

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

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INTRODUCTION

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

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

1 Scope

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

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

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

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

2 Terms and definitions

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

2.1

all dielectric self supporting cable

ADSS

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

2.2

aeolian vibration

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

[IEV 466-01-17, modified]

2.3

anti-twist running board (see Figure 1)

anti-twist headboard

pulling device designed to resist the torque generated by a change in tension of the OPGW cable thus preventing rotation in order to maintain optical fibre strain margin

2.4

blow-out

cable swing caused by the wind

2.5**conductor**

phase conductor

2.6**conductor galloping**

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

[IEV 466-01-19]

2.7**cradle block stringing** (see Figures 2, 3, 4)

system of cradle stringing blocks, spacer rope, pulling rope, a brake unit, and a radio controlled motorized tug, which use the existing earthwire as support when installing the new optical fibre cable

2.8**de-energized**

dead

at a potential equal to or not significantly different from that of the earth at the worksite

[IEV 651-01-15, modified]

2.9**earthwire**

ground wire, shield wire, skywire, static wire

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

[IEV 466-10-25, modified]

2.10**energized**

alive, current-carrying, hot, live

at a potential significantly different from that of the earth at the worksite and which presents an electrical hazard

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

[IEV 651-01-14, modified]

2.11**fault current**

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

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

2.12**fault-rating**

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

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

2.13

induced current

current flowing as a result of induced voltage

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

2.14

optical attached cable

OPAC

ground wire wrapped optical (GWWOP) cable

non-metallic optical fibre cable designed to be wrapped or lashed onto the existing earthwire or phase conductor

NOTE One of the following three attachment methods is used:

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

2.15

optical phase conductor cable

OPPC

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

2.16

optical ground wire cable

OPGW

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

2.17

optical time domain reflectometer

OTDR

instrument which is used to measure and locate point and distributed losses along the length of an optical fibre

2.18

pull section

pull setting, stringing section

section of line where the optical fibre cable is being pulled into place

2.19

sagging

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

2.20

sealing end

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

2.21**stringing**

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

2.22**vibration damper**

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

[IEV 466-11-16]

3 Understanding the hazard – Basic theory

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

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

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

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

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

3.1 Electric field induction from nearby circuits

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

3.1.1 Induced voltage

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

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

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

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

3.1.2 Induced current

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

The two following aspects should be considered.

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

3.2 Magnetic field induction from nearby circuits

3.2.1 Induced current

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

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

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

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

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

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

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

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

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

3.2.2 Induced voltage

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

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

4 General considerations

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

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

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

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

4.1 Engineering considerations

4.1.1 General

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

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

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

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

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

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

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

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

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

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

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

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

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

4.1.2 Specific

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

4.2 Safety issues

4.2.1 Choosing the correct equipment

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

4.2.2 Pre-work check of equipment

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

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

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

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

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

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