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Third-Party Damage to Underground and Submarine Cables

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Third-Party Damage to Underground and Submarine Cables

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1. Executive Summary

1.1 Introduction

Failure statistics show that the risk of third-party mechanical damage is three to five times higher than the risk of internal failures. This is interesting - why is it so? Who are destroying the cable systems, and is it possible to reduce the number of damage events to the cables? This is discussed in the Technical Brochure (TB).

To find out how to reduce the number of failures caused by third-party damage a survey was conducted by Cigré Working group B1.21, Third-Party Damage to Underground and Submarine Cables. The objective was to collect information so as to make it possible to provide guidance about possible ways of reducing the risks of third-party damage. The TB discusses the results of this survey and takes into account the failure statistics from TB 379 from a "third-party-damage viewpoint".

1.2 Description of cable systems

The TB starts off with an overall description of different types of cable systems to ensure that the reader has basic knowledge of the different elements that make up a cable system. If the reader is already familiar with this, he can skip this chapter. AC and DC, underground and submarine cable systems are described.

1.3 Service experience and survey on third-party damage

Underground cables:

Failure caused by external agents is the most frequent type of failure. About 70% of the failures are caused by mechanical work.

About 40% of all third-party damage can be attributed to insufficient information exchange between cable operators and construction companies.

It can be concluded that the installation of cables in concrete ducts and tunnels gives very good protection against external third-party damage. The probability of a failure caused by external mechanical damage is more than 10 times higher for direct-buried cable systems than for cable systems in concrete ducts or tunnels.

Submarine cables:

Because of the small number of failures and responses to the questionnaires it is not possible to present a reliable conclusion concerning the relation between installation method and failure probability.

The average annual failure rate seems to be significantly lower for submarine cables than for underground cables.

External damage is the most common reason for submarine cable failures.

1.4 Main threats to cables

In order to take steps towards risk reduction, it is important to be familiar with the threats to the cables. These threats are discussed in the TB.

Underground cables:
Main threats to underground cables are:
- Excavators
- Horizontal drilling
- Vertical drilling

Other threats are also mentioned in the TB.

Submarine cables:
Main threats to submarine cables are:
- Anchors
- Ocean dumping of dredged material or garbage
- Other installations including pipes, telecommunication cables, etc.
- The influence of other existing cables
- Trawling

1.5 How to discover and detect third-party damage

Damage to cable systems is complex. The damage effect can be very severe and result in automatically outage of the line, or the damage effect can be almost harmless.

If the short-term effect of cable damage is limited to the surroundings or the cable surface, it may be possible to detect the damaged state before the final destroying effect is reached.

Detecting a third-party damage event at an early stage might lead to early repair, which will be much simpler to perform than if the damage event is ignored and the repair work done after the occurrence of an electrical failure.

Different methods and measures of discovering and detecting third-party damage at an early stage are mentioned in the TB.

1.6 How to reduce the risk of third-party damage to underground cables

There are more ways of reducing the risk. The TB discusses the mechanical protection of cables but mentions other solutions as well. One of the most efficient means of cable protection is improving relations with the excavation companies, the purpose being to give them basic knowledge about underground cable systems as well as specific knowledge of cables in their particular area of interest so that they will never get into contact with the cable systems. The TB describes the essential information exchange between the cable operators and "third-parties" in general.

1.7 How to reduce the risk of third-party damage to submarine cables

Burial of submarine cables is one of the most effective ways of reducing the risk of damage from fishing gear and small anchors.

Though submarine cables to some extent can be mechanically protected, it is still very important that information about cable position is available to fishermen and mariners. How to exchange information between cable operators and these third-parties is discussed in the TB.

1.8 Systematic approach to risk assessment of cable systems

The TB introduces a systematic approach to risk assessment of cable systems. The method is explained through an example in the TB.

Each damage event leads to a specific damaged state with a short-term damage effect on the cable system. To minimise the overall risk of the cable system, it is worthwhile looking not only at the possible events but also at the damage effects.

Focus must be on the damaged states and damage events with the most severe effects and the highest probability. The combination (product) of probability (of damaged state caused by a damage event) and severity (of the short-term and final effect) is the 'criticality of damaged states'. The criticality is the risk of the cable system.

There are two possible ways of reducing the risk:
- Reducing the probability
- Reducing the severity

Many damaged states do not make an immediate impact on the network because no failure occurs. But more severe damaged states cause failures in the network resulting in outages of power lines.

Transmission lines are not equally important. Some are extremely important while others are of minor interest. The consequences of a failure will also depend on factors such as network structure, market situation, etc.

Criticality, combined with the consequences of a specific damaged state, indicates the risk of the overall network. The 'Cable Protection Index' (CPI) is defined as the product of criticality (cable risk) and consequences for the network.

When severity, probability and consequence categories are defined in five levels (with values 1-5), it is possible to calculate the CPI.

CPI = Risk * Consequence
= Severity * Probability * Consequence

CPI ≤ 15 OK
CPI > 15 => Further studies
CPI > 25 => Measures to reduce risk or consequence

It is not possible to make reliable calculated absolute indices for the cable systems. But if the procedure outlined in the TB is observed, it will be possible to calculate a relative cable protection index, based on the relative risk and consequence.

The CPI can be used if the cable operator finds it worthwhile. The TB contains a great deal of information that can be used independently of the use of CPI.

2. Introduction

In September 2005, Cigré Study Committee B1 set up a working group with the purpose of providing guidance to all relevant parties involved in assessing and minimizing third-party cable damage.

2.1 Terms of reference

Background:

Utilities have been suffering for a long time from third-party damage, ie the damage to cables caused by so-called external agents: usually digging activities but also indirect aggression such as overheating, corrosion or change of backfill caused by other utilities. Compared with the efforts undertaken to solve 'internal' damage, issues are usually treated in an off-hand or unmanaged way, although in terms of money it is a very serious problem. The last service experience statistics for underground HV cable systems relating to these problems were published in 1991 (for land cables) and in 1986 (for submarine cables).

At the moment, there are no guidelines to help companies responsible for electricity transmission and distribution to reduce third-party cable damage.

Objectives:

To give guidance to all relevant parties involved (cable owners, network operators, contractors, authorities, other utilities) on:

- Defining the correct terminology.
- Collecting information worldwide about third-party damage failure statistics.
- Collecting information about companies which are the main culprits when it comes to causing damage to underground and submarine cables.
- Collecting information about the most sensitive areas and the most 'dangerous' civil engineering techniques.
- Collecting information about existing practices to control/solve the problem in different countries around the world.
- Proposing improvements to present methods following the examination and comparison of present methods/practices.
- Proposing guidelines on how to effectively control/reduce third-party cable damage.

Scope:

- AC and DC cables.
- Underground and submarine cables.
- Medium Voltage (MV) (whenever appropriate), High Voltage (HV) and Extra High Voltage (EHV).
- Mechanical and thermal damage, and - more generally - all damage caused by human activities.
- Natural threats are not included, although users are reminded that in some situations they can present high risks

2.2 Approach applied by the working group

The working group sent out a questionnaire about experiences gained with cable protection, administrative methods, mechanical protection etc. The answers received were taken into account in the descriptions and guidance prepared.

The report covers all types of HV and EHV power cables: Lapped impregnated and extruded cables, AC and DC cables as well as land (i.e. underground) and submarine cables. Lapped impregnated cables can be with low- or high-viscosity compound, pressurized or unpressurized.

The experience gained in respect of third-party damage is largest in the low-voltage and medium-voltage area. As far as it is deemed relevant, experiences from the medium-voltage grid are taken into account. The working group has been aware of the difference between the protection levels of the MV and HV/EHV networks.

There is a great difference between the threats, mechanical protection, administration, consequences and probabilities where underground and submarine cables are concerned. But there are also principal similarities. The report therefore describes both underground and submarine cables. If the reader is only interested in underground cables, it is possible to skip those sections dealing with submarine cables and vice versa.

The reader must pay attention to the difference in the definitions of failure and damage. An external failure is defined as an external damage that leads to a failure (see also chapter 3, Definitions). Failure has to do with unplanned outage. Damage is a destruction of parts of the cable system, but it leads not necessarily to a failure (an outage of the cable).

In this Technical Brochure the definition of failure is the same as the Technical Brochure 379 from B1.10, "Update of Service Experience of HV Underground and Submarine Cable Systems": A failure is defined as “Any occurrence on a cable system which requires the circuit to be de-energised."

In Technical Brochure 279 from B1.04, "Maintenance for HC Cables and Accessories" the definition regarding failure and failure mode is a bit different from the definitions in this Technical Brochure. Generally speaking, "Failure mode" in Technical Brochure 279 is the same as "Damaged state" in this Technical Brochure. The reason to use "Damaged state" here is to avoid misunderstandings in the use of the term "failure".

The reader is invited to also read the above mentioned reports.

3. Definitions

The definitions of the key terms used in this report are listed below.

Administrative procedure
Actions aimed at obtaining permission to perform civil engineering work at places where power cables might be present.

Cable protection index
A unique number making it possible to assess the relationship between *criticality* and *consequence* on a *cable section*.

Cable risk
Denotes the *risk* for the cable only, and not for the accessories.

Cable record
Cable and cable route data, geographical data etc. (e.g. drawings, documentation, mechanical tension calculations (submarine cable), depth).

Cable section
A part of a *cable system* with the same environmental properties.

Cable system
Complete system consisting of one or more *items* between two terminals.

Consequence
The effect on the *network* exerted by a *final effect* on a *cable system*. It focuses on the entire *network*.

Consequence class
An assessment of the relative *consequence* of a *damaged state*. Not every cable system is equally important.

Criticality
The *risk* associated with a *cable section*. It is linked both to the *probability* of a *damaged state* and the *severity* of the resulting *short term* or *final effect*. *Risk* and *criticality* are synonymous.

Criticality matrix
Describes the link between *probability* and *severity*. The *criticality matrix* shows the *criticality* (ie the *risk*) graphically.

Damage
Damage often leads to a *failure*, but *damage* to some *items* (e.g. backfill) does not always require de-energizing of the *cable system*. The definition of *damage* is a more wide than the definition of *failure*.

Damage event
Every action that modifies the normal state of an *item* in the *cable system* (e.g. *damage* to protecting plates).

Damaged state
The new abnormal state of a *cable system* or an *item* after a *damage event* (e.g. after the damage to protecting plates the cable system is in a poorly protected state).

Damage without approach
Damage caused by an action occurring outside the direct cable environment (e.g. acid seepage).

Damage with direct contact
Damage caused by some *items* of the *cable system* being hit.

Detection method
Method indicating how to check for a specific *damaged state*. The specific *damaged state* could perhaps be detected before a *secondary damage event* leads to an electrical break down.

External failure
A *failure* caused by any agent external to the *cable system*. It could, for example, be the result of *third-party damage*, of other physical external parameters (e.g. subsidence, increased burial depth resulting in overheating, etc.) or of an abnormal external system condition (e.g. lightning, etc.).

Failure
A failure is defined as any occurrence in a *cable system* which requires the circuit to be de-energised.

Fault
The state of an *item* characterised by inability to perform a required function. A *fault* is often the result of a *failure* of the item itself, but may exist without prior *failure*.

Final effect
A long-term effect, which could be electrical breakdown (e.g. *failure*).

Imperfection
Lack of cable properties due to problems during the manufacturing process.

Internal failure
A *failure* occurring during the operation of the *cable system* due to a *cable imperfection*.

Item
An elementary component of a specific *cable system*. This could, for example, be one or more cable phases, backfill, a duct, joints, terminations, protecting plates, fibre optic cables etc.

Mechanical protection
An *item* used to increase the mechanical strength of the *cable system*.

Network
The whole transmission grid including all *cable systems*, overhead lines and substations.

Possible damage event
A guess as to the reason for a specific *damaged state.*

Preventive action
What can be done in a *cable system* to lower its *risk* (*severity* and *probability*) and *consequence* to *network*.

Primary damage event

First *damage event* resulting in a *damaged state* with specific short-term effect. Very often the first event immediately leads to the *final effect* (in that case *short-term effect* is equal to *final effect*).

Probability
Defines how often a given *damaged state* is produced by a *damage event*

Probability class
An assessment of the relative *probability* of a *damaged state*.

Risk
Risk and *criticality* are synonymous. Mathematically, risk is the product of *probability* and *severity* (defined in the various classes as being at a level between 1 and 5)

ROV
Remote Operated Vehicle.

Secondary damage event
Each *damage event* occurring with a causal link to the *primary damage event*.

Severity
The importance of the impact of a *short-term* or *final effect* on the operation of a *cable system*.

Severity class
An assessment of the relative *severity*.

Short-term effect
The immediate effect caused by the *damaged state*.

Third-party damage
Damage caused by the actions of individuals or organisations not involved in the manufacturing, installation or operation of the *cable system*.

Threat
Non-natural activities that could lead to a *damage event* in the *cable system*.

Trench damage caused by approach
A disturbance to the environment directly around the cable.

Warning
Any *item* in the *cable system* that could indicate the presence of a cable.

4. Description of cable systems

When a cable system is established, many issues must be considered when it comes to the choice of installation method:

- Safety of workers and the public
- Surface plan and profile
- Cable protection (mechanical protection, warning devices)
- Electrical requirements
- Thermal design
- Mechanical design
- Network or system requirements
- Costs
- Disturbance to traffic and the public
- Cable-laying techniques
- Environmental and natural phenomena (e.g. earthquakes or seabed movements)

This report does not cover all cable-installation aspects but focuses on what can be done to reduce third-party damage. In order to understand the discussions in this report a general description of cable systems and different installation methods will be given.

4.1 Cable types

The main insulation in the cables is impregnated paper or extruded material (polymeric cables). The main cable types are:

Extruded cables:

EPR (ethylene propylene rubber)
PE (polyethylene)
XLPE (cross-linked polyethylene)

Lapped insulated (paper-insulated) cables:

SCFF/SCOF (self-contained fluid-filled/self-contained oil-filled)
HPFF/HPOF (high-pressure fluid-filled/high-pressure oil-filled)
HPGF (high-pressure gas filled) and GC (gas compression)
MI (mass-impregnated) or PILC (paper-insulated lead-covered)

If a fluid-filled cable is damaged, the fluid leaks out of the cable. There will be no leaks from extruded cable types. Because mass-impregnated cables contain fluid with a very high viscosity, there will be no leaks from this cable type in case of damage. There will no harmful leaks from gas-filled cables either.

4.2 Underground cables

A three phase AC cable system consists of one or more sets of three single-core cables. A DC cable system usually consists of one or two single-core cables. The cables can be arranged in different ways.

4.2.1 General description of AC cables

Single cable systems:

Figure 4.1 Different installation formations of single AC cable systems

Multicable systems (A, B . . . and M):

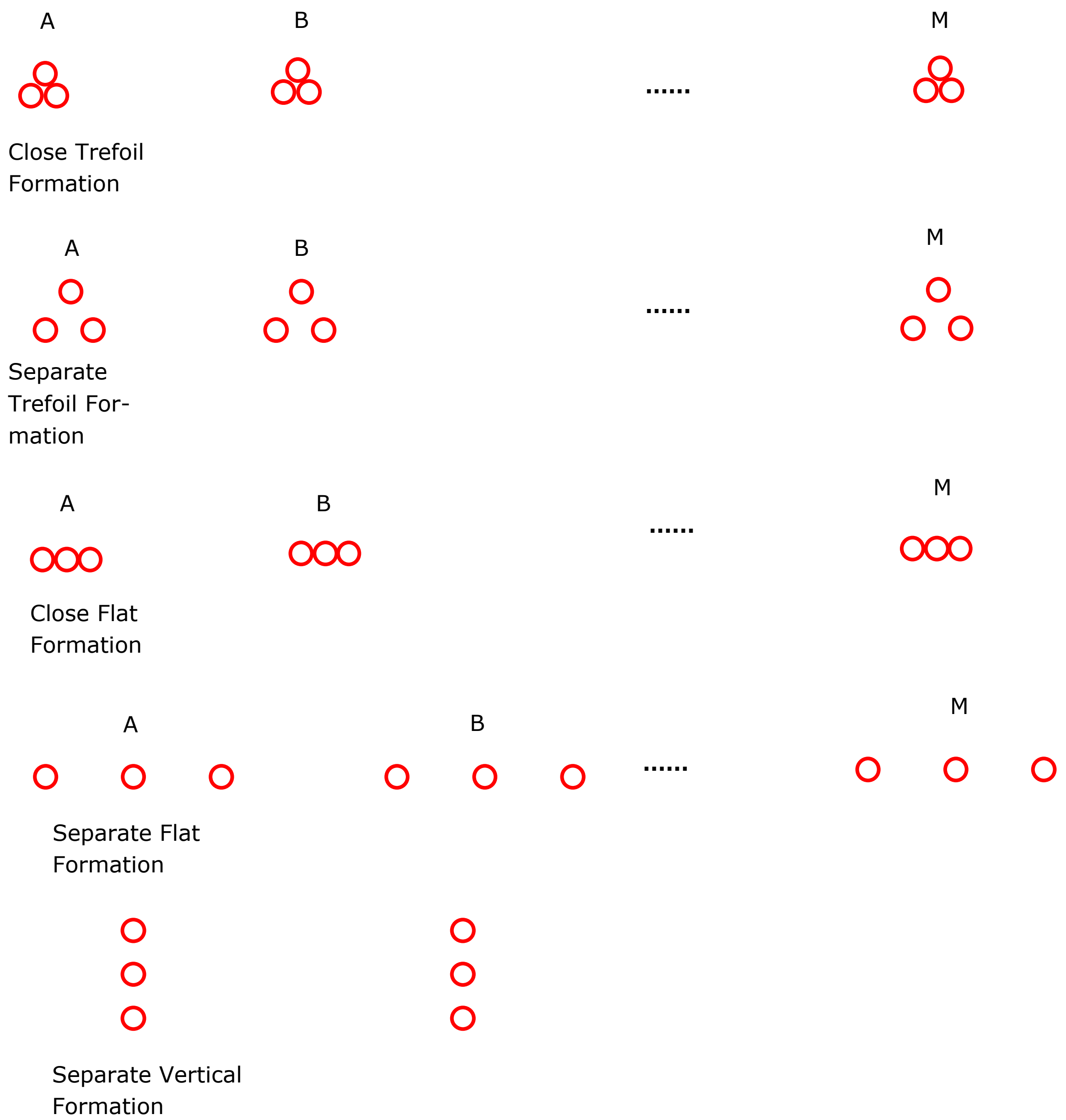


Figure 4.2 Different installation formations of multi AC cable systems

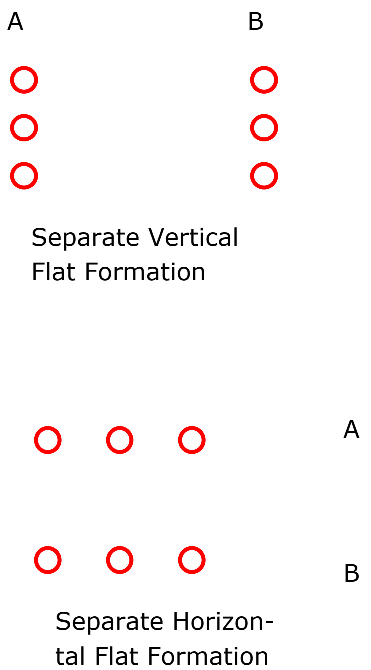


Figure 4.3 Different installation formations of multi AC cable systems in duct banks

The separation between the individual cables and between the cable systems differs from place to place. The distance chosen depends on the available space and influence of the environment area (thermal, vibrations, space and other conditions).

4.2.2 General description of DC cables

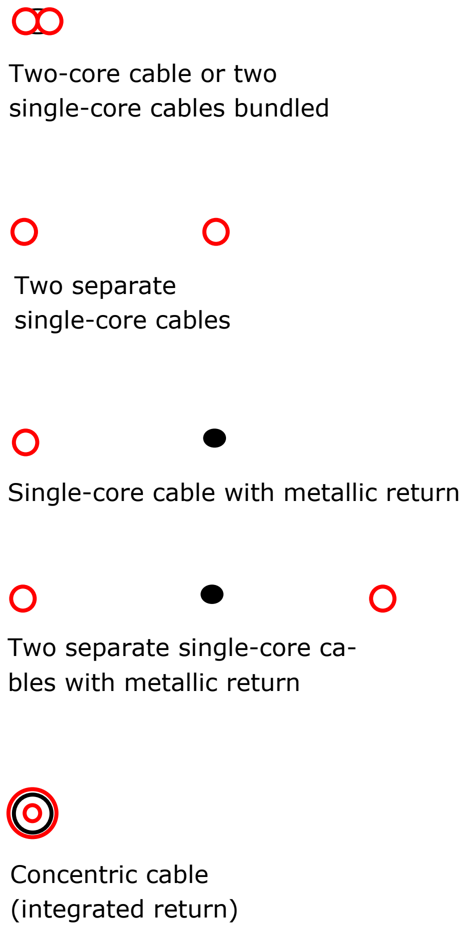


Figure 4.4 Different installation formations of DC cable systems

4.2.3 Installation methods for underground cable systems

This section provides a short introduction to different installation methods. Additional details can be found in [4] and [6]. This report does not focus on the installation methods themselves but on the results of the methods (installation types). What does the type of installation mean for the protection of the cable?

Some of the most commonly used installation methods only offer little mechanical protection. It is the distance between the cables or the distance between the separate cable systems and a relatively thin plate or pipe that protect the cable. The most commonly used installation methods are:

- Direct burial (inclusive of mechanical laying)
- Horizontal directional drilling
- Laying in pipes (metal, PE or PVC)
- Laying in ducts (PE or PVC pipes in fixed arrangement)
- Laying in troughs

In special cases other installation methods can be used, for example:

- Tunnels
- Bridges
- Use of existing ducts or pipes

The reason for choosing one of the expensive methods mentioned above will differ. Very often the installation method is used as a simpler installation method is not possible because of the area in which the cable system is to be installed (e.g. heavy traffic, rocks, river, city area).

The following subsections give a short description of the mentioned installation methods for underground cables.

4.2.3.1 Direct burial

Digging a trench, pulling out the cables and backfilling with sand or other special backfill with good thermal properties around the cables and normal soil on top is (in many countries) one of the most used installation methods due to its simplicity.
The cables are usually placed in a depth of about 1 m.
A plastic cover plate or concrete plates are placed above the cables, and further above a plastic warning net is placed.

Figure 4.5 Direct burial

4.2.3.2 Horizontal directional drilling

Horizontal drilling is often used when it is impossible or inconvenient to carry out digging work, for example when passing roads, rivers or vegetation.
Horizontal drilling is carried out by drilling a hole from the surface or from a pit to the destination required. One pipe or a bundle of pipes is then pulled through the hole, making it possible to pull cables through the pipes at a later stage. If pipes are not considered as being filled with water, bentonite ce-

Figure 4.6 Horizontal directional drilling

ment is usually pumped into the pipes, thus providing better thermal conditions for the cables. The length of a hole dug through horizontal drilling varies but can be up to approx. 1 km.

4.2.3.3 Laying in pipes

If an open trench is only possible for a short period of time, PE or PVC pipes can be buried so that cables can be pulled through the pipes afterwards. Laying cables in pipes is very similar to direct burial, but in this case it is the pipes that are buried direct.

Figure 4.7 Laying in pipes

4.2.3.4 Laying in ducts

When laying in ducts is used, a trench is excavated, the ducts are laid down, and the trench is backfilled. The civil engineering work can be performed before the cable work, and the method is often used where an open trench will obstruct the traffic or inconvenience the public.
Ducts are pipes cast in concrete or other structures.
Ducts cast in concrete is usually done for transmission voltages in North America and elsewhere, to provide good mechanical protection, a low thermal resistivity and a high thermal stability envelope around the cables.

Figure 4.8 Ducts consisting of PE or PVC pipes (left) cast in concrete (right)

4.2.3.5 Laying in troughs

A trough is either prefabricated as a U-shaped housing or it can be cast-in-place as sections or as a continuous concrete casting. The cables are pulled in, and the trough is eventually backfilled. Finally, a cover is placed on top of the trough.

4.2.3.6 Tunnels

Tunnels are used in cities when more circuits or more utilities have to use the same route and when the transmission capacity cannot be obtained by burying the cables.
When the surroundings allow it, the tunnel can be made by excavating from ground level, after which the tunnel is constructed.
When traffic, buildings or other installations in the ground allow for using the excavation method, the tunnel can be dug by using a tunnel excavation machine working underground and placing tunnel segments and joining them together.
Tunnels can also be dug by means of pipe jacking (see description). This method also entails placing segments next to each other and joining them together. The diameter of a circular tunnel can vary from less than 2 m up to 14 m.

Installation in tunnels requires consideration of measures to avoid fire propagation and the establishment of fire doors/sections etc.
In connection with tunnels, shaft and ventilation must typically also be established.

4.2.3.7 Bridges

When possible, bridges can be used for cable systems to cross roads, rivers and railways.
Vibrations, elongation, bending at junctions, expansion joints, heat and wind must also be considered.

4.2.3.8 Use of existing pipes and ducts

The use of existing pipes and ducts makes it possible to establish an installation with little inconvenience to the surroundings and reduces costs and project time.

4.2.4 Thermal conditions

The current in the cables produces heat because of the electrical resistance in the conductors and shields/sheaths. Such cable losses (heat) are proportional to the square of the current. Heavily loaded cables will therefore produce more heat than cables with a lighter load if the cable designs are the same.
Dielectric losses are also generated in AC cables due to voltage applied across the insulation. Higher voltage AC cables will create greater dielectric losses.
It is the cable temperature operating limit that determines the load rating of the cable system. To remove the heat generated, the surroundings of a cable or a cable system and the distance between the individual cables and between the cable systems are important issues that must be taken into account when designing a cable route.

External heat sources (e.g. other power cables, district heating pipes) also influences the power cable system's ability to remove the heat.

4.2.4.1 Special back filling

When the cables are buried or covered, special backfill material can be used to ensure or provide a better thermal environment around the cables.

4.2.4.2 Thermal monitoring

Thermal monitoring of a cable system is rarely installed for medium-voltage cables, but more often for HV and EHV cables. Thermal monitoring can indicate, for instance, a change in the surroundings of the cable, for example if the back filling has been changed or removed, or soil or garden waste has been dumped on top of the cable system.

4.2.5 Warning methods

Normally, underground cables are invisible, and this is also the intention. The drawback is that the risk of damaging the cables is higher if you cannot see them.

There are several methods to effectively and discretely mark the locations of buried power cables.

4.2.5.1 Visible markings

Cable routing markings are situated on or beside the road.

- Trace marks at the surface
- Bronze posts on pavements
- Concrete posts and warning plates in other terrains
- Concrete blocks, warning strips, printed strips

Figure 4.9 Visible cable stand - concrete posts

4.2.5.2 Warning devices

To warn the excavator working in the vicinity of a HV or EHV cable it is common to use warning devices such as warning tapes, warning nets placed above the cables, or red coloured die on top of concrete protecting structure. Before the excavator hits the cable, the warning device will be identified. To make it possible to locate a cable with a cable detector, warning tapes and nets can be manufactured with a metallic strip. Tapes and nets can also be manufactured with a warning text.

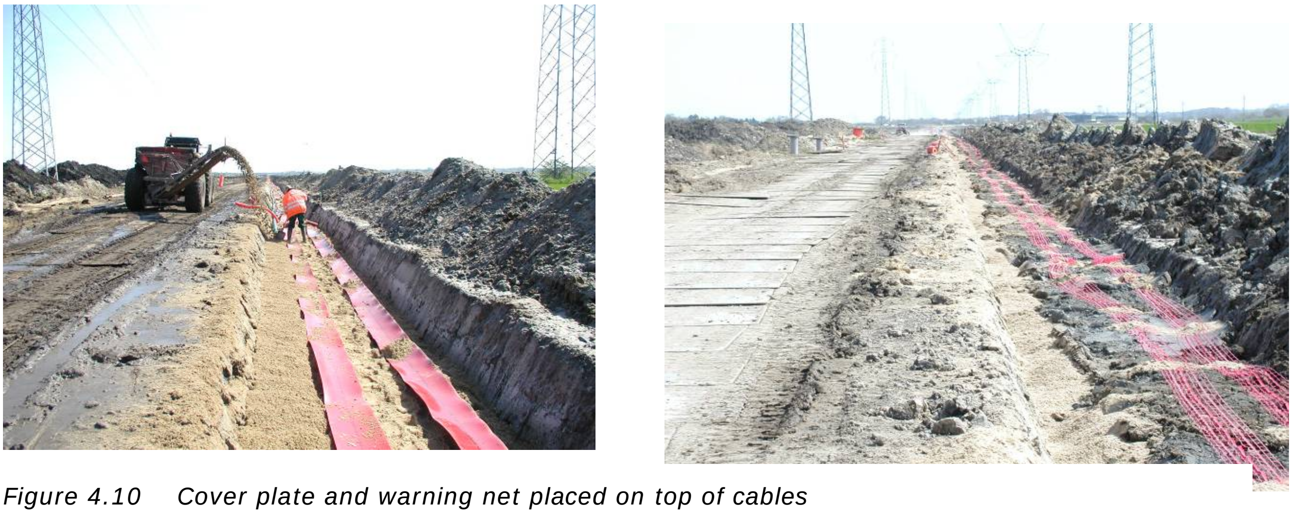


Figure 4.10 Cover plate and warning net placed on top of cables

Figure 4.11 Cover plate on top of cables. The warning net can be seen on the right-hand side over the cover plate

4.2.6 Mechanical protection

Protection against hand tools can be achieved in a fairly simple manner. But it is virtually impossible to establish mechanical protection against large digging or drilling machines.

To protect the public from power cables, authorities demand that there is sufficient distance between the power cable and the ground surface and that the cable is covered with plates to provide good mechanical protection against hand tools and light machinery. Examples are thick plastic cover plates, concrete flagstones or metal cover plates. This method does not provide suitable protection from damage caused by heavy machinery.

In the previous sections different installation methods are described. The preferred method often depends on the local situation, therefore it is not possible to recommend specific methods. The chosen method will depend on what is possible, what is permitted, costs, demands for easy access for maintenance purposes and mechanical protection.

The following drawings focus on the mechanical protection provided by the various installation methods.

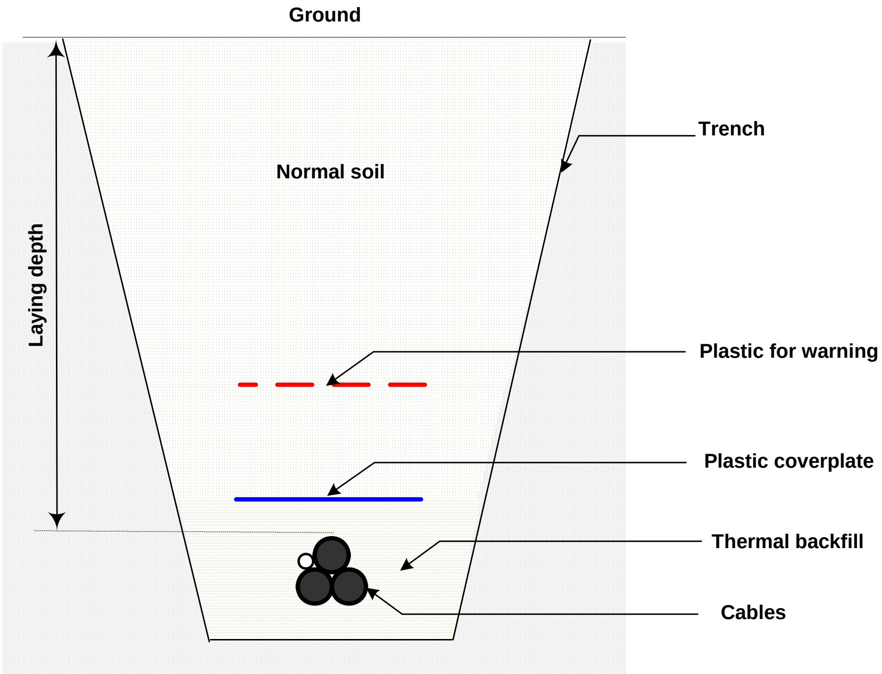


Figure 4.12 Drawing illustrating a trench showing laying depth to ground surface, cover plates and warning tape

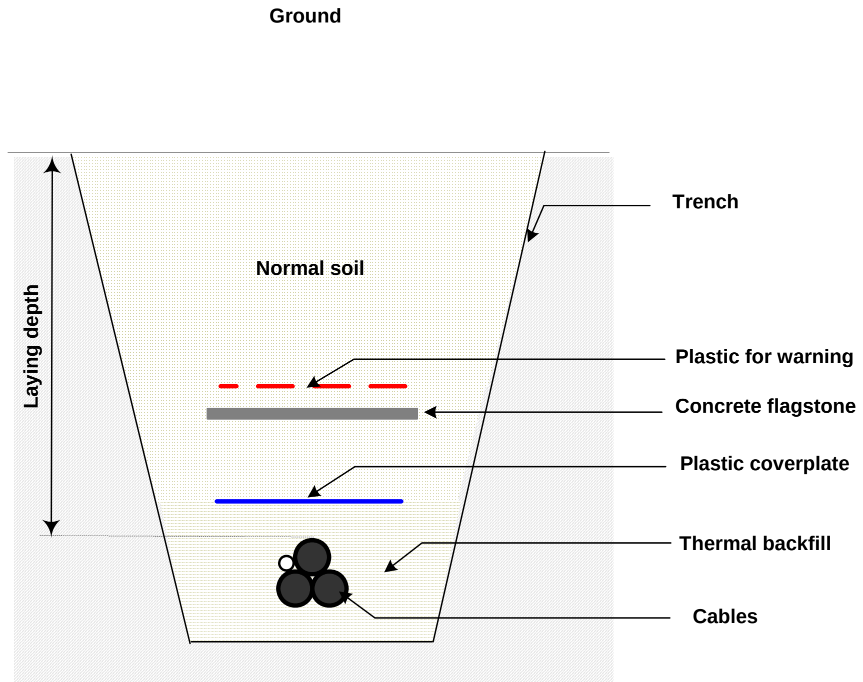


Figure 4.13 Drawing illustrating minor depth but protection with concrete flagstones or metal cover plate

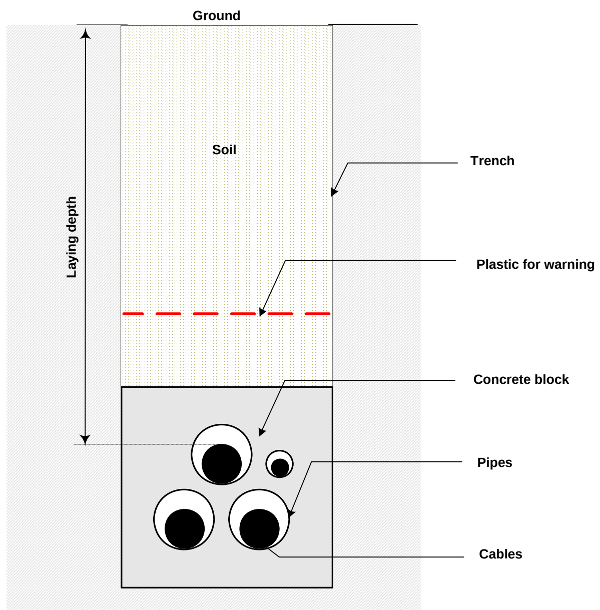


Figure 4.14 Ducts cast in concrete

Ducts can be prefabricated, or the pipes can be cast in-situ.

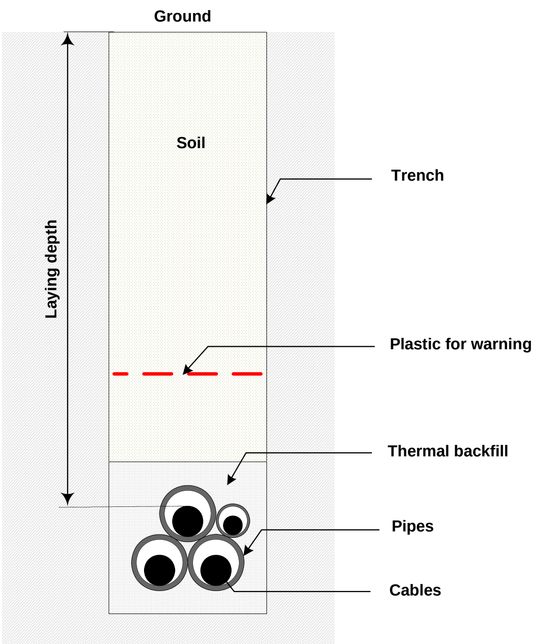


Figure 4.15 PE pipes buried direct with special backfill (with good thermal properties)

Direct buried pipes can have different backfill. Original soil, sand or special backfill with good thermal properties can be used.

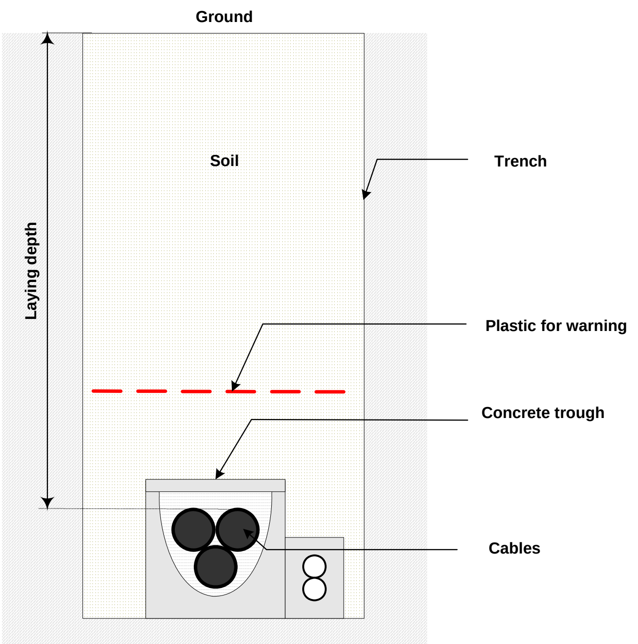


Figure 4.16 Trough cast in concrete

Cables in troughs are sometimes used in substations and at private locations where access to the cables is required. A variation of the trough shown in Figure 4.16 is a concrete trough or chaseway having concrete sidewalls and cover, with cables placed inside in flat formation, at about 300 mm spacing. The inside is filled with special backfill. In Europe many transmission cables have been installed like this.

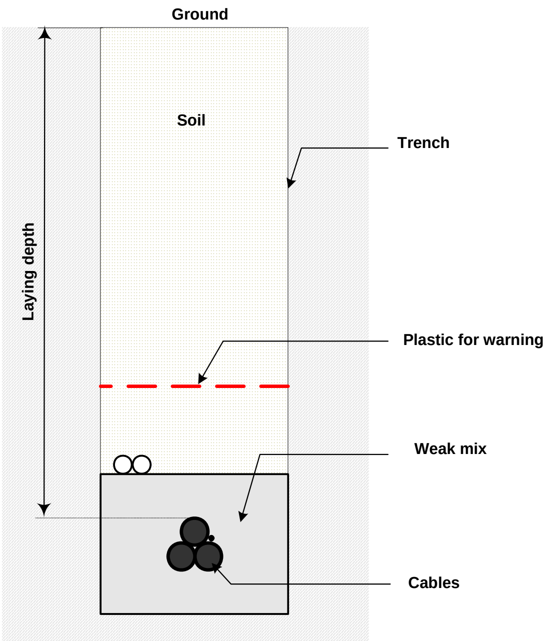


Figure 4.17 Direct buried cables in special backfill (e.g. weak mix)

Direct burial with special backfill is often used to control the thermal conditions. The weak mix is a mix of sand and cement. Other backfill materials may also be used.

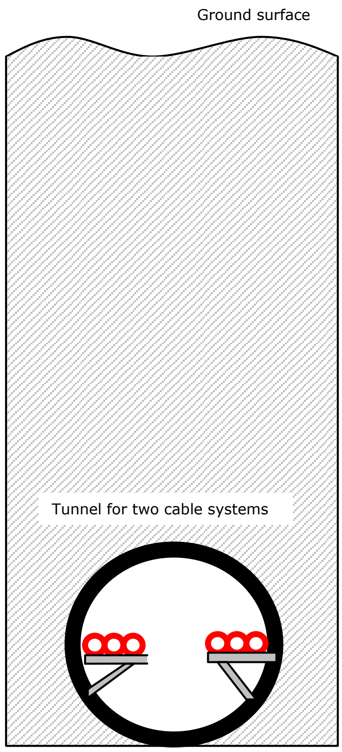


Figure 4.18 Cable systems in bored tunnel

The figures above show different installation methods. Some of the methods offer a certain level of mechanical protection against damage caused by digging or boring machines.

Mechanical protection of cables is expensive. Installations costs increase depending on the civil construction work that has to be done. Direct buried cables with or without visible markings above the ground are virtually unprotected against mechanical damage. Also, warning devices such as warning tape and warning nets do not really protect a cable; the purpose of these systems is to call attention to the presence of a cable.

As already said: Plastic or concrete cover plates protect against damage caused by hand tools and plants, and not against damage caused by digging machines. Cables in pipes, weak mix, troughs and cables installed in concrete encased duct banks offer increasing mechanical protection. But even these systems do not always offer sufficient protection from damage caused by heavy machinery.

Tunnels can be bored or embedded. Bored tunnels are often manufactured with concrete walls, but in case of bored tunnels in rocks concrete walls are not necessary. Tunnels are generally located fairly deep below the surface of the earth. Tunnels are often used by several utilities. When more systems or different types of installations use the same tunnel, there is a risk of failures in one of the installations causing damage to the other systems. Also, maintenance work or inspections performed by other utilities can result in damage. For further information see [7].

4.3 Submarine cables

4.3.1 Overall description, AC cables

Submarine AC cables can either be single-phase cables or three-phase cables with all three phases placed inside a common armouring. Such a cable can be transported, laid and buried as a single, large-diameter cable.

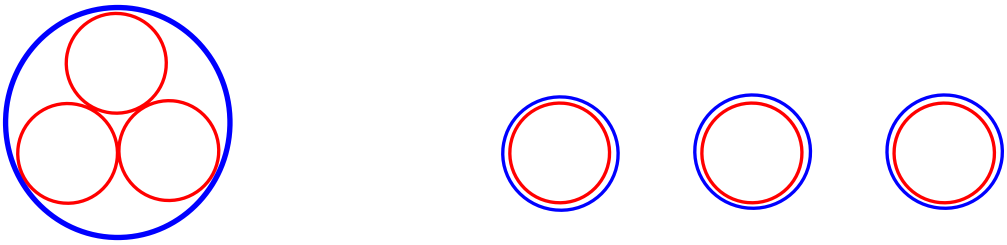


Figure 4.19 Different installation formations for AC submarine cable systems

When the size of the phases is too large for a three-phase cable, the phases are armoured individually and transported, laid and protected as three separate cables. The submarine cables are designed to withstand the seawater environment and the high mechanical stresses during laying. The armour must withstand the axial and torsional stresses during laying, and even the best armour only protects against hand tools, light fishing gear or very small anchors.

4.3.2 Overall description, DC cables

The configuration of DC cables is dependent on the DC system. There are two main systems:

- Mono-polar
- Bi-polar

4.3.2.1 Mono-polar system

In this system one HV cable and a return conductor completes the circuit. The return conductor may be:

- Sea/earth. This method uses electrodes to inject the current into the ground/sea. There are some concerns about corrosion of other metallic structures and effects on the environment, so such systems are only used where these effects can be shown to be inconsequential, with carefully designed electrodes.
- Insulated return conductor. An insulated conductor carries the return current. This conductor may be made into a separate cable that is laid as such, it may be bundled to the HV cable during installation, or it may be integrated into the HV cable.

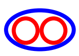
Armoured single-core cable with armoured metallic return

Armoured concentric cable
(integrated return)

Figure 4.20 Different installation formations for mono-polar DC submarine cable systems

4.3.2.2 Bi-polar system

The bi-polar system uses two HV phases with opposite polarity in relation to the ground. The two phases may be two single-core cables laid separately, they may be bundled during laying, or they may be armoured together at the factory. The laying procedures must take this into account.
In order to be able to use the system with only half capacity if one of the HV cables is out of service, mono-polar operation, which is described in the previous section, may be initialised. In such case a return conductor must be used to complete the circuit, so a third cable or a metallic return may be part of the bi-polar system. This is valid for the classic line commutated converters. For the voltage source converters (VSC HVDC converter systems) there must be two HVDC cables in service for the connection.



Two-core cable with common armouring wires or two single-core cables bundled together

Two separate armoured single-core cables

Two separate armoured single core cables with metallic return

Figure 4.21 Different installation formations for bi-polar DC submarine cable systems

4.3.3 Installation methods, submarine cables

4.3.3.1 Submarine installations

The simplest way of installing a cable is just to lay it down on the seabed and leave it there unprotected. Most of the submarine cables are installed in this way.

4.3.3.2 Protection of submarine cables

In areas with high trawling and/or maritime activity, the risk of third party damage may be substantial, and therefore some form of protection is required.

The submarine cables can be buried simultaneously by using a plough or a jetting assisted plough while a vessel lays the cable. Alternatively, they can be buried later by using water jetting, a remotely operated vehicle (ROV) or under the control of a diver. In a seabed with stiff clay it is possible in shallow waters to make a pre-excavated trench using a backhoe on a barge or similar.

If the seabed is composed of very hard clay or rock, it will be necessary to use special tools to make a narrow trench for the submarine cable.

The submarine cables can also be covered with mattresses. Rock dumping is another possibility. The choice is determined by costs and the conditions at the site concerned, waves, tide, current and bottom conditions.

4.3.3.3 Crossing a river

Embedding

When this method is used in a riverbed, a trench is excavated from a barge or an amphibious machine, after which the cables or ducts are buried and finally backfilled.
Damage caused by, for example, anchors must be considered when determining depth and protection.

Directional drilling

If the river is not so wide (up to about 1000 m), it is sometimes possible to make horizontal drilling under the river. Whether this is possible or not depends on the conditions at the site (soil, stones etc.). If directional drilling is used, the cable will normally be a conventional underground cable without armouring, but with longitudinal reinforcement, depending on the mechanical forces on the cable during pulling. Studies must also be done to be assured that cables can be safely pulled into the ducts or pipes.

4.3.4 Thermal conditions

Protection of submarine cables often entails burial of the cable. The deeper a cable is buried, in soft soils, the higher the protection against medium-sized anchors. However, if the burial depth increases, so does the thermal resistance, which again decreases the transmission capacity of the cables. Usually a compromise must be found between burial depth and transmission capacity.

In some areas of the seabed there might be peat or other organic material which has poor thermal conductivity. This must be taken into account when designing the submarine cable and the protection of it.

4.3.5 Warning methods

4.3.5.1 Beacons

Beacons are the only possible permanent and directly visible warnings. They can be used on shore, but will normally only be of any value in fiords, rivers and similar waters where vessels come close to the shore.

Cable beacons can show the direction of the submarine cable from the coast. The line between the front and the rear beacon shows the cable direction.

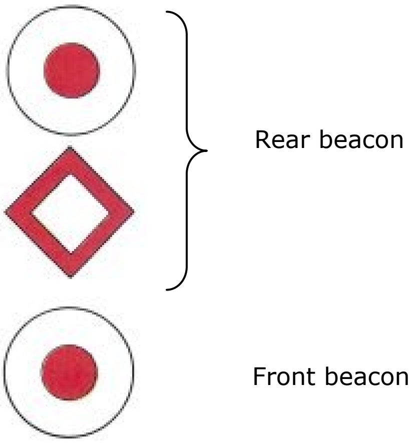


Figure 4.22 Rear and front cable beacon showing the direction of a submarine cable

Figure 4.23 Beacons and submarine cable shown on chart

4.3.5.2 Buoys

Buoys can be used in special cases for marking the cable route for short periods of time - for example during repair or maintenance work.

4.3.6 Mechanical protection

Submarine cables have a single or double layer of galvanised steel wires or in a few cases wires of stainless steel or copper. The armouring must first and foremost be capable of withstanding axial and torsional forces during cable installation and repair. These forces depend to a large extent on the water depth.

Mechanical protection on submarine cables is first of all achieved by burying the cables. Burial depth will typically vary from 0.5 to about 3 m depending on soil conditions and the threats to the submarine cable.

If it is not possible to bury the cable because of the soil conditions (very hard seabed), it can be protected by mattresses or by rock dumping. This is normally only done for shorter distances because of cost.

5. Service experience and survey on third-party damage

Cigré Working Group B1.10, Service experience of underground and submarine HV cable systems, has conducted an investigation and written Technical Brochure 379 [2] with some interesting conclusions regarding third-party damage.
Third-party damage information in Technical Brochure 379 is limited to damage resulting in an instantaneous failure leading to automatic disconnection or an occurrence that requires subsequent unplanned outage.
All other third-party damage information (sheath faults, damage to backfill etc.) was not collected by B1.10.

An external failure is a failure caused by any agent external to the cable system (see also chapter 3, Definitions). In this report there is a distinction between failure and damage. Failure has to do with unplanned outage. Damage is a destruction of one or more parts of the cable system, but it leads not necessarily to a failure (an outage of the cable).

5.1 Underground cables

5.1.1 Results of questionnaires regarding fault statistics for underground cables

On basis of the information received from B1.10, analyses were made from another point of view. All failures regarding DC, PILC, Terminations, Others, Blanks and Unknown were not considered [2]. Where internal failures are concerned, only cable failures (joint and termination failures excluded) were taken into account.

The amount of data is limited - especially for DC and PILC cables. That is why data for these cables are excluded below.
Failures on terminations and unknown failures are excluded in this study. By excluding 'unknown failures' and failures on terminations it should be possible to compare the failure rate for different type of installations.
Assuming that the failure rate of internal failures on cables is independent of the type of installation it should be possible to estimate the relative length of cables in tunnels, in ducts, direct buried cables etc. based on the information about internal failures as a function of the type of installation [2]. That is the reason why internal failures in joints are excluded below.

The cables were classified in three groups:
- SCFF/SCOF
- HPFF/HPOF+HPGF/GC
- Extruded (PE, XLPE, EPR)

Furthermore, this information was divided into two voltage groups:
- 60 to 219 kV
- 220 to 500 kV

Table 5.1 below provides information about the number of registered type of failures for each cable group.

Voltage level	Number of failures from beginning 2001 to end 2005	AC SCFF/SCOF	AC HPFF/HPOF + HPGF/GC	AC Extruded (XLPE, PE, EPR)
60 to 219 kV	km circuits installed (average over 2001-2005)	7366	1240	16836
	External - Other Physical External Parameters	12	12	22
	External - Third Party Mechanical	26	19	76
	External - Total	**38**	**31**	**98**
	Internal (cable only)	**4**	**22**	**31**
220 to 500 kV	km circuits installed (average over 2001-2005)	2982	603	1600
	External - Other Physical External Parameters	12	2	4
	External - Third Party Mechanical	13	4	15
	External - Total	**25**	**6**	**19**
	Internal (cable only)	**16**	**1**	**4**

Table 5.1 Number of failures by cable group (2001-2005).

Table 5.2 below provides the average annual failure rate per 100 km of installed circuit.

Voltage level	Average Yearly Fault rate per 100 km circuit beginning 2001 to end 2005	AC SCFF/SCOF	AC HPFF/HPOF + HPGF/GC	AC Extruded (XLPE, PE, EPR)
60 to 219 kV	km circuits installed (average over 2001-2005)	7366	1240	16836
	External - Other Physical External Parameters	0.033	0.194	0.026
	External - Third Party Mechanical	0.071	0.307	0.090
	External - Total	**0.103**	**0.500**	**0.116**
	Internal (cable only)	**0.011**	**0.355**	**0.037**
220 to 500 kV	km circuits installed (average over 2001-2005)	2982	603	1600
	External - Other Physical External Parameters	0.080	0.066	0.050
	External - Third Party Mechanical	0.087	0.133	0.188
	External - Total	**0.168**	**0.199**	**0.238**
	Internal (cable only)	**0.107**	**0.033**	**0.050**

Table 5.2 Average annual failure rate per 100 km of installed circuit (2001 -2005)

The failure rate is calculated in the following way:

$$Failure\ rate = \frac{\sum_{i=1}^{n} n_i}{\sum_{i=1}^{n} A_i} \cdot 100$$

(No. of failure / 100 circuit km × year)

Where:
n_i = number of failures of the component considered during the i-th year of the period concerned
A_i = quantity of the component in service at the end of the i-th year (ct. km)

For AC extruded cables we can conclude that the risk of third-party –mechanical damage is three to five times higher than the risk of having an internal cable failure.
When we also consider all other types of damage resulting in sheath faults and others faults, the difference is even larger.

Some explanations regarding the different types of external damage:

- Third-party mechanical: The cable is hit mechanically (excavation works, drilling etc.)
- Other physical external parameters: Increased burial depth resulting in overheating, soil dry-out caused by vegetation, subsidence etc.

When all these external failures are taken into consideration, the annual failure rate for extruded cables is around three times higher than that for internal cable failures for cable systems from 60 to 219 kV. For cable systems from 220 to 500 kV the difference is even larger (five times).

For SCOF cable systems from 60 to 219 kV the factor is higher than 10. For the 220 to 500 kV cable systems, the factor is 1.6. Compared to the other cable systems, the internal failure rate (cable only) for 220 to 500 kV SCOF cable systems and 60 to 219kV HPOF+GC systems is very high.

Table 5.3 provides the number of failures by installation type.

Voltage level	**Number of failures from beginning 2001 to end 2005**	Direct Burial	Ducts	Tunnels	In air	Troughs	Bridges
60 to 219 kV	External - Other Physical External Parameters	31	2	0	1	0	0
	External - Third Party Mechanical	89	9	0	0	8	0
	External - Total	**120**	**11**	**0**	**1**	**8**	**0**
	Internal (cable only)	**47**	**7**	**3**	**0**	**0**	**0**
220 to 500 kV	External - Other Physical External Parameters	10	2	2	0	1	0
	External - Third Party Mechanical	19	3	0	0	1	1
	External - Total	**29**	**5**	**2**	**0**	**2**	**1**
	Internal (cable only)	**19**	**0**	**2**	**0**	**0**	**0**

Table 5.3 Number of failures by installation type

For the direct buried cables (60-219 kV) the number of failures due to third-party mechanical damage is about two times higher than the number of failures due to internal cable failures. For 220 to 500 kV systems third-party mechanical damage is the same as for internal cable failures.

If all external failures are taken into account, the factor is 1.5 to 3 compared to the internal cable failures. The external incidents caused by 'Other physical external parameters' is relatively high (around 50%) compared to the 'third-party mechanical' damage.

The survey results show that increased attention needs to be given to mechanical protection against third-party damage, especially for directly buried cables.

5.1.2 Results of questionnaires regarding third-party damage

The information that is received from B1.10, combined with the answers on the questionnaire from B1.21, makes it possible to calculate the average annual failure rate by installation type per 100 km of circuit length.

Table 5.4 provides an idea as to how the cables are installed.

Installation type underground cables		≤ 36kV	> 36 kV and ≤170 kV	> 170 kV
Direct Burial		66%	43%	24%
Direct buried pipes	Plastic	11%	8%	11%
	Metallic	2%	17%	14%
Ducts - pipes in blocks of	Concrete	9%	23%	25%
	Other material	7%	0%	0%
Tunnels		2%	5%	24%
Others		3%	5%	2%

Table 5.4 : Installation type by percentage

For voltages ≤ 36 kV it can be seen that the majority of the cables are direct buried. For voltages between 36 kV and up to 170 kV the principal installation method is still direct burial, but about 20% are installed in concrete ducts.

For voltages above 170 kV (220 kV and 380 kV systems) the principal installation methods are concrete ducts, tunnels and direct burial - equally divided.

Table 5.5 indicates the most commonly used installation types and gives the corresponding average annual failure rate.

Voltage level	Average Yearly Fault rate per 100 km circuit beginning 2001 to end 2005	Direct Burial	Ducts + pipes	Tunnels	Others (Bridges, troughs, Air)
60 to 219 kV	km installed (Info B1.10 and B1.21)	11579	12758	1236	1357
	External - Other Physical External Parameters	0.054	0.003	0.000	0.015
	External - Third Party Mechanical	0.154	0.014	0.000	0.118
	External - Total	**0.207**	**0.017**	**0.000**	**0.133**
	Internal (cable only)	**0.081**	**0.011**	**0.049**	**0.000**
220 to 500 kV	km installed (Info B1.10 and B1.21)	1303	2725	1319	110
	External - Other Physical External Parameters	0.153	0.015	0.030	0.029
	External - Third Party Mechanical	0.292	0.022	0.000	0.044
	External - Total	**0.445**	**0.037**	**0.030**	**0.000**
	Internal (cable only)	**0.292**	**0.000**	**0.030**	**0.000**

Table 5.5 : Average annual failure rate per installation type

The information provided in Table 5.5 is the result of information supplied by B1.10 and B1.21. Since the results of two different questionnaires are merged, the information might not be 100% correct, but it does give a good indication of the difference between the main installation methods.

The average annual failure rate for internal failures was expected to be independent of installation method. The difference evident in Table 5.5 can be the result of a relatively small number of failures being recorded on a short total length.

5.1.3 Conclusion on questionnaire results

For tunnels third-party mechanical damage is in reality very seldom.

The installation of cables in ducts (concrete) also improve the mechanical protection a great deal compared to the direct buried cables.

It is surprising that the cables with the highest voltages have higher failure rates than cables with lower voltages. Normally most attention should be paid to the EHV cables.

Finally, it can be concluded that the installation of cables in concrete ducts and tunnels gives very good protection against external third-party damage. It is up to the cable owner to decide whether the extra cost for this installation method is worthwhile also considering other possible benefits, such as lower construction impact etc.

5.2 Submarine cables

5.2.1 Results of questionnaires regarding submarine cable fault statistics

Table 5.6 below provides information about the number of registered type of failures for each cable group.

Voltage level		AC SCFF/SCOF	AC HPFF/HPOF	AC XLPE	DC MI	DC SCFF/SCOF
60 to 219 kV	km circuit installed (cumulative up to 2005)	10179	104	5675	5239	
	Internal (Cable only)	**0**	**0**	**0**	**0**	**0**
	External - Total	**5**	**2**	**2**	**6**	**0**
	External - Anchor	*4*	*2*	*2*	*1*	*0*
	External - Trawling	*0*	*0*	*0*	*4*	*0*
	External - Excavation	*1*	*0*	*0*	*1*	*0*
	Other + Unknown	**8**	**0**	**2**	**1**	**0**
	Total	**13**	**2**	**4**	**7**	**0**
220 to 500 kV	km circuit installed (cumulative up to 2005)	6779	147		10021	2894
	Internal (Cable only)	**0**	**0**	**0**	**0**	**1**
	External - Total	**2**	**0**	**0**	**5**	**0**
	External - Anchor	*1*	*0*	*0*	*2*	*0*
	External - Trawling	*0*	*0*	*0*	*3*	*0*
	External - Excavation	*1*	*0*	*0*	*0*	*0*
	Other + Unknown	**3**	**0**	**0**	**5**	**0**
	Total	**5**	**0**	**0**	**10**	**1**

Table 5.6: Number of failures by cable group (1990-2005).

Table 5.7 indicates the average annual failure rate per 100 km of installed circuit.

Voltage level		AC SCFF/SCOF	AC HPFF/HPOF	AC XLPE	DC MI	DC SCFF/SCOF
60 to 219 kV	km circuit installed (cumulative up to 2005)	10179	104	5675	5239	
	Internal (Cable only)	**0**	**0**	**0**	**0**	
	External - Total	**0.049**	**1.918**	**0.035**	**0.114**	
	External - Anchor	*0.039*	*1.918*	*0.035*	*0.019*	
	External - Trawling	*0*	*0*	*0*	*0.076*	
	External - Excavation	*0.010*	*0*	*0*	*0.019*	
	Other + Unknown	**0.079**	**0**	**0.035**	**0.019**	
	Total	**0.128**	**1.918**	**0.070**	**0.133**	
220 to 500 kV	km circuit installed (cumulative up to 2005)	6779	147		10021	2894
	Internal (Cable only)	**0**	**0**		**0**	**0.035**
	External - Total	**0.030**	**0**		**0.050**	**0**
	External - Anchor	*0.015*	*0*		*0.0200*	*0*
	External - Trawling	*0*	*0*		*0.030*	*0*
	External - Excavation	*0.015*	*0*		*0*	*0*
	Other + Unknown	**0.044**	**0**		**0.050**	**0**
	Total	**0.074**	**0**		**0.100**	**0.035**

Table 5.7: Average annual failure rate per 100 km of installed circuit (1990 -2005)

The failure rate is calculated in the following way:

$$Failure\ rate = \frac{\sum_{i=1}^{n} n_i}{\sum_{i=1}^{n} A_i} \cdot 100$$

(No. of failure / 100 circuit km × year)

Where:
n_i = number of failures of the component considered during the i-th year of the period concerned
A_i = quantity of the component in service at the end of the i-th year (ct. km)

5.2.2 Results of questionnaires regarding third-party damage

Table 5.8 provides an idea as to how the cables are installed.

Installation method - submarine cables	**≤ 36kV**	**> 36 kV and ≤170 kV**	**> 170 kV**
Installation directly on seabed	26%	17%	21%
Buried more than 0.5 m (fixed target line)	18%	28%	25%
Protection (burial or other measures) close to shore	23%	19%	23%
Burial depth depending on soil conditions	33%	37%	32%

Table 5.8 : Relative type of installation

5.2.3 Conclusion on questionnaire results

Because of the small number of failures and responses on the questionnaires it is not possible to present a reliable conclusion as regards a specific failure probability.

The average annual failure rate seems to be significantly lower for submarine cables than for underground cables.

External damage seems to be the most common reason for submarine cable failures.

Most of the responses on the B1.21 survey come from European countries. The type of installation can be different in other parts of the world. Therefore the failure rate per installation type must be used with care.

6. Main threats to cables

There are several types of failures in underground and submarine cables. The survey made on service experience as described in Chapter 5 shows that most of the failures are caused by third parties.

In this chapter not only external events that lead to failures are taken into account. Damage is a destruction of parts of the cable system and therefore covers more events that those leading to immediate failures. Damage events will also lead to failures - but perhaps not before long time after the original event.

This chapter deals with the different kind of damage events.

6.1 Origin of damage events

In order to systematically assess what kind of damage might be relevant to study for a specific cable system, the causes of damage events can be divided into three main types:

- **Damage caused by direct contact**: The cable or peripheral equipment is 'hit', resulting in damage.
- **Trench damage caused by approach**: The environment directly around the cable is 'disturbed'
- **Damage without approach**: The cable, or its direct environment, is not directly disturbed, but there is still damage (DC currents, heat sources on the surface, ground collapse)

Example: The damage caused through the replacement of backfill soil around the cable can be considered a primary damage event with trench damage by approach, while the damage caused afterwards by sharp objects in the backfill soil when heavy trucks drive over the area is a secondary damage event.

Each of these main types can be subdivided as follows:

Damage caused by direct contact

- Fatal mechanical damage, leading to an electrical incident
- Non-fatal mechanical damage: mainly damage to the sheath (jacket), but also to, for example, cross-bonding boxes
- Internal damage, where the characteristics of the materials in the cable are changed: ill-considered moving of the cable causing damage to the insulation

Trench damage caused by approach

- Changed thermal properties: e.g. different backfill soil (trenching near the cable) or additional cables
- Changed chemical properties: e.g. different backfill soil
- Changed mechanical properties: e.g. other backfill soil containing stones
- Changed warning indications: e.g. presence marking strip
- Changed protection for the cable: e.g. protective plates

Damage without approach

- Changed thermal environment: e.g. surface heat caused by the dumping of garden waste
- Changed thermal environment: e.g. water content changed due to, for example, drainage or trees allowed to grow over the cables
- Changed chemical environment: e.g. acid seepage
- Changed mechanical environment: e.g. ground collapse or landslip
- Changed electrical environment: e.g. change in potential or ground currents
- Changed water content of the backfill and surroundings

A damage event is an action that modifies the normal condition of some item in the cable system. Damage is not the same as failure. A failure is defined as any occurrence in a cable system requiring the circuit to be de-energised.

6.2 Underground cables

6.2.1 Main damage events

Failure caused by an external agent is the most frequent type of failure according to the results of the service experience study (Chapter 5), which states that about 70% of the failures are caused by mechanical works.
The survey on third-party damage has also shown that about 40% of third-party damage has to do with insufficient information exchange between cable operators and construction companies.

6.2.1.1 Civil construction companies

The activity of these companies, especially civil construction companies, can result in damage to underground cables.

These companies often work to tight deadlines, and they sometimes fail to request the relevant information about the existing service infrastructure which would enable them to perform work in a reliable way.

The main causes of damage are:

- Excavators
- Horizontal drilling
- Vertical drilling
- Incorrect information: The construction company does not have the correct information for the cable route and the correct burial depth
- Incorrect use of information: The information about cable route and cable depth is used incorrectly.

Figure 6.1 Cable damage caused by drilling

6.2.1.2 Traffic and heavy-duty vehicles

Heavy vehicles passing on the road under which there is a trench with HV or EHV cables could have a negative impact on cable behaviour.

- Cable vibration
- Ground collapse

- Destroyed link boxes (above ground)

6.2.1.3 Vegetation

The planting of a tree near to the cable trench could also adversely affect the cable. The vegetation can cause drying out of the soil which can result in a rise of the temperature of the cable. Falling trees with deep roots can destroy the cable or the surroundings.

6.2.1.4 Vandalism

This could include the removal of vault covers from earth system boxes, theft of copper etc.

6.2.1.5 Influence from other installations

Installations such as water pipes, drainage systems, heating or other types of installations which give off heat can affect the cable. The change of the conditions could affect cable behaviour.

If the cable has a hole in the outer sheath and metallic sheath, it is very harmful for the cable to be in constant contact with water because water could get into the cable insulation.

6.2.1.6 Change in the thermal conditions of the surroundings

When a third party causes any change in a cable system or any change in the thermal conditions of the cable, which either instantly or later results in a cable system failure , this is considered third-party damage.

The thermal conditions of the cable are changed if:

- The backfill or the soil close to the cable (e.g. closer than 1 m) is changed
- The water content of the soil is changed
- The temperature of the cooling equipment is changed (e.g. air in ducts or tunnels)
- The temperature of the surroundings is changed

6.2.1.7 Others

- Farmers draining fields
- High depth ploughing

6.2.2 Repair costs

One of the main reasons to decrease third party damage is to reduce costs.

Damage by direct contact caused by a third party is an unexpected event that usually requires repairs to be carried out immediately. In that case the costs of these repair activities probably are much higher than in case of planned activities.

Besides, a reduction of the numbers and the severity of third party damage will increase the reliability of the network and it will also reduce the risk of claims from production units or customers. Since higher voltage cable systems usually have higher transmission capacity, the impact of third party damage on network reliability is typically greater than for lower voltage cable systems.

The costs caused by third-party damage can be divided into direct costs and indirect costs as shown below.

6.2.2.1 Direct costs

Repair costs in connection with an underground cable failure could be caused by the reasons described above and could vary greatly. In general, they depend on the following:

- Work on 'localising the failure'
- Spare cable and accessories
- Construction equipment required to do the repairs
- Repair work
- Weather conditions
- Impact on the environment
- Damage to other cables or services near the cable

6.2.2.2 Indirect costs

These costs can be very high in some cases.

- Network and market restrictions could cause a loss of income because of undelivered energy to the customers (lack of transportation capacity). In this case claims from power plants or purchaser are possible.
- Loss of credibility in the electricity company's public image

6.3 Submarine cables

In this report we focus mainly on failures due to human activities (third-party damage), but common natural damage will also briefly be discussed.

Most of the failures in submarine cables are caused by external causes. This is also indicated in the service experience study (chapter 5). Failures caused by external agents may be classified as follows:

- Failures caused by natural causes
- Failures caused by human activities

The main damage caused by natural events in the landing zones and areas with high-current velocity is:

- Corrosion due to tide and waves
- Abrasion because of moving materials on the seabed
- Free-hanging cable sections that may vibrate under certain conditions

Other types of natural events that could cause damage to cables are:

- Underwater slides and turbidity currents, usually triggered by seismic events
- Differential sea bottom movement at seismic fault zones
- Tsunamis coming ashore at terminal stations
- Fish or mammal bites (e.g. sharks)

The best way to control these types of risks is to pay extra attention to the protection of the cables in these areas.

6.3.1 Maritime activities

Maritime activities are every offshore activity excluding fishing, which will be discussed in section 6.4.1.

Failures caused by human activities are numerous. The main risks that submarine cables are exposed to because of human activities are the following:

- Anchors
- Ocean dumping of dredged material or garbage

- Other installations including pipes, telecommunication cables, etc.
- The influence of other existing cables

6.3.1.1 Anchoring

Activities by large commercial vessels involving anchors near or at power cable routes, pose a high risk to power cables. Even small anchors, weighing just a few tons, can sometimes penetrate so deep into the sea bottom that it is not commercially viable to bury cables beyond their reach. On the other hand, the probability of damage caused by anchoring can be low, depending on the site. From experience gained around the Norwegian coast, where there is approximately 1200 submarine cable crossings, the probability of damage from anchoring is 2–5 x 10^{-4} failure/100 km x year. However, in other locations where there are major sea lanes, such as the English Channel, probability of damage from anchors would be high, without cable burial.

A thorough investigation of the cable corridor should be conducted to avoid, if possible, areas of anchoring and narrow, highly congested waterways where the probability of anchoring is higher because of the number of vessels passing through the area.

The number of vessels having anchor chains longer than 300 m is on the increase. So while in earlier times it could be assumed that the cables laid at a water depth lower than 100 m were relatively safe from anchoring, today the depth would be around 400 m. In connection with offshore oil activities several types of vessels have very long anchor chains.

Normally the cable route is shown in nautical maps. In a zone close to the cable route it is prohibited to drop anchors, except under emergency situations. This tremendously reduces the risk of anchors snagging cables. In reality anchors are dropped now and then because the officer onboard the vessel is not aware of the existence of the cable, or inadvertently.

Figure 6.2 indicates how the penetration of an anchor varies depending on the soil hardness.

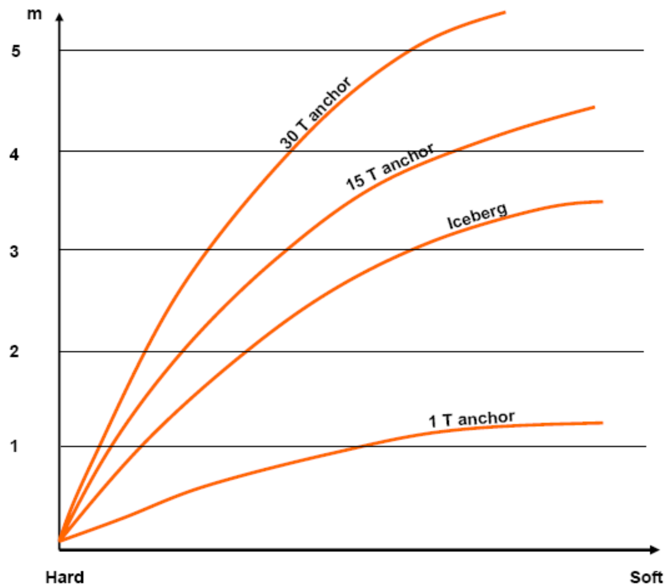


Figure 6.2 Anchor penetration versus soil harness

Figure 6.2 shows that a heavy anchor could penetrate more than 5 m if the soil is not hard.

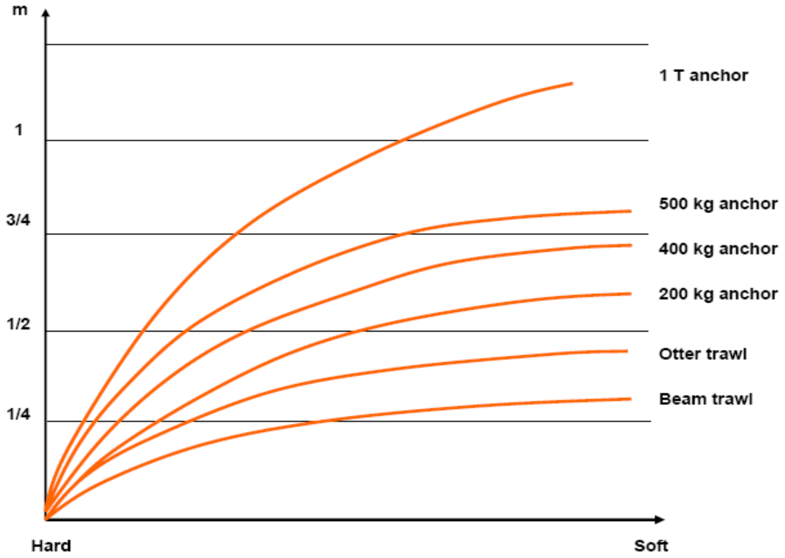


Figure 6.3 Penetration of smaller anchors and fishing gear versus soil hardness

Figure 6.3 shows that an anchor weighing less than 1 ton cannot penetrate much more than 1 m into soft soil while heavy fishing gear penetrates less than 0.5 m into soft soil.

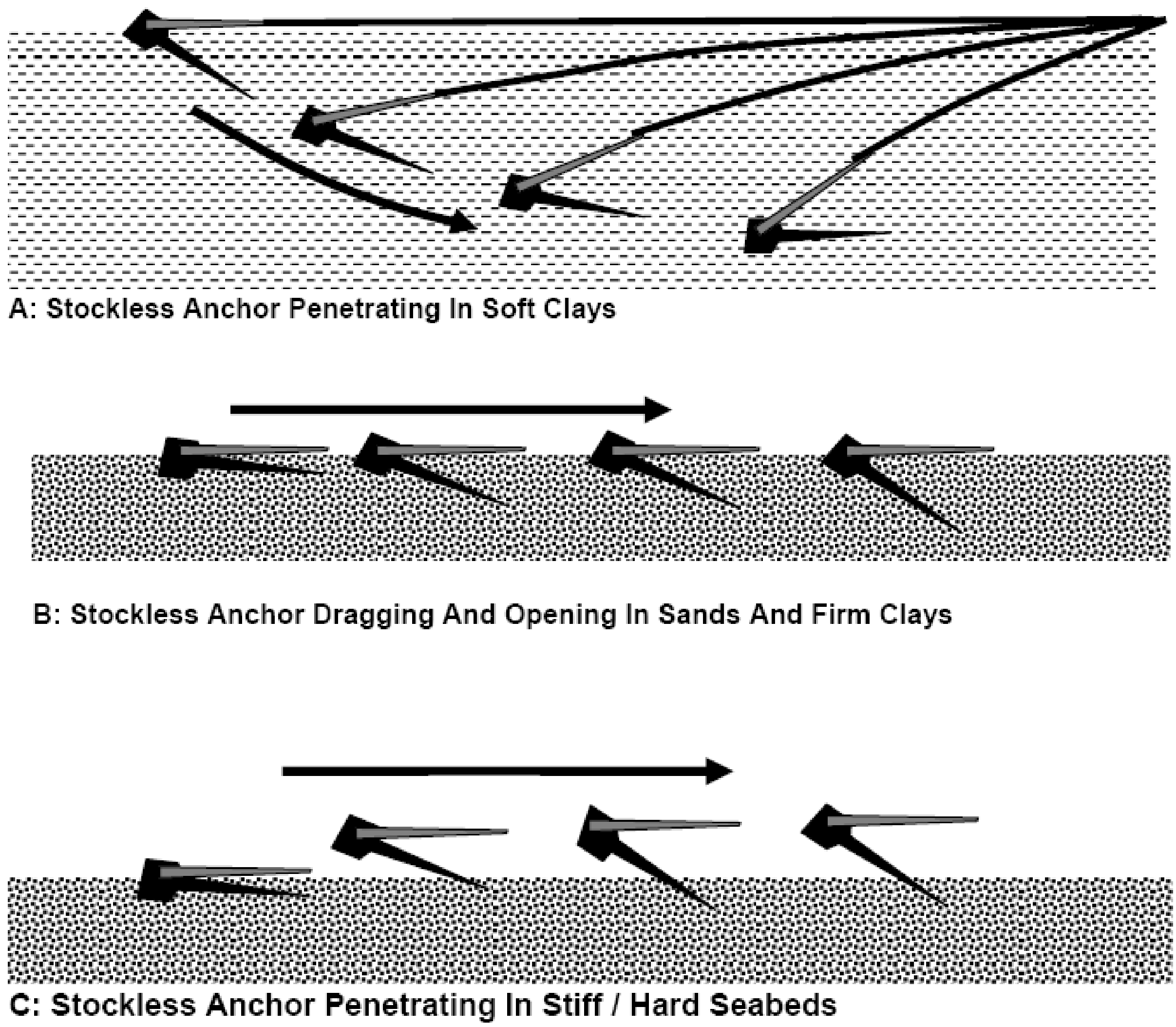


Figure 6.4 Stockless anchors penetrating into different types of soil

If an anchor snags a cable, it will normally cause mechanical damage to the cable and lead to an electrical failure (breakdown). If the anchor only rubs against the cable, it may only destroy the armouring wires and make (invisible) damage to the insulation which later could lead to breakdown. It is noteworthy that anchors do not always make contact with cables perpendicular to their axis. If contact is made at an angle to the axis, damage can extend along the cable's length.

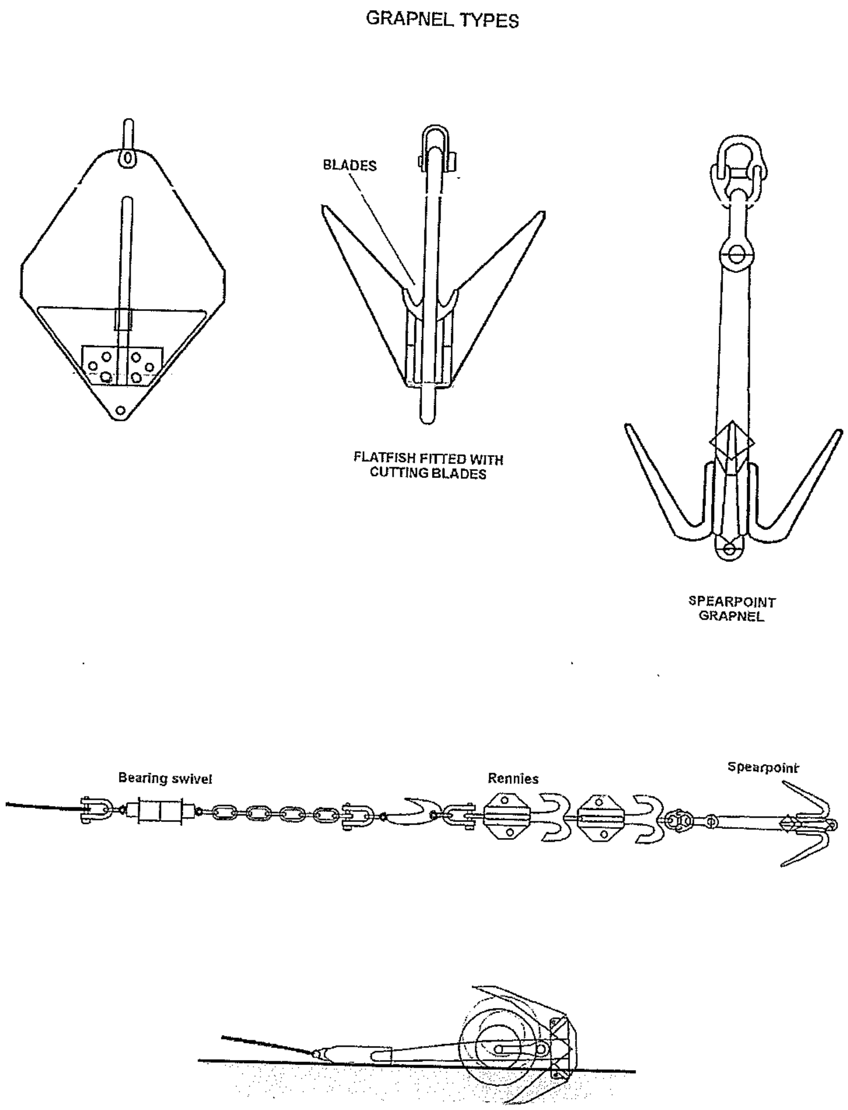


Figure 6.5 Grapnel types

Figure 6.5 shows different grapnel types. Grapnels can also be a minor threat to submarine cables if they lie unprotected on the seabed.

Grapnel definition:
Device/anchor designed to hook objects lying on or in the seabed in order to find/lift them up to the surface.

6.3.1.2 Towing barges on open seas

When towing barges operate on open sea, the tow line is provided with a large weight to prevent snapping. The weight is around 5 tons, and the towing speed is approximately 5 knots or 4.5 m/s. The impact energy is approximately 53 kJ. In shallow waters and rough weather the weight, called 'dead man' often travels on the seabed, and the impact on an unprotected cable will lead to severe damage or breakdown.

6.3.1.3 Dredging
In shipping lanes in near shallow coastal areas the depth of the channels are maintained by dredging the surplus materials at certain intervals. Driven by powerful engines, the bucket chain or suction head employed can excavate up to a couple of metres of material from the seabed. If it is necessary to cross shipping channels, the cable burial depth must be defined in cooperation with the maritime authorities, and the dredging company must be given the co-ordinates and depth profile so that the cable is not damaged by omission.

6.3.1.4 Falling objects
Although such objects may harm the cable anywhere, the probability of such incident is normally very low. At offshore installations many heavy loads are handled by cranes so the probability of an object falling and hitting the cable is higher, and if the slant range is 45 degrees, the cable is usually provided with special protection.

6.3.1.5 Construction activities near submarine cables
Cable protection
Even during the protection phase there is a risk to damage the very cable which shall be protected. During the protection work a surface vessel is located above the cable, and there is therefore a risk of heavy objects being dropped onto the cable.

Near-shore excavation with backhoe
Close to the shore the submarine cables are still close together. In this area the trenches are usually excavated by a backhoe on a barge. While excavating a trench the backhoe may damage cables already installed.

Ploughing
While installing other cables or pipelines, heavy-duty equipment such as ploughs may be employed. The ploughs are pulled by surface vessels and, depending on the type, with a force of 200 – 600 kN. When such a device hits a cable, the cable will be damaged whether it is buried or not.

Ploughs must be handled with great care. If the plough is not suitable or if it is not handled correctly, there is a risk to damage the cable it is supposed to protect. Especially if the seabed soil is inhomogeneous, or if the plough hits boulders, logs or other large embedded objects, the plough can lurch, make a sudden sideway move and perhaps damage the cable.

6.3.1.6 Damage produced by objects and scrap on the seabed
Scrap thrown into the sea could potentially touch the cable and generate periodic mechanical forces that end up damaging the cable sheath, and perhaps causing even greater damage.

One way of preventing these periodic threats from generating a great deal of damage is to do periodic visual submarine inspections. Using such inspections it will be possible, in most cases, to detect objects lying along the cable route that could damage the cable.

6.3.1.7 Thermal conditions of the surroundings
The thermal conditions of the cable are changed if:

- The backfill or the soil close to the cable (closer than 1 m) is changed
- The temperature of the surroundings is changed

However, it is very difficult for a third party to cause any change to a cable system or any change in the thermal conditions of the cable.

Notwithstanding, one way is to dump additional material, normally unintentionally, on the cable, creating a local hot spot, and in the worst case cause a breakdown because of thermal runaway.

6.3.2 Fishing

Some vessels use floating nets such as seine fishing or long lines that may foul a cable lying on the seabed. Normally, their potential for causing serious damage even to power cables lying on the seabed is low.

The largest potential for damage comes from the bottom travelling trawls and from fishing tools deployed on or in the seabed. Trawler activity should be investigated with great care. The seasonal variation in the fishery must be taken into account, and the investigation must therefore cover at least a complete year.

6.3.2.1 Damage caused by trawling

Trawling is performed with a very large net of variable height that is kept open and is pulled across the seabed.

Light trawls (e.g. shrimp trawl)

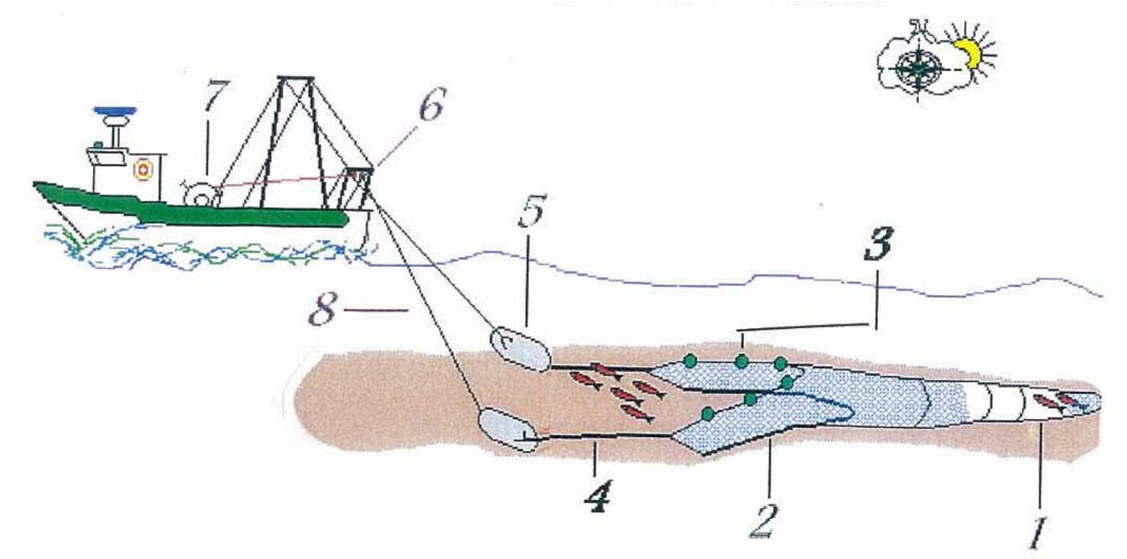
Light trawls penetrate only a few centimetres into loose seabed material. Such trawls have rather light shoes so even a direct impact does not always damage a power cable. However, in some cases, particularly if there is a long free cable span, the trawl can damage the cable by creating such a small bending radius on the cable that the insulation develops cracks resulting in an electric breakdown sooner or later.

Heavy trawls (e.g. beam or otter trawl)

Heavy trawls penetrate up to 0.3 m into loose seabed material (see also Figure 6.3). The weight of the shoe may be up to 8 tons. Such trawls may damage the cable by the impact itself or by creating a very small bending radius. If the cable is not buried to a depth beneath the trawl's penetration area, this type of fishing gear will almost certainly damage a submarine power cable. Depending on whether the trawl shoe hits at nearly right angle, or at low angle, the resulting damage will either be immediate breakdown or a potential for a later breakdown.

Any attempt to design the cable to sustain impact from such a heavy trawl would not be efficient or sufficient to reduce the damage level. So when such heavy gear is encountered at or near the cable route, the cable has to be protected on the seabed. In soft soils the easiest protection method is burial. On hard surface the protection may be some type of covering.

Sketch of trawling at the seabed



1. Net
2. Lead braid
3. Buoys
4. Wires
5. Deflector doors, 'shoes'
6. Frame
7. Machine
8. Steel cable

Figure 6.6 Sketch showing trawling

The weight of the shoe depends on the type of fish. Especially trawls for bottom-dwelling fish such as flounders have shoes weighing up to 8 tons. It is therefore vital to investigate whether this type of fishing is carried out at or near the cable route.

The shoes are not strong enough to cut power cables. However, the trawl shoes may inflict damage in two major ways, as described in the previous section.

For more information about trawling fishing, it is useful to review the document [9], 'Interference between trawl gear and pipelines' (September 1997), from the DNV.

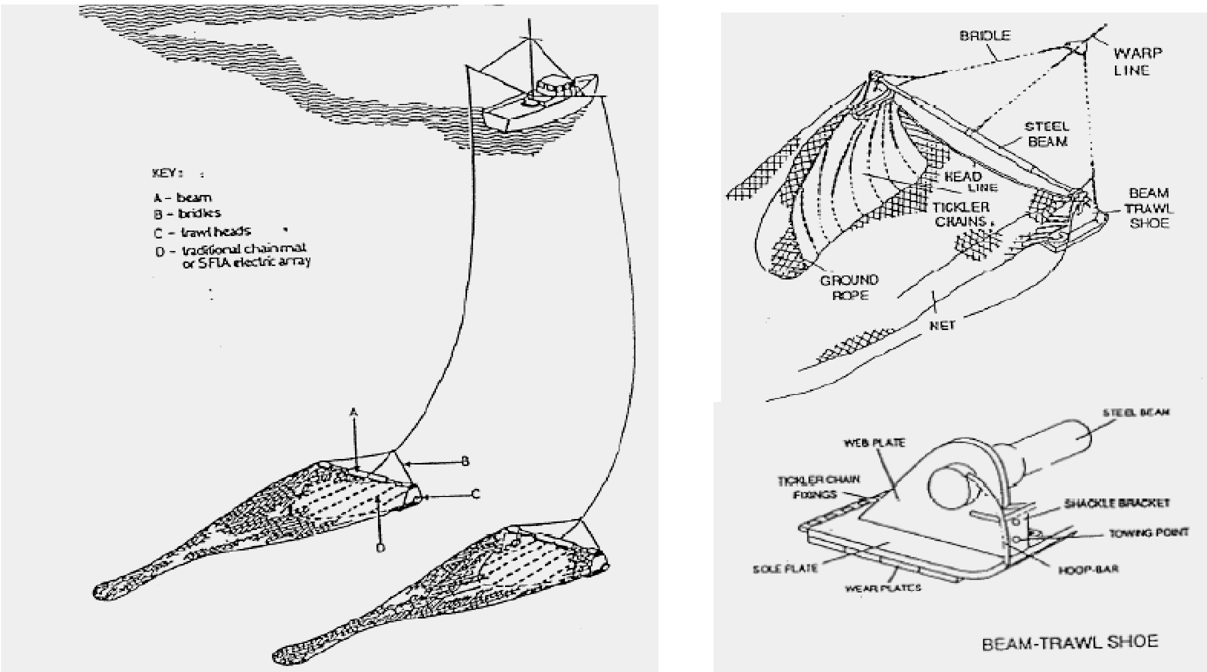


Figure 6.7 Trawl gear - see especially the design of the beam trawl shoe to the right

6.3.2.2 Objects inserted into the seabed; stakes and anchors to hold nets

Stakes may be pounded down to 1.5 m or more into soft seabed. Some type of agreement with the fishermen seems to be the only solution for this type of damage.

6.3.2.3 Fishing with explosives

In relatively shallow waters, fishing with explosives is practiced in some areas in the Far East. This is a self-defeating exercise as most of the fish sinks to the bottom. However, a near hit causes an impact that will damage the insulation, leading to electrical breakdown.

Again, some kind of agreement with the fishermen is necessary to counter this type of threat to cables.

6.3.3 Repair costs

Repair costs are often very high (often more than 10 million Euro) and variable. The most frequent factors influencing this variability are detailed below:

6.3.3.1 Direct costs

Direct costs are all costs related to work done to make the cable connection reliable again.

If a cable is damaged by any of the reasons described above, it will be necessary to remedy the failure. The cost is variable because of the number of unknown factors:

- Repair vessel
    - Cost of mobilisation
    - Cost of repair time
    - Cost of waiting on weather
    - Cost of demobilisation
- Other cables crossing the damaged cables

- Mechanical protections that should be removed
- Manoeuvre spaces for the repair ships
- Localisation of the failure
- Localisation in the seabed and cutting of the damaged cable
- Cleaning up the cable
- Cable repair. Costs will depend on
    - The methodology applied
    - Depth of the failure
- Availability of resources for doing the repair
- Permissions and authorisations necessary to do the repair.
- Weather conditions
    - Bad weather (strong wind, heavy rain, storms, strong submarine currents, etc.) could cause delays in repair times
- Damage to the environment
    - For some cable types the failure could slightly damage the immediate surroundings of the cable. Public authorities may ask the owner of the cable for reimbursement.
    - A leakage of the cable impregnating liquid for SCFF cables. The fluid is highly refined, has a relatively low evaporation point and contains no additives harmful to nature. However, when leaking through the asphaltic corrosion protection layer it will dissolve some heavy compounds, and the leakage can be seen on the water surface
- Damage to other cables or services near the power cable
    - If an anchor or another towed object hits the submarine cable, it could also cause damage to other cables or other types of services

6.3.3.2 Indirect costs

The indirect costs related to serious damage to submarine cables can be very high in some cases. They could be of the same magnitude as direct costs.

Indirect costs might be:

- Network and market restrictions could cause a loss of income because of undelivered energy to the customers (lack of transportation capacity). In this case claims from power plants or purchaser are possible.
- Loss of credibility in the electrical company's public image

7. Damage effects and criticality on the cable system

Third-party damage can be a complex process which some times consists of several interdependent events. A damage event causes a specific damaged state of the cable system. The effects (the results) of the possible damaged states are also different. In many cases only the primary damage event is seen because this leads to immediate breakdown. Sometimes however, it is necessary to distinguish between short-term effect and final effect. In the following sections the terms, which will be used in the next chapters, are defined.

7.1 Primary and secondary damage events

When examining damage caused to cables by third parties ('damage events'), a distinction must be drawn between the first event at the time (t_0) and a later damage event, mostly caused by another third party, at time t_1. The second, later, event is labelled 'secondary' when there is a causal link to the first event, in other words if the second event would have caused no damage or a different kind of damage if the first event had not taken place.

Attention should first be paid to preventing the first damage event, thus ensuring a better delimitation of the scope.

In general, there is a period of time between the two events, which means that in theory it is possible to try to prevent the second event through the early detection of the damage caused by the first event.

7.2 Damaged state, short-term effect and final effect

A typical example is a protective cable plate that is removed during the primary damage event (trench damage). As a result, the cable is then left behind in a poorly protected condition. This poorly protected condition is the 'damaged state' of the cable system. There is no visible or recordable 'short-term effect' on the cable system. The short-term effect is the initial result of the damaged state.

Then, a few months later, the cable is damaged during digging operations (secondary damage event) which was caused by the first event (because there is no protection or warning above the cable). This secondary event leads to a new damaged state. The new damaged state can, for example, be damage to the cable insulation. In this example the 'final effect' on the cable system is a breakdown.

Another example of a first damage event is a damage to the outer sheath of an XLPE cable without inner metallic sheath (water barrier). The damaged state is 'damaged outer sheath'. The cable is still in service, and nobody knows that anything has happened to the cable. This first damage event with the damaged state 'damaged outer sheath' has the short-term effect on the cable that water is penetrating into the cable. After five years (example), there is an electrical breakdown at this specific spot because of poor electrical strength. The final effect was an electrical breakdown - even though there was no external secondary damage event.

Further examples of short-term and final effects:

Damage event: District heat pipe close to cable
Damaged state: Hot spot for cable
Short term effect: Local temperature rise in cable (over-temperature)
Final effect: Accelerated ageing and possibly electrical breakdown

Damage event: Link box hit by car
Damaged state: Damage to link box for a cross-bonded cable system
Short-term effect: Water ingress and imbalance in cross-bonding system
Final effect: Higher losses, hot spot, accelerated ageing of insulation system

The focus must be on the first event - on how to reduce the risk of the first event. If the first event can be prevented, there will be no second event and no final damage effect. Focus must also be on the short-term effects. If the short-term effects can be ascertained in time, it is possible to make a repair and avoid the final effect (e.g. an electrical breakdown).

7.3 Criticality of damaged states, cable risk

Each damage event leads to a specific damaged state with a short-term damage effect on the cable system. To minimise the overall risk of the cable system it is valuable to look not only at the possible events but also at the damage effects. How severe is the damage effect for the cable system? Some damaged states will unfortunately lead to a failure (breakdown), and other damaged states are of minor importance.

Damage event and damaged state represent the same situation, where the damage event is the cause and the damaged state is the result. Both terms are used.

To ensure effectiveness in the struggle against third-party damage the efforts must be prioritised in the correct order. Focus must be on the damaged states and damage events with the most severe effects and the highest probability. The combination (product) of probability (of damaged state caused by a damage event) and severity (of the short-term and final effect) is the 'Criticality of damaged states'. The criticality is the risk for the cable system. It does not say anything about the consequences for the whole network.

Criticality can change along a cable route because the surroundings are different and the threats from third parties will change. Therefore each cable system and each section in every cable system must be analysed. The same solution will not be the best solution everywhere.

To analyse the criticality of the different damaged states, the severity of effect and probability of each damaged state is shown in a criticality matrix (risk matrix).

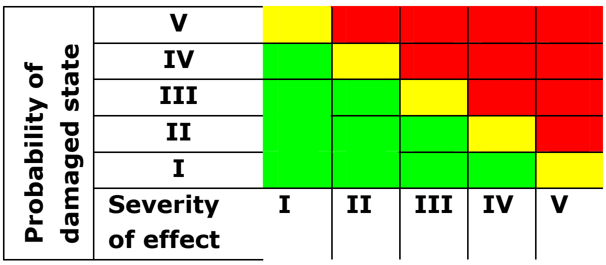


Table 7.1 Criticality matrix

The criticality matrix in Table 7.1 shall be read as follows:
Red - area where further studies must be made and something must be done to reduce the criticality
Yellow - area where it must be checked whether it is possible within certain limits to do something better
Green - area with low risk with no further studies being required

There are two possible ways of reducing the risk:
1. Reducing the probability
2. Reducing the severity

In the following chapters different ways of reducing the risk are discussed.

7.4 Network consequences of damaged states

Many damaged states do not make an immediate impact on the network because no failure occur. But more severe damaged states cause failures in the network with outages of power lines. This section deals with damaged states that have consequences for the network.

Transmission lines are not equally important. Some are extremely important while others are of minor interest. The consequences of a failure will therefore also be dependent on the network structure, the market situation etc.

The criticality, combined with the consequences of a specific damaged state, indicates the risk for the overall network. In Section 11.6 the 'Cable Protection Index' (CPI) is defined as the product of criticality (cable risk) and consequences for the network.

8. How to discover and detect third-party damage (the short-term effect)

If the short-term effect is limited to the surroundings or the surface of the cables it may be possible to detect the damaged state before the final destroying effect is reached. The following sections discuss the methods available for detecting the short-term effect.

8.1 Underground cables

8.1.1 Events involving direct contact

If the first event is an event involving direct contact to the cable, it is often possible to find the damage using a sheath DC-voltage test. The sheath test will check if the insulation between the metallic sheath and the surroundings is damaged. In case of cross-bonding systems or single-point bonded systems where sheath voltage limiters (SVL) are installed in link boxes to protect the sheaths from high overvoltages, the sheath test may also find destroyed limiters or link boxes.

It is recommended to check the sheath at regular intervals (each year or similar) if the probability of third-party damage is relatively high. Many utilities recommend using sheath testing on a regular basis (See Appendix 1 and [1]).

Online monitoring of the sheath current in cross-bonded systems is also possible.

It is recommended to install fibre-optic cables along important power cables. It is also possible to install an empty pipe close to the power cable. This empty pipe must be designed for fibre-optic cables so that it is possible to install the fibre-optic cable at a later stage.

If a fibre-optic cable is installed close to the cable, it is recommended to use simple online monitoring (check if fibres are ok) on some of the fibres. If the fibres are destroyed, there is a risk that the power cable system is damaged as well.

Simple pilot cables could also be installed in the vicinity of the cables. If continuity is broken, an alarm is raised, like a home burglar alarm system.

In case of fluid-filled cables the fluid pressure is often monitored - either online or at regular intervals. An abnormal drop in the fluid pressure - where temperature and load on the cable are taken into account - indicates damage to the cable surface. (See also [1], section 7.6).

8.1.2 Other events

If the first event is an event involving no direct contact to the cable, it is often not possible to make a simple measurement to disclose the damage, unless the burglar alarm idea or monitoring of optical fibres is used (see section 8.1.1).

If the short-term effect of the damage is a high thermal resistivity of the surrounded medium, it might be possible to see this on a thermal monitoring system connected to an optical fibre close to the cable. It is not possible from a single-temperature measurement to assess whether a temperature rise is critical. It is necessary to make a thorough study of the data (cable load, neutral ground temperature, cable temperature, soil conditions) to be able to make an assessment. If a significant change in the temperature is seen at a specific spot, the study might be repeated for this spot. An online monitoring system, which will give an alarm if the temperature rise exceeds a specific limit, can help in finding new hot spots. In most cases the cable load must be relatively high in order to find such a hotspot.

In most situations the primary event will be disclosed by inspection. Patrolling is simple - but often the only reliable way of checking whether the cable system has been damaged by a third party. Inspections are very important, they are not complicated - and they are recommended by many utilities (see Appendix 1). Inspections will often discover if somebody is planning activities close to the cables, and they will also discover if construction companies have worked close to the cables. In such situations the cable system can be checked locally or by using one of the above-mentioned methods.

8.2 Submarine cables

8.2.1 Events involving direct contact

If a submarine cable is damaged through direct contact, there is nothing else to do but make a repair by means of two repair joints and an extra piece of cable - or, if the failure is close to a termination, one repair joint and replacement of the cable to the termination. It is possible to detect that something has happened but there is not much that can be done about it. Detection can warn the cable owner that something might happen to the submarine cable in the near future. And the detection can lead to a decision to better protect the submarine cable.

Submarine cables are protected with an armouring. The purpose of the armouring is primarily to withstand the longitudinal forces during cable installation and repair. But of course the armouring will to some extent protect the cable. Small anchors and fishing gear will not always harm the submarine cable, but in some situations the impact will change the insulation or the screen around the conductor and can cause the electrical field in the cable to rise. If anchors or similar are still hanging on the submarine cable at the seabed, this can be seen on video and sometimes on side-scan sonar pictures. Side scan can also be used to find out how the fishing activity is in the area around the submarine cable. Trawl tracks are visible in sandy or soft sea bottoms.

These problems are mostly seen on cables lying unprotected on the seabed.

Some power cables are installed together with fibre-optic cables. The fibre-optic cables can be installed in the same trench as the power cable. It can be bundled directly to the power cable by means of straps, or the fibres can be integrated into the power cable.

In case of three-core cables there is space enough between the cable cores to install a fibre-optic cable. In this situation the fibre-optic cable can be a conventional cable that is installed beneath the same armour as the power cables.

The same possibilities are available for submarine cables as for underground cables in relation to monitoring of the fibre-optic cables close to the power cable. Monitoring the health of one or more fibres, in particular, can give a good indication of the condition of the power cable. If an anchor has hit the power cable and destroyed the outer armour and perhaps also the metallic sheath - the fibre-optic cable will in all probability also be destroyed.

In case of new installations it is recommended to assess whether fibre-optic cables should be installed together with the power cable. The fibre-optic cable can be used for communication, thermal monitoring and monitoring of the general condition of the cables.

If an electrical breakdown has already occurred, the failure can be found by TDR (Time Domain Reflectometer) or bridge (impedance) measurements and tracer methods. If there is a fibre-optic cable, the fibres can also be used for OTDR measurements (Optical Time Domain Reflectometer) to find the location of failure.

It is also possible to do DC outer sheath tests on submarine cables, provided they are not semi-conducting and the ground connections are removable at the terminations. A damaged jacket could be a pre-cursor to later insulation failure. Pre-emptive repairs could then be made at a more convenient and less costly time.

8.2.2 Other events

Other events close to the submarine cable can be seen if a geophysical survey is made in the cable route. The surveys are made from a vessel equipped with monitoring tools and operated by experts. The following surveys are recommended:

- A bathymetric survey can show if the sub-bottom profile has changed.
- A survey showing the cable burial depth. This can be compared with a similar survey made at an earlier stage and discloses whether the cable still is protected as required or whether the seabed has changed. This is relevant in dynamic areas (sandy areas) but also if dredging or dumping has caused any changes.
- A side scan sonar survey can sometimes show the trawling activity in the area and any objects (anchors, fishing net and trawl, anchor chains etc.) fastened to the cable. The side scan can also disclose whether the submarine cable is visible at the seabed and therefore unprotected.

Seabed changes can reduce the protection level of the submarine cable. Surveys can disclose this and trigger a decision to improve the protection.

A high resolution multi-beam echo-sounder survey can be done shortly after the cables are installed. Periodically the survey can be repeated and changed conditions noted, such as new trawler scars, anchor drag marks, sandwave migration, sea bed mobility exposing buried cables, etc.

9. How to reduce the risk of third-party damage to underground cables

When excavation activities are prepared, avoiding damage to existing underground cables is a shared responsibility of cable owners or operators and the excavation company. Because of their responsibility the authorities are also involved. Everybody who is going to work at sites where cables might be present is responsible for asking for permission to do the work and obtain knowledge of the position of underground cables.

In case of excavation activities the two main reasons for damage to underground cables are:

- Insufficient knowledge of the position
- Wrong working method

Insufficient knowledge of the position of cables

- No information about existing underground cables (contractor did not ask for information, did not wait for information or instruction - or cable operator did not answer or answered too late)
- Geographical maps showing the cable route are incomplete or incorrect
- Local warning indications are lost or damaged
- Misinterpretation of available data
- Cable operator not present even though it was requested

Wrong working method

- Ignorance of the method to be used
- Inability to use the appropriate method
- Deliberate inappropriate action

As can be seen from the above, to reduce third-party damage to underground cables, focus must be on two main issues:

- Knowledge of the position of the cables
- Information to excavators and construction companies on how to do when they prepare and carry out their excavation activities

To reduce the possibility of damaging underground cables several actions are possible. Therefore the following subjects will be discussed:

- Legislation
- Exchange of information between contractor/excavator and cable owner or operator
- Quality of maps
- Warning devices and cable detection
- Mechanical protection
- Education
- Patrols/inspections

9.1 Legislation

The rights and duties of cable owners vary from country to country. It is therefore not possible to give an overview of the legal obligations relating to underground cables and other installations all over the world. Every country has its own rules.

In most of the countries a contractor is obliged to obtain permission before starting work. The contractor must find out which company is responsible for the underground cables or pipelines. Sometimes it is difficult to trace all cable owners or operators in the area in which work is to be performed. Anyone who wants to perform some work needs to obtain permission, but it is not always applied because the procedure can be a bit complicated. Practically, when there is no reply to the demand, the work is also performed.

In some countries there is an obligation to use specific administrative procedures/tools (see next section) to ensure that all cable owners or operators will be contacted (See Appendix 3).

9.2 Administrative procedures to protect underground cables (exchange of information)

9.2.1 Introduction

To avoid damage to underground systems a contractor must be in possession of the information mentioned below before starting the excavating activities:

- Existence and position of underground cables
- Recommendations or technical instructions to be observed

But, to get this information, a contractor faces many issues:

- How to get a complete list of the existing utilities in the area of the planned activities?
- How to contact these utilities?
- What kind of information is relevant to give to and to request from these utilities?
- How to get the information on time?
- How to be sure that the information provided is exact, complete and accurate?
- How to track the exchange of information?

On the other hand, utilities need some guarantees:

- How to check if contractors always ask for this information before starting their activities, and do they ask for the right information?
- How to check if the information provided is in an appropriate manner?

For that reason many countries, provinces, states or cities have established an information system, which specifies how contractors and utilities are to act when preparing excavation or drilling activities in a certain area.

9.2.2 What kind of information?

The information exchanged between contractors and utilities can be divided into two types:

- The information which contractors are required to provide to utilities
  - ✓ Location of civil works
  - ✓ Kind of activities
  - ✓ Planning of work
  - ✓ Time when the work is to be performed
  - ✓ Etc.
- The information which utilities are required to provide to contractors
  - ✓ Location of cables
  - ✓ Recommendations or technical instructions to be observed
  - ✓ Emergency situations
  - ✓ Etc.

The utilities provide this information by sending plans to the contractors or making an on-site appointment with the contractor when this is deemed necessary (low-quality plans).

In some situations there is a need for a safety watcher. At some utilities, excavations are forbidden to take place within 1-2 m of cables unless a utility safety watcher is present. This has obvious safety benefits for workers but also helps reduce third party damage.

The utilities either give the exact location of the underground cable or an indicative location only (exact location must be checked on site).
This location of the cable can be given in analogue data or digital data.

9.2.3 How to exchange information?

To get the relevant information, contractors and utilities are often legally required to follow a fixed procedure and to use specific tools (forms, database, website, etc.) (See Appendix 3).
In general, contractors are responsible for collecting the necessary information. Administrative tools can help to carry out this assignment.

For example, some countries have established a national or regional central contact point offering contractors the possibility to obtain the contacts they need in a fairly simple manner.

Sometimes these central points function like a phonebook, from which contractors can extract a list of the utilities who may have installations in the area concerned.

In other countries the central contact point sends the information about the planned excavation activities direct to the cable and pipeline operators which have interests in the working area. The operator of the utility concerned sends his information to the contractor as soon as possible.

However, the main purpose of these information systems is the same: To reduce damage to underground cable and pipe installations.

9.2.4 Recommendation regarding administrative procedures

To ensure that contractors and utilities exchange the right information, it is important to use administrative procedures which are

- easy to know
- easy to understand
- easy to handle

It is recommended to make national laws about these procedures. It can be seen from Appendix 1 that many civil contractors do not ask for permission and for that reason do not have drawings and other important information at their disposal. Only about 50% of the contractors ask every time (95% or more). To reduce the risk of third-party damage national legislation on how to prepare excavation activities is recommended.

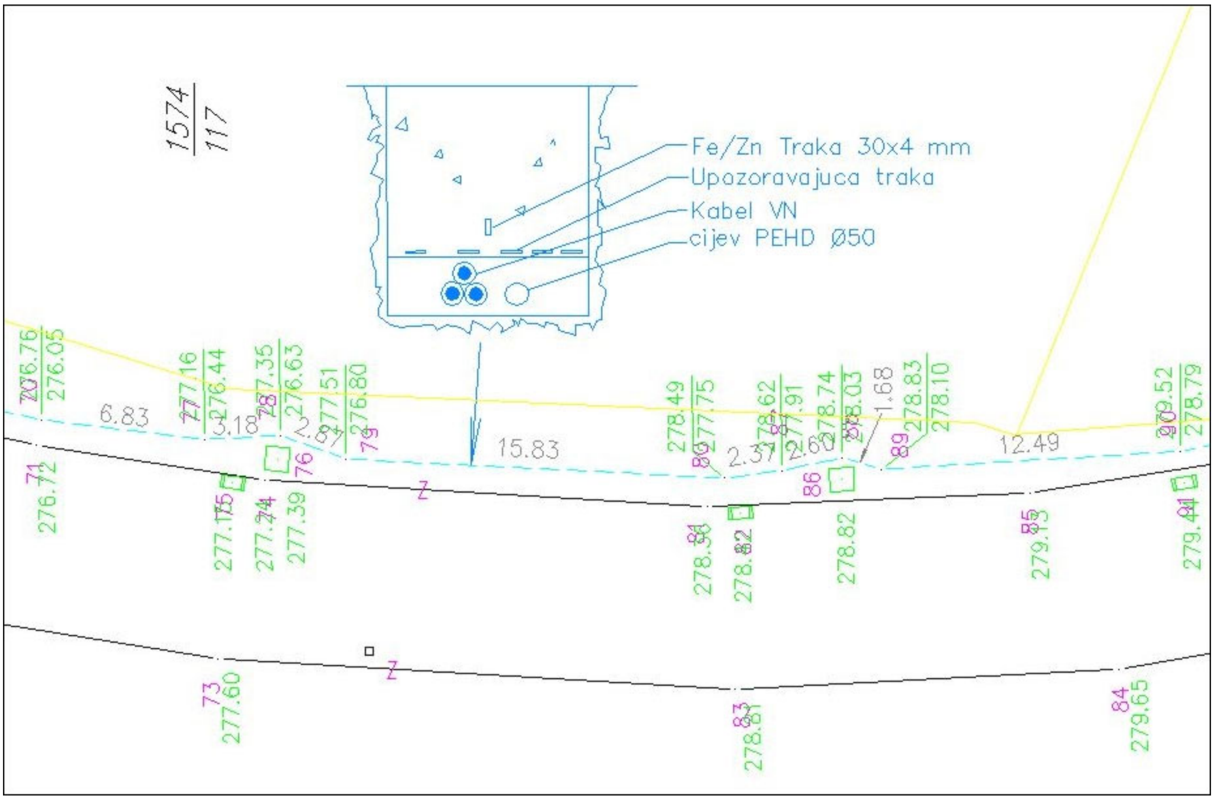
Another possibility is to approach it from a safety aspect. Most countries have a Worker's Compensation Board, or equivalent, that ensures proper safety procedures are followed. They have the power to fine workers and companies for violations. Excavating near energized transmission cables is a safety hazard for workers as well as a hazard for the utility. Recommendations could be made to ensure that proper safety procedures with a utility safety watcher were followed, through organizations such as Worker's Compensation Board, with a side benefit of better third party hazard monitoring and protection.

9.3 Quality of maps of underground cable installations

9.3.1 Introduction

In general, recently installed assets are well mapped. Location data of older cables can be very poor, in some cases they do not even exist (with the exception, perhaps, of the location of the terminating points). Sometimes there is no documentation, and sometimes the records of the installed cables are prepared in different formats - for example: paper, microfilm and digital. Mostly these systems are not compatible because a single common standard for these data has never been prepared. Besides, each company has its own records and there is no easy way of providing an integrated overall view.

Some examples of maps are detailed below.



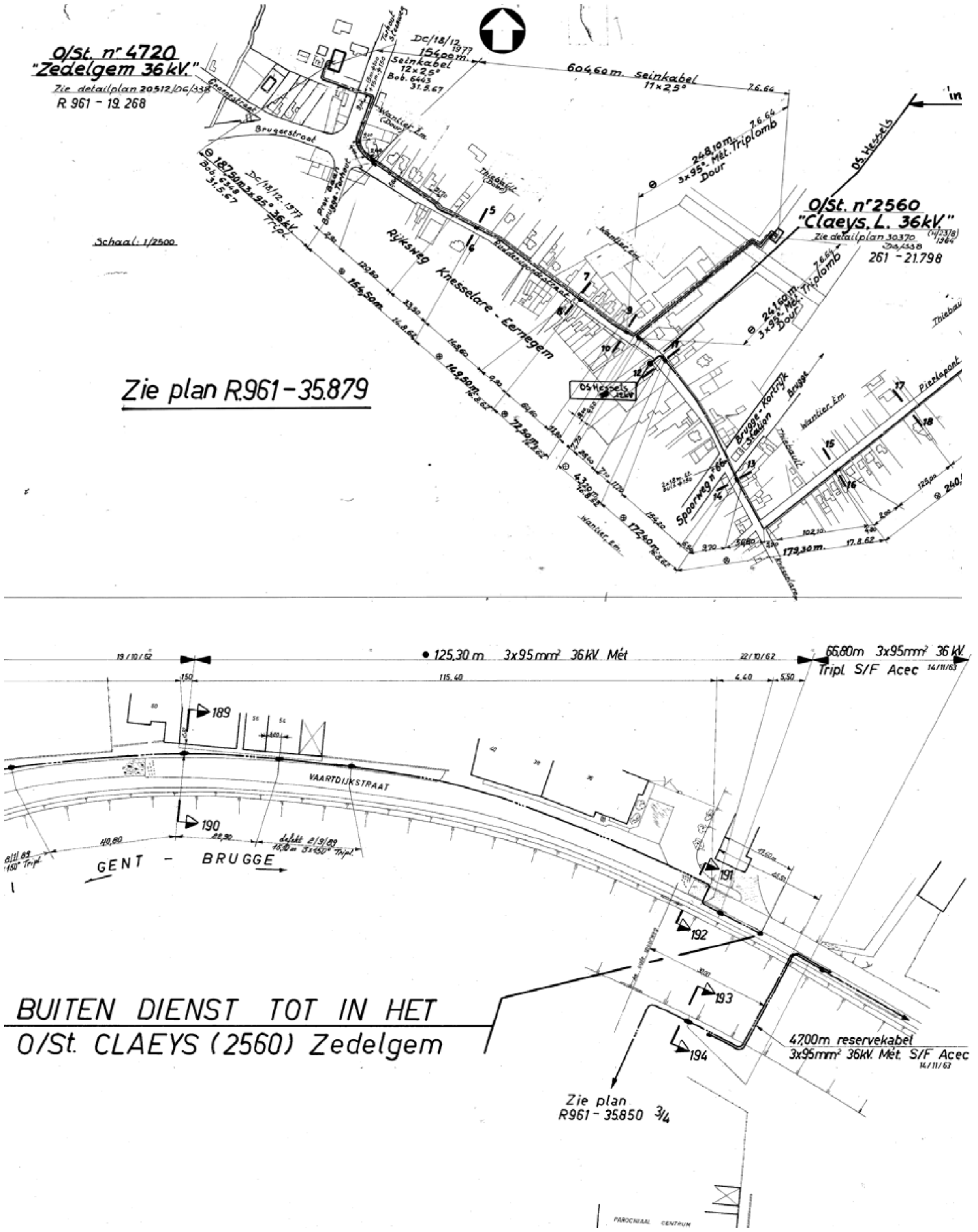


Figure 9.1 Old maps showing underground cables

An example of a new cable map is shown below in Figure 9.2:

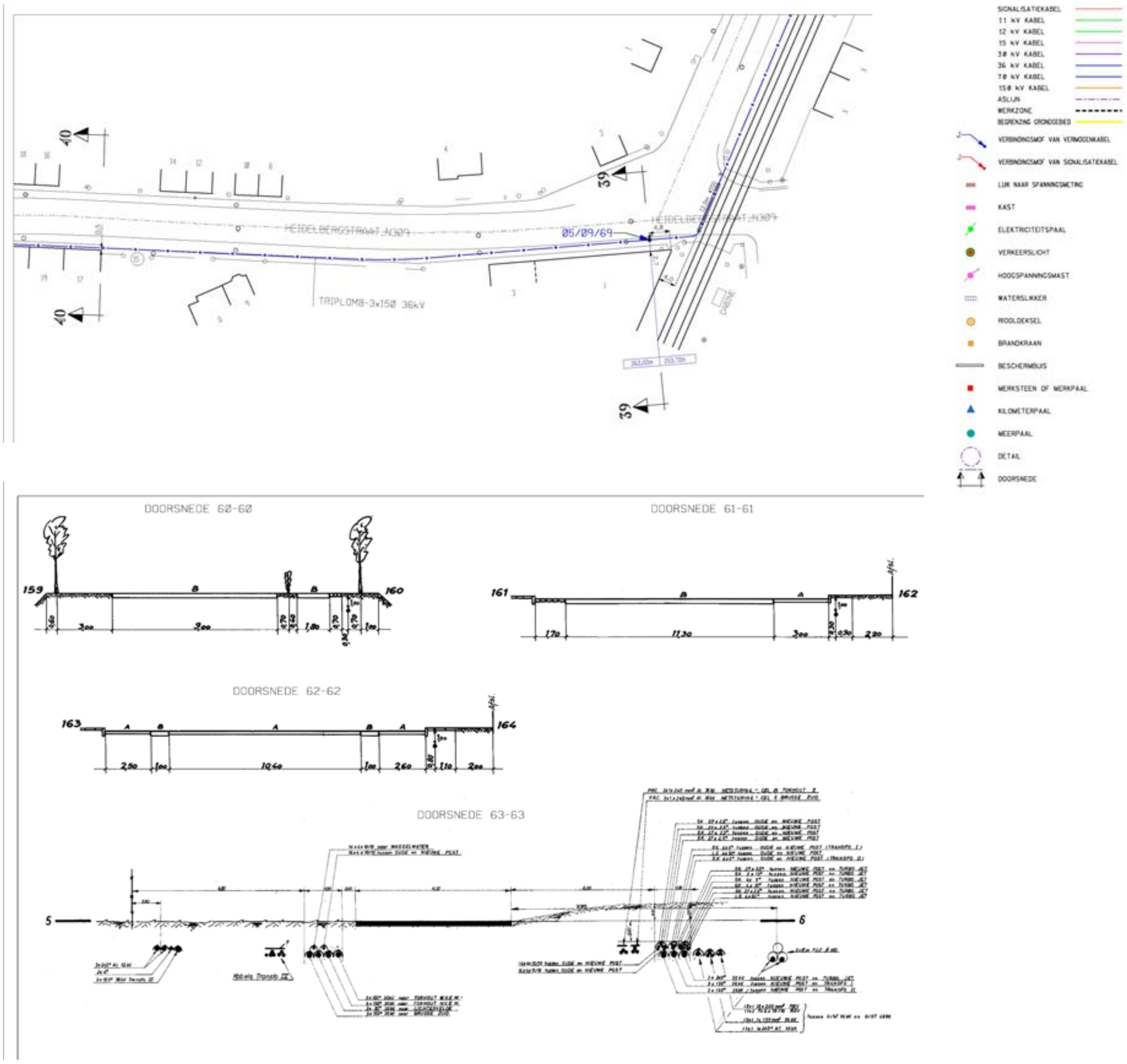


Figure 9.2   New cable map including legends and cross-section drawings

In rural areas, and to help providing a quick overview, photo-maps in correct scale can be used as a background map for cable maps. An example is shown below.

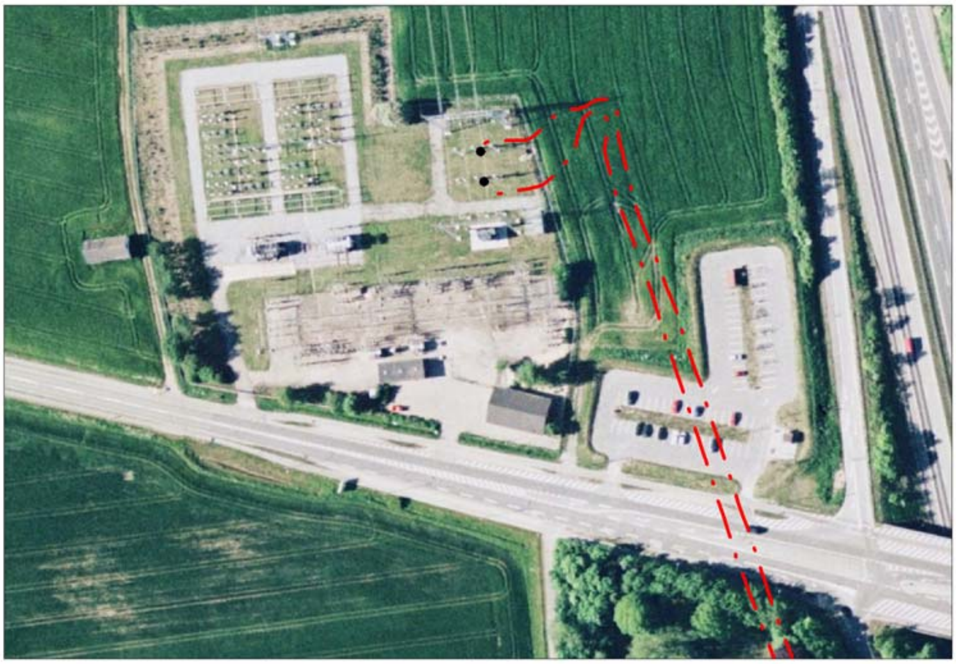


Figure 9.3 Cable route shown on photo map

As already mentioned, in order to prevent damage to underground cables accurate location data of existing underground assets are required. The plan coordinates x, y must be recorded. The cable position must be recorded during cable installation, or it must be recorded at a later stage by means of a precise cable locator.
The aim is to compile all the information in a format that is easy to understand for contractors, utility companies and planners so that it can be displayed visually on a PC in the office or a handheld unit in the street. Printed maps may be necessary too.

It is also recommended to record the cable position relative to the ground surface for new installations. Instead of just measuring the depth it is recommended to record the three-dimensional coordinates for the cables and the ground surface. If all three coordinates (x, y and z) are known, different cable maps can be made, and the cable owner will be prepared for any future developments regarding warning systems.

Once the cable depth and the ground surface are recorded, it is possible to make a map showing the longitudinal profile. See Figure 9.4 below.

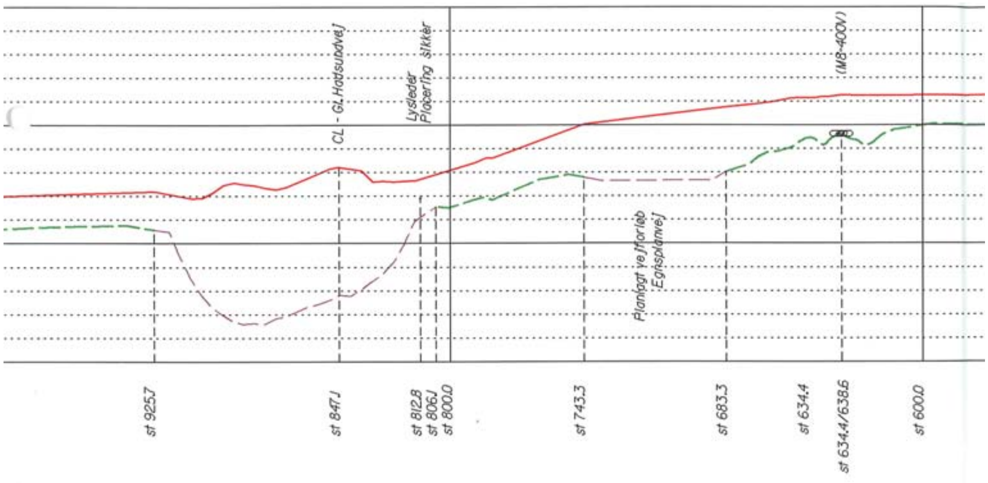


Figure 9.4 Longitudinal profile of direct-buried underground cable and sections using directional drilling and installation in pipes

9.3.2 Future developments

It is expected that new technology will be developed that will facilitate the locating and identifying of underground assets. The new technology will enable the construction of a dynamic map of all the underground assets and the development of novel techniques for displaying the resulting knowledge to digging teams and network planners in an appropriate manner.

One of the challenges facing the researchers is the development of a centimetre-accurate satellite-based location technology that works even in 'urban canyons'. Another challenge is linking these records to existing information held by each utility in order to form a complete picture of what lies underground.

Improved sensor technologies can lead to the use of passive sensors placed close to the cables. These sensors can be located through an electronic signal from a few metres away, making it easy to find the cables. Such devices could be used for automatic warnings. Sensors close to cables can be useful if backhoes and similar machines are equipped with instruments capable of recognising signals from those sensors.

Another possibility could be to load the cable coordinates into the backhoe's computer. If the backhoe gets close to the cable, the computer can warn the driver or prevent the machine from working close to the cable.

9.3.3 Recommendations regarding route records

Where new installations are concerned, it is important to have a well-defined coordinate system. It is recommended to measure all three coordinates. The third coordinate (z-coordinate) might be useful in the future.

Where the old cable systems are concerned, depending on the importance of this system and the probability of third-party damage, it could be valuable to survey and record the cable route again.

It is recommended to use a geographical coordinate system (for example UTM (WGS84) or accepted and well-known regional alternative), and to reference all cable locations to legal survey monuments and pins.

9.4 Warning devices and cable detection

9.4.1 Warning devices

In case of excavating activities the main purpose of warning devices is to call attention to an underground cable or pipeline. The most frequently used warnings are described in 4.2.5.1 and 4.2.5.2.

9.4.2 Early warning systems

In some situations a fibre optic cable placed along and above the power cable can serve as an early warning system. The glass fibre shall be online monitored so that it is possible to detect a break instantaneously. An early warning system can be supplied by an arrangement where it is possible to send personnel to the site immediately.

9.4.3 Cable detection

Cable detection makes it possible to determine the exact location of an underground cable. The benefits of using a cable detector are:

- A larger part of the excavation can be done using a machine
- The risk of hitting the cable concerned is reduced
- Reduction of costs

Cable-detection equipment does not replace information from the cable owner.

9.5 Mechanical protection

It is recommended to provide new cable installations with mechanical protection. The chosen method depends on a combination of the risk of damage compared with the importance of the cable in the network (e.g. in densely populated municipal areas) and the costs of making mechanical protection. It is difficult and expensive to improve the mechanical protection in an existing cable system.

Mechanical protection is also discussed in section 4.2.6.

9.6 Information and education

As mentioned earlier: Avoiding damage to underground cables is a responsibility of all parties involved in excavating activities in the vicinity of cables. Administrative tools, warning devices, cable detectors or mechanical cable protection are useless if the parties involved do not understand the importance of working carefully.

Therefore it is important that contractors employ well educated people who know how to deal with cables in the underground. The project engineer needs to know how to contact the cable owners in the area in which he is preparing excavating activities. The operator of the machine needs to know how to work in the vicinity of underground cables. He must be familiar with the procedure and be aware of the consequences of not following it.

Information and education of all the people involved is one of the most important tasks of the industry in order to reduce the risk of third-party damage to underground cables.

A good relationship with local workers and contractors is often helpful. Regular meetings with contractors working in a local area can be a good opportunity to convince them that reducing third-party damage is a common interest.

9.7 Patrols/inspections

In spite of good administrative tools it can be necessary to watch over the cable systems and discover construction work close to cable systems. The purpose is to stop contractors before they damage the cables. It is not possible to be everywhere but if areas with much building activity are monitored, it is easy to focus on them.

9.8 Flow chart

The following flow chart shows situations where damage may typically occur.

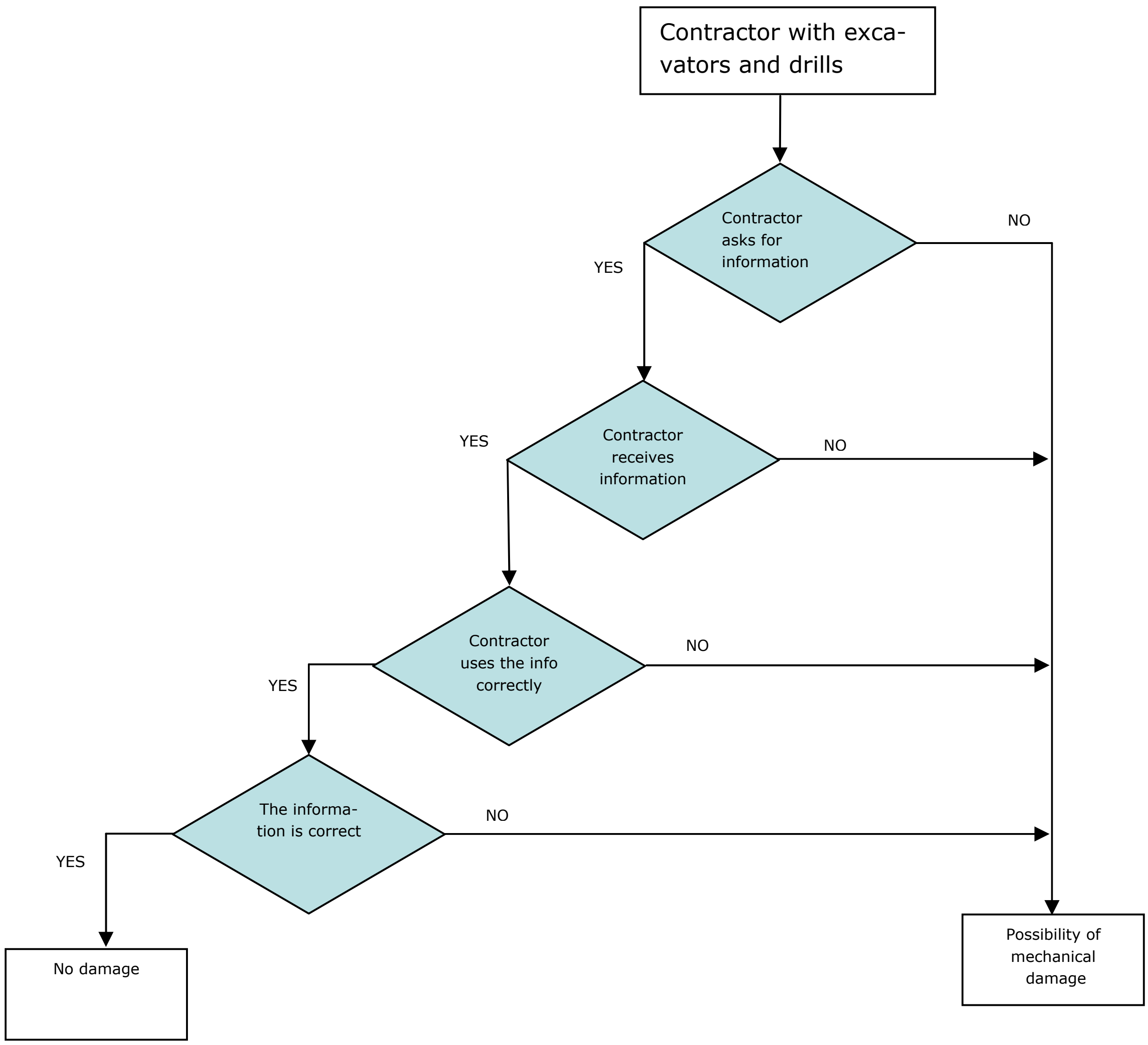


Figure 9.5 Flow chart illustrating typical problems

It can be seen from the flow chart that third-party damage has to do with information and how that information is used. In order to reduce the risk of third-party damage exchange of information is very important.

Generally speaking the following must be done:

- Correct information about cable route (cable record) must be collected and stored by operator
- Third parties must know how to get permission to do their civil construction work or similar jobs
- The central point of contact or the cable operator must provide relevant parties with correct information in time
- The third party must wait for information
- The third party must understand the information correctly
- The third party must act correctly on basis of the information received

10.How to reduce the risk of third-party damage to submarine cables

10.1 Legislation

International submarine cables are the subject to protection under international law. Appendix 4 contains the relevant treaties including the United Nations Law of the Sea Convention (1982) ("UNCLOS"). States which are parties to UNCLOS are required to enact domestic legislation that makes it a crime to damage a submarine cable either wilfully or by culpable negligence. Criminal sanctions are in addition to civil remedies that allow for the recovery of damages and for the arrest of vessels causing damage to cables.

While many nations have enacted the required legislation, many have not. And others have legislation that is in need of revision to comply with UNCLOS. Modern legislation enacted in Australia and New Zealand has been very effective in preventing damage to cables. The important factor is that the penalties must be meaningful so that mariners and fishers will avoid cables.

Civil recovery of damages under general maritime law is also an effective deterrent in addition to providing for the recovery of repair costs and other damages. A cable owner must generally prove five elements to prevail in a civil action:

1. The vessel has been given notice of the cable's location by either actual notice or constructive notice. If the cable is shown on a nautical chart, constructive notice is established. Actual notice through liaison with fishing vessels and other seabed users is also effective.

2. The cable must have failed due to man-made causes. This is established by documenting, photographing or keeping a damaged section of the cable.

3. The culprit vessel must have been in the vicinity of the cable fault at the approximate time of the failure. This fact can be established by aircraft patrols, satellite images, visual sightings, vessel logs, and the now prevalent use of Automated Information Systems (AIS) required on many ships.

4. The culprit vessel must have been engaged in an activity such as anchoring or fishing that could have caused the damage.

5. No other vessels near were involved. Again AIS can be used to determine the culprit vessel when multiple vessels are present.

The value of effective legislation that is enforced and civil recoveries is primarily one of deterrence and prevention in addition to the recovery of damages.

In some countries zones have been set up for the submarine cables where maritime activities, anchoring and sometimes fishery are forbidden (restricted areas). The consequence of this is that many cables can be installed in a relatively narrow corridor. This will on the one hand protect the cables from some activities, but repair and installation work on the other submarine cables might on the other hand lead to more third-party damage because of the concentration of cables.

In some countries the cable owner has to compensate fishermen for lost fishing gear if the gear has become attached to the cable. In forbidden zones the situation can be the exact opposite, and it is therefore important to know the rules in the areas where the cables are situated.

10.2 Administrative procedures to protect submarine cables

10.2.1 Introduction

In order to reduce the probability of third-party damage to submarine cables, fishing authorities and owners/captains of vessels operating in areas where there are submarine cables must know the exact cable positions, the cable protection area or the areas where fishing/anchoring is restricted.

To obtain this information, fishermen and mariners must be in possession of updated charts and be aware of the regulations applying in the area where submarine cables are situated. That is why international organisations (such as the International Maritime Organization, IMO) define standards and each country entrusts national organisations with the responsibility of updating and distributing official charts and recommendations to fishermen and mariners.

10.2.2 What type of information?

The information shared between fishermen, mariners and utilities can be divided into two types:

- Information that fishermen and mariners must have on board
  - ✓ Submarine cables routes
  - ✓ Restrictions of activities in areas where submarine cables are positioned
  - ✓ Protection corridors near submarine cables

- Information that utilities are required to provide to relevant organisations
  - ✓ New cables installed
  - ✓ Re-laid cable after maintenance or repair operations

10.2.3 How to exchange information?

Charts

Each country publishes charts (on paper or electronically) in accordance with the SOLAS convention, which was established by the IMO (International Maritime Organization). These charts meet the quality requirements imposed by the IHO (International Hydrographic Organization).

There are two basic types of electronic charts:

- Vector Electronic Navigational Charts (ENC): ENCs are vector charts compiled from a database of individual items ('objects') of digitised chart data which can be displayed as a seamless chart. When used in an electronic navigation system, the data can then be reassembled to display either the entire chart image or a user-selected combination of data. ENCs are intelligent in that systems using them can be programmed to give warning of impending danger in relation to the vessel's position and movement.

- Raster Nautical Charts (RNC): RNCs are raster charts produced by digitally scanning a paper chart image. The image may be either the finished chart itself or the stable colour bases used in the multi-colour printing process. The resulting digital file may then be displayed in an electronic navigation system where the vessel's position, generally derived from electronic position fixing systems, can be shown. Since the data displayed are merely a digital photocopy of the original paper chart, the image has no intelligence. No other data than visually data can be extracted from the charts.

These updated charts are distributed in each country to fishermen and mariners by national hydro graphic offices.

Electronic Chart Display and Information System (ECDIS)

An Electronic Chart Display and Information System (ECDIS) is a specific form of computer-based navigation information system that complies with International Maritime Organization (IMO) regulations and can be used in lieu of paper navigation charts in some areas. Not all electronic chart systems can be called an ECDIS, but the term is often incorrectly used to refer to any type of Electronic Chart System (ECS).

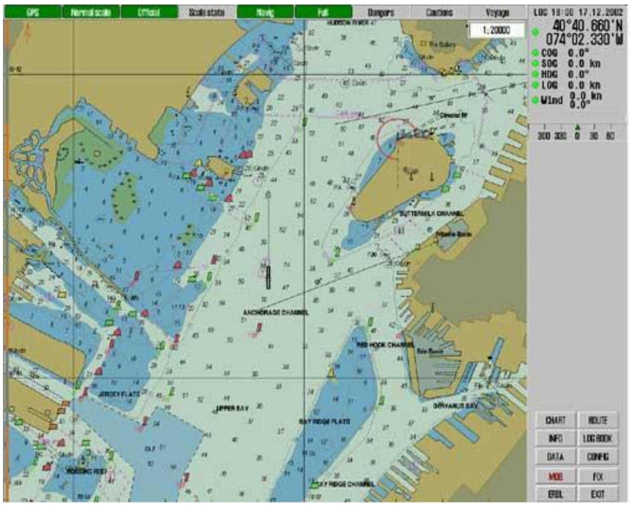
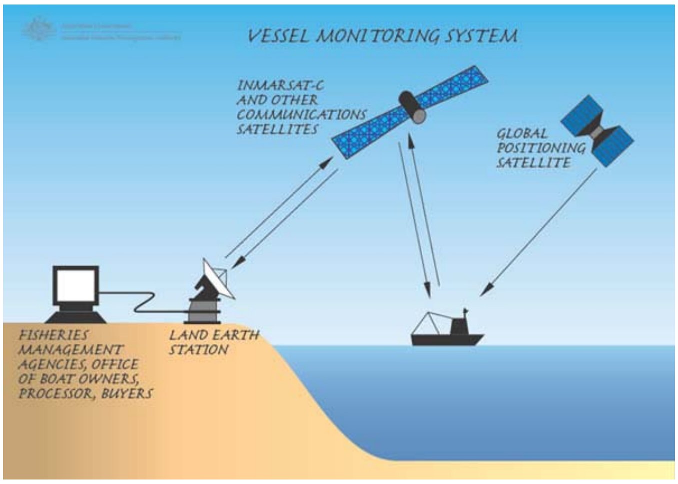


Figure 10.1 Example of ECDIS

The genuine ECDIS system displays information from electronic navigational charts (ENC) and integrates position information from the Global Positioning System (GPS) and other navigational sensors, such as radar, fathometer and automatic identification systems (AIS). It may also display additional navigation-related information, such as Sailing Directions.

It is the submarine cable owner's responsibility to ensure that information about all submarine cables are given to the hydrographic organisation responsible for updating the charts. The recorded data must be delivered in a format suitable for the electronic charts. Demands on formats can be given by the hydrographic organisation.



VMS

Vessel Monitoring Systems is used in most countries. A VMS automatically collects, records and analyses information related to the location and activity of vessels. A VMS system uses electronic transmitters, placed on fishing vessels transmitting information about the vessel's position to enforcement agencies via satellite.

VMS is intended principally for fisheries management, but the country using it may use the data for other purposes. One of the most basic purposes is to monitor the movement of VMS-equipped vessels with respect to restricted fishing areas. A given vessel may have approval to fish in a restricted area, to transit through it without fishing, or it may not be allowed into the area at all.

Figure 10.2 VMS principle

10.2.4 Quality of maps of submarine cable installations

Mapping of submarine cables is a very complex procedure. Since typical minimum requirements for a cable route map call for a 1-kilometer-wide swath of data down to a water depth of about 1,000 m, and a minimum 10-kilometer-wide swath in deeper waters, as much as 12 million square kilometres (nearly 3% of the ocean) have been mapped in great detail just to install cables. There is often a problem because a navy cadastre does not exist, or if it exists, it is designed for security of navigation and not for the management of submarine cables.

Some of the first cables were laid with the help of visible signs - coloured buoys. Cable surveys were often made with the help of buoys connected to the cables. The correct coordinates were available only at the beginning and the end of cables.

At present cables are laid by means of a dual navigation system, usually a GPS surface navigation system that pinpoints the location of the vessel laying the cable with a high degree of accuracy and a subsea sonar system that determines the actual touch-down point of the cable. This system allows the laying of submarine cables within a 10 m wide corridor, or a guaranteed accuracy of +- 5 m - depending on water depth. As the cable route is digitised with the appropriate coordinate system, it could be included directly in an electronic map.

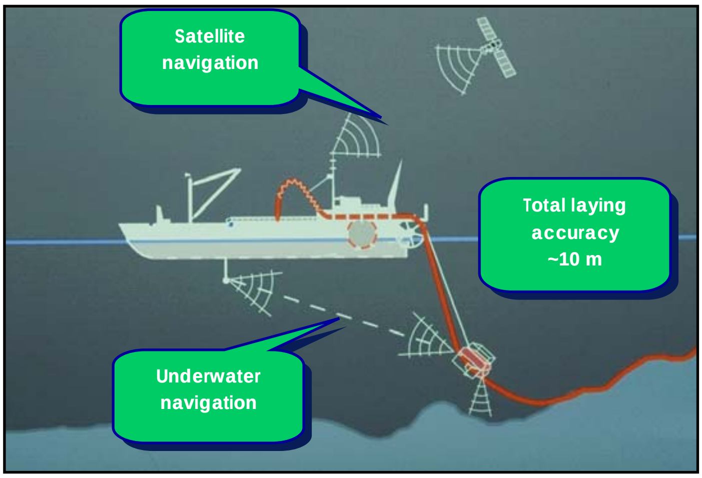


Figure 10.3 Underwater navigation principle

Mapping must include:

- Final chart of the cable laid in an appropriate scale
- Sea depth along the route
- Level of cable installed relative to ordnance datum
- End points of coastal protection in the sea
- Position breakpoints along the route
- Position of each cable connection
- End points of coastal protection on shore
- Landing points
- Positions of marks indicating prohibited anchoring
- Applied geodetic method and coordinate system

There are paper and electronic charts. The life span of electronic charts is unlimited because they are continuously updated. Paper charts are out of date as soon as cable positions are changed, until next revision of the charts is published.

It is also possible to make a cable survey on old cables to record the cable position - the cable route (the plane coordinates), the burial depth and the level relative to the ordnance datum. An ROV equipped with suitable cable tracking equipment can help to record the 3D cable coordinates.

The vast majority of existing mapping information is available on paper only. To increase the usefulness and accessibility of old sea mapping data it is possible to convert old data into GIS databases, using special programs. Once in GIS form, data can be easily integrated and manipulated - always remaining correctly geo-referenced.

The IHO (International Hydrographic Organization), the UN (United Nations), the IMO (International Maritime Organization), and the Geneva Convention on the High Sea (sea not included in the territorial sea or in the internal waters of a State) have the steering roles in submarine mapping. The fact that the IHO that strives for the greatest possible uniformity of nautical charts and for the safest and most efficient methods of conducting hydrographic surveys and producing nautical charts may be of particular interest.

Important, too, is legislation involving international and national law and recommendations (see Appendix 4).

Some general rules:

- When a new cable is laid beneath navigable waters at a depth where interference with navigation or fouling by anchors is probable, or whenever a change is made in the position of any submarine cable presently shown on government charts, the change ought to be registered and the cable area shaded
- Where nothing else has been announced and marked on the charts, the protective zone of a cable area shall cover the area between the outermost beacon lines as well as an area of 200 m outside of these

10.2.5 Recommendations regarding route records

It is important for all submarine cable installations to have a well-defined coordinate system. It is recommended to measure all three coordinates of the cable position. The seabed surface and the water depth must be recorded as well. Tidal references must be maintained during the measuring period.

It is also important to register the burial depth relative to the original seabed in the cable record. The burial depth may change if the seabed changes. The burial depth can be calculated if the absolute position of the cable and the seabed above the cable is known.

It is recommended to use a geographical coordinate system (e.g. UTM (WGS84)) or an accepted and well-known regional coordinate system.

10.3 Warnings

Where rivers and fiords are crossed by submarine cables it is possible to mark the crossing with caution signs and beacons. They only indicate the place where the cable has been led ashore, and they show that there is a submarine cable in the vicinity. The warnings cannot be used as an indication of the exact position of the cable.

See also section 4.3.5.

10.4 Patrols/inspections

Despite good administrative procedures it might be necessary to monitor the submarine cables and warn fishermen and contractors about the power cables. If it is known that some parties do not enforce the law, it might be necessary to patrol along the cable.

Cable inspections will sometimes be made using a ROV (Remotely Operated Vehicle).

Immediately after the installation of the submarine cable it will lay non-protected on the seabed - if not simultaneous burying is used. In this case it is often a good idea to use guard vessels patrolling along the cable to warn the vessels close to the cable route about the existence of the submarine cable. Buoys can sometimes be placed to show the position of the cable.

10.5 Information and education

The law and warnings are worthless if they are not observed or understood by the crew on the vessels. Foreign fishermen in areas governed by other maritime laws must be informed about the legislation in the specific country. It might be a good idea to make flyers for the foreign fishermen about the local laws and procedures so that everybody is well informed.

A good relationship with local fishermen and contractors is important so that everyone is aware of the cables.

Regional or national cooperation between submarine cable owners in order to inform about submarine cables can be one way of ensuring that more people get the message: Be aware of cables - even if they are invisible.

If charts are not updated with all submarine cables, or if the updated charts are not available on board the vessels, the risk of third-party damage to submarine cables will be relatively high. To reduce the risk it might be necessary to use alternative distribution methods. If all submarine cable owners in a region can organise placing all information about submarine cable routes in the region on a portable electronic storage device which can be distributed free to every vessel in the area, the risk might be reduced. It is important that the data on the storage device can be easily loaded into the vessels navigation systems. The storage device with submarine cable information must be updated and distributed regularly.

Most jurisdictions require Marine Pilots to be on board commercial vessels within their territorial waters, if vessel size exceeds a certain limit. Educating the regional Marine Pilots about cable locations is a good way to spread the information to many local and foreign vessels operating in the vicinity of power cables.

10.6 Mechanical protection

Existing cable systems are protected with armouring wires. If a submarine cable is hit by an anchor or a trawl the armour will not offer the cable good protection. The forces from anchors are so large that it is impossible to provide good mechanical protection for the cable itself. Instead the cable must be protected in another way.

In many situations the best solution is to bury the cable into the seabed. If the cable is exposed directly on the seabed, it will be hit by everything crossing its path. Normally fishing gear does not penetrate more than 10-30 cm down into the seabed. A burial depth over 0.5 m is often sufficient to protect the cable against fishing gear.

In some soils, anchors from vessels will penetrate down into the seabed. How deep depends on several factors - in particular the hardness of the soil and anchor size and type. Very large anchors will in soft soil penetrate more than 5 m into the seabed (see Figure 6.2).

The burial depth depends on soil conditions, traffic intensity, size of vessels and anchors, fishing activity, fishing gear and other activity in the seabed (excavation). Before deciding on how to go about protecting the submarine cable, the threats to the cable must be known.

There are different techniques that can be used for burying cables. In sandy soil water jetting is an effective method. Typically, the submarine cable is buried after having been laid down on the seabed. This means that old cables can also be protected long after they were installed if it is possible to use water jetting. There are different types and sizes of jetting equipment. Some small water jetting machines need assistance from divers, and they are typically used in shallow waters. The new large jetting machines are often remote-controlled and are capable of operating in deep waters.

The effectiveness of the cable protection depends not only on burial depth, but also on the amount of material that will be removed from the trench. The best protection is obtained if the trench is narrow and is filled with the original material immediately after the jetting operation. In some areas an open trench will be filled in a few days or weeks because of the natural current and tide and the transport of material in the waters. It is important to avoid a situation where the cable is jetted down to for example 1 m but is lying in a wide open trench without any protection because all material near the cable has been jetted away from the cable.

Another burial method is the use of a suitable plough. The plough is often used with telecom cables and MV cables. It is also possible to use a large plough to protect HV or EHV cables, but this method entails some risks. Heavy machines with enormous mechanical power will be a risk to the power cable if the plough is not handled with great care. The plough can be jetting assisted, which can reduce the needed mechanical power.

A plough can bury cables up to about 3 m. Water jetting will normally only bury the cable to a maximum depth of between 1 and 2 m. A third possibility is to make a pre-excavated trench before laying the submarine cable. The depth of the trench will depend on the equipment used.

Simultaneous laying and burial, where the cable is jetted or ploughed into the seabed in the same operation as the laying of the cable from a cable laying vessel, has the advantage that the cable will not be left exposed on the seabed, but it will be well protected from the very beginning. A disadvantage is that the operation takes longer time than a simple laying operation, and this can be a problem in windy areas and where there are problems with waves or tidal stream.

The required burial depth must be determined before starting the work. A detailed analysis must be made where knowledge of the sub-seabed conditions are important. A risk assessment of damage from anchors and fishing gear and other activities must also be made. On the basis of these studies the target depth must be found.

Before a decision is taken, the thermal properties of the soil must be assessed. If the cable will be too hot if it is buried to a depth of (for example) 2 m, the burial depth must be reduced. In that way a compromise must be found.

In areas with very hard soil or rock, it is much more expensive to provide a submarine cable with mechanical protection. New machinery is capable of cutting through rock and can be used to make a narrow trench for the cable. Anchor penetration depths are less in a hard bottom, so burial depth can be less, as indicated by Figures 6.2 and 6.3. If possible, it is recommended to make the trench before laying the cable in such areas. There is always a risk of cable damage when the cable protection is being prepared.

In areas where it is not possible to bury the cable other methods might be used. The use of mattresses is a well known method which offers good protection against, for example, fishing gear. Rock dumping is another possible solution. This method is often used to make a mechanical separation between more cable systems or between pipelines and cables. A combination of rock dumping and mattresses is also often seen.

In areas with water depth of more than 200 m the risk of damage from anchors is low. Depending on the fishing activity it can be chosen not to establish submarine cable protection in such a situation.

Close to the shore - in shallow waters - protection must be established. Where cables are going onshore, they can be protected in ducts or split pipe articulated mechanical protectors. Sometimes it is possible to use directional drilling from the coast out into the water. In that way the cable will be protected close to the coast line, although costs can be high and transmission capacity can be lost.

The protection of the submarine cable must be checked regularly. The soil around the cable can be washed away or a third party could have been there to perform excavation or sand dredging. A cable survey is often a very good way of checking whether the cable protection is still in order.

10.7 Flow charts

The following flow charts illustrate when the damage typically occurs.

Anchors

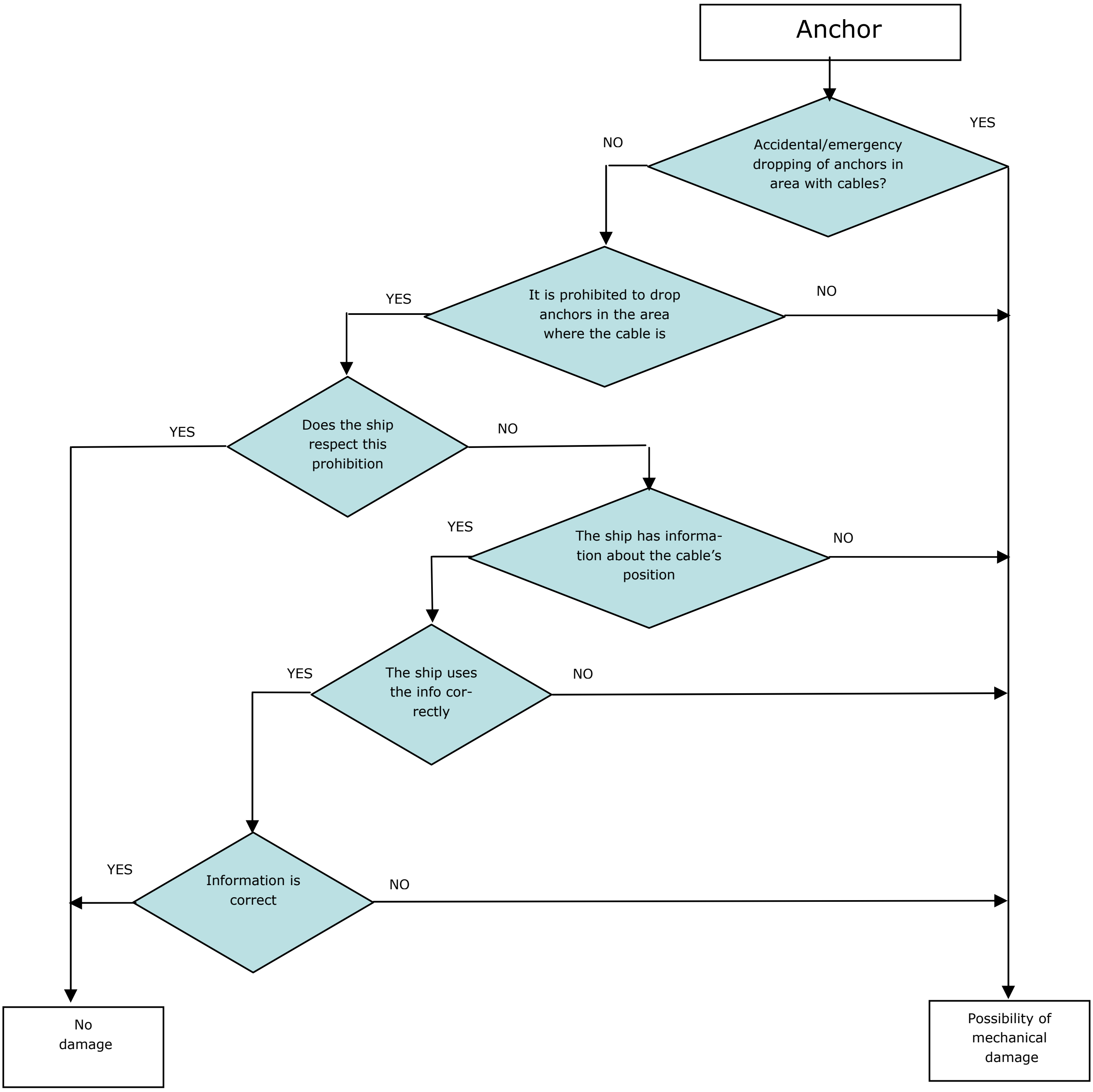


Figure 10.4 Flow chart indicating typical problems with anchors

Trawling

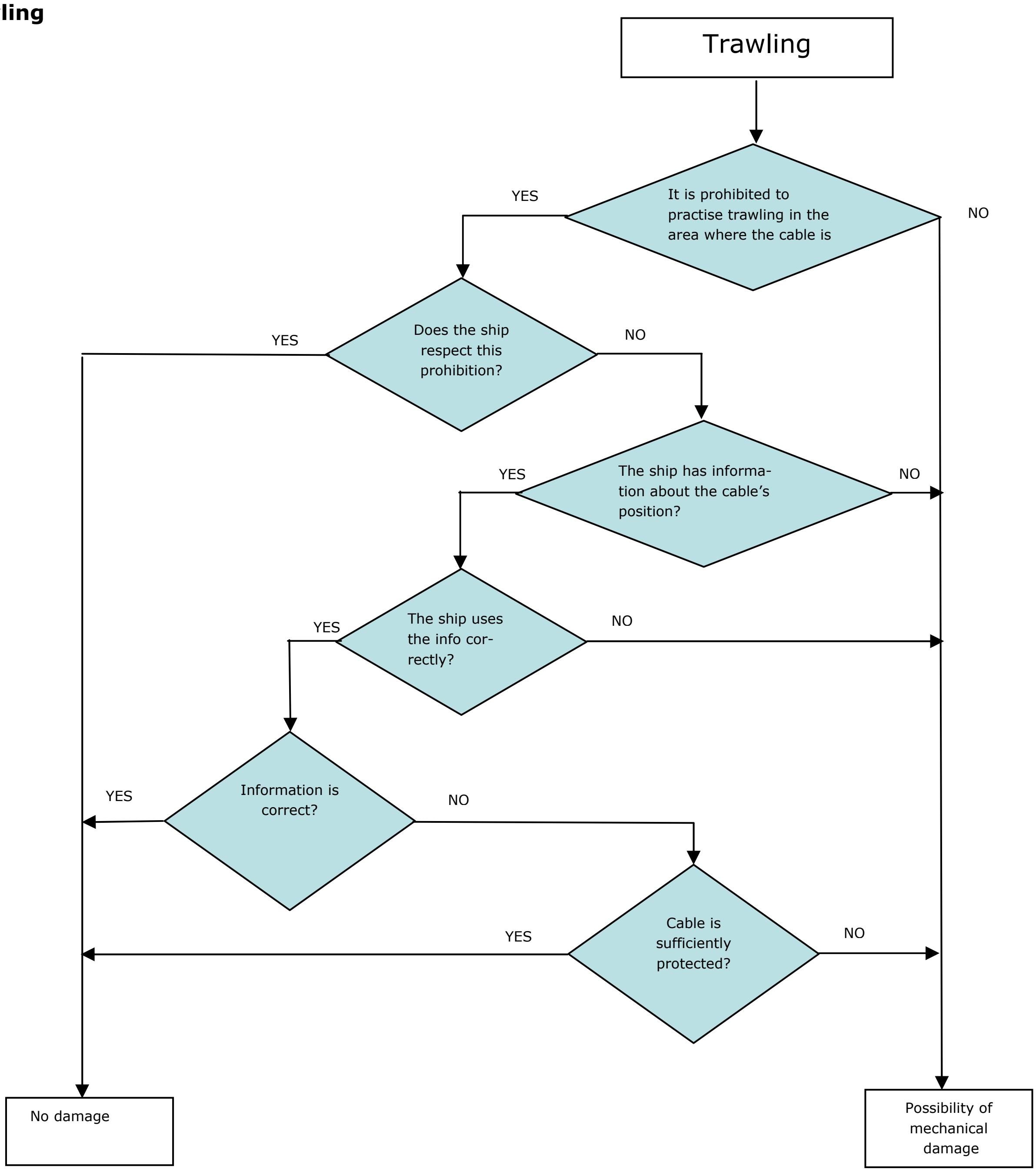


Figure 10.5 Flow chart indicating typical problems with trawling

The flow charts indicate that third-party damage to submarine cables has to do with information, how the information is used, and the quality of the mechanical protection. In order to reduce the risk of third-party damage to submarine cables, exchange of information is very important. It is only possible to make mechanical protection against smaller anchors, but in many cases it is possible to protect against fishing gear.

Anchors dropped from ships during emergency situations or by accident is also a risk which cannot be ignored, but neither it is possible to reduce the risk.

Generally speaking the following must be done:

- Correct information about cable route (cable record) must be collected and stored by the cable operator
- Information about all submarine power cables must be given to the institute (or similar) responsible for updating charts
- Updated charts must be present on vessels
- Marine officers and pilots must be familiar with local conditions and know who to contact in emergency situations
- Fishermen must have updated charts on board their vessels and know the location of submarine cables
- Fishermen must know if it is forbidden to use bottom trawl in a zone
- Fishermen must act correctly when it comes to forbidden zones
- Fishermen must know who to contact if they hit a submarine cable
- The cable operator must know how to act when a submarine cable has been hit by an anchor or fishing gear

11.Systematic approach to risk assessment of cable systems

11.1 Systematic approach

The method developed in this chapter is inspired by the FMEA method (Failure Mode and Effects Analysis, see [11]). In this technical brochure 'failure mode' is replaced by 'damaged state' to emphasize that damage events not always lead to immediate electrical failure. In [1] a similar method is used.

A systematic approach to the risk assessment will help to identify the most severe threats to the cable systems. They will not be the same for the entire cable route. In some sections of an underground cable system it could be trees, while in other parts the greatest risk could come from cars that could destroy an above ground link box. In rural areas it can be the farmers' work (laying backfill above the cable, making new trenches for draining, deep ploughing etc.). In cities and along roads excavating works close to the cable is expected to pose the greatest risk. Examples are digging or drilling and other types of mechanical works.

District heating pipes and other power cables can also act as external heat sources capable of lowering the rating of the present cable system.

The risk is a product of the probability of a damaged state and the severity of the effects. A risk study will help to identify the situations with the highest risk and prepare for lowering the probability or the effects.

Each cable failure has some consequences for the overall network. The consequences are related to the importance of the cable system and the situation of the network (market situation, maintenance work etc.). Taking this into account we can assess the consequences of breakdowns in each cable line (or any other important part of the network).

Table 11.4 (section 11.4) shows one way of organising the possible damage events, damaged states, effects, detecting methods, probabilities, consequences, and possible actions to be taken to lower the risks for the cable system and consequences for the network.

Example

To illustrate how to use the systematic approach discussed in this chapter, an example with an underground cable from substation 'ABC' to 'DEF' will be used throughout the chapter. In the example, the cable screens are cross bonded and the cables are fitted with a water barrier - just to illustrate some specific damaged states.

11.2 Splitting up systems into sections

An underground cable system can be divided into several sections and parts. This will help the study of risk assessment.

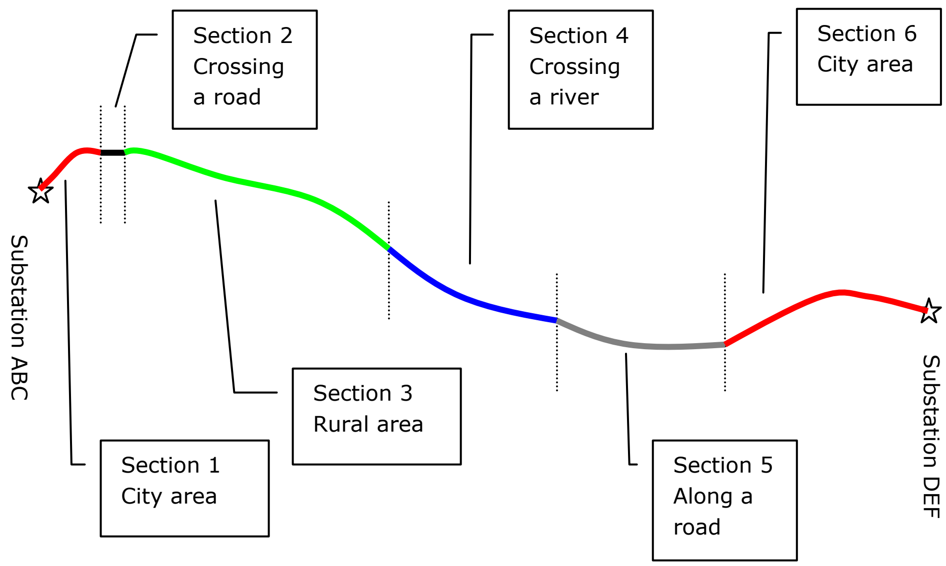


Figure 11.1 Example of underground cable system between two substations

In Figure 11.1 an underground cable system between two substations is shown. The cable system can be divided into several sections. The cable itself might be the same the whole way, but the surroundings of the cable differ in the various sections. The route in the example is divided into six sections according to the environmental conditions.

11.3 Splitting up sections into items

In each section there are different items. Figure 11.2 illustrates some of the items in an underground system.

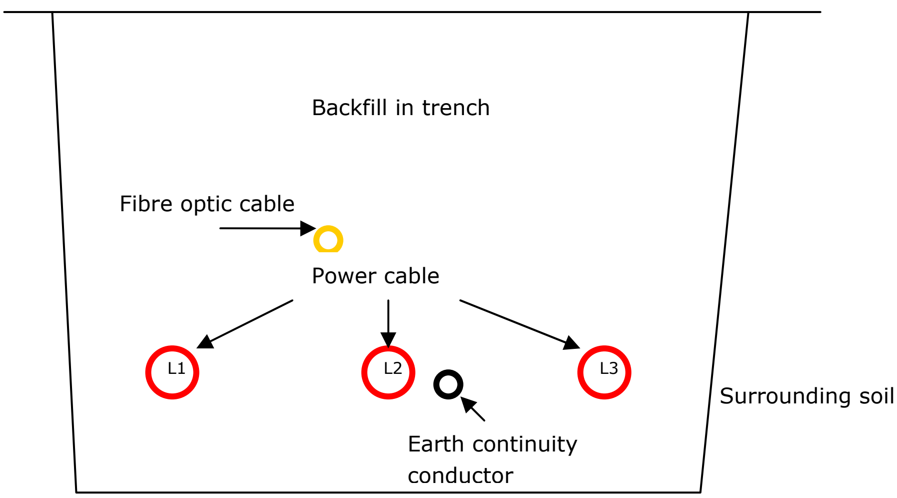


Figure 11.2 Simplified sketch of items in an underground cable section

The items involved may differ from section to section. Where cables are laid in ducts, the duct is an item of the system. Another item might be the earthing system or a link box in a cross-bonded or single-point bonded system.

In order to analyse the risks of third-party damage, the different sections of each cable system and each item in each section must be studied.

It is helpful to organise the analysis in tables like the one shown in Table 11.4.

11.4 Damage events, damaged states and effects analysis

Some of the columns in Table 11.4 are defined and explained in Chapter 7. See also Chapter 3, Definitions.

A damage event causes a damaged state, which describes the state of the damaged cable system. The effects of damage events with specified damaged states can be divided into severity classes.

The probability of each damaged state must be defined by the cable system operator. Fault statistics can give guidance, but in most cases it is necessary for the cable operator to assess the probability himself. The probability is an assessment of the relative probability - that a specific damaged state is caused by a damage event.

The following flow chart illustrates the principles described above.

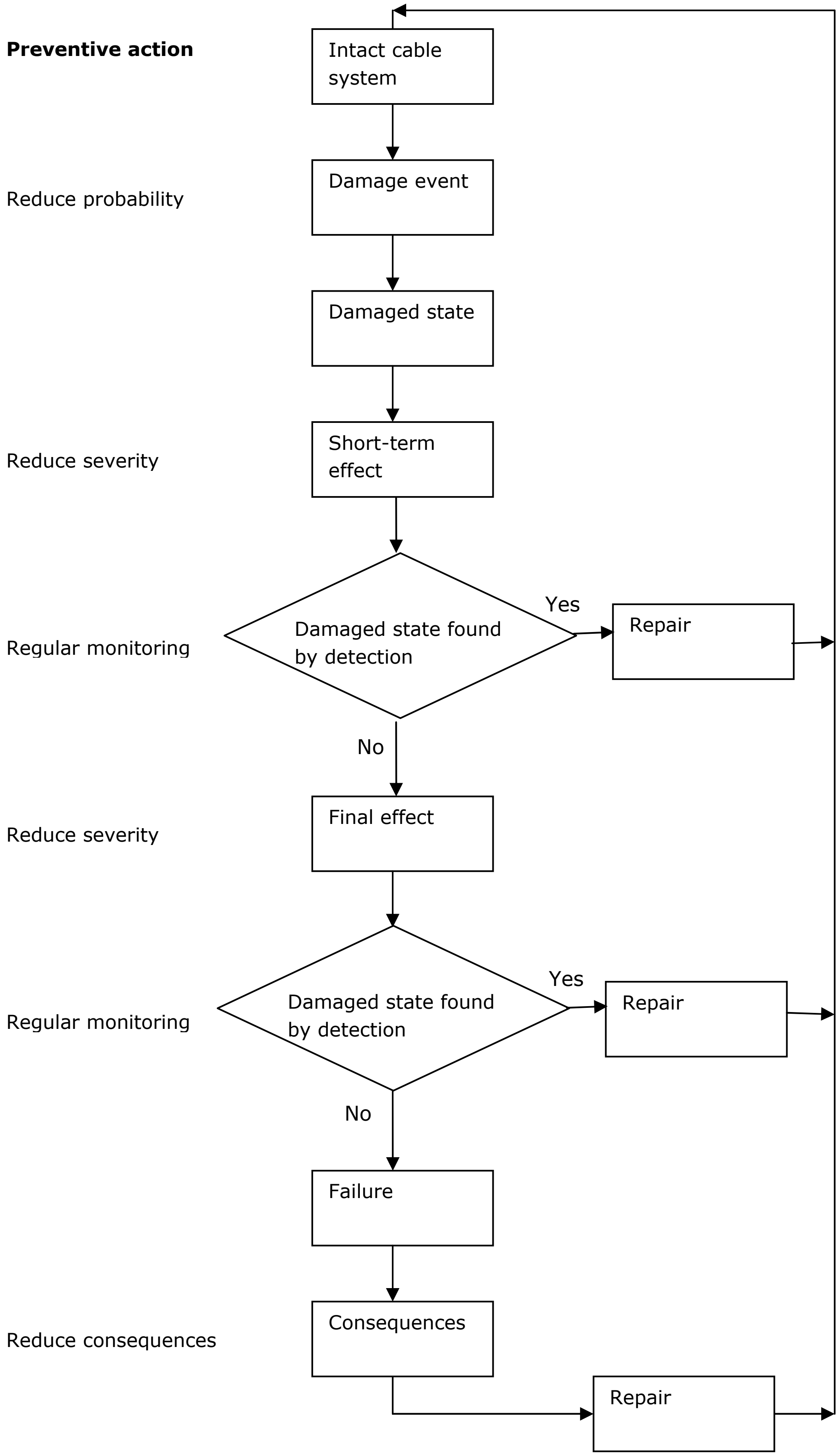


Figure 11.3 Flow chart indicating the principles of third-party damage

When categorising the severity, the probability of damaged state and the consequence into specified classes, it is important to use the whole spectrum. It is not absolute numbers but relative numbers that are interesting.

The examples below are just examples. The cable operator must define his own classes for his cable systems and network.

Example - Severity:

Level	Severity	Description
V	Catastrophic	Breakdown of cable system and long repair time
IV	Critical	Risk of breakdown of cable system. Risk of overloading of cable system
III	Major	Damage to parts of system. Shorter life time
II	Minor	Damage to surroundings. Risk of shorter life time
I	Negligible	Risk of damage to parts of system

Table 11.1 Severity classes

Example - Probability of damaged state:

Level	Probability	Description
V	> 0.5 /(100 km x year)	Very high probability
IV	≤ 0.5/(100 km x year)	High probability
III	≤ 0.25/(100 km x year)	Average probability for cable systems
II	≤ 0.1/(100 km x year)	Low probability
I	≤ 0.05/(100 km x year)	Very low probability

Table 11.2 Probability classes

Example - Consequence:

Level	Consequence	Description
V	Catastrophic	Breakdown of all or part of the network Very high costs for the market
IV	Critical	Breakdown of part of network High costs for the market
III	Major	Breakdown of more than one line High costs for the market
II	Minor	Breakdown of one line Moderate costs for the market
I	Negligible	Planned disconnection of line for repair Low costs for the market

Table 11.3 Consequence classes

Damaged state analysis on items in a specific cable section

Cable system			**ABC-DEF**								
Cable section			**1 (City area)**								
Item	**Damage event no.**	**Damaged state**	**Possible damage event**	**Short-term effect**	**Final effect**	**Detection method**	**Preventive action to reduce risk and consequence**	**Severity class**	**Probability class**	**Consequence class**	**CPI[1)]**
One or more phases L1, L2 or L3	1	Outer sheath damaged	Mechanical excavator or similar	No balance in cross-bonded system	Extra loss and lower rating	Sheath test Monitoring of screen currents	Regular sheath tests Monitor of screen currents Patrolling along cable route	III	III	I	9
	2	Breakdown of insulation	Mechanical excavator or similar	Short-circuiting	Short- circuiting		Redundancy (double system)	V	II	III	30
Earth continuity conductor	3	Cable interrupted	Mechanical excavator or similar		Potential rise during earth-faults	Sheath test Monitoring of screen currents	Regular sheath test	III	II	I	6
Fibre-optic cable	4	Cable bent	Mechanical excavator or similar	High damping Bad connection		OTDR measurements	Redundancy of communication line	II	III	I	6
Sheath voltage limiters in link box	5	Short-circuiting	Water ingress	No balance in cross bonding	Extra loss and lower rating	Sheath test Monitoring of screen currents	Regular sheath test	II	III	I	6

Table 11.4 Damaged state analysis on items in a specific cable section (example from city area)

[1)] See section 11.6

11.5 Criticality matrix

The criticality matrix is described in Chapter 7. If the criticality matrix is used on Table 11.4 (and similar tables for the cable systems), the damage event number from Table 11.4 can be put into the criticality matrix on the correct positions given by the severity level and probability level.

Section 1 - City area

Probability	**V**					
	IV					
	III		4 5	1		
	II			3		2
	I					
	Severity	**I**	**II**	**III**	**IV**	**V**

Table 11.5 Criticality matrix for cable section 1 (city area)

The matrix can be used to identify the most critical damaged states and take the necessary countermeasures.

In the example something must be done to lower the risk of damage event no. 2 (red area). If the consequence is high (in the example it is III), this type of damage must be avoided if possible.

For damage event no. 1 it must be assessed whether it is possible to lower the probability or the severity so that the risk can be moved down into the green area. In this assessment the consequences for the network must be taken into account in order to determine the maximum amount of money to be spent on reducing the risk for the cable system. In the example the consequences are low.

Damage events in the green area can be accepted. The risk is so low that normally the consequences can be ignored.

Many other damage events must be analysed and assessed for the cable system. Table 11.4 only gives an idea as to how to use the approach.

11.6 Cable Protection Index (CPI)

In the previous section, the assessment is given in words. Another possibility is to combine risk and consequence, thus generating a new number: 'Cable Protection Index' (CPI). The CPI can be used in the prioritisation of the different cable sections where something must be done to lower the risk of third-party damage.

Using the class levels from section 11.4 the risk level can be calculated as

Risk = Severity * Probability

If the risk level is higher than or equal to 10 (the red area in the criticality matrix, Figure 11.5) something must be done to reduce the risk.

Risk ≥ 10 => do something

The Cable Protection Index can be calculated as

CPI = Risk * Consequence
= Severity * Probability * Consequence

If the CPI is equal to or less than 15, there is normally no need to change anything.

If the CPI is higher than 15, further studies are recommended to identify cost-effective solutions capable of reducing the risk or the consequence.

If the CPI is higher than 25, something must be done to reduce the risk or the consequence.

CPI ≤ 15 OK
CPI > 15 => Further studies
CPI > 25 => Measures to reduce risk or consequence

12.Recommendations

Focus must be on the primary damage events, because if these can be avoided, some electrical failures can be avoided.

12.1 Underground cables

12.1.1 Preventive actions

Possible preventive actions and detection methods to identify the short-term effect before the damage leads to an electrical failure are recommended as follows:

- Sheath test at regular intervals
- Installation and monitoring of optical fibres close to the power cables
- Check of fluid pressure of fluid-filled cables - online or at regular intervals
- Regular inspections

12.1.2 Warning devices

The use of warning devices such as warning tape, warning nets or red coloured die on top of concrete protecting structures is recommended even though they do not really protect a cable. The purpose of these systems is to call attention to the presence of a cable.

12.1.3 Mechanical protection

Plastic or concrete cover plates are suitable for protection against damage caused by hand tools and plants, not for the protection against digging machines.

Cables in pipes, weak mix, troughs and ducts offer an increasing mechanical protection. Cables in concrete encased ducts (ducts banks, as shown in Figure 4.7), with minimum 75 mm of concrete all around the ducts, provide high levels of mechanical protection. But even these systems do not always offer sufficient protection against damage caused by heavy machines.

Cables in tunnels are well protected against third-party mechanical damage, but the risk of damage caused by other systems installed in the tunnel or fire in the tunnel cannot be neglected.

It is recommended to include an assessment of the mechanical protection for new cable installations. The method depends on the risk of damage compared with the importance of the cable in the network.

In existing cable systems it is difficult and expensive to improve the mechanical protection.

12.1.4 Administrative procedures

It is recommended to make national laws about these procedures. Civil contractors do not always ask for permission to carry out their activities and for that reason they do not have drawings and other important information at their disposal. To reduce the risk of third-party damage national legislation on how to prepare excavation activities is recommended.

To ensure that contractors and utilities exchange the correct information, it is important to use administrative procedures which are

- easy to know
- easy to understand

- easy to handle

12.1.5 Route records

For the new installations, it is important to have a well-defined coordinate system. It is recommended to measure all three coordinates. The third coordinate (z-coordinate) referenced to vertical datum might be useful in the future.

For the old cable systems, depending on the importance of this system and the probability of third-party damage, it could be advantageous to record the cable route again.

It is recommended to use a geographical coordinate system (e.g. UTM (WGS84)) or an accepted and well-known regional coordinate system.

12.1.6 Information and education

Administrative tools, warning devices, cable detectors or mechanical protection of the cables are useless if the parties involved do not understand the importance of careful working.

Information and education of all the involved people is one of the most important tasks of the industry in order to lower the risks of third-party damage to underground cables.
A good relationship with local workers and contractors is often helpful. Periodic consultation with contractors working in a local area might be a way of convincing them that reducing third-party damage is in the common interest.

12.1.7 General recommendation

Generally speaking the following must be done:

- Correct information about cable route (cable record) must be collected and stored by the operator
- Third parties must know how to get permission to do their civil engineering and construction work or similar jobs
- The central point of contact or the cable operator must provide relevant parties with the correct information in time
- The third party must wait for information
- The third party must understand the information correctly
- The third party must act correctly on the basis of information received

12.2 Submarine cables

12.2.1 Preventive actions

Some damage events can be anticipated if a geophysical survey is made of the cable route. The following surveys are recommended:

- A bathymetric survey can show whether the seabed profile has changed.
- A survey showing the cable burial depth which can be compared with a previously made similar survey. The survey discloses whether the cable still is protected as required or if the seabed has changed. This is relevant in dynamic areas (sandy areas) but also if a sand-pump dredger has made changes.
- A side scan or multi-beam sonar survey can sometimes show the trawling activity in the area and any objects (anchors, fishing net and trawl, anchor chains etc.) attached to the cable. The side scan can also disclose whether the submarine cable is visible at the seabed and therefore not protected.

Cable inspections of potential problem areas can be made using an ROV (Remote Operated Vehicle). Because such inspections can be very expensive for long cables, it is recommended that areas to be inspected are based on the results of periodic multi-beam sonar surveys, to monitor changed conditions on the sea bed.

If a fibre-optic cable is installed close to the submarine power cable (or is an integral part of it),it is recommended to monitor one or more of the fibres to check if something happens to the cable.

In case of new installations it is recommended to assess whether fibre-optic cables should be installed together with the power cable. The fibre-optic cable can be used for communication, thermal monitoring and monitoring of the general conditions of the cables.

12.2.2 Mechanical protection

If it is possible to bury the cable into the seabed, the burial depth in sand or soft soil must be at least 0.5 m to protect the cable against fishing gear.

A risk assessment regarding anchors is recommended to clarify if burial at a greater depth can provide better protection.

If it is not possible to bury the cable because of the soil conditions (very hard seabed), the cable can be protected by mattresses or by rock dumping. This is normally done for shorter distances only.

In areas with water depth of more than 200 m the risk of damage from anchors is low. Depending on the fishing activity it can be chosen not to make a protection of the submarine cable in such a situation.

Close to the shore - in shallow waters - protection must be established. Where cables are going onshore, they can be protected in ducts. Sometimes it is possible to make a directional drilling from the coast out into the water. In that way the cable will be protected close to the coast line. However, heating effects may reduce transmission capacity.

12.2.3 Administrative procedures

It is the submarine cable owner's responsibility to ensure that information about all submarine cables is given to the hydrographic organisation responsible for updating the charts. The recorded data must be delivered in a format suitable for the electronic charts. Demands in respect of formats can be provided by the hydrographic organisation.

12.2.4 Route records

It is important for all submarine cable installations to have a well-defined coordinate system. It is recommended to measure all three coordinates of the cable position. The seabed surface and the water depth must be recorded too.

It is also important to register burial depth relative to original seabed in the cable record. The burial depth may change if the seabed changes.

It is recommended to use a geographical coordinate system (e.g. UTM (WGS84)) or an accepted and well-known regional coordinate system.

12.2.5 Information and education

If it is known that some parties do not obey the law, it can be necessary to make patrols along the cable. Giving information to the crew on board the vessels is also an option.

Foreign fishermen in areas with other maritime laws are in force must be informed about legislation in the specific country. It might be a good idea to make flyers for the foreign fishermen about local legislation and procedures so that everybody is well informed.

A good relationship with local fishermen and contractors is important so that everyone is aware of the cables.

Regional or national cooperation between submarine cable owners in order to inform about submarine cables can be one way to ensuring that more people get the message: Be aware of submarine cables!

12.2.6 General recommendation

Generally speaking the following must be done:

- Correct information about cable route (cable record) must be collected and stored by the cable operator
- Information about all submarine power cables must be given to the institute (or similar) responsible for updating the charts
- Updated charts must be present on vessels
- Marine officers and pilots must be familiar with the local conditions and know who to contact in emergency situations
- Fishermen must have updated charts on board their vessels and know the location of submarine cables
- Fishermen must know whether it is forbidden to use bottom trawl in a zone
- Fishermen must act correctly when it comes to forbidden zones
- Fishermen must know who to contact if they hit a submarine cable
- Cable operator must know how to act when an anchor or fishing gear hits the submarine cable

12.3 Cable Protection Index

It is recommended to use the Cable Protection Index (CPI) in the prioritisation of the different cable sections where something must be done to reduce the risk of third-party damage.

Using the class levels from section 11.4 the Cable Protection Index can be calculated as

CPI = Risk * Consequence
= Severity * Probability * Consequence

CPI ≤ 15 OK
CPI > 15 => Further studies
CPI > 25 => Measures to reduce risk or consequence

13.Conclusion

Based on

- data provided by Cigré working group B1.10 (Service experience of underground and submarine HV cable systems)
- data provided by Cigré working group B1.21 (who has made this report) about failures to cable systems
- general knowledge and service experience in the working group B1.21 about cable systems

the working group has assessed which threats underground and submarine cables are exposed to.

The surveys show:

- Failure caused by an external agent is the most frequent type of failure. About 70% of the failures are caused by mechanical works.
- About 40% of third-party damage has to do with insufficient information exchange between cable operators and construction companies.

It has also been studied how to reduce the probability of damage events:

- One of the most efficient ways of reducing the risk of third party damage to underground cables is to focus on good cooperation with construction companies.
- It is also important that construction companies have easy access to user-friendly and efficient tools to help finding out who to ask for permission before starting excavation works and how to get the information about cables in the working area.
- Mechanical protection of cables also seems to be effective to reduce the risks of damage caused by a third party. Especially for submarine cables mechanical protection is important. For underground cables mechanical protection (ducts and tunnels) is a question of risk versus costs.
- Increased attention needs to be given to mechanical protection against third-party damage, especially for directly buried cables.

A systematic approach has been developed to give guidance how to compare risks for all cable systems in service. The method helps to prioritize the work to be done in order to reduce the risk of third party damage to cable systems.

Taking the consequences for the network into account the Cable Protection Index (CPI) has been defined as a product of probability of a certain damaged state, the severity of the damage effects and the consequences for the network. Defining the probability class, the severity class and the consequence class as numbers between 1 and 5, the CPI is a number too, giving a quick overview of the status of a specific cable section.

In numbers the conclusion is:

CPI ≤ 15 OK
CPI > 15 => Further studies
CPI > 25 => Measures to reduce risk or consequence

Appendix 1: Survey on third-party damage to underground cables

In this appendix the answers (21 responses) to the questionnaire sent to the utilities from WG B1.21 are summarised.

Exchange of information		
#	**Questions**	**% Yes**
1	**Is the 'Contractor' obliged to ask/search for information regarding the presence of possible underground cables before starting his activities?**	95
	- Is there an act, a regulation or a recommendation that governs or describes this system?	71
	- Details about act, regulation, recommendation - please fill in 'extra explanations' if possible	
2	**If the answer to question 1 is YES, please indicate with YES which statement is appropriate:**	
	- Required by the Government?	57
	- Required by the Insurance Companies?	29
	- Is there a Central Contact Point (regional or national)?[1]	62
	- Must the Contractor search for all necessary information by himself?[2]	67
3	**How is this information distributed to the Contractor?**	
	- Detailed plans are sent to the Contractor	90
	- On-site appointments are made with the Contractor	76
	- Others - please fill in 'extra explanations' if possible	10
4	**What is the accuracy of the given information?**	
	- Exact location of the underground cables	33
	- Only indicative, exact location to be checked on site	71
5	**What type of information was given to the contractor?**	
	- Analogue data	71
	- Digital data	48
	- Data in a local coordinate system	38
	- Data in a geographic information system (GIS)	48
6	**When was the information given to the Contractor?**	
	- Within a week	71
	- Between 1 and 2 weeks	29
	- More than 2 weeks	5
7	**If the Contractor is obliged to ask (see question 1) - how often, relative to the number of times that he is forced to ask, does he actually ask?**	
	> 95 %	52
	> 75 %	24
	> 50%	5
	< 50 %	10
8	**If the answer to question 1 is NO, please give a short explanation of common practice:**	

Table App. 1. 1 Exchange of information

[1] By means of an internet access/central organisation with logbooks (file) that can be contacted

[2] The question here is: Is the contractor himself responsible for collecting all the information necessary, or does the utility organisation have to provide all the information necessary?

How are the underground cables installed, as a percentage of the total installed cable length for each voltage level?										
		All - number of hits			**All - Average**			**All - Average, adjusted to 100% sum**		
		# replies	21							
Submarine cables by installation type?		**≤ 36kV**	**> 36 kV and ≤170 kV**	**> 170 kV**	**≤ 36kV**	**> 36 kV and ≤170 kV**	**> 170 kV**	**≤ 36kV**	**> 36 kV and ≤170 kV**	**> 170 kV**
Direct burial		10	14	7	112%	77%	59%	**66%**	**43%**	**24%**
Direct buried pipes	Plastic	6	8	4	19%	14%	28%	**11%**	**8%**	**11%**
	Metallic	1	4	1	3%	30%	35%	**2%**	**17%**	**14%**
Ducts - pipes in blocks of	Concrete	2	7	2	15%	41%	61%	**9%**	**23%**	**25%**
	Other material	1	0	0	12%	0%	0%	**7%**	**0%**	**0%**
Tunnels		3	5	2	3%	8%	60%	**2%**	**5%**	**24%**
Others		2	6	1	6%	9%	5%	**3%**	**5%**	**2%**
					170%	179%	248%	**100%**	**100%**	**100%**

Table App. 1. 2 Cable installation method

Which additional measures to protect the cable are used?		
Additional protective measures		**# YES**
Direct burial or pipes	Protective plates/tiles	18
	Warning tapes	17
	Marking poles	10
	Others	4
Ducts	Warning tapes	11
	Marking poles	4
	Others	3

Table App. 1. 3 Additional measures

Give the percentage of the possible causes as specified below, regarding to total Third-Party Damage (TPD)			
Causes of TPD	**# Hits**	**Average % number of replies**	**Average % number of replies - adjusted to 100% sum**
Digging works	17	62%	**69%**
Horizontal drilling	12	10%	**12%**
Vertical drilling	13	14%	**16%**
External heat sources	0	0%	**0%**
Others	5	3%	**3%**
		89%	**100%**

Table App. 1. 4 Possible causes of TPD

How often (relative to what he is obliged to do) does the contractor himself inform the cable owner that he has damaged the cable (even if no breakdown occurred?	
Information from Contractor when TPD	**# YES**
> 75%	7
> 50%	4
< 50%	6

Table App. 1. 5 Contractor's information about TPD to cable operator

Are the cables' outer anti-corrosion sheaths electrically tested on a regular basis? (for direct buried cables with semiconducting outer sheath - see IEC 60229)	
	# YES
Regular sheath test?	11
If yes: Periodicity? Average # of months	16
If no: Why not?	

Table App. 1. 6 Outer sheath tests

Third-party damage was caused by the following			
Cause of TPD	**# Hits**	**Average % number of replies**	**Average % number of replies - adjusted to 100% sum**
Third party did not ask if there were any cables	17	28%	**33%**
Third party did not use the information provided	10	15%	**17%**
Third party used the information in a wrong way	16	33%	**38%**
Cable owner did not answer	2	1%	**1%**
Cable owner did not provide sufficient information	8	3%	**3%**
Third party damaged the cable system even if he had the correct information and used the information in the correct way	7	5%	**6%**
The physical protection of the cable had changed	2	0%	**0%**
Other	3	1%	**1%**
		86%	**100%**

Table App. 1. 7 Reasons of TPD

How could the third-party damage have been avoided?			
How avoid TPD?	**# Hits**	**Average % number of replies**	**Average % number of replies - adjusted to 100% sum**
Better administration	5	4%	**4%**
Better control/visual inspections	12	24%	**25%**
Better physical protection	6	7%	**7%**
Better instruction to contractor	8	8%	**8%**
Better general education and information to contractors	11	20%	**21%**
Better communication between contractor and cable company/owner	15	24%	**25%**
Other	4	4%	**4%**
It could not have been avoided	3	5%	**6%**
		96%	**100%**

Table App. 1. 8 How to avoid TPD

How could third-party damage have been detected before it lead to electrical breakdown?			
How to detect TPD?	**# Hits**	**Average % number of replies**	**Average % number of replies - adjusted to 100% sum**
Sheath test	11	14%	**19%**
Thermal monitoring	1	0%	**0%**
Visual inspections	9	16%	**21%**
Better communication between contractor and cable company/owner	13	36%	**47%**
Other	3	9%	**13%**
		75%	**100%**

Table App. 1. 9 How to detect TPD

Suggestions to avoid third-party damage	
1	**Exchange of information**
1.1	*Central contact point? How? What? Regulated by government?*
	- We suggested that the central contact point, which is regulated by the local authorities, should centralise information and imposes on all companies and utilities a duty to search for data on underground interferences before starting their activities. - Central registration of the contractor's projects in the area, one month before the start. The power companies can organise route inspections. - Government regulation would help, if enforced. - Third party should ask for information before starting work - It would be a very good idea if the owners were obliged to give the information to a contact point. Such a scheme should be regulated by the government or by the local authorities at least. - Yes, I think that a central contact point for our local area (the city) will be established in the future. This central contact point will not be subject to any regulation, but will be a natural cooperation between the owners of underground cables and pipelines, also with participation from the parties responsible for roads. We already have such a co-operation when somebody asks for information for design purposes, but it has not been extended to include digging works as well. - Our electrical company has a call centre, operating 24/7 that could provide constructors with the necessary information - Central DBYD (Dial Before You Dig) for all services
1.2	*Others?*
	- Local authorities can organise own inspections. - Insurance company enforcement. - Municipal government could be in possession of all plans of undergrounds cables, pipelines, ducts, etc. with contacts of companies to give extra information
1.3	*Information to contractors*
	- The contractors should ask for information and explanation about underground interferences. - On site extended assistance. - We occasionally provide contractors with information and education. More regular information about the regulation may help. - Careful work procedure implemented by third party - The relationship between the contractor and the owner is very important. It would be a good idea for contractor and owner to sign a document before starting the work. In this document, they should express a commitment to share information and have periodical meetings. - Must always be done on a regular basis. - All the utilities must play their roles, not relying too much on contractors. An institute or the like with representatives from power, telecom, gas, water, sewer, subway and roads could be established to perform enlightenment activities. - We have cable surveillance officers monitoring 110 kV feeders and oil-filled cables on a regular basis (monthly). They also get DBYD (Dial Before You Dig) info and are present when contractors are working around 110 kV & OF cables (those cables that are expensive to fix).

2	**Mechanical protection and marking**
	- We suggest using encased ducts in concrete with signalising tapes. - In connection with risk assessment of the route (old or new) a risk class for mechanical damage from 1 to 3 (3 stands for highest risk) must be assigned. Cables in zone 3 must be protected with metallic plates, pipes, special constructions. - The physical protection is assessed from time to time (money/requirement) - It would be good for security to build service corridors (at least for high-voltage underground lines, 220 kV and 400 kV). - Depends on the type, voltage and importance of the cable. - Reinforced concrete plates - Improve a remote monitoring system to detect failures in the covers of the cables (through leakage current and oil-pressure measurement) - Use concrete encased duct lines for HV cables. Improve sidewall impact protection from horizontal drilling (probably uneconomical against benefits) - After getting the cables location and information if the contractor ensure the actual cable location by potholing then a lot of incidents can be avoided
3	**New methods to indicate the cable route?**
	- Radio, battery-powered generators (battery life 5 years) - More use of digital information - Maybe it is very difficult to mark all the cables, but it would be useful to mark at least the joints. - Warning board along cable route - We intend to use GPS to identify the line - Electric Marker System may be helpful even if it can only be used for new constructions - High-precision GPS may be helpful - Encourage use of service location companies and electronic detection methods. Encourage use of on-call contact number if in doubt.
4	**Additional methods to better protect existing cables?**
	- Marks on the route. Reviving an old method. Metal plates cast in asphalt/concrete on the roads (valid in risk 3 town area). - A good relationship between contractor and owner is the best way to protect cable routes. Legislation should be more accurate and stipulate, for example, how often contractor and owner should meet. - Increase the number of warning boards with a more frequent survey of the cable route to garrison the territory - Maintain cable markers where cable crosses parklands or unmade ground
5	**Measurements and tests to detect third-party damage before breakdown?**
	- Depends on the cable type. Oil-filled cables very rarely break down. Damage to outer sheaths is easy to detect, but difficult to localise. Damage to XLPE cables can be detected through electrical testing of the outer sheaths. Difficult to localise. - Sheath tests when there is suspicion of TPD. - Sheath tests every year and temperature monitoring. - Oil-pressure measurement (for oil-fluid cables only) - Alarm of leakage current added to the alarm of low pressure in the underground cables - Sheath voltage test or sheath current measurement can be used, but there is no cost-effective method
6	**How to improve new installations and thus minimise the risk of third-party damage?**
	- Cables inside ducts cast in concrete with signal tape. - Better information to third party - Provide good information: Digital plans and data. - Selection of good cable routes where future digging works might be minimal (easier to say than to do!). More use of tunnels and directional drilling. - Improve the remote electrical monitoring system

7	**Other suggestions to avoid third-party damage?**
	- Make regular presentations to all the utilities and other companies in order to find a compromise. - We offer a free cable-locating service, but we also carry out constant surface route monitoring of our cables. This is done by the cable personnel carrying out the free cable-locating service. - Periodic meetings with contractors working in the area. - Penalties to be increased. - Make the contractors observe existing legislation - Signing a document (see point 1) would be very useful - Promote meetings among contractors and companies making use of the underground - Monitoring the route every day - Route inspections once a year - Oversight of civil engineering works performed close to underground cables (check the nature of the civil engineering work and the instructions to be observed by contractors) - HV cables in tunnels

Table App. 1. 10 Suggestions to avoid third-party damage

Appendix 2: Survey on third-party damage to submarine cables

In this section the answers to the questionnaire sent to the utilities from WG B1.21 are summarised.

Table App. 2.1 shows a statistic on the administrative tools used in connection with the exchange of information and ways of exchanging information between the utilities and the possible parties causing the damage. Table App. 2.2 shows the results of the survey on third- party damage to submarine cables. Table App. 2.3 lists the suggestions from the utilities to avoid third-party damage to submarine cables.

Exchange of information		
#	***Questions***	***% Yes***
1	Is there a national authority responsible for updating charts?	75%
	- Are the updated charts used onboard the ships?	42%
2	What kind of information was sent to other parties (fishermen, fishery organisations etc.)	
	- Analogue charts	58%
	- Digital information with position lists, etc.	33%
	- Other information	([3])
3	Is there a central authority responsible for sending notices to mariners about new submarine cables and work being performed on submarine cables?	58%
4	Are Vessel Monitoring Systems (VMS) used to make it possible to control and contact vessels close to the submarine cables?	25%
5	Is there a protection zone close to the submarine cable where restrictions are enforced on activities?	67%
	- If YES - what kind of restrictions?	([4])
6	Are there special corridors for submarine cables which act as protection zones?	33%
7	Are bottom-fishing trawlers fishing over the submarine cables?	33%
	- If YES - is it done legally?	50%

Table App. 2. 1 Exchange of information

[3] Some answers:
- cable owner contacts the fishery organisations;
- other parties are informed about the cable route.

[4] Some answers:
- casting anchors, fishing, digging are not allowed between beacons as well as in a 200 metres wide corridor on both sides;
- anchoring or using bottom-trawling equipment is not legal;
- there is a no-anchoring zone.

Third-party damage to submarine cables					
1	***How are the submarine cables installed, as a percentage of the total installed submarine cable length for each voltage level?***				
	Submarine cables by installation type		**%**		
			≤ 36kV	**> 36 kV and ≤170 kV**	**> 170 kV**
	Installation direct on sea bed		26%	17%	21%
	Buried more than 0.5 metres (fixed target line)		18%	28%	25%
	Protection (burial or other measures) close to shore		23%	19%	23%
	Burial depth depending on soil conditions		33%	37%	32%
2	***Which additional cable protection measures are used?***				***% Yes***
	Rock dumping	where burial is not possible			25%
		crossing other lines			0%
		other			0%
	Mattresses	where burial is not possible			17%
		crossing other lines			0%
		other			0%
	Pipes	crossing other lines			8%
		shore sections			33%
		other			0%
	Other				42%
3	***Give the percentage of the possible causes as specified below regarding total third-party damage***				***% of total TPD***
	Anchors				69%
	Fishing gear				5%
	Explosions				0%
	Excavation				13%
	Tow wires with heavy load ('dead man')				0%
	Other				13%
4	***Do you control or monitor the burial depth of submarine cables on a regular basis?***				
	Regular control?		% Yes		42%
	If yes: Periodicity?		Months		46
5	***TPD was caused by the following reason***				***%***
	Cable not on chart				1%
	Chart not onboard of vessel				31%
	Cable not located as shown on chart				0%
	Emergency situation				26%
	Vessel not aware of cable				42%
	Cable protection had changed				0%
6	***How could TPD have been avoided?***				***%***
	Better administration				1%
	Better control/visual inspection				26%
	Better physical protection				19%
	Better charts				2%
	Better information to mariners				29%
	Other				4%
	TPD could not have been avoided				19%

Table App. 2. 2 Result of the survey on third-party damage to submarine cables

Suggestions to avoid third-party damage to submarine cables	
1	***Exchange of information***
1.1	How could the distribution of new charts and information about existing and new submarine cables be improved?
	- National authority needs to centralise information and imposes a duty on all mariners and fishermen to search for data on underground interferences before starting their activities. - Updated maps distributed every year to the central authority responsible for maritime traffic.
1.2	How could information to local fishermen, mariners etc. about submarine cables be improved?
	- Make regular presentations in order to find a compromise.
2	***Mechanical/physical protection and marking***
	What is working well? What new ideas would achieve good physical/mechanical protection?
	- The cables are anchored in concrete on the shore, and sand sacks are used in between as protection - Cooperation with central authority responsible for maritime affairs. - Drilling near the shore. Burial depth between 0,6 and 1 metre. Where this is not possible, the cable should be protected with concrete mattresses. - Embedment
3	***New methods of indicating the cable route?***
	Experience and new ideas?
	- Cable detectors onboard vessels. - Geo-referencing the cable route during cable laying.
4	***Additional methods of improving the protection of existing cable routes?***
	- Improve electronic charts.

Table App. 2. 3 Suggestions to avoid third-party damage to submarine cables

Appendix 3: Examples of administrative procedures, underground cables

In Appendix 3 four different examples on administrative procedures involving specific tools are shown. The examples are from The Netherlands, Belgium, Denmark and France.
Another interesting example - not shown in this appendix - is from Singapore (SP Powergrid).

Klic (The Netherlands)

(Cable and pipeline information centre)

Purpose:

- to avoid damage to cables and pipelines

History:

- Developed 1980 – 1990 by a few large national and regional operating cable and pipeline operators
- Started as four regional organisations
- In 2002, a decision was made to merge the four organisations into one
- Since 1 January 2005 one national organisation and service in one operational call centre
- Regulated by legislation since 1 January 2008

Organisation:

- Nearly all (about 1000) pipeline and cable operators collaborate within Klic (telecom, water, gas, electricity, cable-TV, sewage, etc). Membership was voluntary. Steering committee consisting of the five or six largest operators
- Regulated by legislation since 1 January 2008. Since that date the Land Registry is responsible for the operation of the system
- About 160,000 annual requests for information (telephone, fax, e-mail)
- About 1,100,000 messages to digging companies

Proces Klic

- Klic knows where the participating operators have their cables or pipelines in each area.
- Cable and pipeline operators indicate their interests with polygons
- Contractor notifies Klic about the excavation works he is planning in a certain area
- Klic knows which operators have interests in the area in question and informs all these operators
- Klic sends a message to the contractor: he knows that the operator in question has been informed
- Contractor receives the required information (analogue or digital) from the cable and pipeline operator within three days.
- In the future information will be exchanged through an internet application.

Process member Klic

- Sends information to Klic about new/replaced cables and/or pipelines.
- Receives requests for information from Klic
- Sends information to contractor within three days and gives information about location, if necessary

Responsibility

Klic:	Information to cable and pipeline operators and sends back a message for conformation to the contractor
Operator:	Information to Klic about location of new/changed cables and pipelines
Operator:	Correct information to contractor/information on location
Contractor:	Avoid damage

The Belgian KLIM/CICC - Project

CICC = Federal Contact point for Information about Cables and Conduits

How did it start?

On 20 July 2005 the Federal Government, Utility companies (Elia, Fetrapi = federation of Utility companies using pipelines) and the Building federations has signed an agreement to create a national information point for underground cables (from 36 up to 150kV cables) and conduits and overhead lines.

Fetrapi and Elia have taken the initiative to create this national information point. The project was called KLIM/CICC.

The purpose is to create a Web-browser based information point. After registration, everyone can consult this information point.

How does it work?

1. Utility companies with underground infrastructure provides the following information to KLIM/CICC:
   - Geographic information regarding underground infrastructure. This information is translated in areas of interest (interception).
     This information is not visible for the users.
   - Central and/or regional contact persons.

2. Users, consulting the site, need to provide following information:
   - On a detailed map the user marks his work area.
   - Description of work.
   - Coordinates of contact person

3. KLIM/CICC
   - KLIM/CICC makes a crosscheck of the work area with the different areas of interest for all the utility companies.
   - KLIM/CICC sends a confirmation of the request to the user.
   - KLIM/CICC sends a list of all involved Utility companies to the user, including contact persons.
   - KLIM/CICC sends a demand for detailed information to the involved Utility companies together with the coordinates of the user (requester).

After this process further correspondence and contacts are directly between contractor and Utility Company.

Timing:

Website ready: December 2005
Security tests: January – February 2006
Step 1: Necessary Legal approval for official use - January 2006
Step 2: Federal law which obliges the use of KLIM/CICC – January 2007

The Danish Register of Underground Cable Owners

General
The Danish legislation on the building, servicing, maintenance and safety of electrical installations oblige contractors to ask the utilities for the exact location of their cables before starting digging. In other words, there is a general obligation for contractors to ask the utilities for information.

''The Danish Register of Underground Cable Owners'
In 2005, Denmark introduced legislation concerning the registration of underground cables. The legislation obligs all cable owners to have their underground cables in public roads and private roads registered in 'The Danish Register of Underground Cable Owners' called 'LER'.

The purpose of the legislation was to prevent accidental damage to underground utility cables (carrying gas, electricity, telephone signals, drinking water, heating water, waste water etc.), to lower administrative expenses in the contracting sector and to increase the security of supply. The immediate beneficiaries are professional cable owners and contractors and, in the long term, the end-users of utilities.

The LER contains information about all companies and associations owning underground cables in Denmark. All cable owners have registered their areas of interest in the register. An area of interest is the geographical area where a cable owner has his cables. The exact location of cables is thus not registered. Since 1 September 2005, all companies performing underground construction activities have been legally obliged to make enquiries in the register before starting up activities.

The LER basically works like a phone book ensuring contact between cable owners and contractors. When a contractor make an enquiry in relation to a specific construction site, the contractor receives contact details on all owners of underground cables at the site. Based on this information the contractor can easily contact the correct cable owners and receive detailed information about the specific location of cables. Private citizens are not obliged to register their cables in the LER. In addition, they are not obliged to make enquiries in the register when they perform construction activities on their own property, although they can choose to do so.

Facts:
- The LER is based on an internet database with GIS maps.
- The LER is financed by the users asking for information.
- Cables placed under public and private roads must be registered in the LER. This information must always be updated.
- Contractors must always consult with the LER before starting digging in public and private roads.
- Requests to the LER must be answered as soon as possible – at the latest within 14 days.

Surveying
In Denmark the positions of all new power cables are registered in X and Y coordinates and often also in Z coordinates. The cable position is drawn on a map. This means that it is easy to give detailed information about the specific location of cables to the contractors.

The situation for old power cables is different because some of them are only registered on a map (paper drawing). This means that if changes occur in the area (change of buildings, roads etc.) it can be difficult to be sure of the exact position of the cables.

The French system

Who is covered by the French Legislation?

The French legislation relating to construction work performed close to underground installation involves the following major actors: the local authorities in the village/town involved in the civil engineering work, the cable owners, the project manager of the civil engineering work and the contractors or subcontractors in charge of the work.

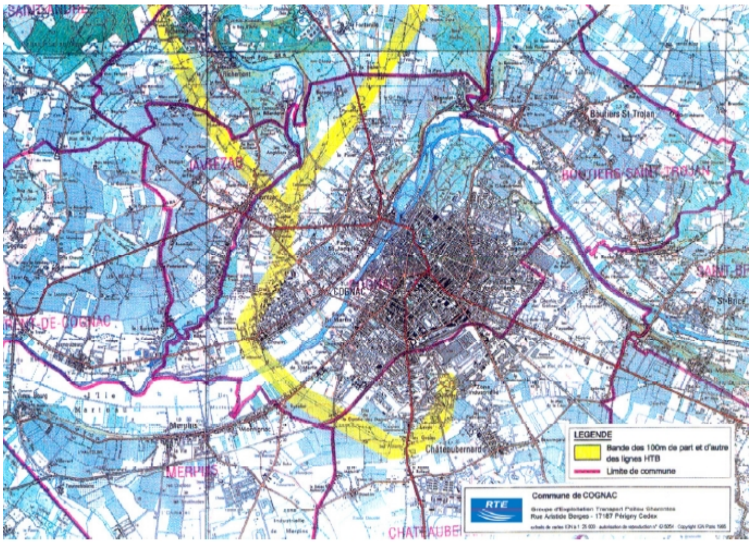
Who, what, when?

Legislation defines two phases:

- during the examination and project studies
- immediately before the start of construction work.

During the examination and project studies:

- ✓ The project manager must ask the local authorities in the villages/towns affected by the earth-work about the presence and location of potential underground cables in the area of the earthwork.
- ✓ To do that, the project manager consults (with the local authorities or on their website) 'zoning maps'. These zoning maps, established and updated by each cable owner, list all the points situated less than 100 metres from an underground installation.
  NB: cables owners are responsible for the information collected from local authorities. The cables owners must update their address, telephone number and the zoning plan of their installations.



- ✓ If the earthwork is performed in a zone defined by the zoning map, the project manager must send a 'DR', i.e. an information request (DR = Demande de Renseignement) to each cable owner concerned, written in a legal form.
  If the earthwork is not performed in a zone define by the zoning map, the earthwork is allowed to start without any other requirements having to be met.
- ✓ The cable owners must respond within one month.
  If the earthwork is located close to an underground cable (for example, a power cable, less than 1.5 m from the cable), the contractor or the subcontractor in charge of the work will have to send a 'DICT', i.e. a declaration of intent to start the work (DICT = Déclaration d'Intention de Commencement de Travaux) to the cable owner before starting the work.
  If the cable owner does not respond within the time limit, the earthwork is allowed to start within a period of six months without any other requirements having to be met.

Just before the start of the construction work:

- ✓ If a DR reveals that the earthwork is performed close to underground cables (cf. previous section), the contractor or the subcontractor in charge of the work must send a 'DICT' to each cable owners concerned, in a legal form.
- ✓ The cable owners must be in receipt of this DICT at least ten days before the work commences.
- ✓ The contractor or the subcontractor must be in receipt of a response from the cable owners at least nine days after the cable owner has received the DICT.

- ✓ The cable owners must notify the contractor or subcontractor, with their responsibility and with a maximum of information and details, the location of their installations and attach any technical recommendations adapted to the work and to the underground installations.
  NB: Earthwork performed close to a power cable (less than 1.5 m from the cable) is not allowed to begin without this response from the operator concerned.

Appendix 4: International conventions regarding submarine cables in international waters

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UNITED NATIONS LAW OF THE SEA CONVENTION (UNCLOS) (1982)

Article 3. Breadth of the territorial sea.
Every State has the right to establish the breadth for its territorial sea up to a limit not exceeding 12 nautical miles, measured from baseline determined in accordance with this Convention.

Article 33. Contiguous zone.
1. In a zone contiguous to its territorial area, described as the contiguous zone, the coastal State may exercise its territory or territorial sea;
(a) prevent infringement of the above laws and regulations or sanitary laws and regulations within its territory or territorial sea;
(b) punish infringement of the above laws and regulations committed within its territory or territorial sea.
2. The contiguous zone may not extend beyond 24 nautical miles from the baselines from which the breadth of the territorial sea is measured.

Article 57. Breadth of the exclusive economic zone.
The exclusive economic zone shall not extend beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured.

Article 58. Rights and duties of other States in the exclusive economic zone.
1. In the exclusive economic zone, all States, whether coastal or land-locked, enjoy subject to the relevant provisions of this Convention, the freedoms referred to in Article 87 of navigation and overflight and of the laying of submarine cables and pipelines, and other internationally lawful uses of the seas related to these freedoms, such as those associated with the operation of ships, aircraft and submarine cables and pipelines, and compatible with the other provisions of this Convention.
2. Articles 88 to 115 and other pertinent rules of international law apply to the exclusive economic zone in so far as they are not incompatible with this Part.
3. In exercising their rights and performing their duties under this Convention in the exclusive economic zone, States shall have due regard to the rights and duties of the coastal State and shall comply with the laws and regulations adopted by the coastal State in accordance with the provisions of this Convention and other rules of international law in so far as they are not incompatible with this Part.

Article 77. Rights of the coastal State over the continental shelf.
4. The natural resources referred to in this Part consist of the mineral and other non-living resources of the sea-bed and subsoil together with living organisms belonging to sedentary species, that is to say, organisms which, at the harvestable state, either are immobile on or under the sea-bed or the subsoil.

Article 79. Submarine cables and pipelines on the continental shelf.
1. All States are entitled to lay submarine cables and pipelines on the continental shelf, in accordance with the provisions of this article.

2. Subject to its right to take reasonable measures for the exploration of the continental shelf, the exploitation of its natural resources and the prevention, reduction and control of pollution from pipelines the coastal State may not impede the laying or maintenance of such cables or pipelines.
3. The delineation of the course for the laying of such pipelines on the continental shelf is subject to the consent of the coastal State.
4. Nothing in this Part affects the right of the coastal State to establish conditions for cables or pipelines entering its territory or territorial sea, or its jurisdiction over cables and pipelines constructed or used in connection with the exploration of its resources or the operations of artificial island, installations and structures under its jurisdiction.
5. When laying submarine cables or pipelines, States shall have due regard to cables or pipelines already in position. In particular, possibilities of repairing existing cables or pipelines shall not be prejudiced.

Article 86. Application of the provisions of this Part.
The provisions of this Part apply to all parts of the sea that are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State. This article does not entail any abridgement of the freedoms enjoyed by all States in the exclusive economic zone in accordance with Article 58.

Article 87. Freedom of the high seas.
1. The high seas are open to all States, whether coastal or land-locked. Freedom of the high seas is exercised under the conditions laid down by this Convention and by other rules of international law. It comprises, *inter alia*, both for coastal and land-locked States:
(a) freedom of navigation;
(b) freedom of overflight;
(c) freedom to lay submarine cables and pipelines, subject to Part IV;
(d) freedom to construct artificial islands and other installations permitted under international law, subject to Part IV;
(e) freedom of fishing, subject to the conditions laid down in section 2;
(f) freedom of scientific research, subject to Parts IV and XIII;
2. These freedoms shall be exercised by all States with due regard for the interests of the States in their exercise of the freedom of the high seas, and also with due regard for the rights under this Convention with respect to activities in the Area.

Article 112. Right to lay submarine cables and pipelines.
1. All States are entitled to lay submarine cables and pipelines on the bed of the high seas beyond the continental shelf.
2. Article 79, paragraph 5, applies to such cables and pipelines.

Article 113. Breaking or injury of a submarine cable or pipeline.
Every State shall adopt the laws and regulations necessary to provide that the breaking or injury by a ship flying its flag or by a person subject to its jurisdiction of a submarine cable beneath the high seas done willfully or through culpable negligence, in such a manner as to be liable to interrupt or obstruct telegraphic or telephonic communications, and similarly the breaking or injury of a submarine cable pipeline or high voltage power cable, shall be a punishable offence. This provision shall apply also to conduct calculated or likely to result in such breaking or injury. However, it shall not apply to any breaking or injury caused by persons acting merely with the legitimate object of saving their lives or their ships, after having taken all necessary precautions to avoid such breaking or injury.

Article 114. Breaking or injury by owners of a submarine cable or pipeline of another submarine cable or pipeline.
Every State shall adopt the laws and regulations necessary to provide that if persons subject to its jurisdiction who are the owners of a submarine cable or pipeline, cause a break in or injury to another cable or pipeline, they shall bear the cost of the repairs.

Article 115. Indemnity for loss incurred in avoiding injury to a submarine cable or pipeline.
Every State shall adopt the laws and regulations necessary to ensure that the owners of ships who can prove that they rectified an anchor, a net or any other fishing gear, in order to avoid injuring a submarine cable or pipeline, shall be indemnified by the owner of the cable or pipeline, provided that the owner of the ship has taken all reasonable precautionary measures beforehand.

GENEVA CONVENTION ON THE HIGH SEAS

Article 1
The term 'high seas' means all parts of the sea that are not included in the territorial sea on in the internal waters of a State.

Article 26
1. All States shall be entitled to lay submarine cables and pipelines on the bed of the high seas.
2. Subject to its right to take reasonable measures for the exploration of the continental shelf and the exploitation of its natural resources, the coastal State may not impede the laying or maintenance of such cables or pipelines.
3. When laying such cables or pipelines the State in question shall pay due regard to cables or pipelines already in position on the seabed.
In particular, possibilities of repairing existing cables or pipelines shall not be prejudiced.

Article 27
Every State shall take the necessary legislative measures to ensure that the breaking or injury by a ship flying its flag or by a person subject to its jurisdiction of a submarine cable beneath the high seas done willfully or through culpable negligence, in such a manner as to be liable to interrupt or obstruct telegraphic or telephonic communications, and similarly the breaking or injury of a submarine pipeline or high-voltage power cable shall be a punishable offense. This provision shall not apply to any breaking or injury caused by persons acting merely with the legitimate object of saving their lives or their ships, after having taken all necessary precautions to avoid such breaking or injury.

Article 28
Every State shall take the necessary legislative measures to ensure that if persons subject to its jurisdiction who are the owners of a cable or pipeline beneath the high seas, in laying or repairing that cable or pipeline cause a break in or injury to another cable or pipeline, they shall bear the cost of the repairs.

Article 29
Every State shall have the necessary legislative measures to ensure that the owners of ships who can prove that they have sacrificed an anchor, a net or any other fishing gear in order to avoid injuring a submarine cable or pipeline shall be indemnified by the owner of the cable or pipeline provided that the owner of the ship has taken all reasonable precautionary measures beforehand.

Article 30
The provisions of this Convention shall not affect conventions of other international agreements already in force, as between States Parties to them.

GENEVA CONVENTION ON THE CONTINENTAL SHELF (1958)

Article 4. Subject to its right to take reasonable measures for the exploration of the continental shelf and the exploitation of its natural resources, the coastal State may not impede the laying or maintenance of submarine cables or pipelines on the continental shelf.

INTERNATIONAL CONVENTION FOR THE PROTECTION OF SUBMARINE CABLES 1884

Article 1

The present Convention shall be applicable, outside of the territorial waters, to all legally established submarine cables landed in the territories colonies or possessions of one or more of the High Contracting Parties.

Article 2

The breaking or injury of a submarine cable, done willfully or through culpable negligence, and resulting in the total or partial interruption or embarrassment of telegraphic communication, shall be a punishable offence but the punishment inflicted shall be no bar to a civil action for damages.

This provision shall not apply to ruptures or injuries when the parties guilty thereof have become so simply with the legitimate object of saving their lives or their vessels, after having taken all necessary precautions to avoid such ruptures or injuries.

Article 3

The High Contracting Parties agree to insist, as far as possible, when they shall authorize the landing of a submarine cable, upon suitable conditions of safety, both as regards the track of the cable and its dimension.

Article 4

The owner of a cable who, by the laying or repairing of that cable, shall cause the breaking or injury of another cable, shall be required to pay the cost of the repairs which such breaking or injury shall have rendered necessary, but such payment shall not bar the enforcement, if there be grounds therefore, of Article 2 of this Convention.

Article 5

Vessels engaged in laying or repairing submarine cables must observe the rules concerning signals that have been or shall be adopted, by common consent, by the High Contracting Parties, with a view to preventing collisions at sea. When a vessel engaged in repairing a cable carries the said signals, other vessels that see or are able to see those signals shall withdraw or keep at a distance of at least one nautical mile from such vessel, in order not to interfere with its operations. Fishing gear and nets shall be kept at the same distance.

Nevertheless, a period of twenty-four hours at most shall be allowed to fishing vessels that perceive or are able to perceive a telegraph ship carrying the said signals, in order that they may be enabled to obey the notice thus given, and no obstacle shall be placed in the way of their operations during such period. The operations of telegraph ships shall be finished as speedily as possible.

Article 6

Vessels that see or are able to see buoys designed to show the position of cables when the latter are being laid, are out of order, or are broken, shall keep at a distance of one quarter of a nautical mile at least from such buoys.

Fishing nets and gear shall be kept at the same distance.

Article 7

Owners of ships or vessels who can prove that they have sacrificed an anchor, or net, or any other implement used in fishing in order to avoid injuring a submarine cable shall be indemnified by the owner of the cable. In order to be entitled to such indemnity, one must prepare, whenever possible, immediately after the accident, in proof thereof, a statement supported by the testimony of the men belonging to the crew, and the captain of the vessel must, within twenty-four hours after arriving at the first port of temporary entry, make his declaration to the competent authorities. The latter shall give notice thereof to the consular authorities of the nation to which the owner of the cable belongs.

Article 8
The courts competent to take cognizance of infractions of this Convention shall be those of the country to which the vessels on board of which the infraction has been committed belong.
It is, moreover, understood that, in cases in which the provision contained in the foregoing paragraph cannot be carried out, the repression of violations of this Convention shall take place, in each of the contracting States, in case of its subjects or citizens, in accordance with the general rules of penal competence established by the special laws of those States, or by international treaties.

Article 9
Prosecutions on account of the infractions contemplated in Articles 2, 5 and 6 of this Convention, shall be instituted by the State or in its name.

Article 10
Evidence of violations of this Convention may be obtained by all methods of securing proof that are allowed by the laws of the country of the court before which case has been brought.
When the officers commanding the vessels of war or the vessel specially commissioned for that purpose, of one of the High Contracting Parties, shall have reason to believe that an infraction of the measures provided for by this Convention has been committed by a vessel other than a vessel of war, they may require the captain or master to exhibit the official documents furnishing evidence of the nationality of the said vessel. Summary mention of such exhibition shall at once be made on the documents exhibited. Reports may, however, be prepared by the said officers, whatever may be the nationality of the inculpated vessel. These reports shall be drawn up in the form and in the language in use in the country to which the officer drawing them up belongs; they may be used as evidence in the country in which they shall be invoked, and according to the laws of that country. The accused parties and the witnesses shall have the right to add or to cause to be added thereto, in their own language, any explanations that they may deem proper; these declarations shall be duly signed.

Article 11
Proceedings and trial in cases of infractions of the provisions of this Convention shall always take place as summarily as the laws and regulations in force will permit.

Article 12
The High Contracting Parties engage to take or to propose to their respective legislative bodies the measure necessary in order to secure the execution of this Convention, and especially in order to cause the punishment, either by fine or imprisonment, or both, of such persons as may violate the provisions of Articles 2, 5 and 6.

Article 13
The High Contracting Parties shall communicate to each other such laws as may already have been or as may hereafter be enacted in their respective countries, relative to the subject of the Convention.

Article 14
States that have not taken part in this Convention shall be allowed to adhere thereto, on their requesting to do so. Notice of such adhesion shall be given, diplomatically, to the government of the French Republic, and by the latter to the other signatory Governments.

Article 15
It is understood that the stipulation of this Convention shall in no way affect the liberty of action of the belligerents.

Article 16
This Convention shall take effect on such day as shall be agreed upon by the High Contracting Parties.
It shall remain in force for five years from that day, and, in case none of the High Contracting Parties shall have given notice twelve months previously to the expiration of the said period of five years, of its intention to cause its effects to cease, it shall continue in force for one year and so on from year to year.
In case one of the Signatory Powers shall give notice of its desire for the cessation of the effects of the Convention, such notice shall be effective as regards that Power only.

Maritime

LEGAL JURISDICTION OVER INTERNATIONAL SUBMARINE CABLES

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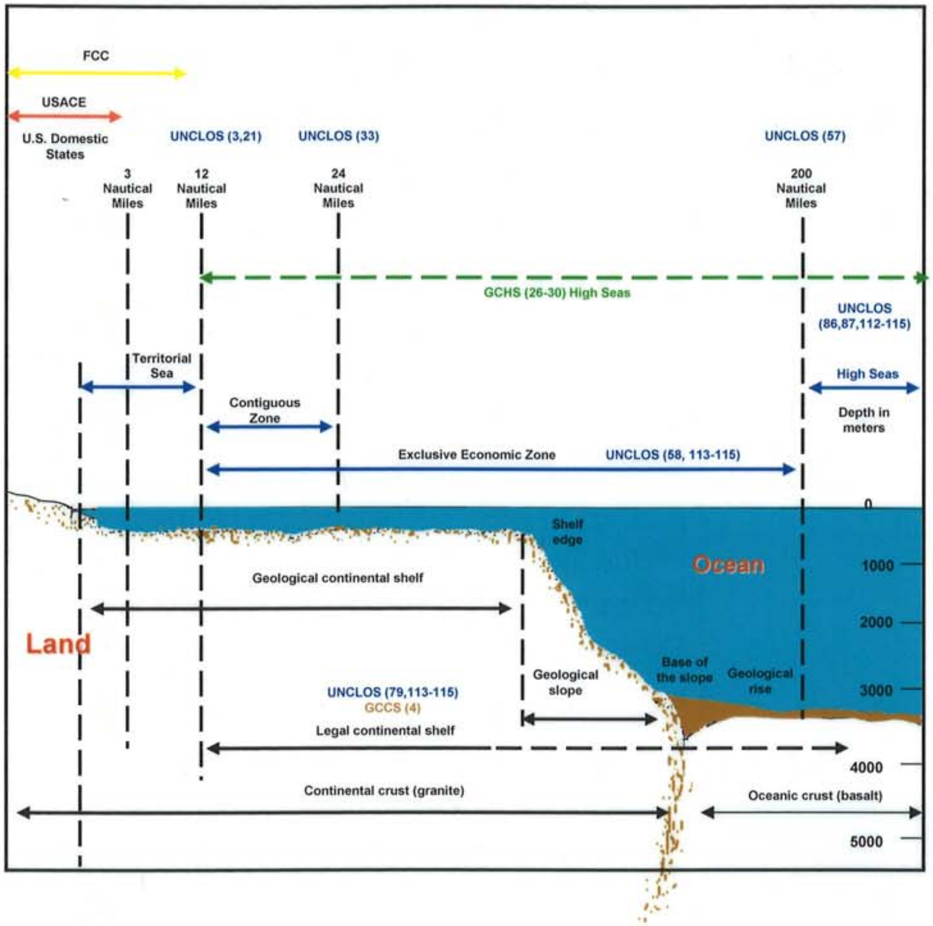

LEGAL REGIMES

UNITED NATIONS LAW OF THE SEA CONVENTION 1982 (UNCLOS)
Articles 3, 21, 33, 57, 58, 79, 86, 87, 112-115, 297

GENEVA CONVENTION ON THE HIGH SEAS (April 29, 1958) (GCHS)
Articles 1, 26-30

GENEVA CONVENTION ON THE CONTINENTAL SHELF (April 29, 1958) (GCCS)
Article 4

INTERNATIONAL CONVENTION FOR PROTECTION OF SUBMARINE CABLES (1884) (ICPSC)
Articles 1-16

FEDERAL PERMITTING AUTHORITY

(1) U.S. TERRITORIAL SEAS (a), CONTIGUOUS ZONE (b) AND EEZ (c)

(a) PRESIDENTIAL PROCLAMATION 5928 (54 F.R. 77) - 12 MILE
(b) PRESIDENTIAL PROCLAMATION 7219 (64 F.R. 48701) - 24 MILE
(c) PRESIDENTIAL PROCLAMATION 5030 (48 F.R. 10601) - 200 MILE

(2) FEDERAL COMMUNICATIONS COMMISSION (FCC)

SUBMARINE CABLE ACT 47 U.S.C. §§ 34-39

EXECUTIVE ORDER NO. 10530 (May 11, 1959), § 5(a)

19 FED REG. 2709
3. U.S.C. § 301
47 C.F.R. § 1.766
33 C.F.R. § 322.5(h)(1)(3)

(3) U.S. ARMY CORP OF ENGINEERS (USACE)

33 U.S.C. § 403
33 C.F.R. § 329.12 - 3 MILE

(4) DOMESTIC STATES OF THE UNITED STATES

U.S. v. CALIFORNIA 332 U.S. 19 (1947);
U.S. v. MAINE 420 U.S. 515 (1975) - 3 MILE

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Appendix 5: Bibliography

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    Recommendation No. 1 Recovery of Out of Service Cables
    Recommendation No. 2 Cable Routing and Reporting Criteria
    Recommendation No. 3 Telecommunications Cable and Oil Pipeline / Power Cables Crossing Criteria
    Recommendation No. 4 Co-ordination Procedures for Repair Operations Near In Service Cable Systems
    Recommendation No. 5 Standardisation of Cable Awareness Charts
    Recommendation No. 6 Actions for Effective Cable Protection (Post Installation)
    Recommendation No. 7 Offshore Civil Engineering Work in the Vicinity of Active Submarine Cable Systems
    Recommendation No. 8 Offshore Seismic Survey Work in the Vicinity

	of Active Submarine Cable Systems
Recommendation No. 9	Minimum Technical Requirements for a Desktop Study
Recommendation No. 10	The Minimum Requirements for Load and Lay Reporting and Charting
Recommendation No. 11	Standardization of Electronic Formatting of Route Position Lists
Recommendation No. 12	Mechanical Testing of Submarine Telecommunications Cables
Recommendation No. 13	Proximity of Wind Farm Developments and Submarine Cables

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