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TECHNICAL REPORT

Live working – Guidelines for the installation of transmission and distribution line conductors and earth wires – Stringing equipment and accessory items

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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LIVE WORKING – GUIDELINES FOR THE INSTALLATION OF TRANSMISSION AND DISTRIBUTION LINE CONDUCTORS AND EARTH WIRES – STRINGING EQUIPMENT AND ACCESSORY ITEMS

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IEC TR 61328 has been prepared by IEC technical committee 78: Live working. It is a Technical Report.

This fourth edition cancels and replaces the third edition published in 2017. It incorporates some technical changes to update equipment work methods and procedures, bringing them in line with the state of the art. This edition constitutes a technical revision.

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

a) Keeping the content of the previous edition 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
78/1455/DTR	78/1475/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.

In this document, the following print types are used:

- Terms defined in Clause 3 are given in *italic* font.

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- withdrawn, or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.

INTRODUCTION

This document discusses general tensions, *stringing* methods of transmission and distribution line *conductors*. Special attention is given to the equipment involved, such as *tensioners*, *pullers*, grips, *blocks* and rollers. Due to the hazards involved in *stringing* near *energized* lines, the general concepts of electric and magnetic induction are presented along with safe application methods of earthing equipment.

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 prescribe methods and requirements beyond the scope of this document.

LIVE WORKING – GUIDELINES FOR THE INSTALLATION OF TRANSMISSION AND DISTRIBUTION LINE CONDUCTORS AND EARTH WIRES – STRINGING EQUIPMENT AND ACCESSORY ITEMS

1 Scope

This document, which is a Technical Report, provides information for the selection of *conductor stringing, earthing* and *bond*ing equipment used for the installation of bare and insulated overhead distribution *conductors*, as well as overhead transmission *conductors* and overhead *earth wire*s.

Procedures are given for installation and maintenance of distribution and transmission conductors. A discussion of electric hazards is provided as well as relevant *earthing* and *bond*ing techniques.

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 60050-651:2014, *International Electrotechnical Vocabulary (IEV) – Part 651: Live working* (available at www.electropedia.org)

IEC 60743:2013, *Live working – Terminology for tools, devices and equipment*

3 Terms, definitions and acronyms

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

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 terminology databases for use in standardization at the following addresses:

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

3.1 Terms and definitions

3.1.1
anchor
anchor log
deadman
sledge
snub
device that serves as a reliable support to hold an object firmly in place

3.1.2
basket
bucket
device designed to be attached to the boom tip of a line truck, crane or aerial lift to support workmen in an elevated working position

3.1.3
block
tackle
pulley
device designed with one or more sheaves, a synthetic plastic or metal shell, and an attachment hook or shackle

3.1.4
bond
equipotential connection
connection
electrical connection used to bring all personnel and objects in the work area to the same potential

3.1.5
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

3.1.6
circuit
<of an overhead line> *conductor* or system of *conductors* through which an electric current is intended to flow

Note 1 to entry: In transmission and distribution lines, a *circuit* usually consists of three phases for AC lines, and two poles for DC lines.

[SOURCE: IEC 60050-466:1990, 466-01-07]

3.1.7
clearance
minimum separation between two *conductors* operating at different voltages, between *conductor*s and supports or other objects, or between *conductor*s and the earth

3.1.8
clipping-in
clamping-in
clipping
transferring of sagged *conductor*s from the *stringing block*s to their permanent suspension positions and the installing of the permanent suspension clamps

3.1.9
compression joint
conductor splice
sleeve
splice
tubular compression (or implosive) sleeves designed and fabricated from aluminium, copper or steel compressed to join or terminate *conductor*s or overhead *earth wires*

3.1.10
conductor
cable
wire
bare or insulated wire or combination of wires, suitable for carrying an electric current

3.1.11
conductor bundle
set of individual *conductor*s connected in parallel and disposed in a uniform geometrical configuration, that constitutes one phase or pole of a line

[SOURCE: IEC 60050-466:1990, 466-10-20]

3.1.12
conductor car
cable buggy
cable car
conductor trolley
line car
spacer buggy
spacing bicycle
spacer cart
device designed to carry workmen riding on sagged single or bundle *conductor*s, enabling them to inspect the *conductor*s for damage or install spacers, dampers or other attachments

3.1.13
conductor clamp
chicago grip
conductor grip
come-along
come-along clamp
preformed, bolted or wedge-type device designed to permit the pulling or temporary holding of the *conductor* or of the rope without *splicing* on fittings, eyes, etc.

3.1.14
connector link
pulling rope connector
link
peanut
fixed joint
rigid link designed to connect *pulling rope*s and usually designed to pass through the grooves of *bullwheels* on the *puller* when under load

3.1.15
dead-ending
procedure which results in the termination of *conductor*s at an *anchor structure*

3.1.16
earthing cable
flexible *conductor* usually of stranded copper with a transparent cable protective sheath, and attached at both ends to clamps, designed to connect *conductor*s or equipment to *earth* or to an *earth mat*

3.1.17
earth clamp
clamp forming part of an *earthing and short-circuiting* device connecting an *earthing cable*, or a *connecting cluster* to an earthing conductor, or an earth electrode or a reference potential

[SOURCE: IEC 60050-651:2014, 651-25-03]

3.1.18
earth mat
counterpoise
earth grid
system of interconnected bare *conductor*s arranged in a pattern over a specified area on, or buried below, the surface of the Earth

3.1.19
earth rod
earth electrode
rod driven into the Earth to serve as an earthing terminal

EXAMPLE Copper-clad steel rod, solid copper rod, or galvanized steel rod.

3.1.20
earth 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 *conductor*s to provide a degree of protection against lightning strikes

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

3.1.21
earthing stick
earthing pole
insulating component equipped with a permanent or detachable *end fitting* for installing clamps, *short-circuiting bars* or *conductive extension components* onto *electrical installation*

[SOURCE: IEC 60050-651:2014, 651-25-05]

3.1.22
earthing system
system consisting of all interconnected earthing connections in a specific area, such as a *pull section*

3.1.23
electromagnetic induction
electromagnetic coupling
phenomenon that produces both an induced voltage and current either through electric or *magnetic field induction*

3.1.24
electric field induction
capacitive coupling
process of generating voltages and/or currents in a conductive object or electrical *circuit* by means of time-varying electric fields

3.1.25
energized
alive
current-carrying
hot
live
at a potential significantly different from that of the *earth* at the work site and which presents an electrical hazard

Note 1 to entry: 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.

[SOURCE: IEC 60050-651:2014, 651-21-08]

3.1.26
equipotential
set of points all of which have the same potential

3.1.27
fault
physical condition that causes a device, a component, or an element to fail to perform in a required manner

3.1.28
fault current
earth fault current
current flowing at a given point of a network resulting from a *fault* at another point of this network

3.1.29
hold-down block
block designed to prevent uplift and to maintain the *pilot rope* or *conductor(s)* inside the sheaves of the *stringing block* installed on the tower

3.1.30
isolated
<device or *circuit*> disconnected completely from other devices or *circuit*s, and thus separated physically, electrically and mechanically from all sources of electrical energy

Note 1 to entry: Such separation may not eliminate all effects of *electromagnetic induction*.

3.1.31
jumper
dead end loop
conductor that connects the *conductor*s on opposite sides of a dead-end *structure*

3.1.32
magnetic field induction
inductive coupling
process of generating voltages and/or currents in an electrical *circuit* by means of time-varying magnetic fields

3.1.33
pilot rope
lead line/rope
leader
P-line/rope
straw line/rope
pre-pilot rope
lightweight rope, either wire rope or synthetic fibre rope, used to pull heavier *pulling rope*s which in turn are used to pull the *conductor*

3.1.34
pilot rope puller
device designed to payout and rewind *pilot rope*s during *stringing* operations

3.1.35
portable earth interrupter tool
portable switching device designed to break high circulating currents, and which prevents an unmanageable large arc from occurring in the removal of the last *earth* in an *earthing system*

3.1.36
pull section
pull setting
stringing section
section of line where the *conductor* is being pulled into place by the *puller* and *tensioner*

3.1.37
pull site
puller set-up
location in a *pull section* where the *puller*, *reel winder* and *anchors* (snubs) are located

3.1.38
puller
drum
hoist
tugger
equipment designed to pull *pulling rope*s during *stringing* operations

[SOURCE: IEC 60743:2013, 14.1.3, modified – Admitted terms have been changed, "conductor(s)" has been deleted from the definition, and Notes to entry have been deleted]

3.1.39
puller-tensioner
equipment designed to pull *pulling ropes* or *conductor*(s) or to hold mechanical tension against a *pulling rope* or *conductor*(s) during *stringing* operations

[SOURCE: IEC 60743:2013, 14.1.5, modified – Notes to entry have been deleted]

3.1.40
pulling rope
bull line/rope
hard line/rope
sock line/rope
anti-twisting braided rope
high strength rope, normally steel wire rope or less frequently synthetic fibre rope, used to pull the *conductor*, with formation and construction that ensure non-twisting capability under pull operation

3.1.41
pulling vehicle
pulling tractor
towing vehicle
piece of mobile ground or air borne equipment capable of pulling *pilot rope*s, *pulling rope*s or *conductor*s

3.1.42
reel stand
reel elevator
reel trailer
reel truck
drum stand
drum elevator
device designed to support one or more reels and having the possibility of being skid, trailer or truck mounted

3.1.43
reel winder
takeup reel winder
takeup stand
takeup winder
machine designed to work in conjunction with a *bullwheel puller* or *puller-tensioner*, and to serve as a recovery unit for the *pulling rope*

3.1.44
running board
headboard
pulling device designed to permit *stringing* several *conductors* simultaneously with a single *pulling rope*

[SOURCE: IEC 60743:2013, 14.2.3, modified – Notes to entry have been deleted]

3.1.45
running earth
earthing roller
moving earth
rolling earth
travelling earth
portable device designed to connect a moving *conductor* or a pulling/*pilot rope* to an electrical *earth*

[SOURCE: IEC 60743:2013, 14.2.1, modified – In the definition, "used" has been replaced by "designed", and Note 1 to entry has been deleted]

3.1.46
sagging
process of pulling *conductor*s up to their final tension or sag

3.1.47
slack stringing
method of *stringing conductor*(s) slack without the use of a *tensioner*, with some minimal braking applied to the *conductor* reel

3.1.48
spacing
spacering
process of installing the spacers between the bundle *subconductor*s in each phase

3.1.49
splicing
jointing
process of joining the ends of *conductor* lengths to form a continuous mechanical and electrical connection

3.1.50
stringing
process of pulling *pilot rope*s, *pulling rope*s and *conductor*s over *stringing block*s supported on *structure*s of overhead lines

3.1.51
stringing block
block
conductor running block
dolly
running out block
sheave
stringing sheave
stringing traveller
traveller
pulley
sheave, or sheaves, complete with a frame used separately or in groups and suspended from *structure*s to permit the *stringing* of *conductor*s

[SOURCE: IEC 60743:2013, 14.2.2, modified – Note 1 to entry has been deleted]

3.1.52
stringing block earth
conductor running block earth
sheave earth
traveller earth
portable device attached to a *stringing block* and designed to connect a moving conductor or pulling/*pilot rope* to an electrical *earth*

3.1.53
structure
pole
tower
tower or pole which supports the *conductor*s on insulators, usually steel lattice or tubular type for transmission and distribution line and wood, metal, synthetic, or concrete for distribution line

3.1.54
subconductor
each *conductor* in a *conductor bundle* arranged in a vertical, horizontal, square, round, or other suitable configuration

3.1.55
swivel
bullet, swivel joint
device joining one *pulling rope* to a *conductor* or *conductor*s to a *running board* relieving torsional forces on conductors

3.1.56
tension site
conductor payout station
payout site
reel set-up
tensioner set-up
location on a *pull section* where the *tensioner*, *reel stand*s, conductor reels and *anchor*s (snubs) are located

3.1.57
tension stringing
process of using *puller*s and *tensioners* to give the *conductor* sufficient tension and positive control during the *stringing* operation to keep it clear of the ground surface and other obstacles which could cause damage to the surface of the *conductor*

3.1.58
tensioner
bullwheel tensioner
brake
retarder
equipment designed to hold mechanical tension against a *pulling rope* or *conductor*(s) during the *stringing* operation

[SOURCE: IEC 60743:2013, 14.1.2, modified – Note 1 to entry has been deleted]

3.1.59
tractor
cat
crawler
sag tractor
tracked unit employed to pull pulling/*pilot rope*s, sag *conductors*, at clear pull and *tension site*s and provide a temporary *anchor*

3.1.60
woven wire grip
kellem
mesh sock
sock
stocking
wire mesh grip
device designed to allow the temporary joining or pulling of *conductor*s without the need of special eyes, links or grips

3.2 Acronyms

AC	alternating current
DC	direct current
HTLS	high temperature low sag
HVDC	high voltage direct current
OPGW	optical ground wire
TV	television
TW	trapezoidal wire

4 Understanding the hazards – 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* and *bond*ing *system*s.

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 *circuit*s 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.

4.2 Electric field induction from nearby circuits

4.2.1 Overview

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.

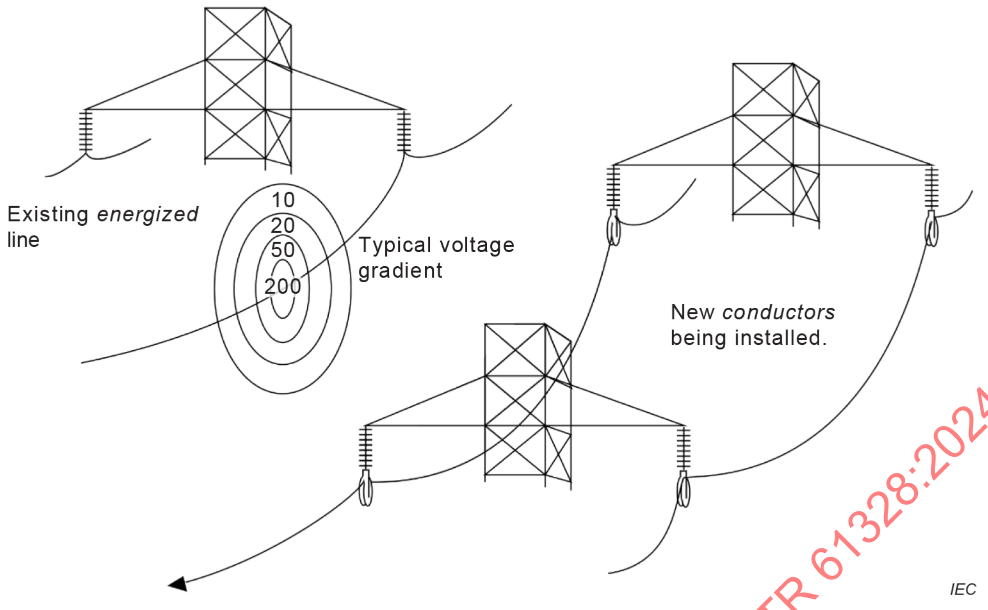
If the nearby line is an *energized* DC transmission line, the induced voltage is the result of ion drift, and can result in even higher voltages than if the nearby line were an AC line. Magnetic induction would only be related to the ripple effect and is therefore much less than would be the case if the nearby line were an AC line.

4.2.2 Induced voltage

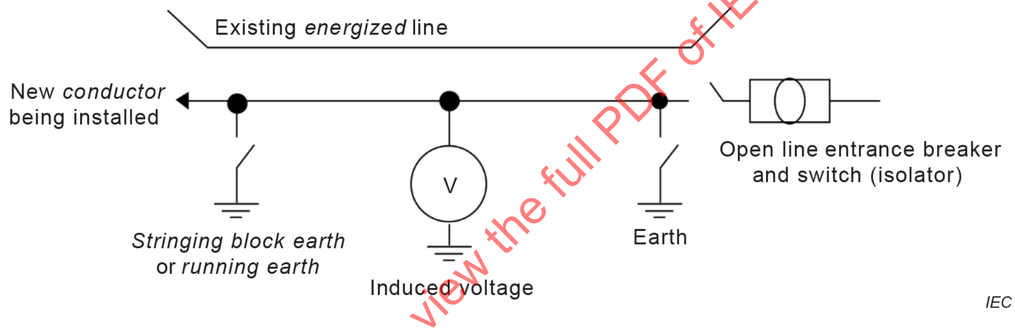
The electric field around an *energized conductor* produces a voltage on an *isolated* and unearthed conducting object nearby (see Figure 1).

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 These figures are simplified. The three phases of the existing *energized* line are involved in the induction.

Figure 1 – Electric field induction from nearby circuits – Induced voltage

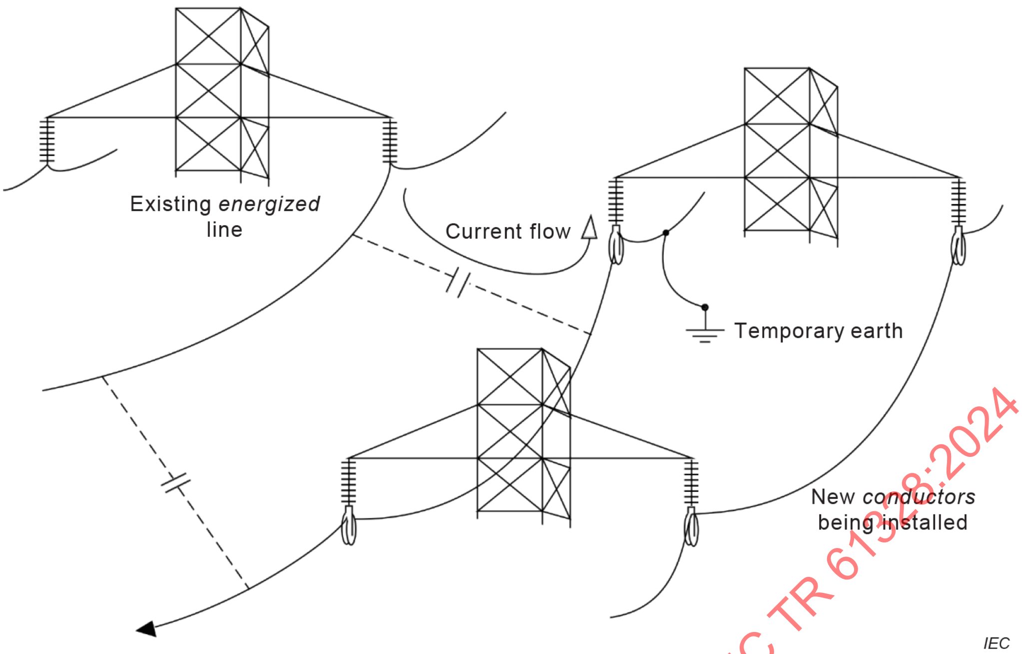
4.2.3 Induced current

With an AC system, the *energized* lines and the earthed *conductor* being installed act like the plates of a capacitor, and a charging current flows across the air gap between them (see Figure 2).

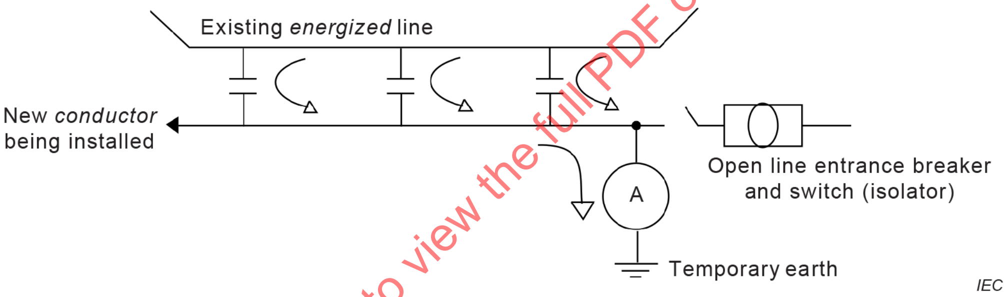
The two following aspects are considered.

a) A current flows through the temporary *earth* from the *conductor* to *earth*. It is proportional to the length of the parallel between the *energized conductor* and the new *conductor* 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 worker attempts to contact the *conductor* or connected parts, he will receive a dangerous discharge current, since the induced voltage can be high enough to cause arc-over. Also, the steady-state capacitive current occurring after the contact can reach a dangerous level.



a) **Pictorial view**



b) **Diagrammatic view**

NOTE These figures are simplified. The three phases of the existing *energized* line are involved in the induction.

Figure 2 – Electric field induction from nearby circuits – Induced current

4.2.4 Electrostatic charging

A potential hazard exists where a line to be worked on is still insulated but has been *isolated*, as it can have a voltage due to electrostatic charging resulting from atmospheric conditions, or trapped charges from switching. This hazard is mitigated by earthing the line at only one point to discharge the electrostatic charge.

4.3 Magnetic field induction from nearby circuits

4.3.1 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 *conductor* being installed can be looked upon as the primary and secondary windings of an air-core transformer.

If the new *conductor* is earthed at two places, it acts like the secondary coil of an air-core transformer, short-*circuit*ed through the *earth*. A circulating current will flow along the new *conductor*, through one *earth* connection, back through the *earth* and up the other *earth* 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.

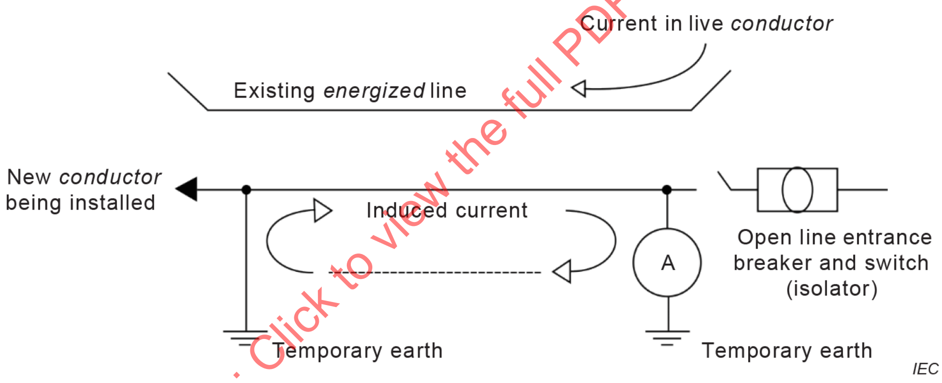
If a series of *earth*s is applied, a series of loops is formed, each carrying current (see Figure 3b).

It would appear that the currents would cancel in the intermediate *earth*s.

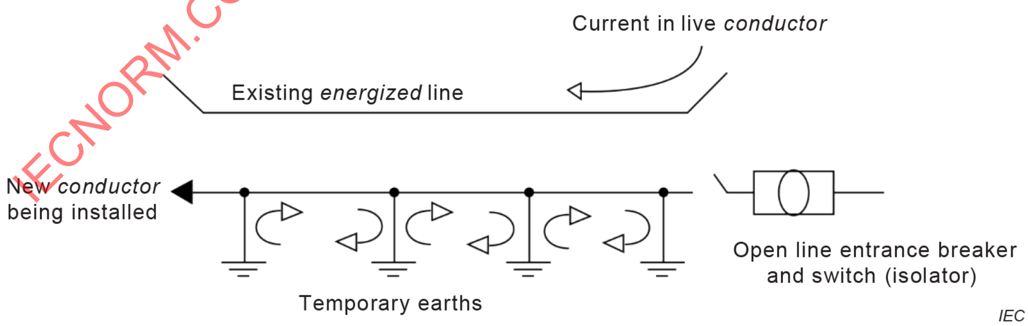
If there is a great difference in impedance of the *earth*s in adjacent loops, for example a lake in the *earth* return of one, and rock in the other, the intermediate *earth* can carry almost the full circulating current.

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 new *conductor* being installed can be very large and can affect the choice of earthing assemblies.



a) Two earths on new conductor allow circulating current to flow



b) Circulating currents with multiple earths

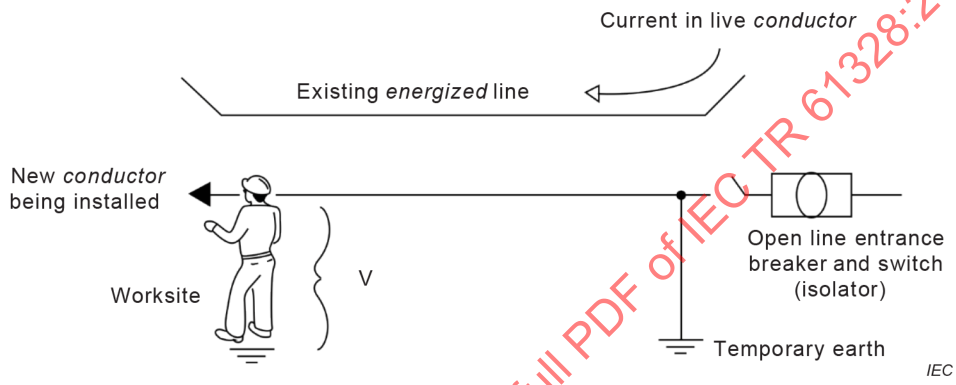
NOTE These figures are simplified. The three phases of the existing *energized* line are involved in the induction.

Figure 3 – Magnetic field induction from nearby circuits – Induced current

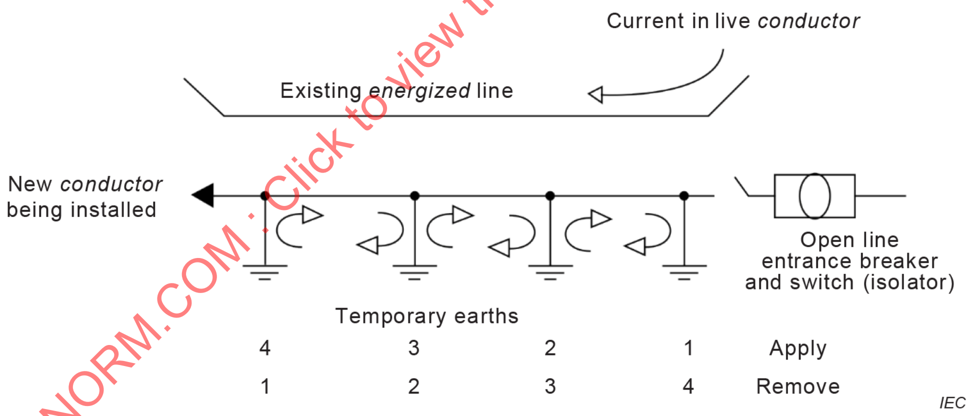
4.3.2 Induced voltage

Continuing the analogy of an air-core transformer, if the new *conductor* being installed becomes earthed at one point only, for example by the removal of the last but one temporary *earth*, an open *circuit* secondary voltage to *earth* appears on the line. 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*, the circulating electromagnetic 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 new *conductor* being installed. It might have to be limited by a technique of sequential earthing, in which the new *conductor* is subdivided by intermediate *earth*s. The sections are then short enough to limit the open *circuit* voltage because the *earth*s are sequentially removed (Figure 4b)).



a) Open circuit voltage with one earth only



NOTE In area 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 induction from nearby circuits – Induced voltage

4.4 Re-energization

Accidental contact with an *energized conductor*, or a switching error, can occur. *Equipotential* earth systems applied on each site are an effective means of providing a safe work zone in these situations.

4.5 Mechanical risk

The maximum pulling tension applied is usually different from that applied at the *tensioner* This depends on the design of the line and the orography of the line path. In the case of mountainous areas, the maximum value of the pull force applied could be much greater than sag tension. Moreover, tension values are close to the *sagging* tension values when crossing existing lines where limited *clearance* must be respected.

It is possible that the weight of the *stringing* equipment is not able to provide the necessary stability and can need additional *anchor*ing. Equipment manufactures usually specify the proper set up methods to avoid unexpected movement of the equipment under load.

Operation involving handling of material, lifting of material and tools on the tower or working activity at height are normally detailed in the safety procedure and instruction for all job-site activities.

5 Conductor stringing methods and equipment

5.1 General

The *stringing* methods used to install the *conductor* (including *earth wire*) currently employed in the electric power industry are many and varied. Outlined below are the basic methods currently in use, but they are invariably modified to accommodate equipment readily available. The methods also depend somewhat on the type and size of the line, and the ground over which the line is to be built.

Installation of transmission and distribution *conductor* is made by *stringing* one phase (one or more *subconductor*s in bundle) at a time, by using a multi-conductor *tensioner* and a *running board*. The *running board* is smoothly shaped to pass through the *stringing block* and usually has a flexible pendulum tail suspended from the rear to prevent the *conductor bundle* from twisting during the pulling process. The *conductor*s and *pulling rope* are normally connected to the *running board* with *swivel*s to prevent twisting loads being transferred to the *running board*. The rope formation and construction grant non-twisting capability under pull operation. *Swivel*s do not normally pass through the *bullwheel*s of a *puller* or a *tensioner,* but some of them are designed to pass through *tensioner / puller-tensioner bullwheels*.

*Stringing block*s are sometimes bundled with a centre sheave for the *pulling rope* and two or more *conductor* sheaves and used to string more than one *conductor* simultaneously. For mechanical protection of *conductor*s, sheaves are often lined with non-conductive or semiconductive polychloroprene, polyurethane or other elastomer, or polyamide. Where conductivity of the *stringing block* is required, aluminum linings are used.

Installation of distribution *conductor*s can be made one *conductor* (phase) at a time; however, it is possible to install all three phases plus neutral at one time with a multi-conductor *tensioner* and a *running board*. Insulated *conductor*s can be in the form of three or four *conductor*s with a messenger wire twisted together as a bundle. This bundle is usually installed on the *structure*s in the same manner as one *conductor*.

Temporary *anchor*s are often used at pull and *tension site*s. The term *anchor* is normally associated with cone, plate, screw or concrete *anchor*s, but the terms snub, dead-man and *anchor* log are usually associated with pole stubs or logs set or buried in the ground, to serve as temporary *anchor*s. A sledge with *block*s of concrete sitting on top of the ground and of sufficient weight to hold the load has also served as a temporary *anchor*.

There are some mechanical and electrical characteristics which are important in the choice of *stringing* equipment. They are detailed hereafter.

5.2 Slack stringing method

The *slack stringing* method is illustrated in Figure 5a) and Figure 5b).

The *slack stringing* method for installation of transmission and distribution line *conductor*s can result in surface damage to or contamination of the *conductor* causing corona losses and excessive radio, TV and communication interference.

This method is used for the installation of distribution line *conductors* where applicable.

There are two commonly used methods for *slack stringing*.

a) Stationary reel method

   This method is when the *conductor* reels are located at one end of the *pull section*. The *conductor* is dragged along the ground of the right of way by means of a towing vehicle (see Figure 5a)).

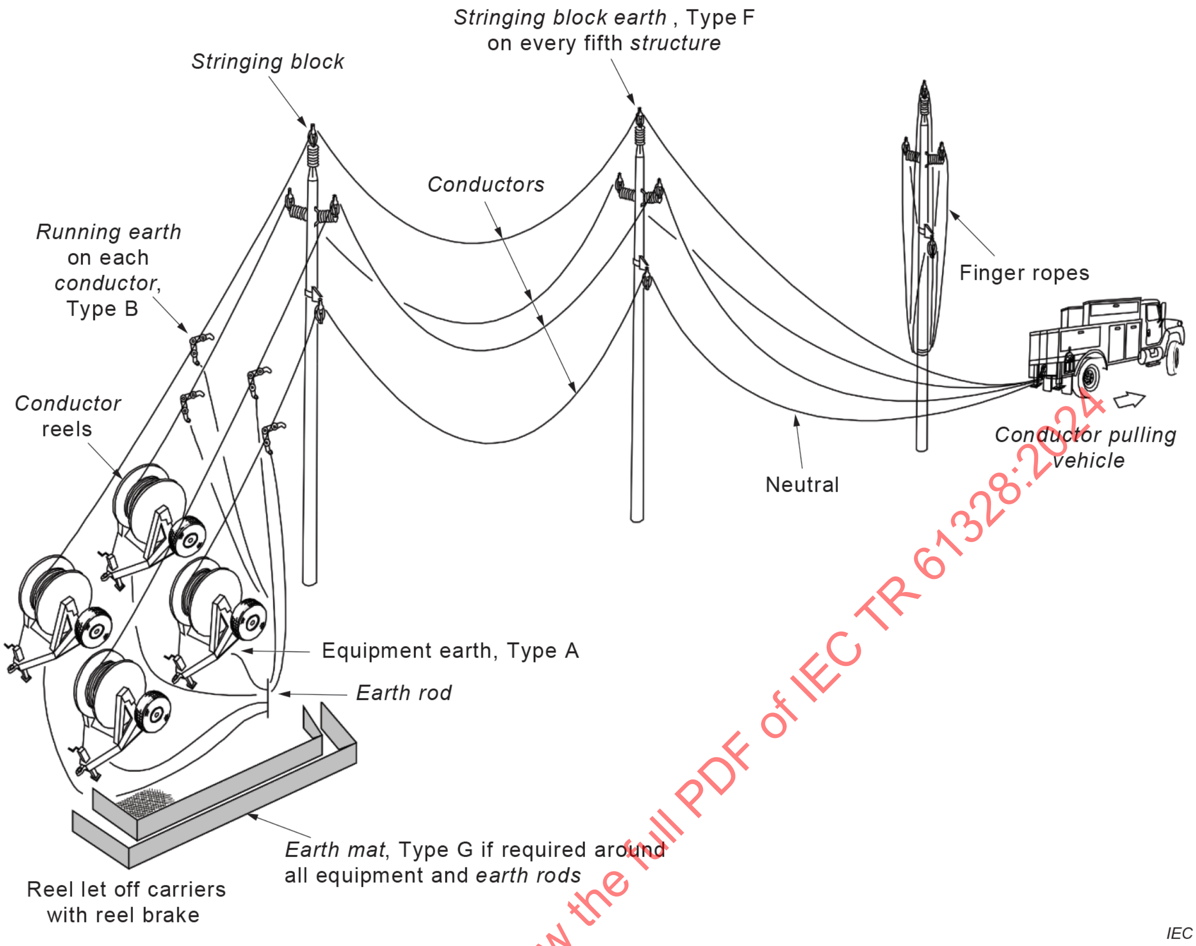
b) Rolling reel method

   Another variation of the *slack stringing* method is when the reels are towed along the right of way on a trailer behind a towing vehicle, and the *conductor* is deposited on the ground (see Figure 5b)).

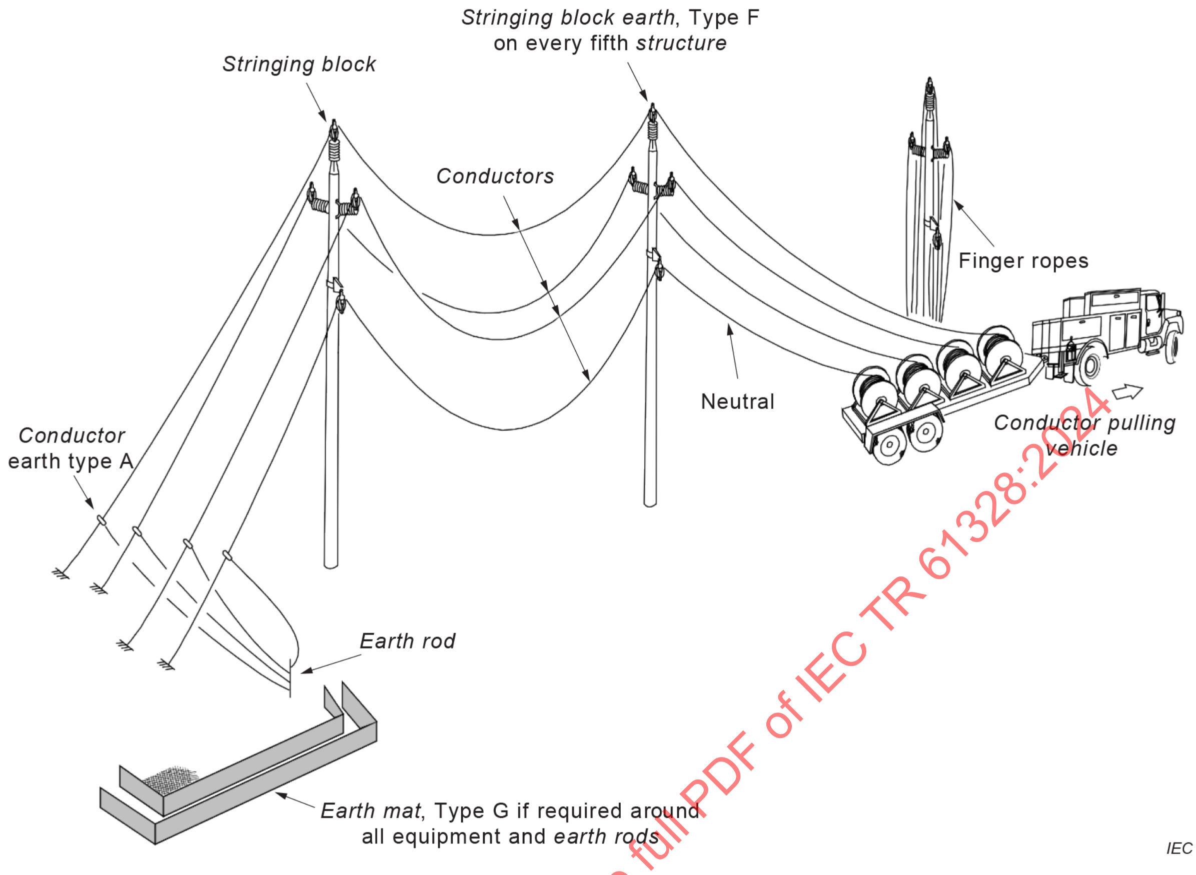
The *conductor* reels are held in *reel stand*s either placed on the ground or mounted on a trailer. These stands are designed to support the reel on a shaft, permitting it to turn as the *conductor* is pulled out. Usually, a braking device is provided to prevent overrunning of the reel when the pulling is stopped.

When the *conductor* is towed past each supporting *structure* or tower, the towing vehicle is stopped and the *conductor* placed in *stringing blocks* attached to the *structure* before proceeding to the next *structure*.

This method is chiefly applicable to the construction of rural distribution lines, where the line right of way is easily accessible to a towing vehicle. The method is not practical to use in congested urban locations where hazards exist from traffic or where there is danger of contact with *energized circuit*s. Nor is it practical in mountainous regions where the towing vehicle cannot proceed along the right-of-way.



a) Installing conductor – Stationary reel



b) Installing conductor – Rolling reel

Figure 5 – Slack stringing method

5.3 Tension stringing method

The *tension stringing* method is applicable for both transmission and distribution lines and is considered the state of the art of the *conductor* installation methods.

This method is illustrated in Figure 6a), Figure 6b), Figure 6c) and Figure 6d) for distribution lines and Figure 6e), Figure 6f), Figure 6g), Figure 6h), Figure 6i), Figure 6j), Figure 6k), Figure 6l) and Figure 6m) for transmission lines.

Using this method, the *conductor* is kept under tension during the *stringing* process to keep the *conductor* from contacting the ground surface or other obstacles between towers since this will cause *conductor* surface damage. The tension in the *conductor* also allows it to pass over *energized circuit*s, railway or major road crossings, etc. without contacting them.

For multi*conductor* per phase lines, the *tension stringing* method requires the installation of a light synthetic or metallic *pilot rope* into the *stringing block*s. This is normally done using the *slack stringing* stationary reel method by either a towing vehicle or a helicopter or a drone. The *pilot rope* is used to pull in a heavier *pulling rope*, and the *pulling rope* is then used to pull in the *conductor*s.

For single *conductor* per phase installations, the *pulling rope* can be installed directly with a towing vehicle or by helicopter eliminating the use of a *pilot rope* completely.

All the *subconductors* of each bundle are strung at the same time and with the same tension applied, to avoid difference sag behaviour once installed.

The first and most common method for *tension stringing conductor*s uses one or more *tensioner*s, depending on the number of *subconductors* in a bundle, and one *puller*. This methodology can be named as "1 by n", where 1 means one *pulling rope* and *n* means the number of *subconductors* of the bundle (see Figure 6i)).

In case of a large number of *subconductors* in a bundle, another possible *stringing* methodology is to provide a *pulling rope* for each *conductor*, by using one or more *tensioner*s and one or more *puller*s. This methodology can be named as "n by n", where the first n means the number of *pulling rope*s and the second n means number of *subconductors* in the bundle (see Figure 6j)).

Where a transmission or distribution line is reconductored, often the old *conductor* is used as a *pulling rope* to pull in the new *conductor*, and the *puller* machine becomes a *puller-tensioner* machine. This methodology is equivalent to the previous "n by n" method, where the first n means the number of old *subconductors* used as a *pulling rope* and the second n means the number of *subconductors* in the bundle (see Figure 6k)).

When the mechanical strength of the old *conductors* is in question, a *pulling rope* is used as a tensioning element while recovering the old *conductor*s in order to keep them suspended from the ground and to minimize the tension. Then the installed rope can be used as a pilot or *pulling rope* for the new *conductor* installation. This methodology can be named as "n by 1" method, where n means the number of old *subconductors* to be recovered and 1 means one tensioning rope to be used to keep tension in the old *conductor bundle*.

The mechanical strength of the old *conductor* is unpredictable particularly because of the *compression joint*s. Passing old joints around the *bullwheel*s of the *puller-tensioner* where they are bent and then straightened as the joints pass from groove to groove on the *bullwheel*s, can cause sudden failure of the joints and the *conductor* can drop, causing damage to the *conductor* or the line *structure*s, A common procedure is to cut out the *compression joint* when it arrives in front of the *puller-tensioner*, and to fit a *woven wire grip* on both ends of the severed *conductor*. This grip is passed through the *bullwheel*s and can be removed before the *conductor* is wound on the *reel winder*.

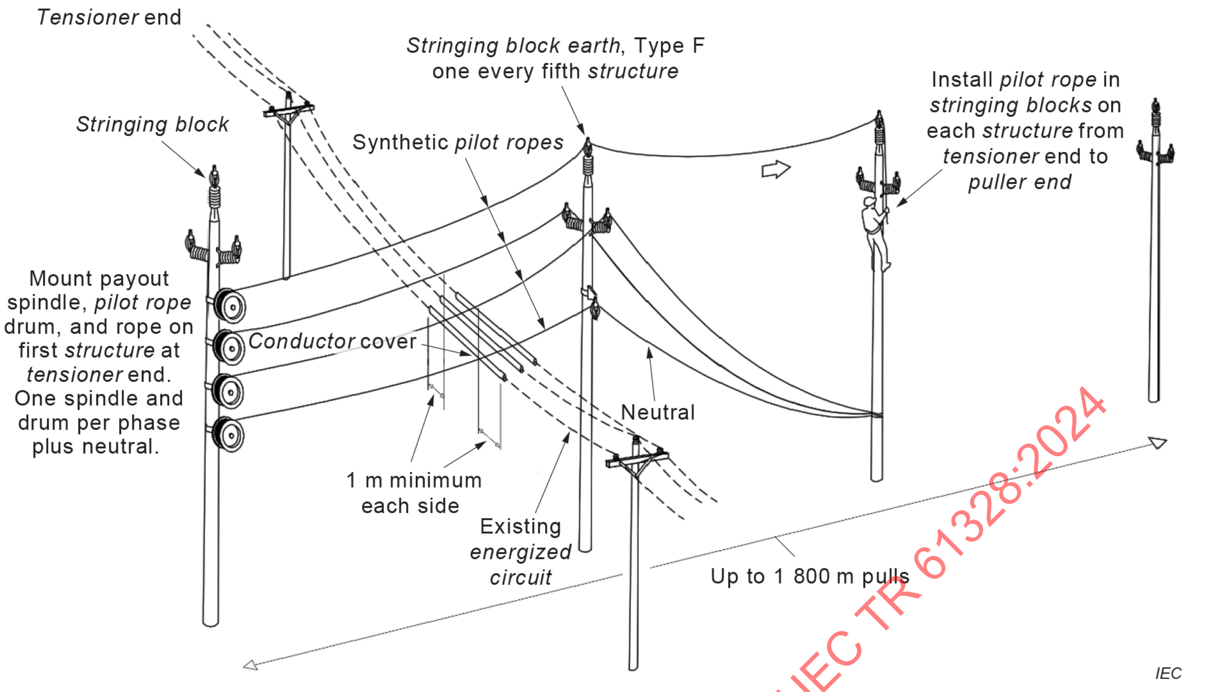
The same procedure is applied in case of *earth wire* replacement when several sections of *earth wire* are included in a *stringing* section. The *compression joints* or the tension clamps of single sections are removed and both ends of the *earth wire* connected with a *woven wire grip*.

Recent development of *stringing* technology is a combination of the two previous methods for *stringing* new power lines. In particular, in case of a large number of bundle conductors (from 6 up 10), a "2 × (1 × n)" method is used, where two traditional *stringing* methods "1 × n" can be coupled to reach the total number of *subconductor*s of the bundle (see Figure 6l)). This results in a large number of *stringing* machines.

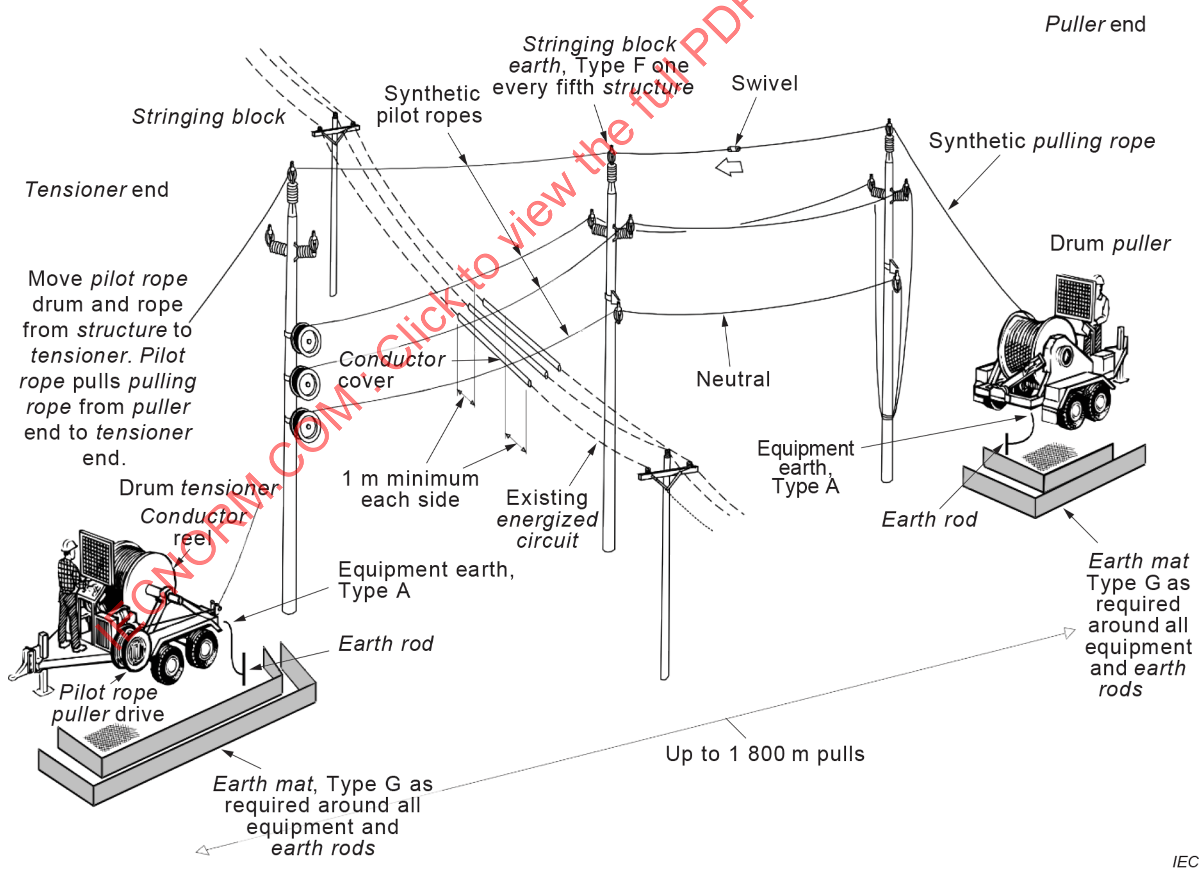
All the machines working in combination at the same station (for example two or more *tensioners* at the *tensioner* station and two or more *pullers* or *puller-tensioners* at the *puller* station) are electronically connected. They are then operated by a single operator controlling all the working parameters avoiding any unbalancing effect on each *subconductor* of the bundle.

In case of double (or multiple) *circuit* power lines, it is becoming popular to operate with one of the *circuits energized* while the other *circuit* is strung or reconductored. The *energized circuit* will generate severe induced currents on the line being strung. Proper earthing equipment will provide the *equipotential* condition of the entire working area.

Wind can reduce the *clearance* between the *circuits* resulting in electrical arcing. Adequate earthing will mitigate this hazard.

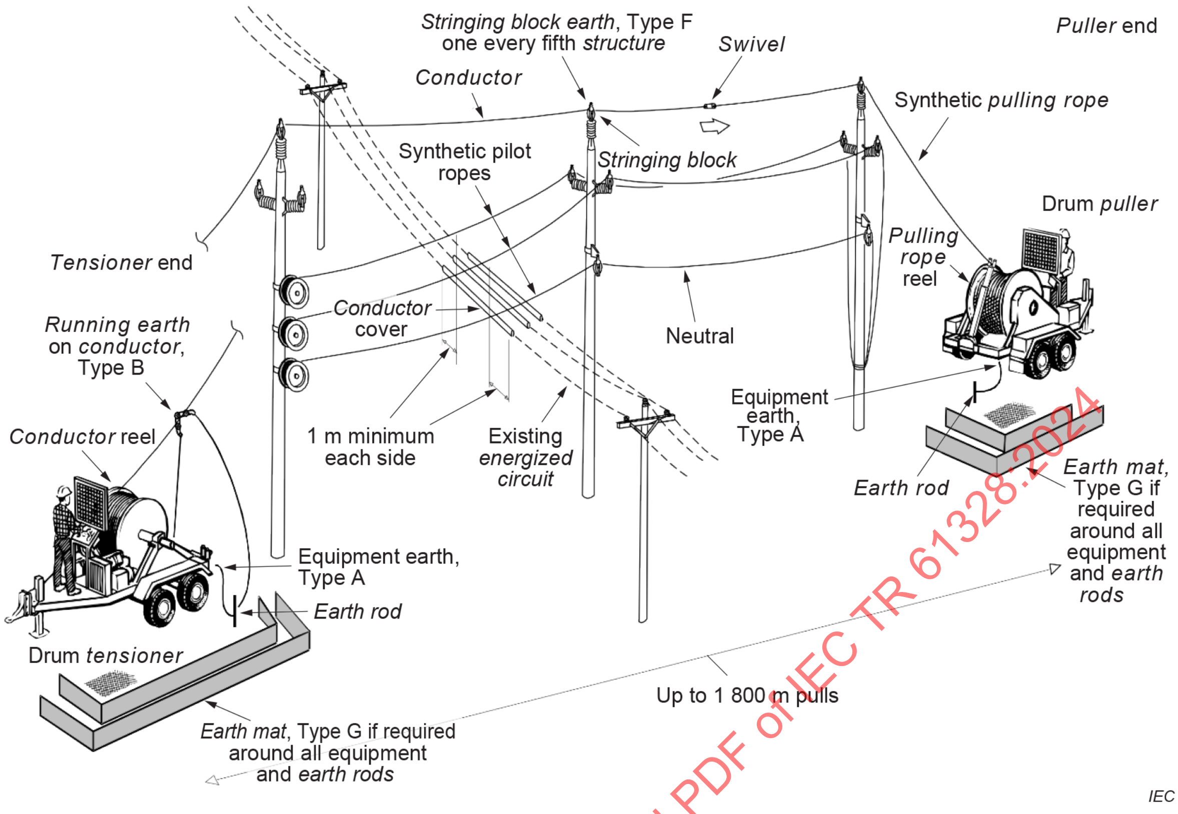


a) Distribution – Installing pilot rope on structure



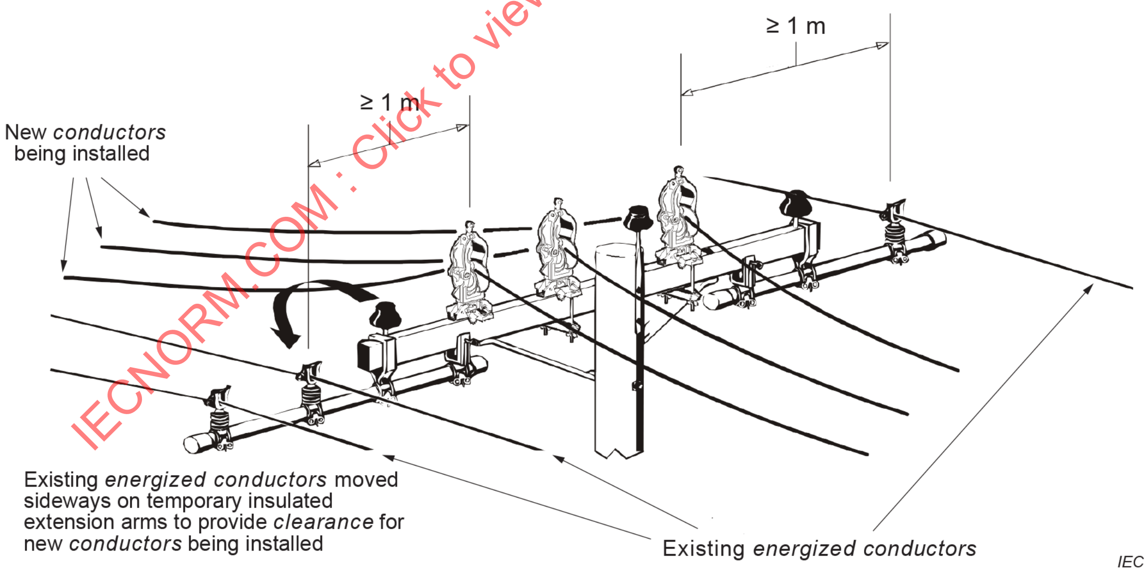
NOTE The *puller* and *tensioner* are located at a minimum distance from the first and last *structures* of three times the height of the *stringing block* above the machines.

b) Distribution – Installing the pulling rope

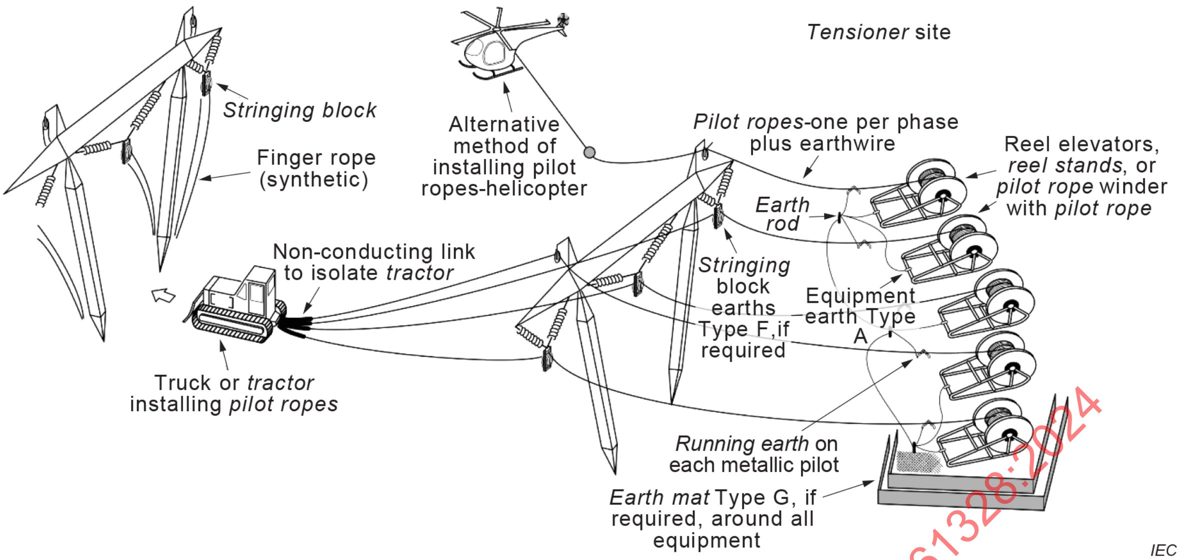


NOTE The *puller* and *tensioner* are located at a minimum distance from the first and last *structures* of three times the height of the *stringing block* above the machines.

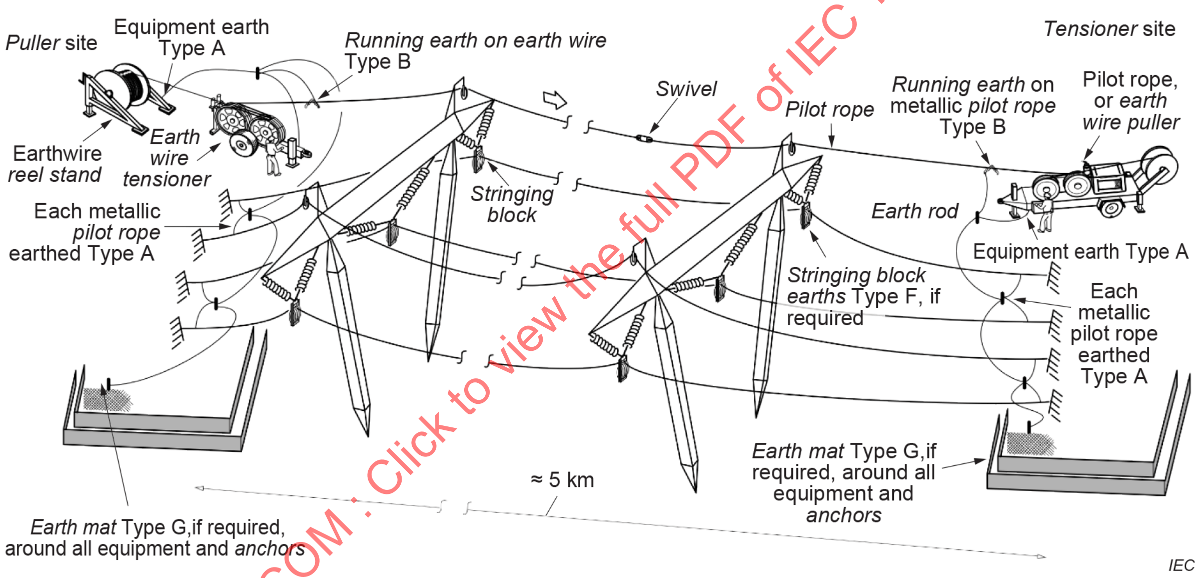
c) Distribution – Installing conductor



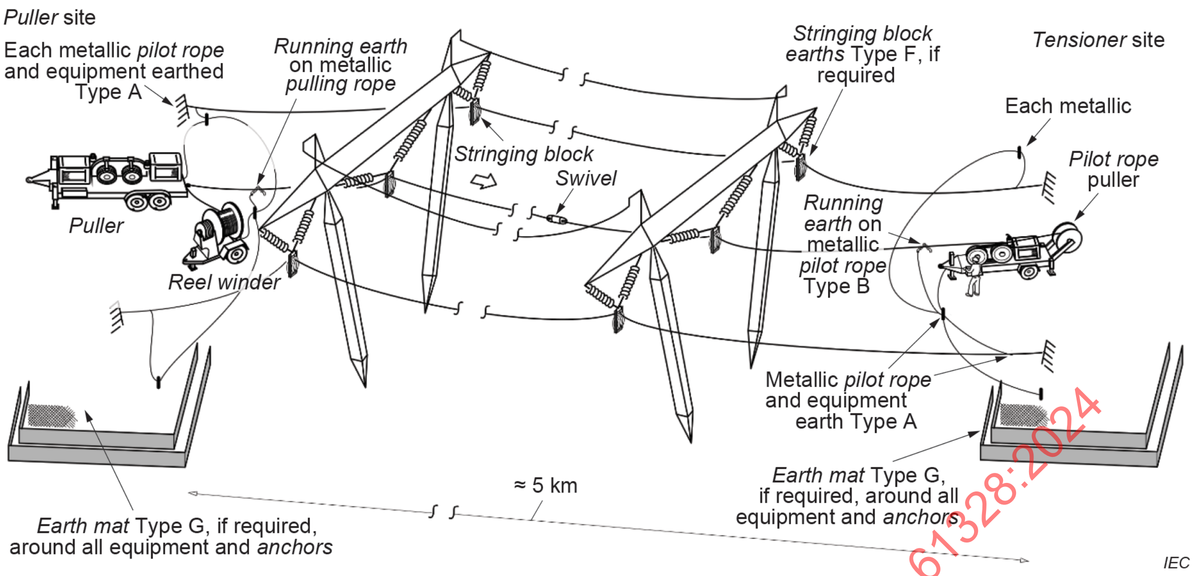
d) Distribution – Reconductoring project with existing circuit energized



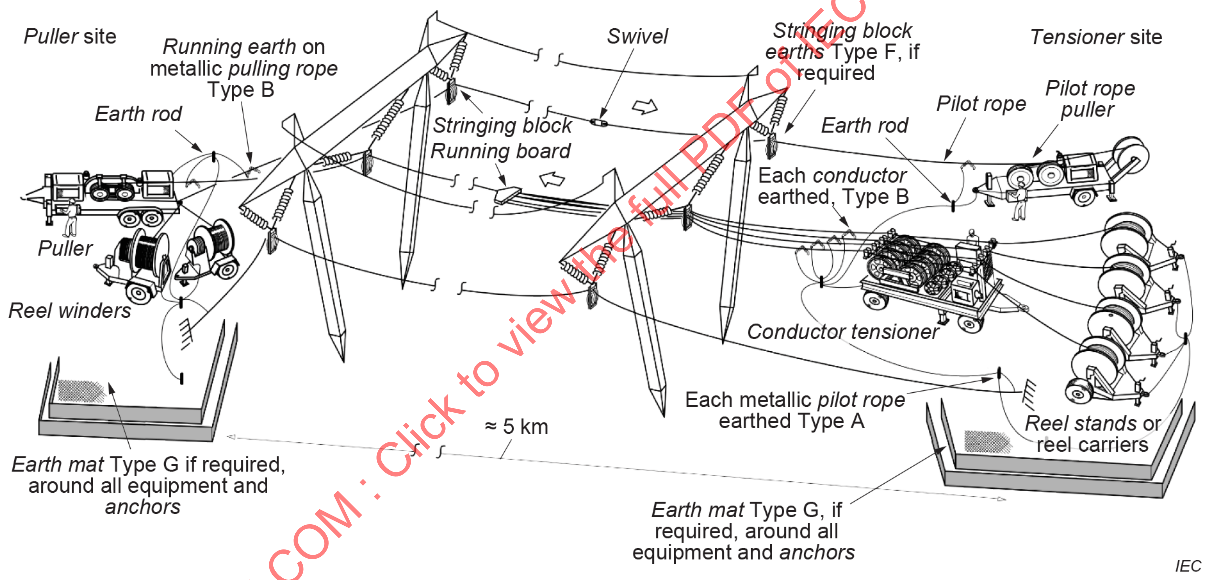
e) Transmission – Installing the pilot ropes



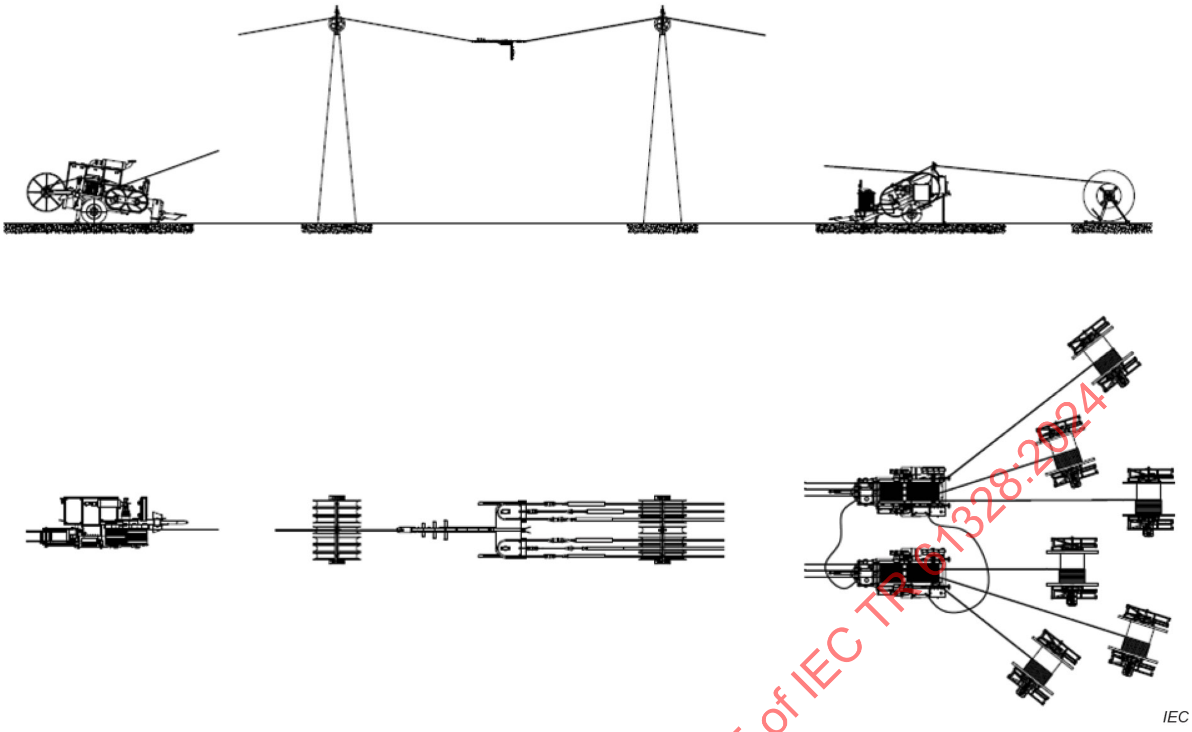
f) Transmission – Installing the earth wire



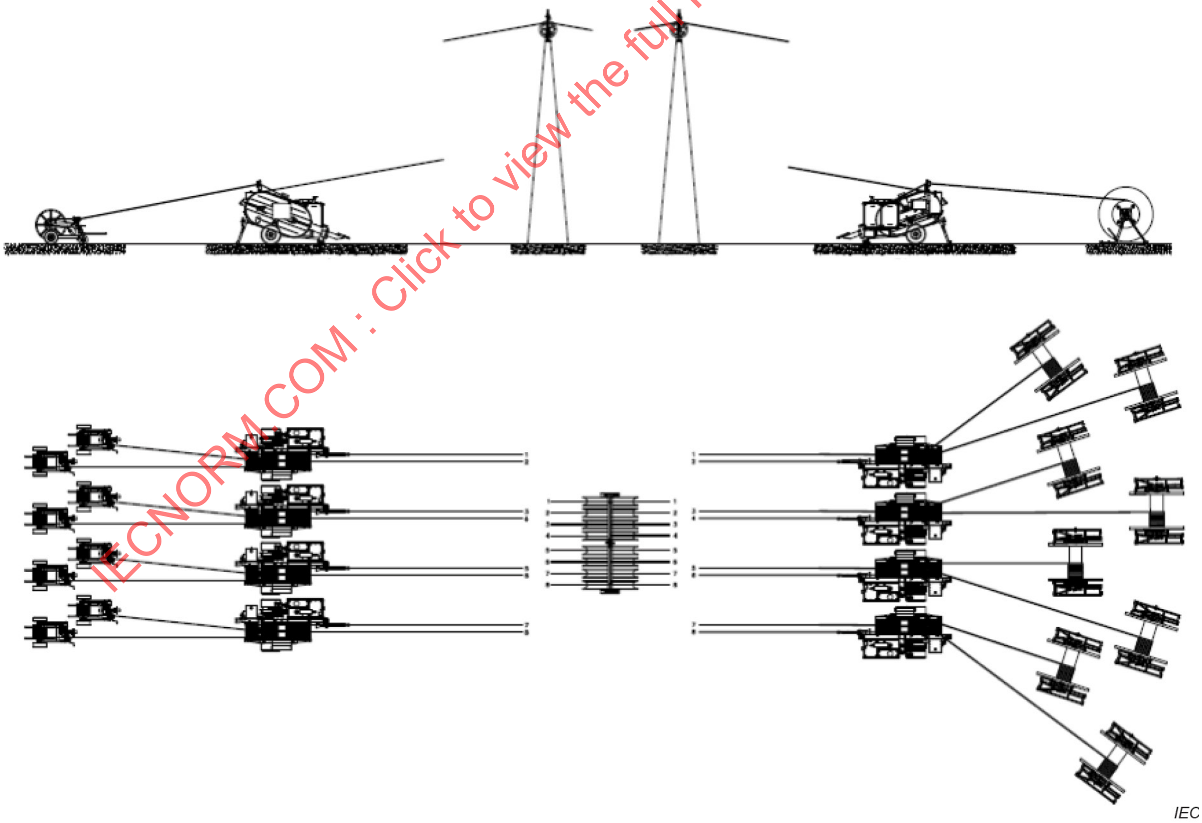
g) Transmission – Installing pulling rope in first phase



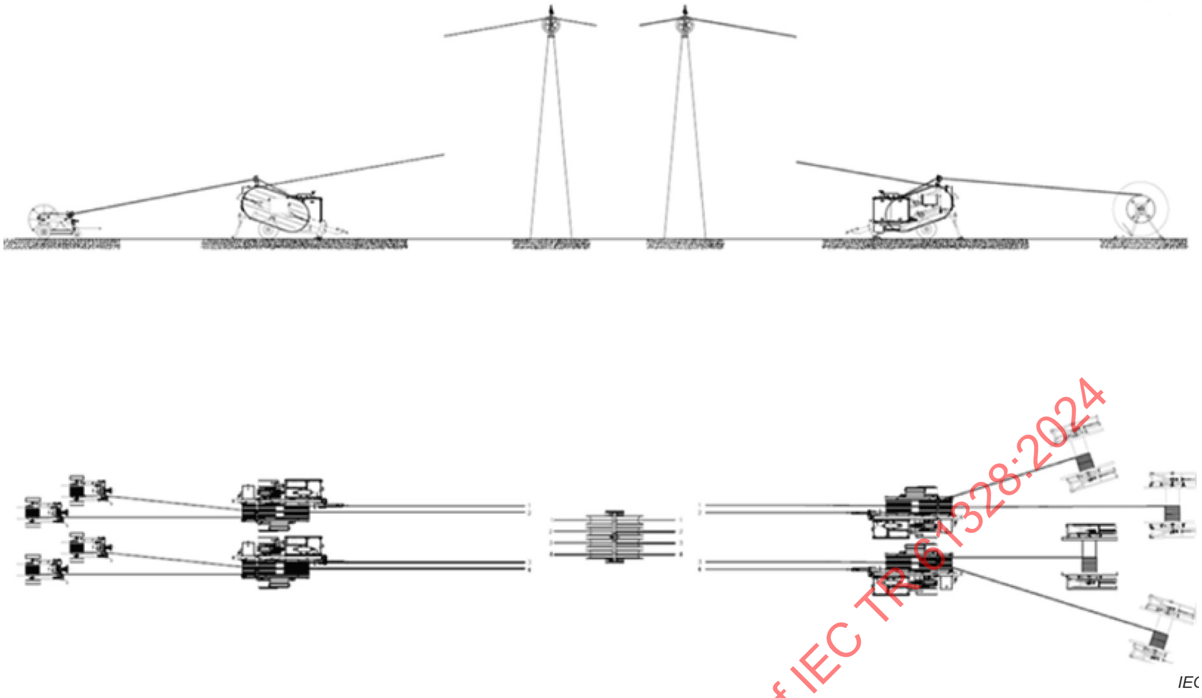
h) Transmission – Installing conductor in first phase



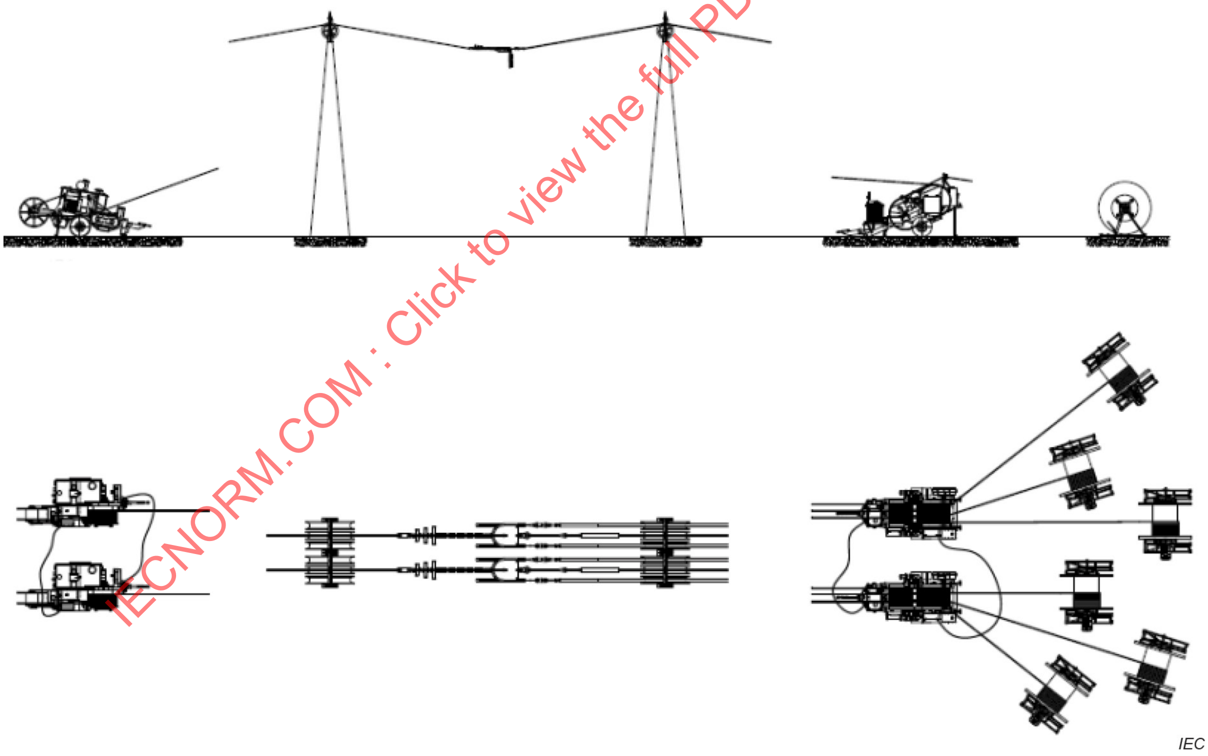
i) Transmission – 1 × n stringing method



j) Transmission – n × n stringing method



k) Transmission – n × n reconductoring stringing method



l) Transmission – 2 × (1 × n) stringing method

Figure 6 – Tension stringing method

5.4 Stringing equipment

5.4.1 General

Subclause 5.4 deals with the equipment used in the *tension stringing* method of installing *conductor*s, and gives some general criteria for choosing these machines, including safety measures for protection of personnel from electrical hazards. The same basic criteria will also apply to this equipment used with the *slack stringing* method.

5.4.2 Tensioners

5.4.2.1 Overview

For distribution *conductor*s, where the tension used to string *conductor*s is usually less than 5 kN, a drum type *tensioner* or *reel stand* is normally used. The *conductor* reel itself is inserted in the machine and the reel is retarded or braked to the *stringing* tension.

For distribution *conductor*s, where the tension needed to string the *conductor* is more than 5 kN, and for transmission and distribution *conductor*s, *tensioner*s are usually *bullwheel* type.

There are two types of *bullwheel tensioner*s:

a) multigroove *tensioner*s with two *bullwheel*s having multiple grooves per *subconductor* on the *bullwheel* (see Figure 7a) and Figure 7b)) – A sufficient number of grooves for each *subconductor* will prevent the outer layer of wires of multilayer *conductor*s from slipping over underlying layers resulting in bird-caging. A lining is used to reduce friction between the *conductor* and the grooves of the *bullwheel*s.

b) The total number of grooves to be use for each sub-*conductor* is related to the maximum tension required. The *conductor* manufacturers recommend particular installation procedures.

c) V-groove *tensioners* with *bullwheel* having a single V-groove *profile are* typically used for scrapping old multilayer *conductor*s.

5.4.2.2 General considerations

General and desirable characteristics that apply to *bullwheel tensioner*s are the following.

a) Fully hydraulic *tensioners* install the *conductor* smoothly without jerking or bouncing, avoiding sudden overload on machines and equipment providing a safe quality *stringing*. The braking system provides for a constant tension in the *conductor* at all *stringing* speeds and holds this tension even when the pull is stopped. Mechanical braking of the *tensioner bullwheel*s gives less smooth control of the tension than full hydraulic braking.

b) For multi*conductor* per phase (bundle) installations, all *subconductors* are installed at the same time and the same tension is applied to each. The tensioning system will have independent control of each pair of *bullwheel.* The *subconductors* in a bundle being installed together are all taken from the same manufacturer's production run or lot.

5.4.2.3 Choosing the correct capacity of the tensioner

*Tensioner*s are usually rated by the maximum tension that can be applied to each *conductor* or *subconductor* in the case of a multi*conductor tensioner*.

A proper *tensioner* will have the capacity to tension the *conductor* with enough *clearance* from the ground or other obstacles to be crossed between towers. A *tensioner* with at least 15 % to 20 % overcapacity with respect to the expected maximum line tension will have sufficient ability to properly manage unexpected situations in which extra tension can be required.

5.4.2.4 Other considerations for the selection of tensioners

The following represents specific considerations when choosing a *tensioner* for a particular project.

a) The *bullwheel* grooves are lined with a material which will prevent damage to the surface of the *conductor* and allow the *conductor* to rest on the bottom of the groove, to avoid torsional stress that can generate birdcage damage. Appropriate materials for the groove liner minimize side friction.

b) The minimum *bullwheel* diameter at bottom of groove is 35 times the *conductor* diameter.

c) The minimum *bullwheel* groove diameter is 1,1 times the *conductor* diameter, to allow the mesh sock joint installed on the *conductor*'s head to pass through the groove in the proper way.

d) Two *bullwheels* of the same pair rotate at the same speed to avoid overstress of the *conductor*.

e) Fairlead sheaves or rollers placed below and on each side of the *conductor* guide it into the correct groove of the *bullwheel* linings from the *conductor* reel. For TW or HTLS *conductor* rollers are designed in such a way so as to minimize the *conductor* angle between reel-stand and *tensioner* side (see Figure 7c)).

f) Fairlead guiding rollers are not used in front of the *tensioner* because they are acting on the *conductor* under tension. *Tensioner* guides have at least the same diameter as that required for the stringing *block*s (see 5.4.9.2).

g) A holding brake incorporated in the drive train for each *bullwheel* pair, is usually a hydraulic off spring type applied so as to hold the *conductor* at *stringing* tension in case of a drive train or hydraulic component failure. This allows the operator to apply and release the holding brake from the control console. In certain applications, such as *conductor stringing* by helicopter, alternate procedures prevent critical situations involving closure of the brake while tensioning.

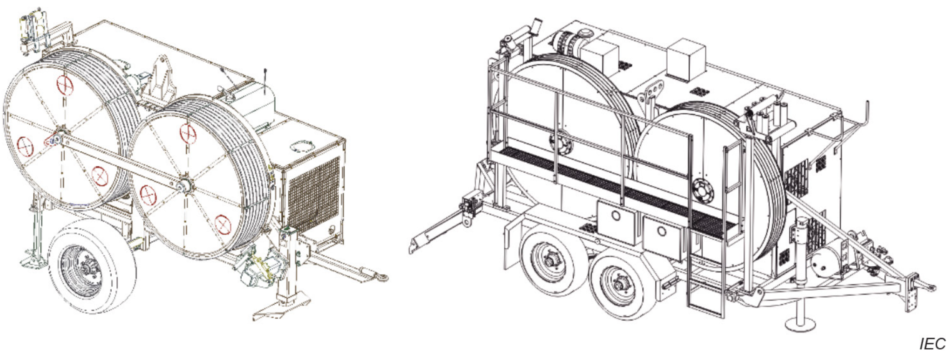
h) A tension indicating gauge or gauges on the *tensioner* control console shows the tension in each *conductor* or *subconductor*. The *tensioner* control console is located so that the operator has good visibility of the *conductor* reel and the *stringing* process. Remotely operated controls can be used to allow a better vision of the working area. A proper installation of an *equipotential* earthing grid with earth connection will protect the remote operator in case of an accidental electrical contact or induction.

i) *Tensioners* are stabilized with ground *anchors* attached to integral *anchor* lugs.

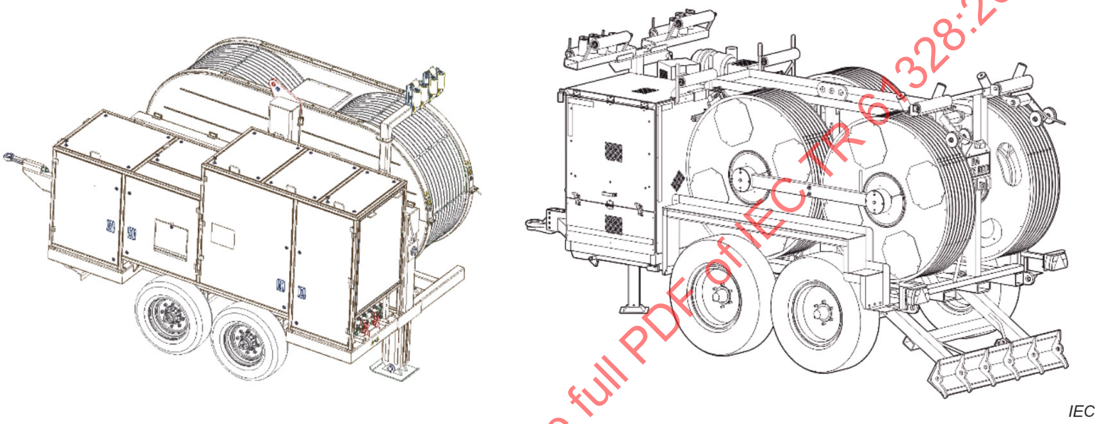
j) An integral earthing lug or bar on the *tensioner*, free of paint or other coating or surface contamination, provides a good electrical connection between an *earth clamp* and the *equipotential* grid around the machine.

k) If the *tensioner* has an operator's cab, installed on vibration damper to isolate noise or vibration, then an earthing strap is installed to connect the cabin frame to the *tensioner* frame.

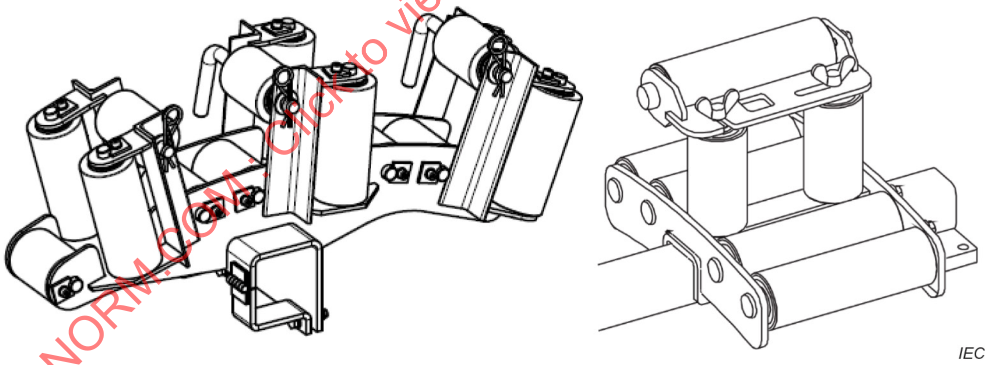
l) If the *tensioner* is too large and heavy for transportation, a modular design allows the machine to be separated into single parts. This is especially convenient where transportation and assembly is done by helicopter.



a) Multigroove tensioners with one pair of bullwheels



b) Multigroove tensioners with multiple pairs of bullwheels



c) Minimizing angle fairled

Figure 7 – Bullwheel tensioners

5.4.3 Pullers

5.4.3.1 Overview

Four basic types of *conductor puller*s exist:

a) drum *puller*s, with either single drum, or one for each rope to be pulled (see Figure 8a));

b) *bullwheel puller*s with separate *reel winder* (see Figure 8b));

c) *bullwheel puller*s with integral *reel winder* (see Figure 8c));

d) *puller-tensioner*s (see Figure 8d)).

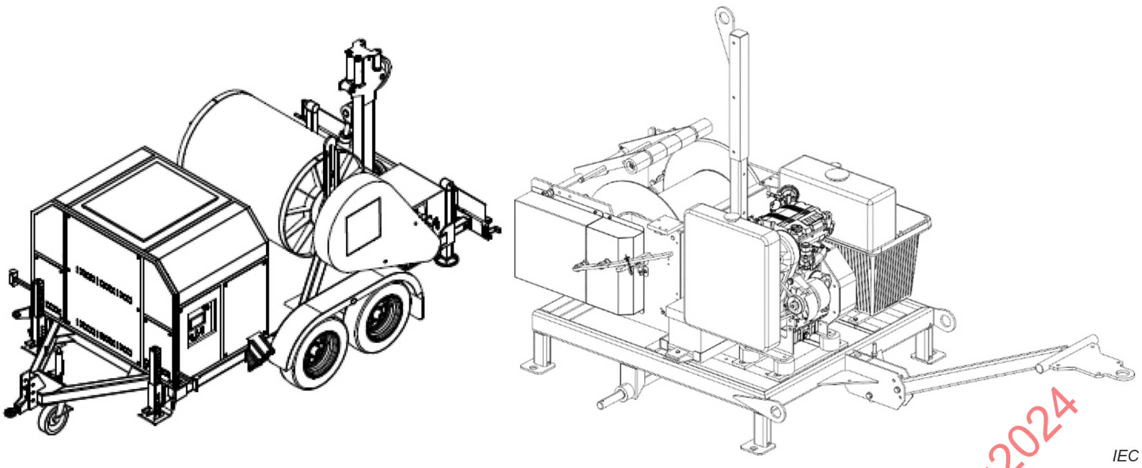
e) detachable *puller* (see Figure 8e)).

The first three types are designed to primarily act as *pullers* only for the *pilot rope* or *pulling rope*.

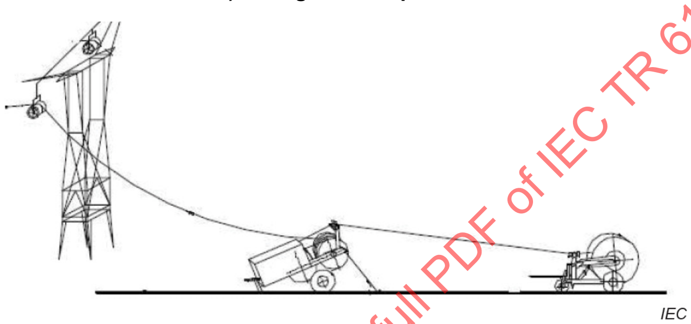
*Puller-tensioner*s can be either of the drum type, which are normally used just for work on distribution lines with limited distance to be covered, or of the *bullwheel* type for work on both distribution and transmission lines, in particular for re*conductor*ing operation.

Puller-tensioners can act as *puller*s for a *pulling rope* and, acting at the other end of the *pull section*, the same machine can be used to tension out the *conductor* as a *tensioner*. When acting on a re*conductor*ing job, the *puller-tensioner* can also recover the old *conductor* that is used as a pulling element to string the new *conductor*.

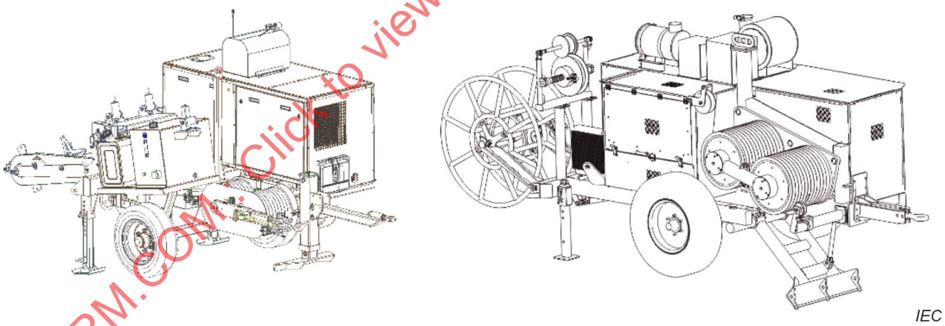
Usually the diameter of the *bullwheel*s for a *puller-tensioner* is larger than that of a *puller* only, and the *bullwheels* for a *puller-tensioner* will have the grooves lined with a material which will prevent damage to the surface of the *conductor*, since this machine can also be used for the tensioning of the *conductor* (see 5.4.2.4a)).



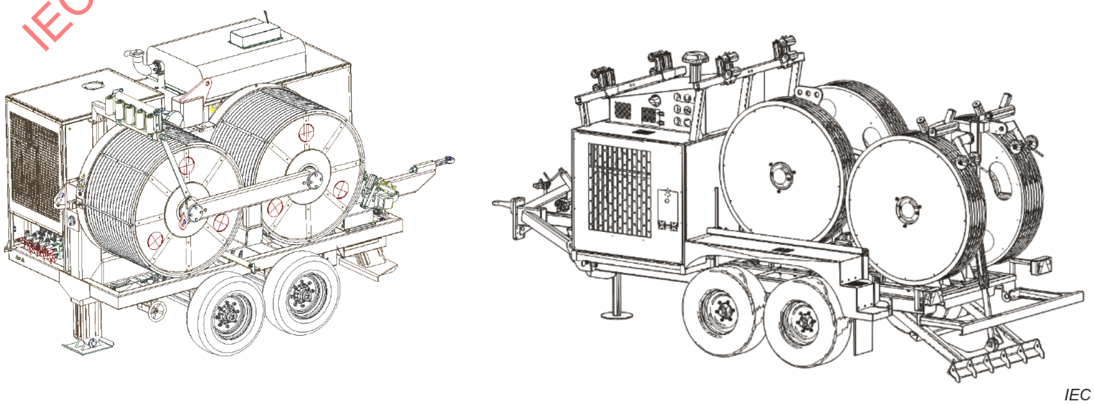
a) **Single drum puller**



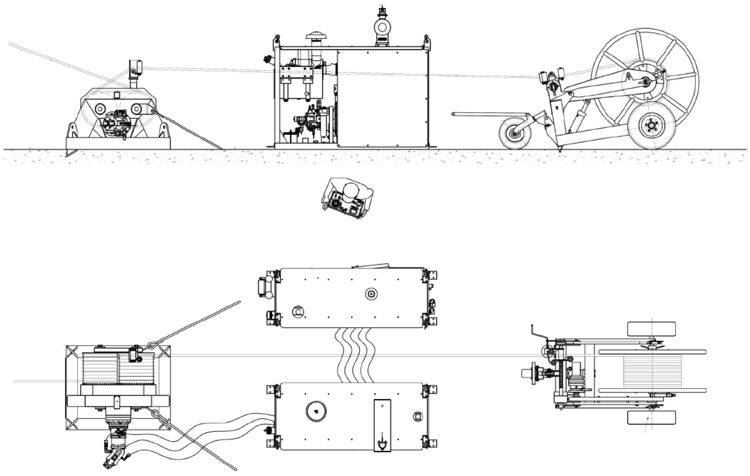
b) **Bullwheel puller (puller-tensioner) with separate reel winder**



c) **Bullwheel puller with integral reel winder**



d) **Puller-tensioner**



e) "Detachable" puller

Figure 8 – Bullwheel pullers

5.4.3.2 General considerations

General and desirable characteristics that apply to *pullers* are the following:

a) They are able to pull the *conductor* and change speeds smoothly without jerking or bouncing.

b) They are able to start the *conductor* moving at full *stringing* tension after a stop.

5.4.3.3 Choosing the correct capacity of puller

Drum *puller*s are usually rated by output torque. This is converted to maximum line pull at the diameter of the *pulling rope* on the drum when the drum is fully wound with the rope.

*Bullwheel puller*s are usually rated according to the maximum line pull that can be accomplished at a lower *stringing* speed, normally rated at approximately 2,5 km/h, while the maximum operating speed is normally rated at approximately 5 km/h.

The *puller* size chosen for any particular project takes into account the *stringing* tension per *conductor* and the number of *conductor*s per phase to be pulled at one time, which determine the total *stringing* tension value, and the length and the path of the *pull section*, which determine how much the total tension value has to be incremented to be able to pull the line. Additionally, a *puller* with at least 20 % to 25 % overcapacity with respect to the expected pulling line provides the ability to properly manage unexpected overload on the line that can arise for any reason.

5.4.3.4 Other considerations for the selection of pullers

Operational characteristic for the selection of *puller*s are as follows:

a) The *puller-tensioner bullwheel*, having appropriate materials for the groove liner, effectively minimizes the side friction effect when stringing *conductor* and grant wear resistance characteristic when stringing steel rope. The groove geometry and the material are designed for *connector link*s passing through the bullwheels.

b) The diameter of *the puller bullwheels* is not as important as that of the *tensioner*. However, a *puller* with *bullwheel* diameter at least 25 times the rope diameter for a steel *pulling rope* or 20 times the rope diameter for synthetic ropes will maximize the working life of the *pulling rope*. With some types of steel *pulling rope*s, a larger ratio of rope to *bullwheel* diameter can be desirable according to the type of the rope.

c) A *puller-tensioner* used in re*conductor*ing operations to pull out the old *conductor*, which is used as a *pulling rope* to pull in the new *conductor*, will have a *bullwheel* diameter of at least 35 times the *conductor* diameter. This will allow for unpredictability associated with the old *conductor* condition and behaviour. Smaller diameters will increase the stress on the old *conductor* being pulled and could create issues due to undisclosed defects.

d) Two *bullwheels* of the same pair rotate at the same speed to avoid overstressing of the rope or *conductor*.

e) Holding brake is incorporated in the *puller* drive train. This is typically a hydraulic off spring type automatically applied so as to hold the *pulling rope* at *stringing* tension in case of a drive train failure, or during a normal stop sequence. The holding brake will automatically release when *stringing* operation resumes.

f) The *puller* control console with a line pull indicating gauge, including an overload device can be pre-set by the operator to a maximum pulling value. The *puller*s will automatically stop when this level of line pull is reached. This prevents the *puller* from continuing to pull up to dangerous levels should the *conductor*, rope or *running board* become snagged and held up somewhere along the *pull section*. A double overload system is also achieved by hydraulic or electronic control of the unit.

g) The controls for the *reel winder* of *bullwheel* type *pullers* gives the *puller* operator full control of the *pulling rope* winding operation.

h) The *pulling rope* is guided into the correct groove of the *bullwheel* from the *reel winder* with fairlead sheaves or rollers placed below and on each side of the *pulling rope*.

i) For drum type *puller*s, a level winder will ensure that the *pulling rope* is evenly wound across the width of the drum.

j) A tension indicating gauge or gauges on the *puller* control console shows the tension in the *pulling rope*. The *puller* control console is located so that the operator has good visibility of the *conductor* reel and the *stringing* process. Remotely operated controls can be used to allow a better vision of the working area. A proper installation of an *equipotential* earthing grid with earth connection will protect the remote operator in case of an accidental electrical contact or induction.

k) *Pullers* are stabilized with ground *anchors* attached to integral *anchor* lugs.

l) An integral earthing lug or bar on the *puller*, free of paint or other coating or surface contamination, provides a good electrical connection between an *earth clamp* and the *equipotential* grid around the machine.

m) If the *puller* has an operator's cab, installed on vibration damper to isolate noise or vibration, then an earthing strap is installed to connect the cabin frame to the *puller* frame.

n) If the *puller* is too large and heavy for transportation, a modular design allows the machine to be separated into single parts (see Figure 8e)). This is especially convenient where transportation and assembly is done by helicopter.

5.4.4 Reel winders

5.4.4.1 Overview

Reel winders are used to wind up a *pulling rope* behind *bullwheel pullers*.

*Reel winder*s are usually incorporated on the same frame as the *bullwheel puller*s, but sometimes, for larger *puller*s, the *reel winder* is a completely separate machine to reduce the overall weight of each component (see Figure 9).

They can have their own power source for driving the rope drum, or more frequently they are powered from a hydraulic drive on the *puller* by means of hydraulic hose connections.

They are always driven faster than the *puller*. This ensures that the *pulling rope* always remains taut between the *puller* and the *reel winder* so that the rope does not loosen on the *puller bullwheel*s.

5.4.4.2 Considerations for choosing reel winders

The considerations for choosing *reel winder*s are as follows.

a) *Reel winder*s have a level-wind system for winding the *pulling rope* evenly across the rope drum, preventing uneven build-up that could cause snarling of the rope on the drum.

b) The *reel winder* accommodates the size and weight of the *pulling rope* drum. Normally the rope lengths are multiple, and therefore the reel is replaced when full of rope. The *pulling rope* is provided with a proper connector to detach or connect between the single section lengths. Larger reels will reduce or eliminate the need to change reels for every section, but will increase the overall weight of the *reel winder*.

c) The *reel winder* is normally arranged to allow installation of the *pulling rope* from the *puller* end to the *tensioner* end of the *pull section*. In case the take-up drive can be disconnected, an over spin brake on the *reel winder* transmission will keep the rope under tension.

d) A holding brake or reverse motion brake incorporated in the *reel winder* drive train holds the *pulling rope* at normal tension between the *reel winder* and the *puller bullwheel*s in case of a drive train failure or during a normal stop sequence. In certain applications, such as *conductor stringing* by helicopter, alternate procedures prevent critical situations involving closure of the brake while tensioning.

e) *Reel winder*s are stabilized with ground *anchors* attached to integral *anchor* lugs.

f) An integral earthing lug or bar on the *reel winder*, free of paint or other coating or surface contamination provides a good electrical connection between an *earth clamp*, and the *equipotential* grid around the machine.

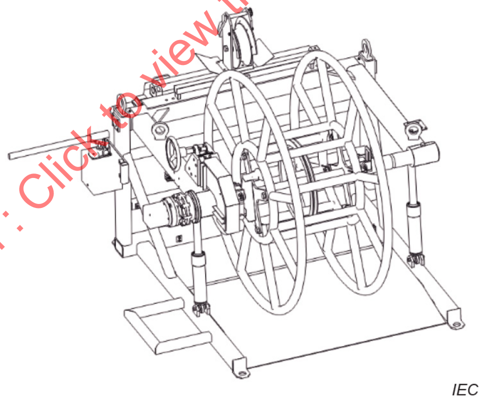


Figure 9 – Reel winder

5.4.5 Reel stands

5.4.5.1 General

*Reel stand*s are used to hold the *conductor* reels. They are usually positioned behind the *tensioner*, and used to wind off the *conductor* from the reel as it is fed to the *tensioner*. They can be self-loading, and therefore called reel-elevators, but usually the reels are loaded into the *reel stand*s by crane, or other lifting means. One *reel stand* is used for each *subconductor* of the phase.

For distribution lines *reel stand*s or reel carriers are used to hold the *conductor* reels. They can be used to directly tension the distribution *conductor* when such *conductor*s are very small (less than 13 mm) and there is no possibility of contact between the new *conductor* being installed and existing *energized conductor*s.

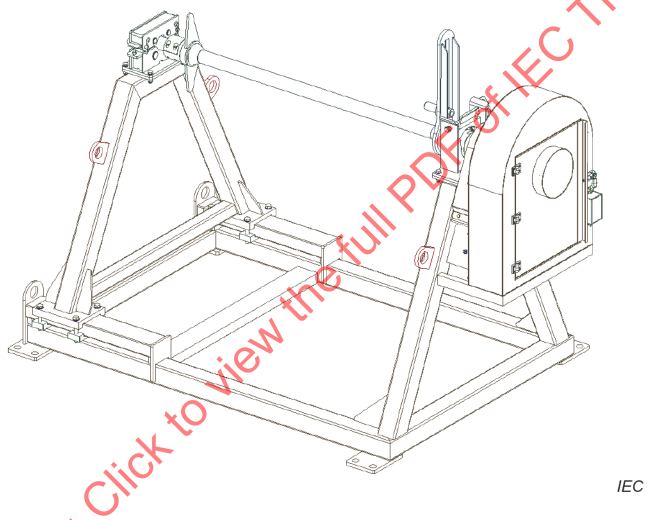
*Reel stand*s are rarely incorporated on the same frame as the *tensioner*, but usually only for single *conductor tensioner*s.

The *reel stand* has a brake to hold tension in the *conductor* between the *reel stand* and the *tensioner*. This holds tension at normal *stringing* speeds until the reel has been emptied of *conductor*. Hydraulic braking systems reduce jerking or bouncing at the *conductor*. Normally the drive system is fed directly by the *tensioner* machine.

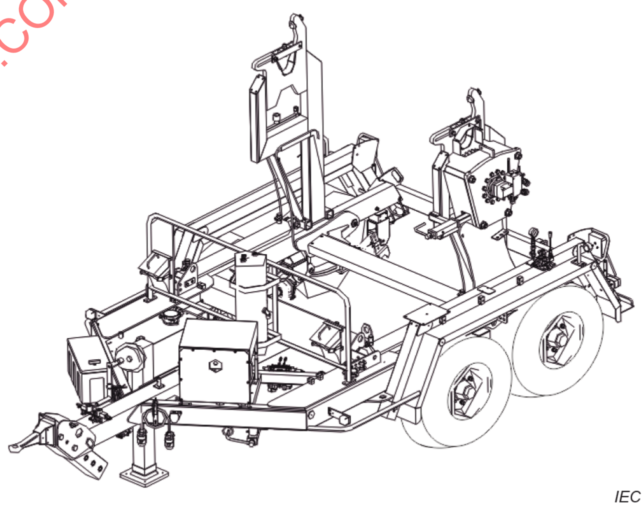
5.4.5.2 Considerations for choosing reel stands

Considerations for choosing *reel stand*s are as follows.

a) The *reel stand* matches the size and weight of the *conductor* reel used on the project (see Figure 10).
b) *Reel stands* are stabilized with ground *anchors* attached to integral *anchor* lugs.
c) An integral earthing lug or bar on the *reel stand*, free of paint or other coating or surface contamination provides a good electrical connection between an *earth clamp*, and the *equipotential* grid around the *reel stand* frame.



a) Reel Stand



b) Reel Carrier

Figure 10 – Reel stand and carrier

5.4.6 Pilot rope puller

*Pilot rope puller*s will have essentially the same characteristics as those of a *conductor puller* (see 5.4.3). They are used on the larger transmission line construction projects to pull the *pulling rope* from the *puller* end to the *tensioner* end of the *pull section*.

*Pilot rope puller*s are usually the removable drum type, and sometimes they are powered from the *tensioner* or *puller-tensioner*.

*Pilot rope puller*s are rarely used to pull in the *earth wire*, while they cannot be used to pull in the optical ground wire (OPGW), which needs a dedicated *tensioner*.

5.4.7 Pilot rope and pulling rope

A *pulling rope* for transmission and distribution line work is usually a high strength steel wire rope specially constructed for this purpose. High strength synthetic ropes have been used for this purpose as well.

*Pilot rope*s and *pulling rope*s for distribution line work are usually high strength synthetic ropes, specially constructed for this purpose. Each *pilot rope* is a different colour for each phase plus neutral (if used), so that the *pilot rope* is always put in the same phase *stringing block* during installation.

One of the most important characteristics of a pilot or *pulling rope* is its non-twisting capability so that it does not impart twist or spin to the *conductor* or the *running board*.

Steel ropes are normally made by several independent braided strands to achieve the non-twisting characteristic. The number of individual strands ranges from 8 up to 18. The material is normally high-resistance grade steel able to withstand fatigue effect related to use on the multiple *bullwheel* grooves.

The rope manufacturing process ensures equal distribution of the stress in all the individual strands to avoid dangerous overload.

A smooth outer surface of the rope will minimize vibration and wear as the rope passes around *bullwheel*s and over *stringing blocks*.

Steel *pulling rope* is normally pre-greased when manufactured. Traction is maintained by a sufficient number of grooves on the *bullwheels* of the *puller* and proper control of the *reel winder*. Dry *pulling rope* has a better grip on the *bullwheel*s but decreases the working life of the rope due to fatigue damage.

Synthetic pulling or *pilot rope*s are not electrically insulating. New rope can have excellent insulating properties, but with use, the surface becomes sufficiently contaminated to be conductive, particularly in wet conditions.

Synthetic rope can have a better strength to weight ratio than steel rope though it is more easily damaged. Synthetic ropes used as pulling or *pilot rope*s are chosen with a stretch or elongation not exceeding 3 % at breaking load. Common practice is to calculate the elongation starting from that measured at 4 % of breaking load, to allow for the self-adjusting effect of the *structure* of the rope. All rope stores considerable elastic energy which can be dangerous in case of breakage. Sudden release of the elastic energy can result in injuries or damages. Heavy storage reels are used to resist the crushing forces resulting from this elastic energy.

The steel rope breaking strength is typically at least three times the expected maximum working load. The synthetic rope breaking strength is typically at least five times the expected maximum working load. Rope manufacturers provide the maximum working load for these ropes.

Normally the *pulling ropes* are provided with eye splices at each end of the section. This allows for the connection of multiple sections using the proper links (fixed joints) or *swivel* joint in front of the head section of a single *conductor* or *running board*. The *pulling rope* breaking strength is limited by the presence of an eye splice as indicated in the rope manufacturer's technical specification.

5.4.8 Woven wire grip

The *woven wire grip* is selected according to the type of the *conductor* and is designed to properly distribute the load on the whole *conductor* cross section matching the *conductor* breaking strength.

5.4.9 Stringing blocks

5.4.9.1 Overview

*Stringing block*s are hung on each tower, usually at the end of each phase insulator string and at the *earth wire* position. They are used to position and pass the *conductor* as it is being strung.

On heavy angle towers, the *stringing block* can be hung directly from the tower-bridge or crossarm. In this case, if the *stringing block* has a lined *conductor* sheave, it is *isolated* from the tower *structure* with an insulating link or use a *stringing block earth*.

To allow the *conductor* to rest on the bottom of the groove, while in the correct position for *stringing* operation, the *stringing block*s are suspended in a way that they can self-adjust to the working position. On heavy angle towers, the *stringing block*s are tied to the tower *structure* in such that they hang at the normal swing angle which they will assume when they come under load from the *pulling rope* or the *conductor*. During *stringing* operation this position can change while passing from *pulling rope* to *conductor*s and can need further adjustment.

*Stringing block*s for distribution *conductor* usually have an unlined sheave with a smooth groove surface to protect against damage to the *conductor*. *Blocks* with an elastomer lining are also used.

*Stringing block*s for transmission *conductor* are normally made by casting wheels with *conductor* sheave linings. Single casting *blocks* are preferred to composed casting *blocks*, due to a better stability and mechanical behaviour under load.

Conductor sheave linings are used to protect the surface of the *conductor* from scratches or other damage as the *conductor* moves through the *stringing block*. Linings can be made of rubber, polychloroprene, polyurethane or other elastomer, polyamide or aluminium, normally applied on the bottom of the groove. Polyamide or aluminium lining provides better treatment on the outer layer of the *conductor* due to the reduced friction, which allows the *conductor* to easily self-adjust on the bottom of the groove, where the *conductor* is supposed to work in any *stringing* configuration.

Polyurethane, polyamide or aluminium lining are used where both the *pulling rope* and the *conductor* will pass through the same sheave, such as on single *conductor stringing block*s or for the *pulling rope* sheave on odd number *subconductor*s per phase *stringing block*s (e.g., three *subconductor*s per phase). For transmission lines with more than one *conductor* per phase, *stringing block*s will rarely consist of an unlined *pulling rope* sheave and lined *conductor* sheaves.

The sheave lining material is considered to be non-conductive even if it contains a conductive element. Experience has shown that so-called conductive linings become essentially non-conductive after a period of use. An exception is represented by aluminium lining or unlined sheaves, which can be considered fully conductive.

The *stringing block* sheaves have sealed or greaseable high-quality roller or ball bearings to minimize friction of the *block* during *stringing*.

The load rating of the *stringing block* is specified by the manufacturer. The *stringing blocks* used on angle towers are usually chosen with a larger load rating and a larger sheave diameter. In some cases, more than one *stringing block* is used in a tandem *block* application on heavy load towers to better distribute the load on each wheel.

To allow installation of *pilot rope* by helicopter, *stringing blocks* can be designed with open frame design and proper finger guides, to automatically position the rope on the central wheel and to ensure the correct positioning of the rope during *stringing* operations.

5.4.9.2 Considerations for choosing stringing blocks

Considerations for choosing *stringing blocks* are as follows (see Figure 11).

a) For best results during the *stringing* and *sagging* operations, the minimum diameter D_s at the bottom of each *conductor* sheave groove (sometimes called root diameter) is:

$$D_s=20D_c \tag{1}$$

where D_s and D_c are in millimetres and D_c is the diameter of the *conductor* to be installed.

On *stringing blocks* located on the angle *structures* with more than 30° breakover angle and on the *structures* in front of the *puller* and *tensioner*, larger diameter *blocks* or tandem solution is used due to the increased loads. Different ratios are used for TW or HTLS *conductors* as specified by the manufacturers.

b) The minimum depth of the sheave groove is:

$$D_g = 1{,}25D_c \tag{2}$$

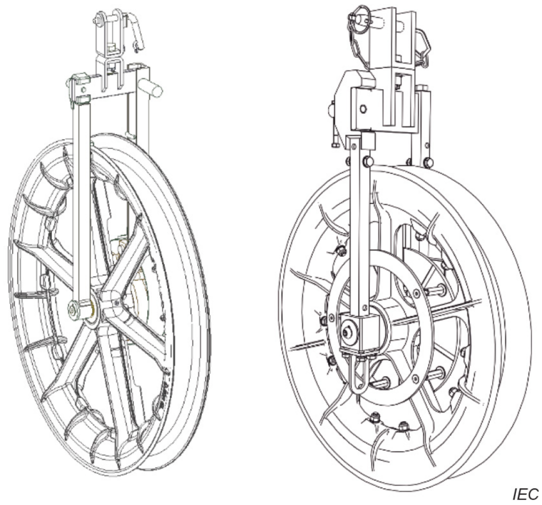
c) The minimum groove radius at the bottom of the groove is:

$$\frac{1{,}1D_c}{2} \tag{3}$$

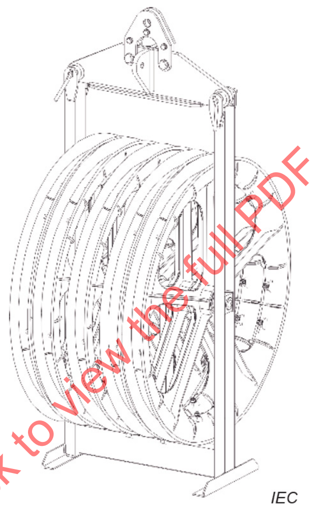
The groove profile and the groove radius is wide enough to allow passage of *conductor swivels*, *conductor* splices and *woven wire grips* without these riding high in the groove and imparting a shock load to the sheave. The *conductor* mid-span joints or splices will have split rubber collars or cones at each end to protect the *conductor* from damage where it exits at the end of the sleeve. Side grooves normally flare 3° to 5° from the vertical when sheave linings are applied on the bottom of the groove.

d) The *stringing block* frame opens at the top or side for easy removal of the *conductors* during the *clipping-in* operation.

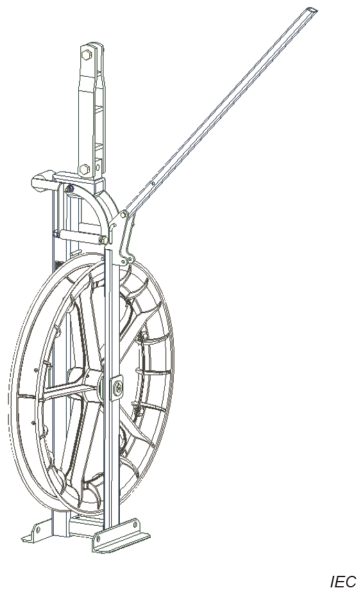
e) The groove of the *stringing block*, or the area where the *conductor* passes through, allows for the smooth passage of a *running board* in the case of bundle *blocks*, or *conductor* mid-span joints, *swivels*, *pulling rope* eyes, etc., without contacting with the *block* frame.



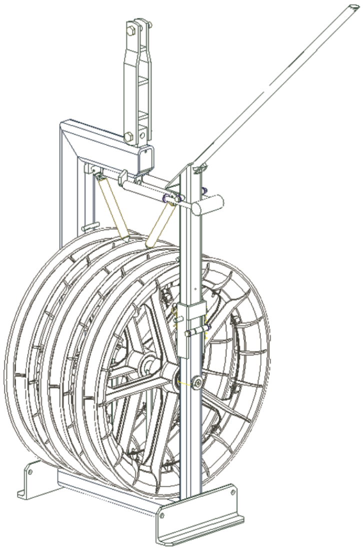
a) **Stringing block – single**



b) **Stringing block – bundle**



c) **Stringing block – single – helicopter**



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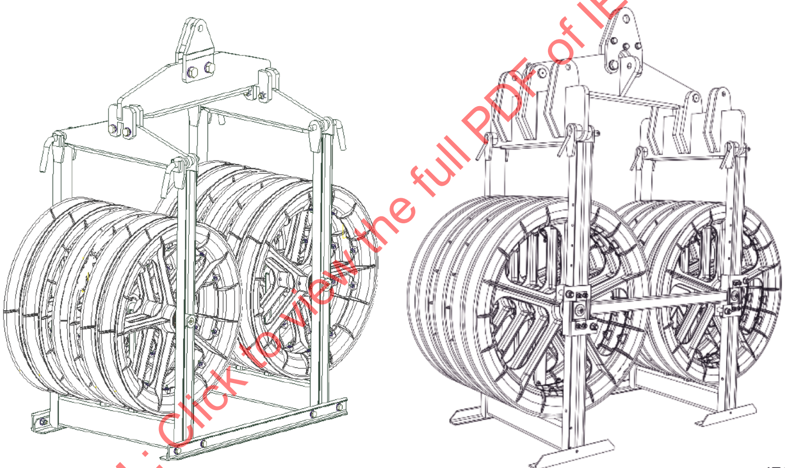
d) Stringing block – bundle – helicopter



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e) Stringing block – tandem (bundle)

Figure 11 – Stringing blocks

5.4.10 Stringing rollers

Stringing rollers are a possible alternative to the traditional *stringing block*s, in particular when large radius is desired.

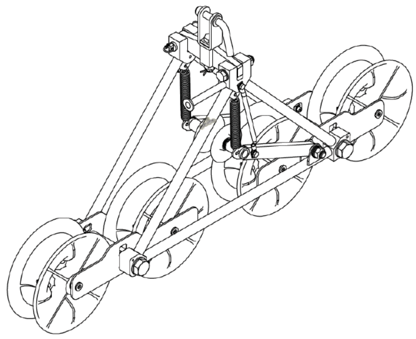
They are made by a series of rollers, placed on an equivalent radius equal to the expected diameter of a *stringing block*, arranged with self-orientation possibility, to reach the desired configuration when *stringing* (see Figure 12a) and Figure 12b)).

Material of rollers and lining is the same as traditional *stringing block*s. Due to the high rotation speed of the rollers, linings such as hard polyamide or metal are used.

The groove profile and the groove radius are wide enough to allow passage of *conductor swivel*s, mid-span splices or joints, and *woven wire grip*s without these riding high in the groove and imparting a shock load to the rollers.

The *stringing* roller's frame allows for opening of the top or side for easy removal of the *conductor*s during the *clipping-in* operation.

The throat of the *stringing* rollers, or the area where the *conductor* passes through, is designed to allow for the smooth passage of a *running board* in the case of bundle rollers, or *conductor* mid-span joints, *swivel*s, *pulling rope* eyes, etc. without contacting the roller's frame.



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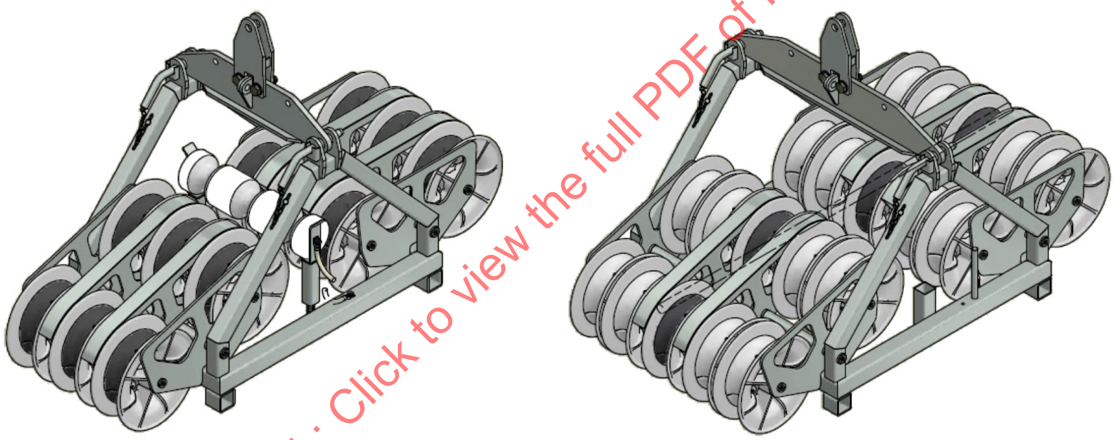
a) Stringing rollers for single conductor



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b) Stringing rollers for bundle conductor

Figure 12 – Stringing rollers

5.4.11 Stringing block earth

Stringing block earths are attached to the *stringing block* and are placed on moving *conductor*s or pulling/*pilot rope*s and used to provide an electrical path to earth. They are primarily used to provide safety for personnel during construction or reconstruction operations. This device is placed on the *stringing block* at a strategic location where an electrical earth is desired.

Some characteristics of a *stringing block earth* include the following:

a) It is capable of withstanding a specified current.

b) It has an earthing bar, free of paint or other coating or surface contamination which would prevent a good electrical connection, specifically when attaching an *earthing cable* with *earth clamp* (see Figure 14f)).

c) The sheaves are normally of aluminium for the part of the earth contacting the *conductor*, and of hardened steel for the part of the earth contacting the steel pulling/*pilot rope*.

Blocks arranged with aluminium casting groove or aluminium linings are considered integrally conductive.

5.4.12 Running earth

Running earths are placed on moving *conductor*s or pulling/*pilot rope*s and used to provide an electrical path to earth. They are normally used at the pull and *tension site*s. They are designed to allow *conductor compression joint*s, woven wire mesh joints with *swivel*s, or rope joints to pass through without having to be removed from the *conductor* or rope.

Some characteristics of a *running earth* include the following:

a) It is capable of withstanding a specified current.
b) It has an earthing bar, free of paint or other coating or surface contamination which would prevent a good electrical connection, specifically when attaching an *earthing cable* with an *earth clamp* (see Figure 14b)).
c) The sheaves are normally of aluminium for *running earths* used on *conductor*s, and of hardened steel for *running earths* used on steel pulling/*pilot rope*.
d) The *running earth* has an attachment point for an *anchor* rope which will hold the earth stationary while the *conductor* or rope moves through it. The *earthing cable* is not used as an *anchor*.

5.4.13 Hold-down block

As the *pilot rope* is much lighter than the *conductor(s)*, during the *stringing* an uplift could occur at some towers. The *hold-down block* is used to maintain the *pilot rope* inside the sheaves of the *stringing block* of the tower.

The *hold-down block* has an attachment hook or shackle to hold it down and generally a device allowing to take it off during the *stringing* without necessity to climb up the tower (see Figure 13).

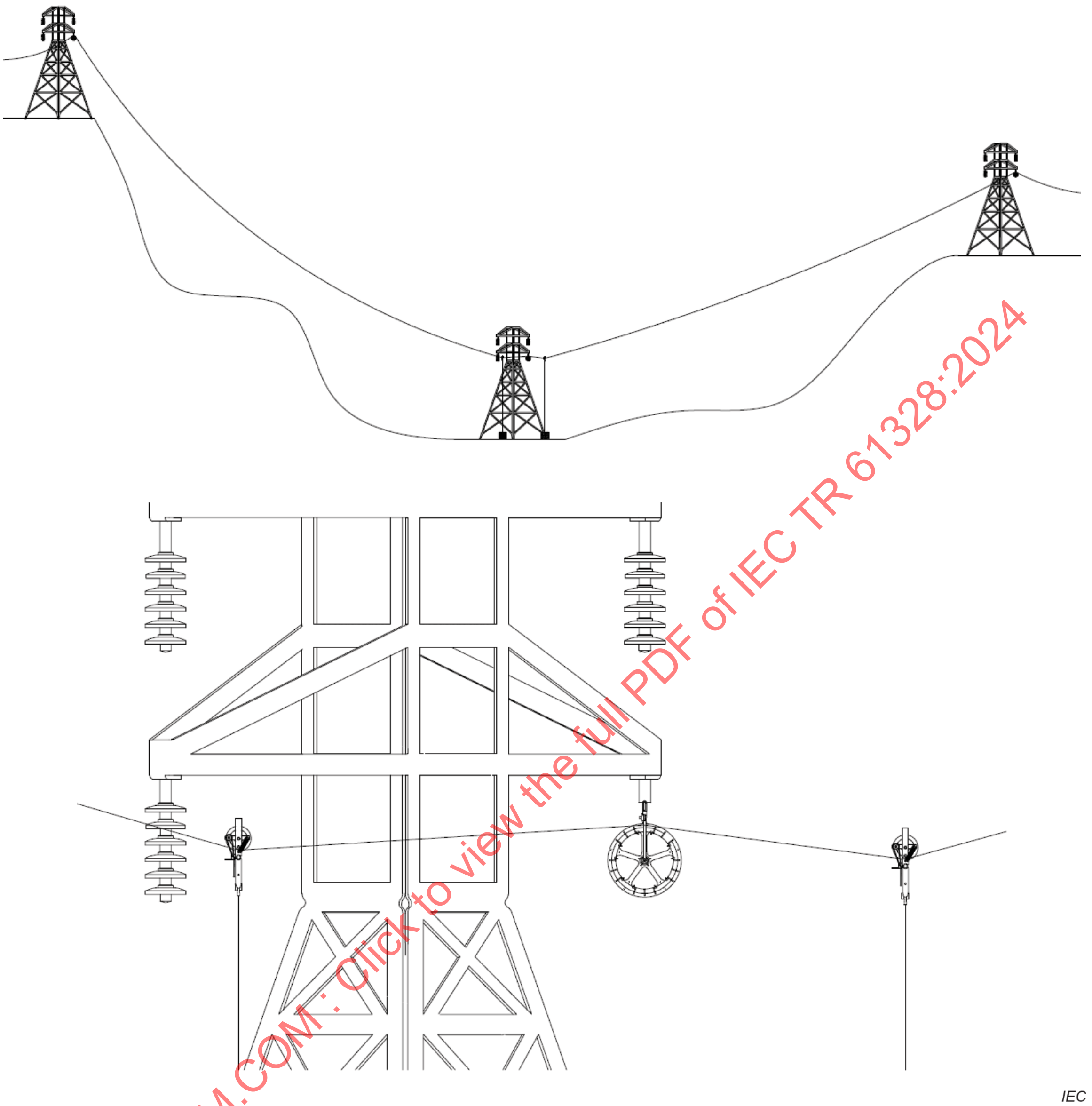

Figure 13 – Hold-down block diagram of use

6 Special earthing applications

6.1 General

This clause presents temporary *earthing system*s for each of the work procedures used in the installation of *conductor*s.

Most of the earthing protection described below applies to bare distribution and transmission *conductor*s. However, covered overhead distribution *conductors* are subject to many of the same hazards during installation.

It is generally recognized that the insulation on these *conductor*s is not relied on for protection of equipment and personnel if a direct contact with an *energized conductor* occurs. Also, during the *stringing* process, the core of a covered *conductor* is exposed at the pulling end where a metallic *woven wire grip* is often used.

Where special techniques apply to insulated overhead distribution *conductor*s, they will be identified as such.

When new *conductor*s are installed in a remote area removed from other *energized* lines or parallel adjacent lines, and with no thunderstorm activity present, some of the *earthing systems* and procedures are not applied such as the use of earthing mats. The earthing procedures included in Subclause 6.3 assume that the line is installed in a congested area involving exposure to numerous *energized* parallel lines or the crossing of existing *energized* lines, and/or where there is a high probability of thunderstorm activity and adverse weather conditions.

These procedures include *bond*ing and earthing of equipment, the use of *running earths*, *earth mat*s at work sites, and *stringing block earths*. These earths are designed for a *fault current* where direct contact with an *energized* line is probable.

Figure 14a), Figure 14b), Figure 14c), Figure 14d), Figure 14e), Figure 14f), Figure 14g) and Figure 14h) show the possible earthing procedures for the *conductor stringing*.

6.2 Earthing systems

6.2.1 Overview

For transmission and distribution *conductor stringing*, *earthing* is applied to *conductor*s, overhead *earth wire*s, *pulling rope*s and *pilot rope*s. Hereinafter for brevity, the word *conductor* will be used to refer to overhead *earth wire*s, metallic pulling and *pilot rope*s, unless specifically stated otherwise. Subclauses 6.2.2, 6.2.3, 6.2.4, 6.2.5, 6.2.6, 6.2.7, 6.2.8, 6.2.9 and 6.2.10 give specific *earthing system* information for equipment and components other than *conductors* used in the *stringing* process.

For distribution *conductor stringing*, where a system neutral *conductor* is available on an adjacent *circuit*, it is common to interconnect the *earth mat*, the *conductor*s and the equipment earths to this existing system neutral, since the neutral provides a known low resistance path to earth. Normally, an *earth mat* is *bonded* to *earth rod*s driven around and within its perimeter to increase its earthing capabilities and provide convenient connection points for earthing devices. The primary purpose of the mat is to provide safety for workmen by limiting potential differences within its perimeter to safe levels in case of high currents which can flow if the *circuit* or *conductor* being worked became *energized* for any reason. Metallic surface mats and gratings are sometimes utilized for this same purpose. When used, these mats are employed at pull, tension and midspan splice sites.

6.2.2 Use of earth rods

6.2.2.1 General

Where *earth rod*s are used, the resistance of the *earth rod*s is electrically tested. The resistance of the *earth rod* is typically less than 25 Ω. Protection equipment on adjacent *energized* line are designed to clear *fault current* if the impedance of the earth is less than 25 ohms.

If an *earth rod* resistance of less than 25 Ω is not obtained, an *earth mat* (see Figure 14h)) is used at ground level, or an *equipotential earthing system* is used in elevated work sites.

6.2.2.2 Use of earthing sticks

All *earth clamp*s are designed so they can be applied and removed with an insulated *earthing stick*. The *earthing stick* is made of insulating material such as fibreglass, reinforced plastic or similar, with a particular, highly resistant connection and is of sufficient length to allow safe gripping and installation of *earth clamp*s.