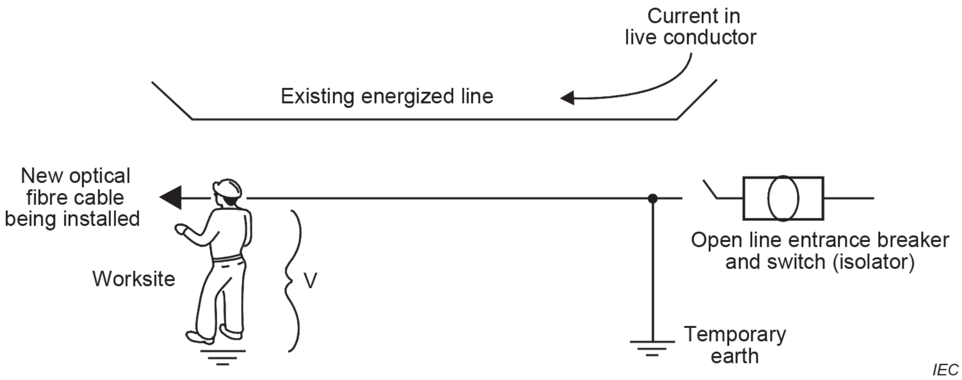
NOTE This figure is simplified. The three phases of the existing energized line are involved in the induction.

Figure 3 – Magnetic field *induced current* on a parallel optical fibre cable

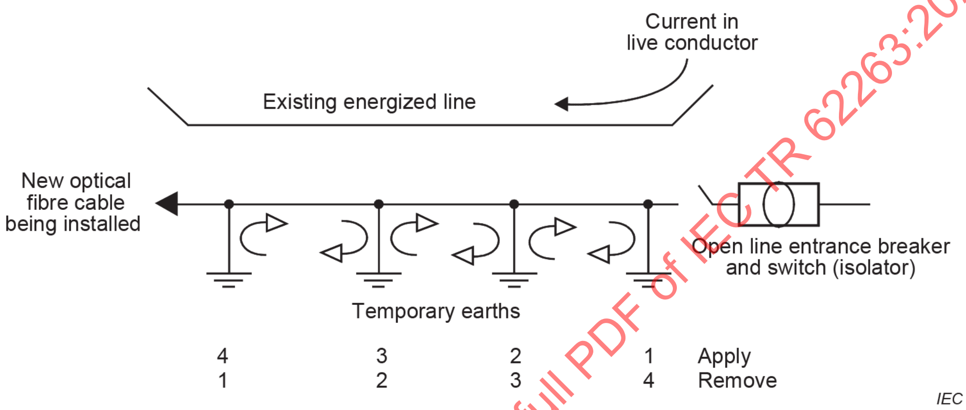
4.3.3 Induced voltage

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 4a)).

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 can 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 4b)).



a) Open circuit voltage with one earth only



NOTE In areas of high induction, removal of the last earth can be done with a portable earth interrupter tool.

b) Temporary earths to be applied and removed sequentially

Figure 4 – Magnetic field induced voltage on a parallel optical fibre cable

5 *Stringing* methods and equipment

5.1 *Cable* and *stringing* considerations

Optical fibre *cables* on single and multi-circuit overhead power lines include (see Figure 5):

– *optical ground wire (OPGW)* fibre *cable;*
– *optical phase conductor* fibre *cable (OPPC);*
– *optical attached fibre cable (OPAC);*
– *all dielectric self-supporting (ADSS)* optical fibre *cable*.

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

Minimum bending radius is specified by the optical fibre cable manufacturer to preserve the integrity of the optical fibres. This will affect the minimum diameters of tensioner *bullwheels*, *stringing blocks*, *sagging*/tensioning devices, and clamps.

The optical fibre cable manufacturer can indicate an elastomer lined sheave. In this case, an external *stringing block* earth device with proper connection provides an earthing path.

If maximum *stringing* speed is not recommended by the cable manufacturer, a conservative value is 40 m/min.

The tension on the optical fibre cable during *stringing* is measured at the tensioner. Manufacturer's maximum tension recommendations are normally 15 % of the ultimate tensile strength of the cable. Some installers use a strip chart recorder incorporated into the tensioner to provide a printed or electronic record of actual tension on the *cable*.

Under certain circumstances, to maintain clearance from *energized conductors*, the manufacturer can approve increasing the *stringing* tension above 15 % of the ultimate tensile strength of the *OPGW* fibre optic *cable*. Also, the length of the woven *wire* mesh grip could 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 is allowed to settle into place for 24 h after pulling and before clamping in.

The continuity of all fibres for each reel of optical fibre *cable* is checked when the reel arrives at the work site, then the *cable* ends are re-sealed against moisture entry.

Continuity is also checked after the optical fibre *cable* has been installed on the transmission line and after splicing to ensure continuity remains.

Cables are checked for attenuation loss when the repeater section has been completed.

Cables are installed according to the usual maximum temperature, ice and wind loading conditions.

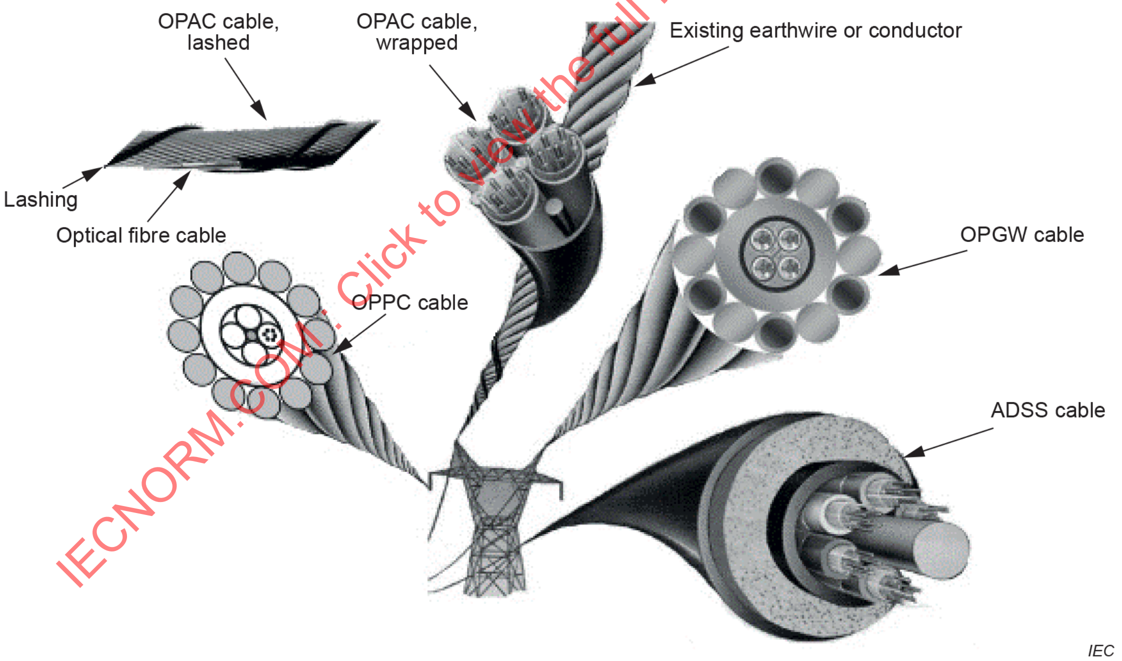


Figure 5 – Typical types of optical fibre *cable*

5.2 Equipment considerations

The puller and the tensioner have controls which will allow the operator to pre-set the maximum tension to prevent overstressing of the optical fibre *cable* as it is being installed. Tension is controlled to maintain the *sag* during the *stringing* operation, in particular when replacing *earth wire* over an *energized* line.

To help maintain required electrical clearances due to *sagging* of the pulling rope, the weight per metre of the pulling rope is chosen to be less than or equal to the weight per metre of the optical fibre *cable*.

Where an existing *earth wire* is to be replaced with an optical fibre *cable*, the existing *earth wire*, if in good condition, is used as a pulling rope to pull in the new optical fibre *cable*. Compression joints can be replaced with woven *wire* grips prior to entering the puller if the condition of the joint is questionable. The woven splice is then retrieved prior to the reel winder.

Where the minimum optical fibre bending radius allows, ropes and *cables* at the puller and tensioner ends of the *pull section* are routed through the body of the tower from the tower peak to the tensioner or puller at ground level.

5.3 Earthing

For the use of equipotential zones, earth mats, running earths, earth rods, and earth clamps, refer to IEC TR 61328.

6 *Optical ground wire (OPGW) cable* installation

6.1 General

OPGW cable is the most secure of the four alternatives of installation due to the mechanical protection by the outer strands of the *ground wire*. This system is installed on new and existing lines.

6.2 *Stringing* methods

6.2.1 The conventional tension *stringing* method

The conventional tension *stringing* method is used for pulling and tensioning operation. It can be implemented by using the *cradle block stringing* method in the span where the required electrical clearance cannot be achieved.

General features of pullers and tensioners are described in IEC TR 61328.

Helical fittings with a reinforcing layer are used for maximum mechanical protection of the optical *cable*. They will ensure that mechanical loads are evenly spread without affecting the optical performance. Traditional self-gripping clamps are used having interchangeable jaws made with material that prevents damage to the optical *cable*.

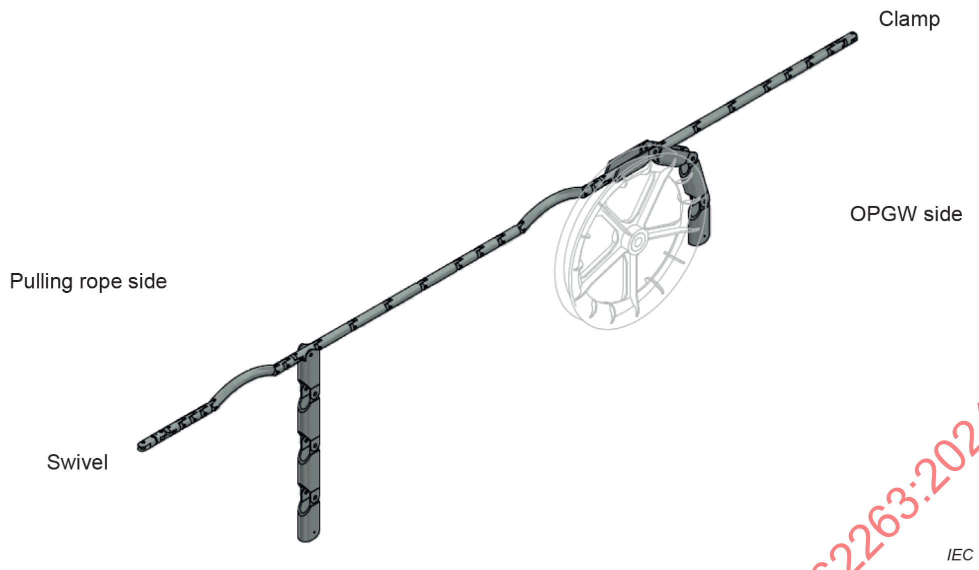
The conventional tension *stringing* method uses an *anti-twist running board* for a single layer and possibly two-layer *OPGW cable*. This running board keeps the optical fibres rotation-free during installation. It can be:

- an articulated long type with a fixed/solid connection (typically a clamp) on the *OPGW cable*, with a swivel on the pulling rope (see Figure 6 a) and b)).
- a clamp type directly applied to the *OPGW cable* (see Figure 6 c)).

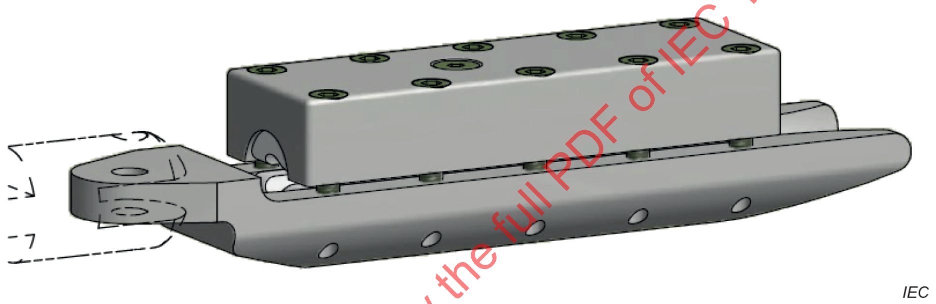
The running board is able to pass through the *stringing blocks* with minimum effort, even on angle support structures. The running board has two weighted tails to offset the twisting tendency of the *OPGW cable*.

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 cable*.

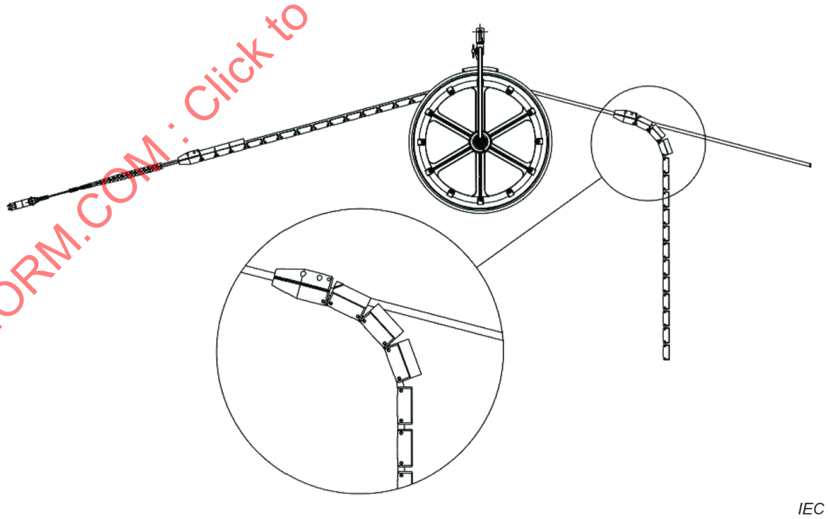
If a specific tensioner *bullwheel* diameter is not available from the *cable* manufacturer, a conservative *bullwheel* diameter is 70 times the diameter of the *OPGW cable*.



a) Typical ***anti-twist running board*** **– articulated long shape**



b) Clamp device to be used with articulated long shape running board



c) Clamp type running board

Figure 6 – ***Anti-twist running boards***

When replacing old *earth wire* with *OPGW cable* in an *energized* line, the *anti-twist running board* is not used due to the weight bringing the tail elements too close to the *energized conductors*.

6.2.2 *Cradle block stringing* method

Cradle block stringing is generally used in specific spans where the required clearance for conventional tension *stringing* methods cannot be achieved.

Tension values used with the *cradle block stringing* installation process are lower than those applied in the conventional *stringing* method.

The general layout of the *cradle block stringing* method is represented in the Figure 7.

The equipment includes a puller, tensioner, *earth wire* recovery reel-winder and an *OPGW cable* reel stand.

Cradle block method of installation involves the unrestricted travel of a radio-controlled motorised tug along the existing *earth wire* and includes *cradle stringing blocks*, spacer rope, pulling rope and a brake unit.

The motorized tug is a set of traction wheels driven by motors. The power to the motors and controls is provided by a battery or by a small generator installed as an integrated part of the tug unit. The movement of the tug is controlled by a remote control (see Figure 8).

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

In a typical *cradle block stringing* procedure, the motorized tug unit is used to pull one or two ropes across the span to the next tower simultaneously installing the *cradle block*s on the existing *ground wire*.

A safety tether is used to secure the tug while transferring around the tower peak from one span to the next in the case of multi-span *cradle block* installation.

The *cradle blocks* are clipped onto the spacer rope at approximately 5 m to 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 required electrical clearance.

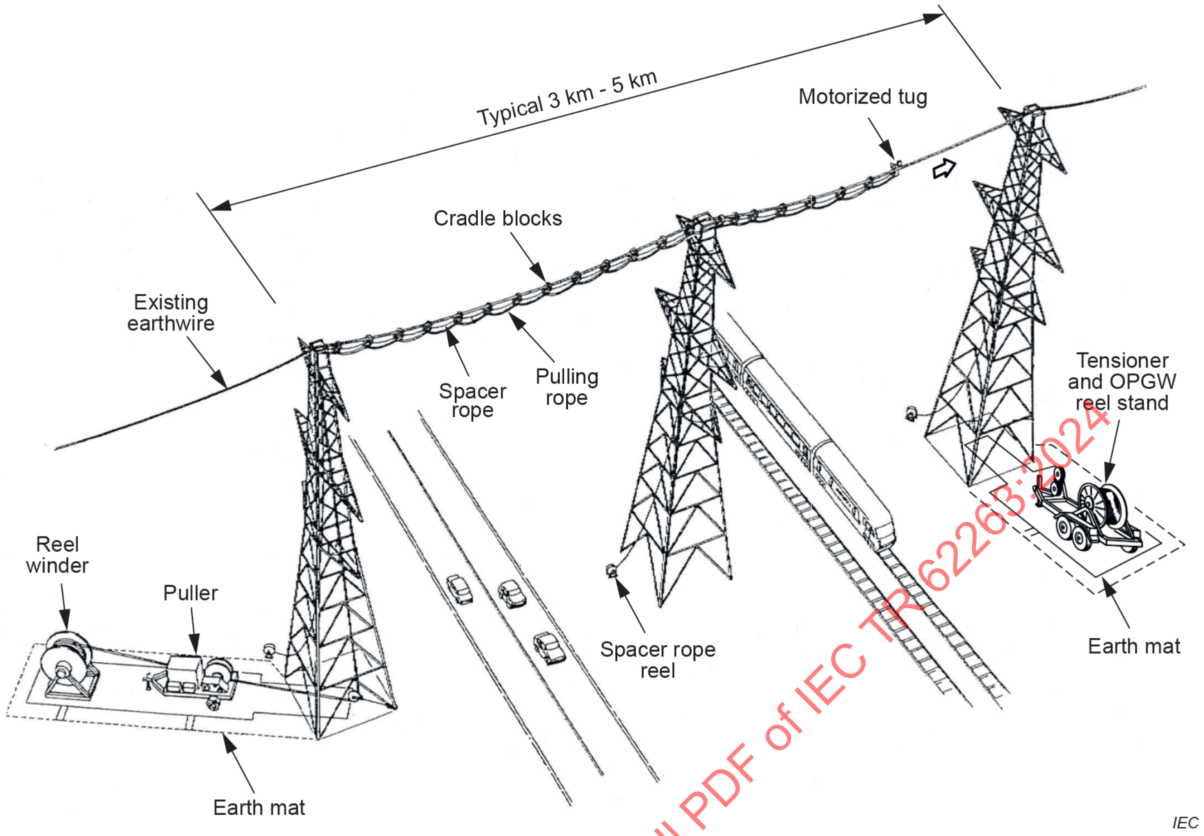


Figure 7 – General layout of multi-span *cradle block stringing* system

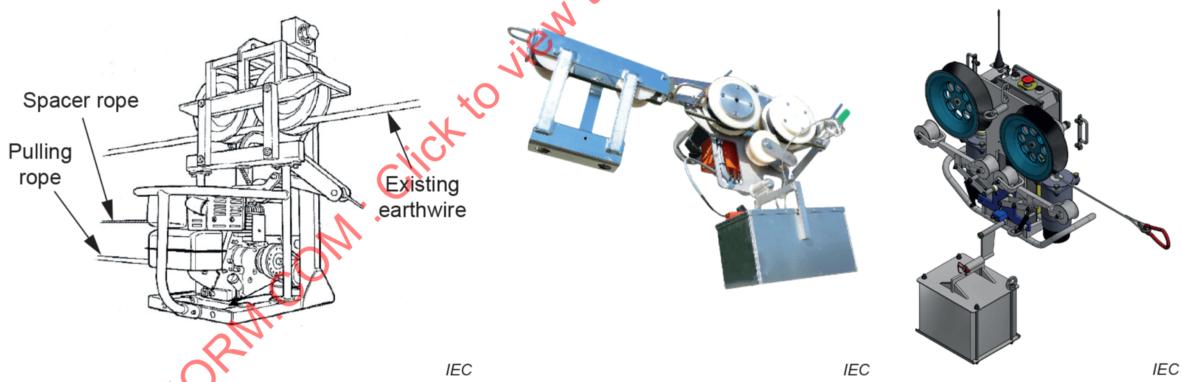


Figure 8 – Typical motorized *cradle block* tugs

The *cradle block stringing* method can have one or two ropes involved. Each method uses different *cradle block* design and operational sequence.

6.2.3 "Two ropes, single rotation" *cradle block* method

This method is normally used for multi-span installation, but it can also be used for single span installation. The entire installation sequence is described in Figure 9 to Figure 19.

The motorized tug unit (Figure 9) is used to pull two ropes across the span to the next tower. The lower rope is used as a pulling rope for the *OPGW cable*, while the upper rope, called supporting rope, is also attached to the tug unit to allow *cradle blocks* to be pulled out along the existing *earth wire*.

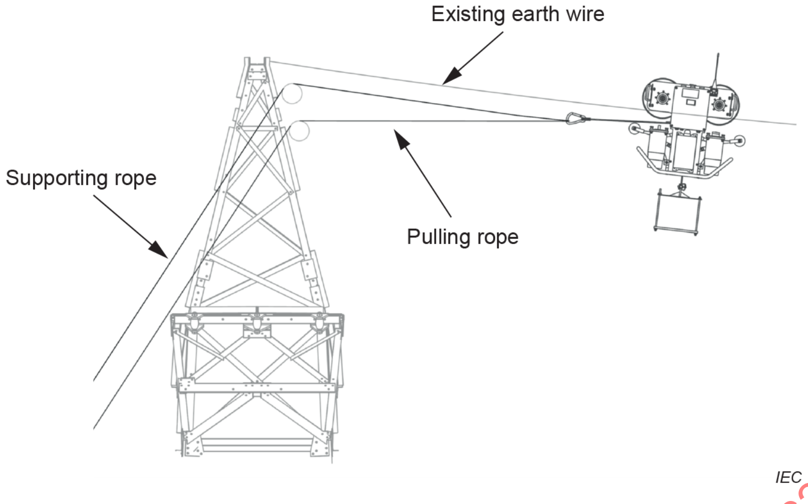


Figure 9 – Two ropes connected to the traction machine

The ropes and the *cradle blocks* are installed from tower to tower (Figure 10). The pulling rope is installed as a continuous length over the *pull section*. *Stringing blocks* carry it through the intermediate towers.

Dimensions in metres

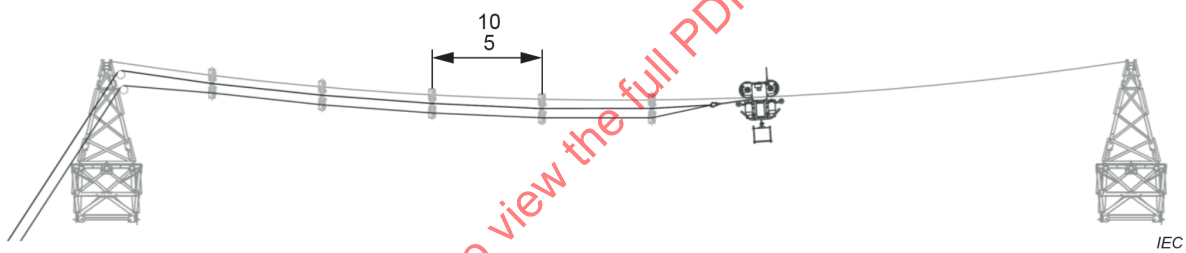


Figure 10 – Traction machine moves on the span installing ropes and cradle blocks

The *cradle block* (Figure 11 and Figure 20) is designed to allow the installation and the use of two ropes. It has an opening gate on each side and at least two rollers. The top pulley runs along the existing *earth wire* while the bottom supports the pulling rope.

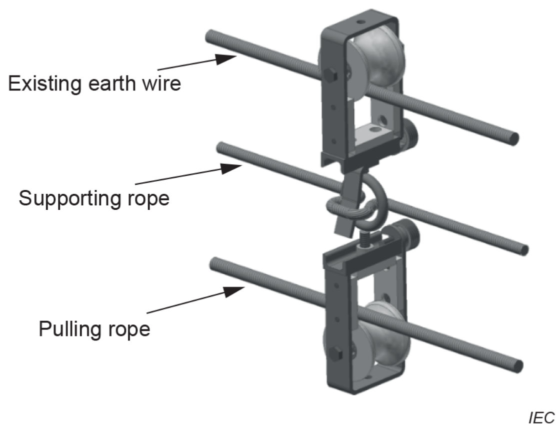


Figure 11 – *Cradle block* configuration

Once the ropes and the *cradle blocks* have been installed over the *pull section*, the supporting rope is connected to each side of the towers (Figure 12).

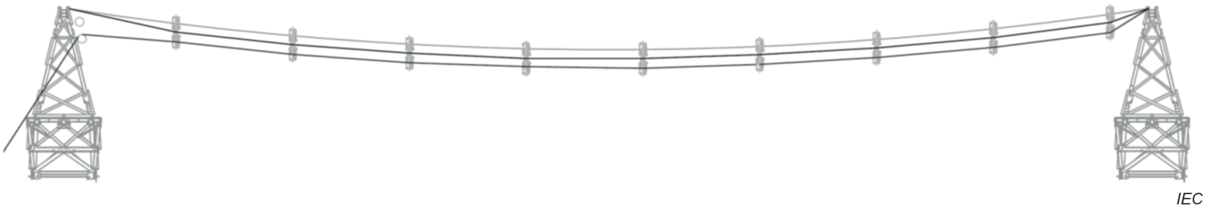


Figure 12 – Supporting rope connection to the towers

Once the pulling rope has been installed over the *pull section*, it is used to pull in the new *OPGW cable* on the bottom using a puller located at the puller end of the section (Figure 13). The *OPGW cable* is tensioned during installation at the tensioner end.

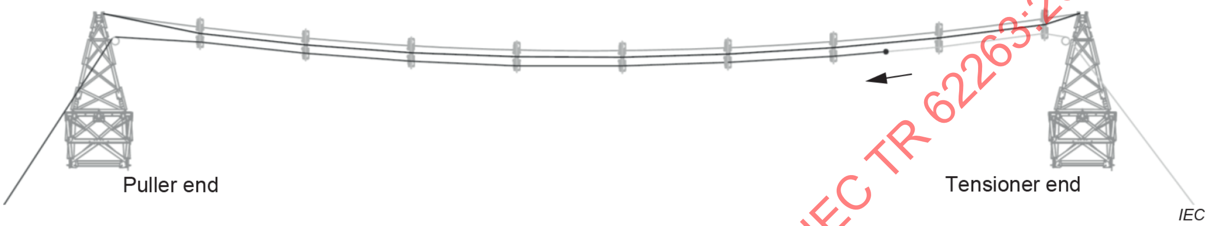


Figure 13 – *OPGW cable* installation

The *OPGW cable* is then connected and bonded electrically to every tower (Figure 14), thus maintaining the earth continuity.

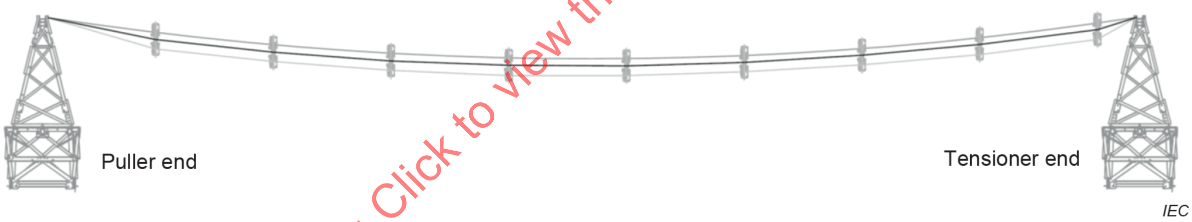


Figure 14 – *OPGW cable* connection to towers

Then the existing *earth wire* on top is disconnected from its support at each structure, and the tension is released. This generates a "rotation" of the *cradle blocks* around the supporting rope. At the end of the rotation, the new *OPGW cable* is now on the top of the bundle, while the existing *earth wire* is on the bottom side (Figure 15).

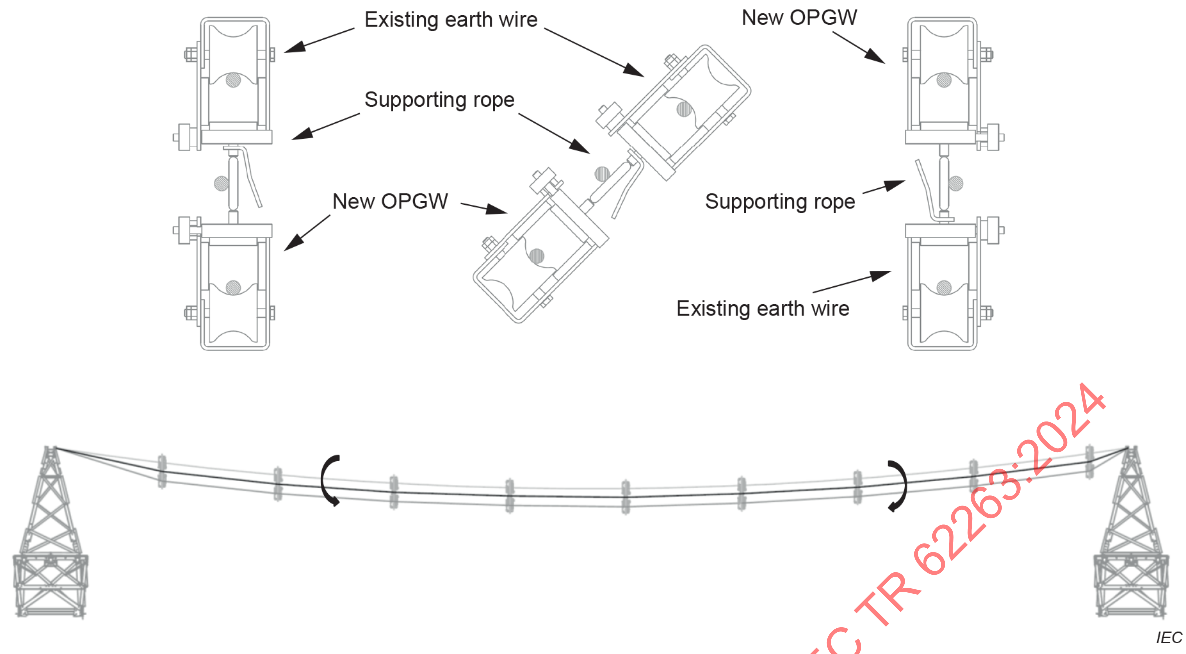


Figure 15 – Bundle rotation

The *OPGW cable* is then sagged and clipped to its anchor's points on the towers.

The tensioner end of the lower existing *earth wire* is then connected to a light pulling rope, and while the existing *earth wire* is being pulled through the *cradle blocks* by the puller, the existing *earth wire* is held by the tensioner using the light pulling rope (Figure 16).

Figure 16 – Existing *earth wire* recovery

Once the recovery of the old *earth wire* is completed, the supporting rope is disconnected from the tower in order to prepare for cradle recovery (Figure 17).

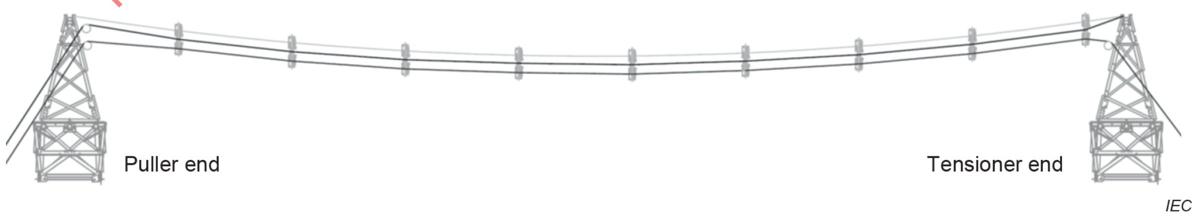


Figure 17 – Supporting rope disconnected from towers

The upper supporting rope and the lower light pulling rope are now connected to a brake unit (Figure 18 and Figure 21). This brake unit provides back tension to maintain *cradle block* spacing.

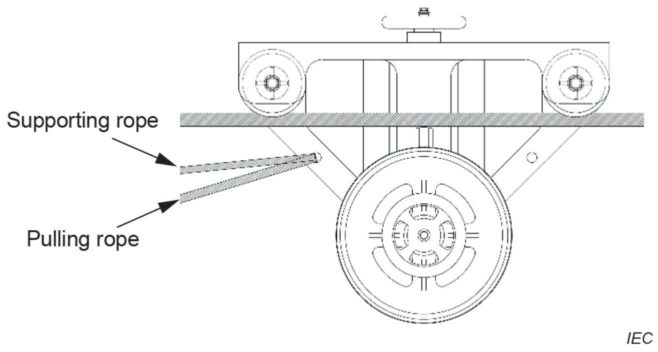


Figure 18 – Ropes connected to the brake unit

The ropes and the *cradle blocks* are pulled along the *OPGW cable* (Figure 19). The *cradle blocks* are recovered from the *OPGW* at each tower as the ropes are wound up at the puller side.

Figure 19 – Recovery of ropes and *cradle blocks*

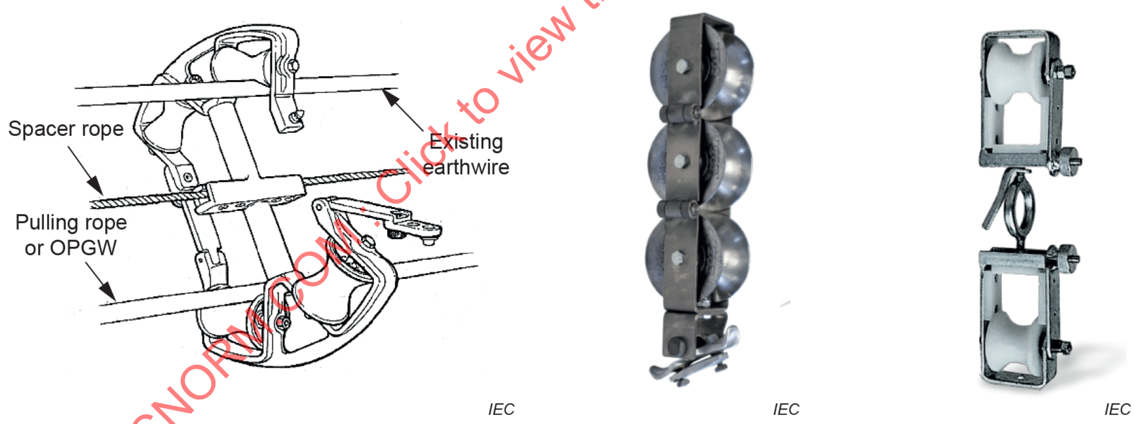


Figure 20 – Typical "two ropes" *cradle blocks*

Figure 21 – Typical brake units

6.2.4 "One rope, double rotation" *cradle block* method

This method is normally used for single span installation, but it can also be used for multi-span installation. The entire sequence is described in Figure 22 to Figure 32.

The motorized tug unit (Figure 22) is used to pull the supporting rope across the span to the next tower. The supporting rope allows *cradle blocks* to be pulled out along the existing *earth wire*.

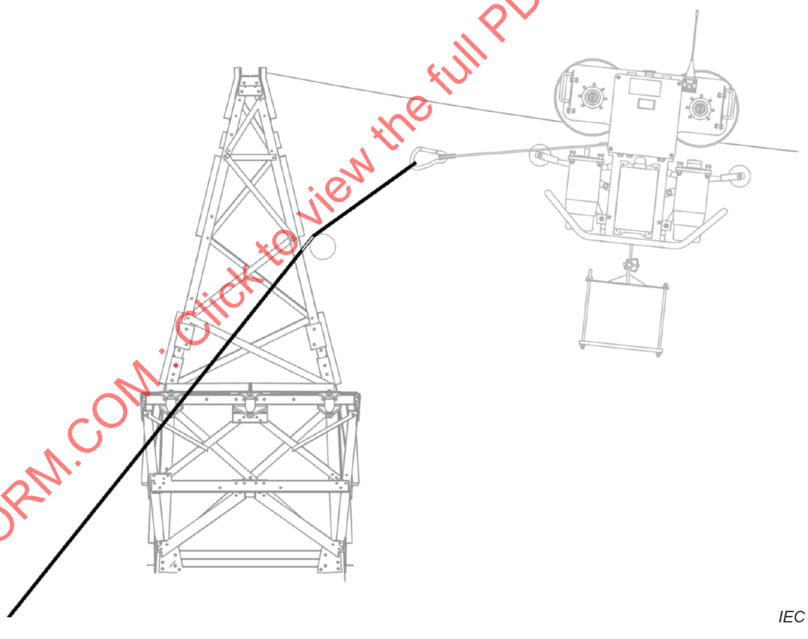


Figure 22 – Supporting rope connected to the traction machine

The rope and the *cradle blocks* are installed from tower to tower (Figure 23).

Dimensions in metres

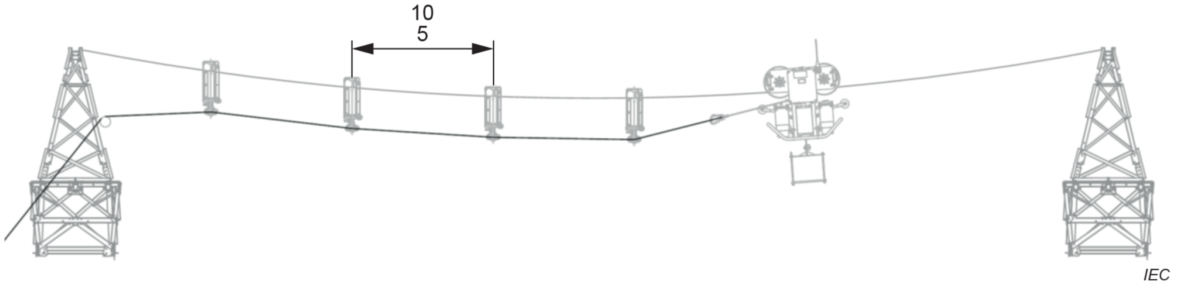


Figure 23 – Traction machine moves on the span installing rope and *cradle blocks*

The *cradle block* (Figure 24 and Figure 33) is designed to allow the installation and the use of the supporting rope. It has an opening gate on one side and at least one roller. The pulley runs along the existing *earth wire*, while the supporting rope is connected to a dedicated clipping system.

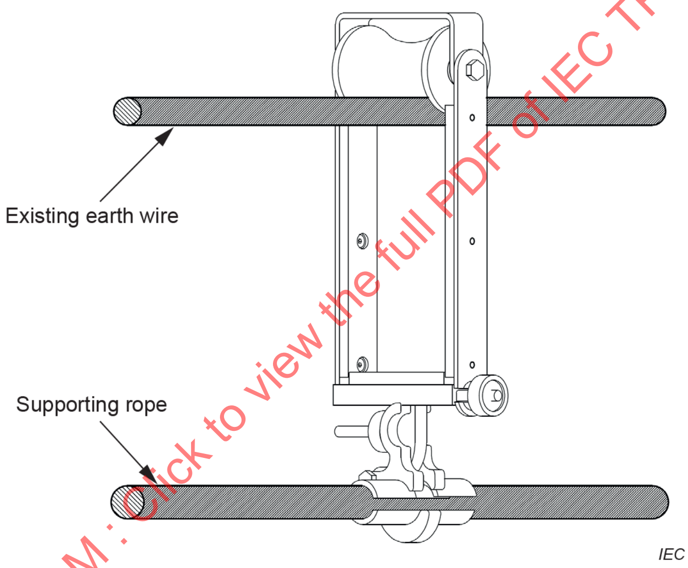


Figure 24 – *Cradle block* configuration

Once the rope and the *cradle blocks* have been installed over the *pull section*, the supporting rope is connected to each side of the towers (Figure 25).

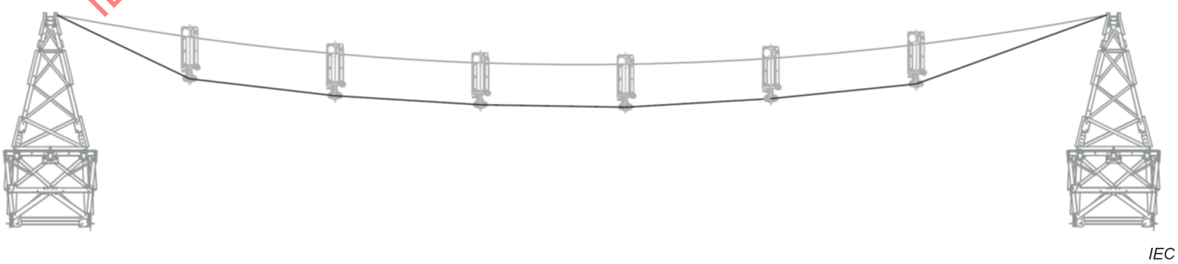


Figure 25 – Supporting rope connection to the towers

Then the existing *earth wire* on top is disconnected from its support at each structure, and the tension is released. This generates a “rotation” of the *cradle blocks*. At the end of this first rotation, the supporting rope is now on the top of the bundle, while the old *earth wire* is on the bottom side, supported by the *cradle blocks* (Figure 26).

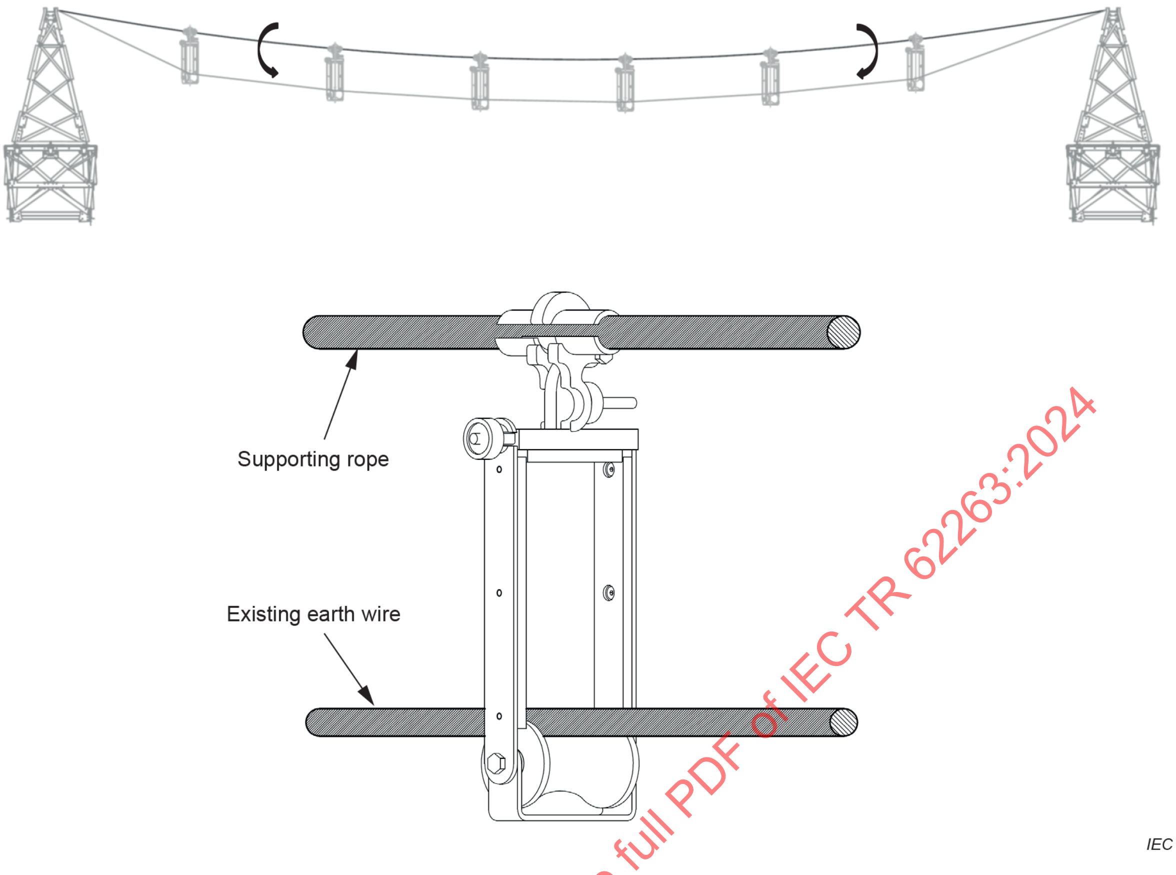


Figure 26 – First bundle rotation

The old *earth wire* is used to pull in the new *OPGW cable* using a puller located at the puller end of the section (Figure 27). The *OPGW cable* is tensioned during installation at the tensioner end.

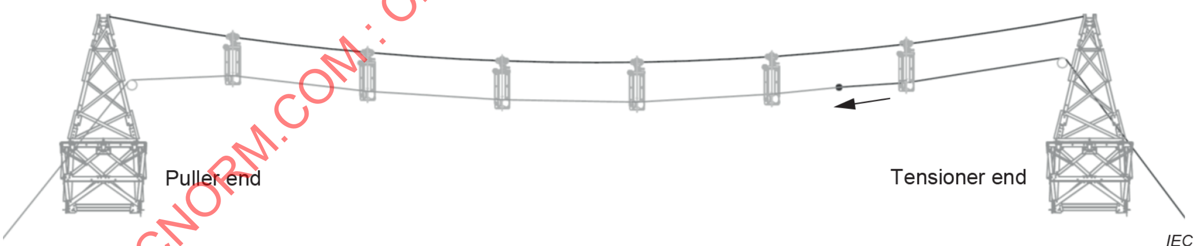


Figure 27 – *OPGW cable* installation

The *OPGW cable* is then connected and bonded electrically to every tower (Figure 28), thus maintaining the earth continuity.

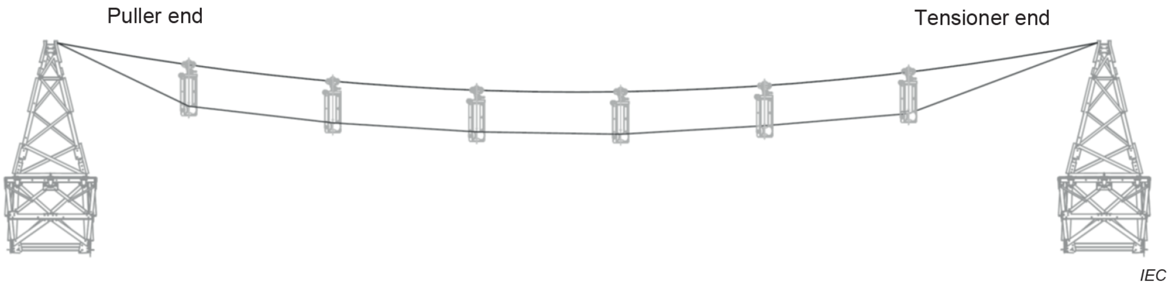


Figure 28 – *OPGW cable* connection to towers

The supporting rope is disconnected from its support at each structure, and the tension is released. This generates a “rotation” of the *cradle blocks*. After this second rotation, the new *OPGW cable* is now on the top of the bundle, while the supporting rope is on the bottom side (Figure 29).

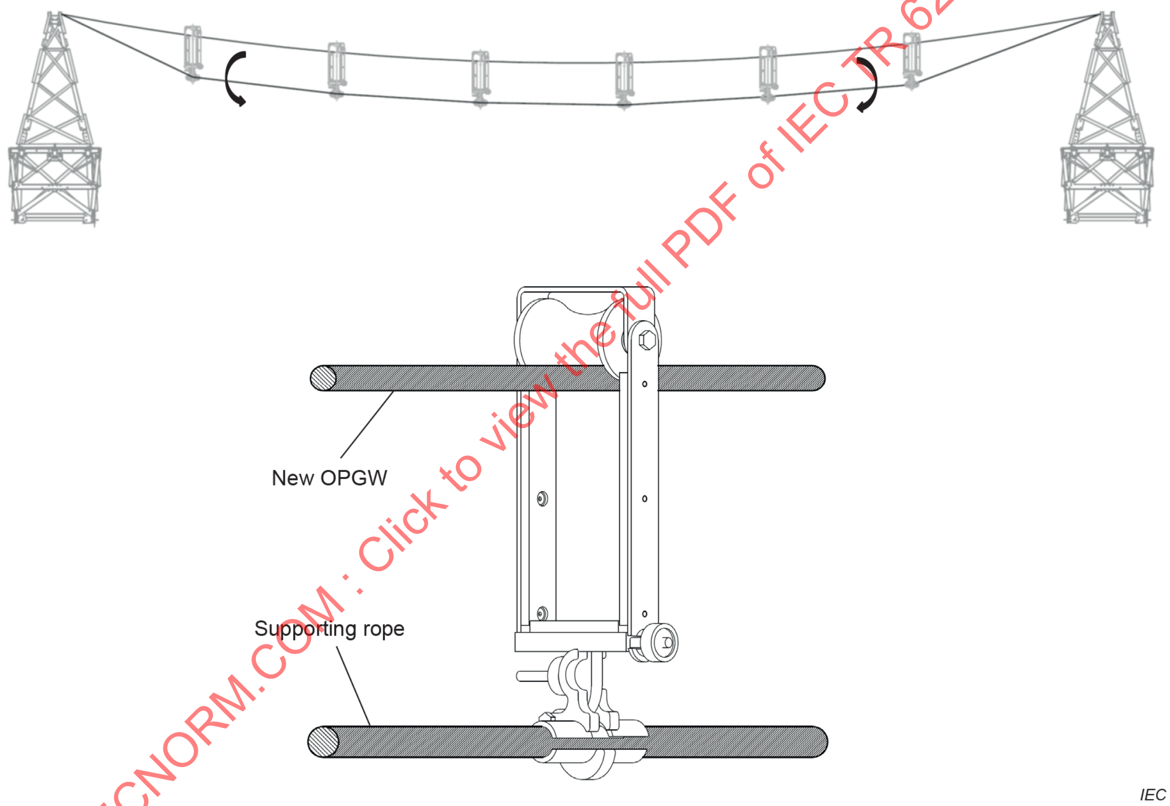


Figure 29 – Second bundle rotation

The *OPGW cable* is then *sagged* and clipped to its anchor’s points on the towers, and the supporting rope is disconnected from the tower in order to prepare the final recovery stage (Figure 30).