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COMPARISON BETWEEN UNDERGROUND AND OVER HEAD POWER LINE IN THE DISTRIBUTION OF ELECTRICITY IN MIDDLE AND LOW VOLTAGE

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Introduction

Smart cities are a global concept which is spreading in each case study of modern city: new ways of communication, transmission of data, waste management, water supply and treatment, etc., parallel universes with a unique goal, sustainability. It is an easy adjective in the case of “beginning from zero” centers, but what about the old ones? Is it possible to transform an old city in a smart city? From this word, sustainability, I thought, up to all, to the integrated mobility, and the electrical mobility: then I went upstream, to the network of electricity distribution, a capillary system of cables, pylons, conductors: are they sustainable? How many losses are there per linear meter?

A lot of questions I had to answer, and I started to combine different questions in order to diminish the number of variables: I started looking for the best effective technologies against losses: ceramic superconductors was the answer. Is it feasible to replace the whole distribution network to the suppliers, in medium and low voltage in preexisting centers? No, it is not due to the high cost of investments which do not justify the savings.

Professor suggested me, in order to be a practice engineer, to consider an argument that concerns to reality, for example considering a reality easy to understand and where was possible to have a check. With these preambles the idea of a comparison was born between two technologies consisting in different laying typologies: an older an well known one, the over head distribution network, and a newest one, used up to all in the case of high voltages, the underground wiring.

The thesis is structured in four chapters: the first one describes the electricity distribution network systems, with components relative to the over head or underground solution, and the reference to the italian legislation. The second chapter consider an indirect effect of electricity distribution, the generation of electromagnetic fields: research was focused to low and medium voltage, the range of human daily exposition in their homes, offices, and recreational places. Only hypothesis were evidenced of the effects on the human healths, cause the only sure effect are visual sensations and micro sensations, in the short term, while on long term exposure there is already a lot of uncertaintes. The third chapter will treat the remediation strategies adopted in order to reduce the impacts of the networks, especially those due to over head networks, which have the higher visual impact. A general overview will be done in order to show the reasonings that public administrations, private companies, etc. have to do in the planning phase of such opera. Finally a comparison will be done, considering the different impacts treated in the third chapter: a life-cycle assessment has be done, due to the complexity and the different time scales of the effect. What is the best solutions? It depends on the goal that has to be preserved! It is not a definitive answer, but shows the variability of the solutions and of the effects, according to the most complex system ever existed: nature.

Chapter 1

Generalities on electricity distribution

Energy distribution is the instrument which permits a widespread and homogeneus supplying of current: before the study of direct and indirect effects of the electric transmission treated in the next chapters, this one will briefly describe the components of the networks, the typologies of possible structures, the existing plants present in Italy and the relative law regulations, in order to have a general view of the cause object of the following considerations.

1.1 System of transmission and distribution

Usually the electricity sources do not reside close to centers of consumption, so it is necessary to provide for its transport by transmitting it at a distance and then distribute it to individual users through power lines. A power line is formed by a given number of conductors within which the current passes, usually in alternating current, and the system is three-phase. In Europe the frequency is of 50 Hz while in the U.S. it is present a 60 Hz one. The wording electric line indicates an electrical system that has the aim to connect two sections of an electric network, transferring power from the point of origin to the point of arrival. The lines, according to the type of conductor used, are divided in:

- over head lines, formed from non-insulated conductors placed in air and fixed on supports of various kinds;
- cable lines, employing electrical cables with insulated conductors, placed in various ways. Moreover, depending on the waveform of the transmitted current, the lines are divided further in direct current lines and lines in alternating current, the latest divided into single-phase and three-phase. The direct current and single phase lines employ two wires for the transmission, while the three-phase may have three or four wires depending on the presence or not of the neutral conductor. Depending on the voltage of the inter phase of exercise the electrical lines are classified in:

- Low Voltage distribution: $V < 1$ kV;
- Medium Voltage distribution: $1 < V < 40$ kV;
- High Voltage distribution: $40 < V < 150$ kV;
- Extremely High Voltage distribution: $V > 150$ kV.

The distribution of energy stands in medium voltage distribution, which in Italy is generally carried out at voltages of 15 and 20 kV, and a low voltage distribution LV (usually in cable), in areas of high density of users. The various configurations of networks vary according to the voltage levels. For medium-voltage networks are of the ring type, ie the lines and the cabins are an open or closed loop on itself so as to ensure that each cabin can be fed from at least two parts. The low-voltage lines can be radial or meshed: in the first case the network of each cabin is separate and independent of the other and between them are only possible emergency connections, in case of failures. In the second case the cabins are interconnected with each other, thus having the advantage of a greater continuity and security of supply and a better distribution of loads between the different cabins.

An additional classification for over head lines is established by the norm IEC 11-4, made law by decree DMLP n .449, march 21 1988:

1. zero class lines: lines are telephone, telegraph, signaling and remote control in service of electrical systems, which have all or at least part of their support in common with power lines for transmission or distribution and those that, while having no support in common, have been declared to belong to this category in the authorization phase;
2. first - class lines: transmission and distribution lines of electricity with rated voltages of 1 kV, and cable lines for street lighting with a rated voltage of 5 kV;
3. second class lines: transport and distribution lines of electric power whose voltage is higher than 1 kV but less than or equal to 30 kV;
4. third class lines: transport and distribution lines of electricity with rated voltage above 30 kV and with tensile strength ≥ 34340 N.

1.2 Italian electricity transmission network

The national electricity transmission network forms the main backbone of the electricity transmission system, and it is interconnected with the electric grids of neighboring countries such as: France, Switzerland, Austria, Slovenia and via a fluid oil cable laid on the seabed with Greece; these interconnections allow, inter alia, the reliability of the electrical system of our country. Through the company Terna and Enel Distribution, ENEL owns the majority of the national transmission grid and a large part of the distribution networks. Over the past three decades, electricity transmission lines at 380 kV increased from 250 km to 9.000 km, while the distribution network from 300.000 to 900.000 km. The FS company manages a network of approximately 9.000 km power line of which 6.300 km of power voltage ≥ 132 kV. The primary stations are currently more than 1.400, while the secondary are over 300.000. There are also 83 transformer stations at 380 kV and 116 kV transformer stations at 220 kV. Most of the consistency of the Italian electricity network is constituted by lines in medium and low voltage (voltage 40 kV), which represent the final stage of the process of production, transmission and distribution of electricity and which occur therefore with a density significantly greater on the territory compared to the lines at higher voltage; the average km of lines with voltage 40 kV represent about 5% of the total.

1.3 Features of the electric lines

A puntual description of the single components will be done, with relative properties and operation conditions, in order to have a general overview of the potential of this elements.

1.3.1 Electric over head lines

Over head lines are constituted by bundles of bare conductors supported by means of insulators by appropriate vertical supports, said shelves, so as to form the spans that assume the characteristic catenary trend. The term catenary indicates the locus of points along which has a heavy rope, homogeneous, inextensible and perfectly flexible, suspended for two end points, subject only to its own weight: those conditions are met, with great approximation, by the conductors of electric over head lines, for which the condition of flexibility is ensured by the great length of cables in relation to their diameter. The general expression for the sought curve is the following:

$$z(\xi) = k\cosh\left(\frac{\xi}{k} + C_1\right) + C_2 \tag{1.1}$$

The two arbitrary constants of integration C1 and C2 should be determined based on the coordinates of the starting and ending points of the span. In other words, given two points in space, and a value for the parameter of stringing k, there exists one and only one catenary passing through the given points and has the value of the laying parameter. The active conductors, current carrying, are usually arranged in groups of three, to constitute three-phase form of triads in which the potential difference in the three conductors results as amplitude equal to the nominal operating voltage, but shifted by 120° from one to another. The power lines can be arranged in single or double triads.

1.3.1.1 Conductors for over head lines

The active conductors have the task to allow the passage of electric current along the line, with the minimum expenditure of energy. A good conductor must possess certain requirements regarding the electrical resistivity, the specific weight and the mechanical strength:

- low value of electrical resistivity, so as to present an electrical resistance as small as possible. With equal length, the value of the line resistance is proportional to the ratio (r/S), therefore the lower is the resistivity value the higher is the reduction of the required cross-section;
- low value of the specific weight, so that the total weight of the conductors is as lower as possible. This concept also affects the cost of the supports, which can be lower and less robust;
- adequate value of the mechanical load, in relation to the efforts to which the conductor is subjected because of stringing (k) between the supports, the self weight and overload for wind and ice, efforts which may also assume considerable values and to whom the conductors must withstand with a sufficient degree of safety.

The conductors in the airlines may be either single wire or string, ie composed of a number of wires of smaller diameter; the ropes have the advantage of having greater flexibility and ease of installation. The composition of the conductor is indicated by the formation, corresponding to the number of wires forming the rope and their diameter expressed in mm. Usually the single-wire conductors are made of copper, but there are also copper rope conductors. In the following table are shown the characteristic values of copper and aluminum at 20 ° C:

Conductor material	Resistivity (mm^2/km)	Specific weight (N/dm^3)	Unitary failure load for elementary cables (N/dm^2)
Rude copper	17.8	87	370
Rude aluminum	28.4	26.5	147

Table 1.1. *Characteristic values of copper and aluminum at 20 ° C*

For the calculation of the drive section and the electrical resistance for bimetallic ropes is considered only the aluminum section, because the current conducted by steel is negligible; in fact the electrical resistivity of the steel is much greater than that of aluminum and the section is about 5-7 times smaller. Therefore, the electrical resistance of the steel will be much greater than that of aluminum: the case of resistors in parallel, the equivalent resistance practically coincides with that of aluminum. For the computation of the breaking load are taken into consideration both materials.

1.3.1.2 Guard cable

In the lines are also present conductors or guard cord, mounted on top of the supports, in number of one or two depending on the type of support, that serve to protect the lines from lightning surges. Act, in practice, by lightning rods and convey it to the ground, by means of the supports to which they are linked and the corresponding plant to the ground, the pulse current generated by lightning. Another task is to put them in parallel all the supports in order to reduce the total resistance of the line. They consist of galvanized steel wire ropes or alumoweld (made from steel coated with a layer of aluminum). To the guard cables is not required an electrical resistance particularly low, but is necessary a good tensile strength as they are subjected to the same efforts of active conductors.

1.3.1.3 Insulators for over head lines

In over head lines, in which bare conductors are used, insulation is achieved by spacing the lines accordingly, between them and the straps. The function of insulators is twofold: to mechanically isolate the parts of different voltage and connect the wires to mechanically support, preventing the various distances between live parts as a result of fluctuations in conductors, may dangerously decrease. The distance between the conductors and to earth must be proportional to the line voltage; accordingly the choice of the number and the type of insulators must depend on this magnitude.

The characteristics for the proper functioning of the insulators can be resumed in:

- mechanical strength, sufficient to counteract the forces transmitted by the conductors, with adequate safety;
- electrical resistivity, both bulk and surface, high in order to reduce the current leakage;
- dielectric strength, high in order to avoid electric arcs along the surface of the insulator as a result of line’s overvoltage and high mass dielectric rigidity to prevent the insulator

perforation in the case of overvoltage and the consequent necessity of a substitution;

- high surface development: (vanishing line) obtained by suitably shaping the insulator, so as to increase the voltage required to produce surface discharges.

The types of isolators are manifold; a first distinction can be made between the normal ones and those made to operate with salt and fog, which have a greater line of flight and are used in areas where particular environmental and atmospheric conditions favor the onset of electric arcs. A second distinction concerns the type of insulator and the manner of attachment to the support, which leads to distinguish two types of insulators:

- rigid insulators, which comprises an unique element and are rigidly fixed to the support, subjected to the strains acting on the conductors; these elements are normally used for airlines with tensions lower than 20-30 kV;
- suspension insulators, formed by one or two chains of individual elements coupled together, in Italy are used exclusively hood and pin insulators: they are constituted by a bell of porcelain or glass that widens at the base, where it has a certain number of undulations, and a hood of malleable cast iron or steel to which is fixed the insulating element. Each insulator has an upper cavity, said orbit, and a lower pin which engages into the orbit of the one below. The two elements of the chain are fixed respectively to the support and to the conductor: given that among the various elements there is a certain freedom of rotational movement, a connection is made flexible enough. The number of items making up the chain of insulators is determined according to the operating voltage of the line. The main constituent materials insulators are tempered soda lime glass for insulating parts, cast iron malleable for hoods, stainless steel for the pins. All materials must be corrosion resistant or made so by means hot-dip galvanizing. The glass is much preferred to porcelain for the lowest cost, the more control the homogeneity of the mass of the isolator and the total evidence from the ground fault along the line.

1.3.1.4 Supports for the lines

The supports have the function of maintaining the conductors far between themselves, from the ground and from any foreign bodies. They have different characteristics depending on the voltage level of the network which are intended, of the mechanical stresses and the type of material used. Supports usually adopted in our country for the transmission lines and distribution high voltage pylon are made of steel or reinforced concrete, while for the medium and low voltage using supports more concrete or wood.

1.3.2 Power lines in cable

Electrical cable means a set of conductors gathered together (can also be a single conductor), each isolated from the other and towards the outside; each conductor with its insulating constitutes a core of the cable. The cable lines may be aerial or underground.

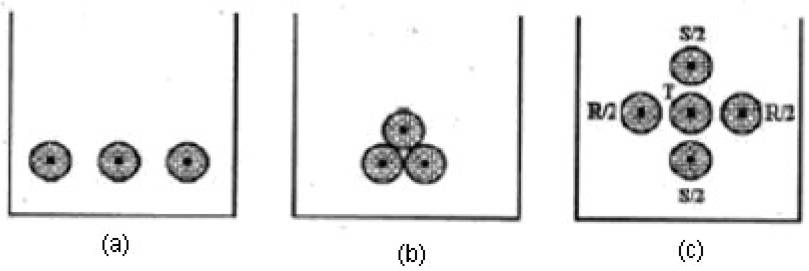
The aerial cable is a well established technology for low-voltage lines, and following the resolution of structural problems resulting from the greater weight of the conductors, has recently become feasible even for medium voltage lines. The three phases, covered with insulating material, are intertwined to form a single cable that is supported by a pole; such a configuration eliminates the electric fields and drastically reduces the magnetic fields.

It does not require safety distances for the protection against electric shocks and therefore better suited crossing of forest areas, thus avoiding cuts and relevant pruning to the environment. For low-voltage lines Enel normally uses the aerial isolated cable in suburban and rural areas; for the medium-voltage the usage generally occurs in areas with particular environmental requirements, such as forests.

The use of underground cables is the best solution from the point of view of the visual impact, even if it has impact problems during laying and maintenance because open trenches have to be opened, with consequent disturbance of surrounding environment and circulation. The underground cable is used in urban areas for low-voltage lines; it has also been adopted outside urban centers in those cases there are particular reasons or constraints that require the burying of the line. In the case of high voltage lines the technical, economic and environmental difficulties increase enormously; for these reasons the lines at 132-150 kV are carried in cable only in urban crossings to reach the primary substations. For higher voltage lines (380 kV) the technical problems, the environmental impact and costs are such that the buried cable cannot be a solution. In no country in the world in fact is used underground cable in transmission at 380 kV, unless for very short connections and in particular situations. Underground utility lines are made up of three-phase triplets with various geometries placed in a special underground trench.

The most used cables are single-core ones, propeller coated and mono pole cables with copper conductor and rubber insulation. Typically the cables are buried to a depth of 0.8 to 1.20 meters from the ground level, unless a greater depth in the crossing of special works.

The cables can be laid directly in the ground in the trenches and linearly arranged on the same plane (flat triad available) or in other configurations of installation, for example, can be arranged in a triangle (available in clover).



(a) (b) (c)

Fig. 1.1. *Laying cables: a) flat triad b) clover c) with phase separation*

A first distinction can be done, according to the number of cores, in single-core cables, three-pole and multi pole, depending on the presence or absence of the protective conductor for connecting the ground. Moreover, depending on the type of insulation, the cables are distinguished in:

1. insulated cables with impregnated paper, in which the insulation is made from thin layers of pure cellulose paper, impregnated with thick oil or appropriate mixture of oil-resin, wrapped around the conductor. They can be used for low voltage up to 60 kV.
2. cables with solid insulator, consisting of thermoplastic resins or elastomeric material, consisting of mixtures based on natural or synthetic rubber and silicone rubber, such as ethylen propylene resin (EPR); insulation is arranged in a uniform and compact way around the conductor, by means of extrusion process. There are butyl rubber cables for voltages up to 20 kV cables, cross-linked polyethylene and EPR cables for voltages up to 132 Kv;
3. oil fluid cables: cables are of mixture type that replace the dense oil of cables with impregnated paper, oil fluid, at low or high pressure, while the insulator is still consisting of layers of paper; cables are used for high voltages up to 380 kV.

This technology has been gradually abandoned due to the complexity and cost of the laying and operation conditions: deepest considerations will be explained later. The insulation is a key part of the cable; from its characteristics depend largely on the performance of the cable in terms of isolation voltages, current transmitted, thermal behavior. In multi core cables of high section a filling material is present, generally consisting of textile fibers, which serves to fill the interstices between the cores, giving to the cable the round shape.

For cables with a rated voltage of ground insulation greater than 3.6 kV screen is required, it consists of a thin copper strip coiled and is applied on all the souls individually or around the insulation of each. The shield serves to modify the lines of force of the electric field that are formed within the cable, in order to decrease the stresses on the insulation dielectric and confine the field itself between conductor and screen.

In fact conductor and the screen can be seen as the two plates of a cylindrical capacitor: the lines of force of the electric field will develop in the radial direction. The presence of unwelcome tangential components for the insulator is thereby avoided; a cable of this type is called a radial field.

The outer insulation (belt), the metal armor and the outer jacket have the task of protecting the cable from environmental agents, from mechanical influences and interference. The wires are generally copper or aluminum, with a prevalence of the first; may be either single wire or string. The copper conductors may be bare or coated: the coating consists of a thin layer of suitable metal, such as tin, tin alloy or lead alloy.

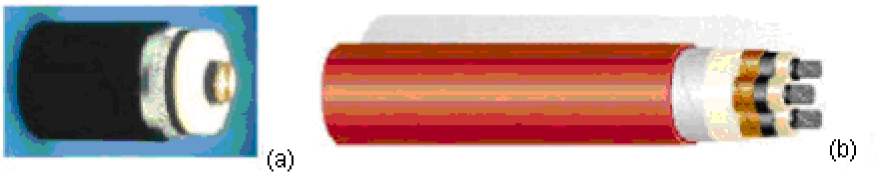


Fig. 1.2. *a) Single core cable - b) Three-core cable for underground MV lines*

1.3.2.1 Functional characteristics of the cables

Rated voltages: when a cable is used it is necessary to choose a level of insulation suitable for the voltage of the electrical system in which it is to be used.

The reference voltages for which the insulation is provided are:

- rated insulation voltage to ground (U0), ie between conductor and ground;
- rated insulation voltage between phases (U) can not be assessed in the case of single core cables.

As the value of the nominal operating voltage increases, it is necessary to choose cables with higher isolation voltages. Another key feature for the choice of cables is the flow: the flow rate is the maximum intensity of current that can flow in each conductor, under certain conditions of installation and service life, without the temperature exceeds the allowable by the insulation. The permissible temperature in exercise is also a characteristic of the cable, established by the regulation based on the type of insulation.

1.3.2.2 Type of laying

The laying conditions are of crucial importance in the design of a cable, as regards both the determination of the scope of the cable itself, and the protection from external stresses. It is possible to perform the following types of installation:

- direct in the ground: it achieves a trench in which the cable is deposited, surrounded by a layer of sand and clay. Above the cable is put a layer of bricks or a concrete slab for protection;
- in channels: it makes use of the available channels in the soil of cement later filled with sand;
- in solid elements: an excavation is made where to place the clay or concrete element. Inside lies a galvanized iron wire to allow the subsequent laying of the cable, which is tied at the end of the wire;
- in tunnels: normally takes place inside the transformer stations or industrial buildings to make it more affordable cables;
- in air: the cables are employed in replacement of bare conductors, almost exclusively for low-voltage lines.

1.3.3 Electrical cables in low voltage field

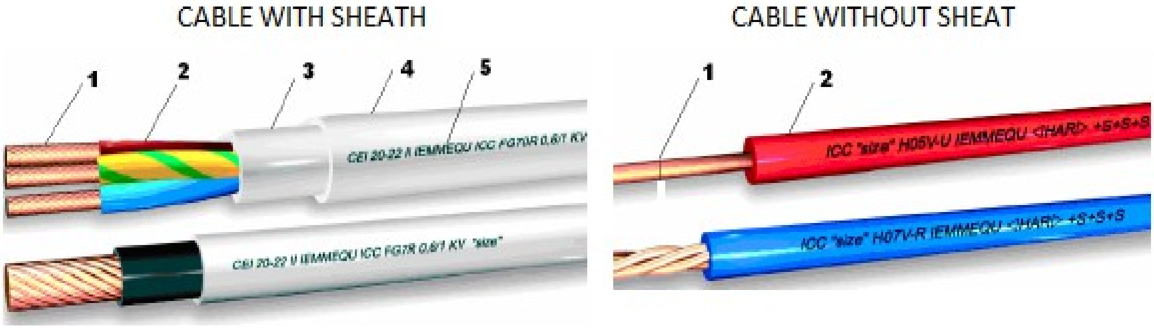


Fig. 1.3. *Cables with and without sheaths*

The constituent elements shown in the figure can be defined as follows:

1. Copper or aluminum conductor (rarely used in HV), which may be rigid or flexible. The section of this element determines and characterizes the rate in amperes and the mechanical strength of the cable, more specifically the tensile strength.

2. Insulator usually in PVC or rubber: it is used to isolate voltage in the cable, avoiding in this way the possibility of dissipation or current losses. The thickness of the layer of insulation around the cable is proportional to the voltage of the cable crossing; compounds used in this role are:

Thermoplastic (PVC): have the drawback of soften after a certain maximum temperature, identified by Tmax of 70 ° C.

Thermo hardening (EPR rubber or HEPR) with maximum operating temperature set at Tmax = 90 ° C.

Polyolefin (LSOH): this configuration has the advantage of having a low emission of opaque smoke and toxic and corrosive gases in the case of fire.

3. Filling in soft insulating material that conforms to the souls, so as to ensure no gaps between the insulating layers.

4. Chain to bring an additional mechanical strength and chemical to environmental stresses (sun, water). It may be made of insulating material or metal (spiral), and become indispensable for cables laid underground, on suspended walkway (a wire or perforated channel), in channel without cover, in sight, in the ceiling or under a raised floor.

5. Marking: used to identify the cable.

The representation of these elements is clarified in more detail in the following image:

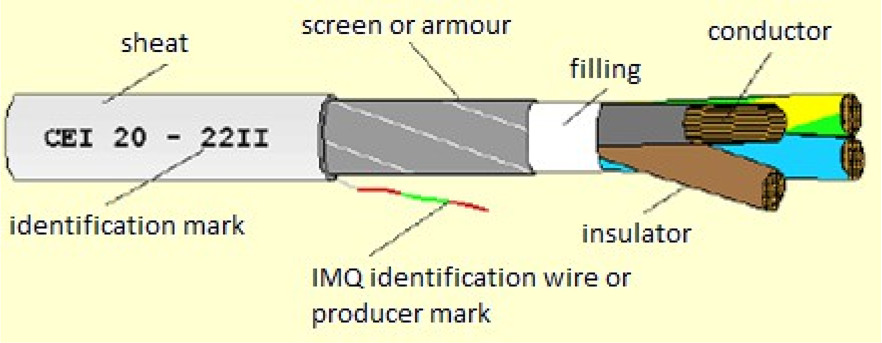


Fig. 1.4. *Cable representation*

Based on the flexibility of the conductor wires can be classified into:

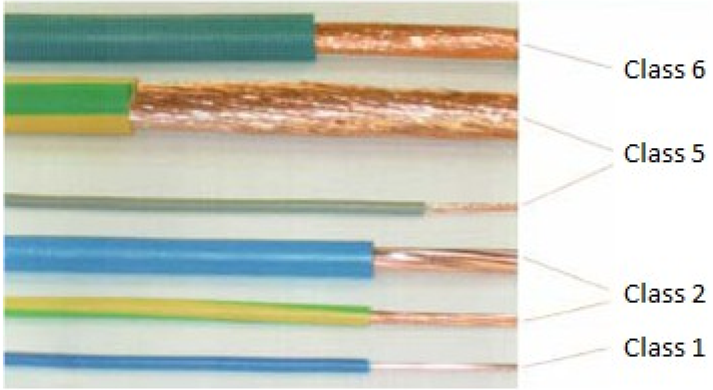


Fig. 5. *Cable classification due to flexibility*

Class 1: rigid conductors with circular cross section single wire for fixed installation. Little used in Italy but admitted in other countries.

Class 2: rigid conductors string for fixed installation

Class 5: flexible conductors for fixed or mobile installations

Class 6: conductors very flexible for dynamic applications, for special applications, requiring constant movement (lifts, welders, etc.).

While for the standardized sections, the following are the ones counted:

mm^2	0.5	0.75	1	1.5	2.5	4	6	10	25	50	70	95	120	150	185	240

Depending on the type of laying distinguishes the fixed one, in which the cable is not moved after installation, by the mobile in which the cable is moved with a certain frequency during its use (power appliances and portable tools).

Another parameter of identification of electrical cables in low voltage is the rated voltage, given by the ratio of the voltage to earth U0 and the voltage between the phases U; a relationship referred to the industrial frequency set at 50 Hz; the table below highlights the different acronyms designation depending on the value of the rated voltage in question:

Rated voltage U_0/U	**Designation mark**
100/100 V	01
300/300 V	03
300/500 V	05
450/750 V	07
0,6/1 kV	1

Table 1.2. *Unified rated voltages in LV cables*

The burying of the cable can be direct, resulting in intimate contact with the soil, or indirect, in which the cable is laid in a pipe, conduit or tunnel: however in both cases cable may come in contact with water and for this reason they must be sheathed. The burial depth does not have any limit in the case of laying in tunnels, mullioned windows, pipes 450 or 750 N, and does not require reporting; in the case of direct burial or installation in tubes of 250 N, the minimum depth is 50 cm with resulting mechanical protection (tile): the intervention will be marked with tape unless the cable is reinforced.

In the case of burial under public roads, the depth increases to 1 meter, with the exception of the lines of street lighting; shallow depths in the case of burial in camping or touring with the planned use of stakes, where should be guaranteed at least 60 cm and additional protection with tile; 50 cm are sufficient structures for agricultural or livestock are moved where vehicles and agricultural machinery. It 'also need to estimate distances from other pipelines, such as water, gas and other underground utilities.

The insulators and casings are made with petroleum-derived fuels, and then, during the exercise a cable can cause a fire, due to a possible overheating in the vicinity of a readily combustible material, facilitate the spread of fire along the route and develop opaque smoke and toxic and corrosive gases during combustion: fire victims are mainly due to the gases and fumes that stun and reduce visibility.

In relation to fire the cables are distinguished in:

- flame retardant (self-extinguishing single cable);
- fire retardant (self-extinguishing beam);
- fire-resistant (continue to operate during the fire);
- low emission of smoke and toxic and corrosive gases (LSOH Low Smoke Zero Halogen).

At the moment there are no flame retardant cables ... who knows in the future!

In the definition of the current flow of a cable, are taken into account the thermal energy dissipated by the Joule effect in the conductor, **WT**, given by the product of the resistance **R** of the cable by the square of the current **I** passing through the cable. The resistance value R is given by the product of the resistivity **r** and the cable length, dividing finally to its section; another factor is the **WD**ispersed, equal to the thermal energy dissipated to the outside of the cable, and finally the working temperature conductor, **TL**av

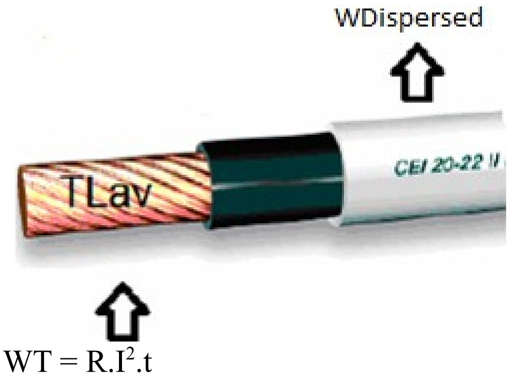


Fig. 1.6. *Energy flux in a cable*

1.3.3.1 Heating of the cables

When the current through the cable is zero, the cable is considered at room temperature, set at 30°C; when the cable is traversed by a given current at a temperature of work TLav, its temperature begins to increase: up to that WT > Wdipersed, TLav of the cable continues to increase; when these two energies assume the same value, TLav stabilizes at a steady-state value.

A definition implies also the term of maximum working temperature equal to 70 ° C for PVC cables, 90 °C for rubber cables (EPR or HEPR): keeping the TLav below those values is possible to guarantee a life expectancy of 20-30 years of the cable.

1.3.3.2 Capacity of the cables

It is defined as the maximum current that can flow in a wire with the same section of the conductor, it depends on:

- the type of insulation (PVC or rubber);
- the mode of installation, and consequently the possibility to dispose a certain amount of heat;
- the maximum value of current that can flow into it, in continuous operation and under certain conditions without which its temperature exceed the values of maximum Tlav before defined (70 or 90 °C), is given by the product

$$I_Z = I_{Z0} . K_1 . K_2 \tag{1.2}$$

With I_{Z0} equal to the flow rate at 30 °C with a single cable installed, K_1 the correction factor for ambient temperature different from 30 °C, K_2 equal to the coefficient of reduction for groups of cables in a bundle or layer.

The condition of laying depends if the cable is provided or less of sheath, the type of hose, the number of cables inside the same conduit and the ambient temperature.

1.3.4 Medium-voltage power over head lines: types, positioning and construction features

The lines in medium voltage (MV) are for the most part consist of bare conductors. The insulated cables, in which the different phases are isolated between them and are in turn contained in a further protective outer casing, are used by less than 5% of the lines. More significant however, is the portion of the buried line which, with regard to Enel Distribution, is equal to a little less than a third of the total of 335,135 kilometers of development (Enel - Environmental Report 2006).

The supports for the medium voltage lines routes are constituted by both metal towers, both from centrifuged reinforced concrete piles or steel, the latter are fitted in kind of concrete or metal shelves that support the insulators.

Even in the case of medium-voltage lines the insulation is obtained by means of glass insulators, ceramics or composite material; insulators used can be either rigid or suspended.

1.3.4.1 Over head lines with rigid insulators

Insulators carriers represent some of the most common types of weaponry, both on supports of concrete or on metal towers:

Fig. 1.7a. *Simple supporting insulator*

Fig. 1.7b. *Double supporting insulator*

The anchoring insulators also represent a very common type, and both are mounted on supports of concrete or on metal towers:

Fig. 1.8a. *Rigid anchoring insulator*

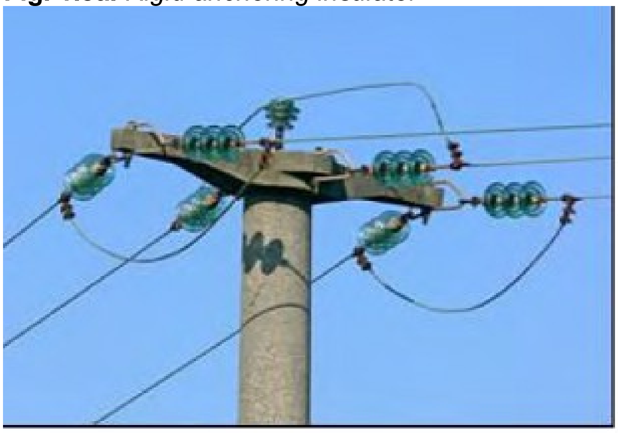
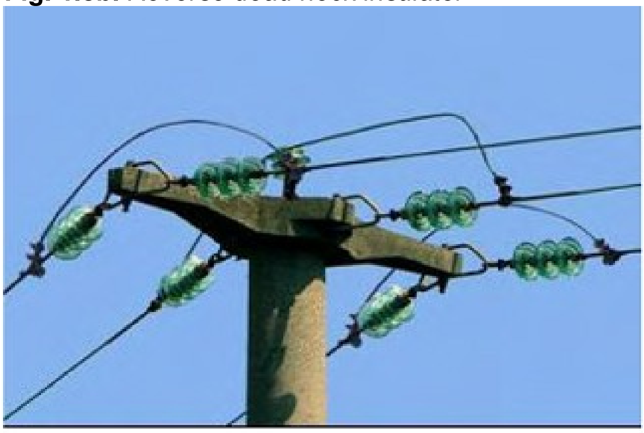


Fig. 1.8b. *Reverse dead neck insulator*



Achoring is a rigid support that has the function to maintain the conductor stretched. The interruption of continuity of the conductors is exceeded by a dead neck, a length of cable slack left between two insulators. The dead neck can be reversed. This type of solution is, however, less common.

1.3.4.2 Over head lines on suspended insulators

Suspended simple armaments have the conductors suspended below the insulators, supported themselves by their own shelf. There are also double insulators in suspension that is flanked by two insulators that hold the conductor.

Single or double armaments for anchoring in suspension, appear to be very similar to those on rigid insulators for anchoring.

Fig. 1.9a. *Suspended insulator*

Fig. 1.9b. *V shelf*

Fig. 1.9c. *Boxer shelf*

Two typologies with suspension insulators are often used, the V shelves and Boxer shelves, both considered among the safest models for birds.

1.3.4.3 Particular mountings

The derivations are lines that branch off from through lines at an angle of typically 90 °. These typologies are made with anchoring arms with single or double insulators.

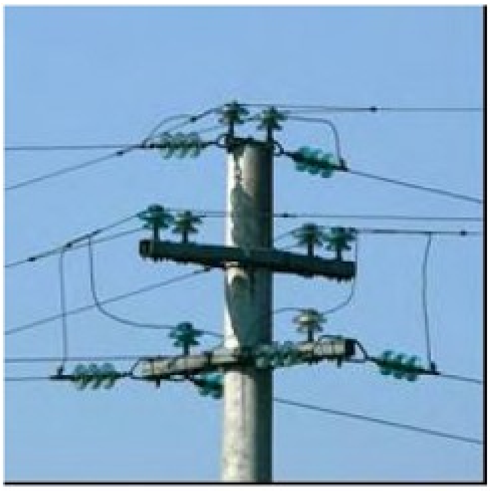


Fig. 1.10a. *Derivation*

Fig. 1.10b. *Arrester facility*

The arrester devices have the task of protecting the line from surges, dumping at the ground when the voltage on the line exceeds a predetermined limit. These devices are mounted on supports such as terminal and at the input of transformer stations.

Disconnections allow to interrupt the supply of a line section. The circuit breakers are operable manually from the base of support.

Fig. 1.11a. *Disconnection*

Fig. 1.11b. *Terminal*

The terminal supports represent the end of an airline and allow the passage of the cable. These structures, in addition to understanding the arrester devices, present the bare conductors that converge toward the end of the cable. A similar situation exists in the case of transformers on a pole.

1.3.5 Underground electrical cables and TLC wires

The laying of underground cables must be carried out, (except in special conditions) in accordance with the mode of N CEI 11-17 V1 (2003 Edition). In particular, as regards the coexistence of power cables and other channels, works and underground structures, reference must be made, during the execution of the works, in addition to the standards mentioned above, the requirements contained in the Ministerial Decree of 24/11/84.

The cables must be routed in cable ducts that can be PVC heavy series, unalloyed steel Fe33 normal range according to UNI 3824 (the type without welding) or galvanized steel externally and internally according to UNI 5745 (with verification adhesion of the layers of zinc). The pipes may have a diameter of 1/2" to 3". The braided outer covering must be neoprene or plastic smooth, adherent to the wall, self-extinguishing, anti-aging, resistant to abrasion, wear and resistance to solvents, oils and salinity, and must withstand thermal stress by -15 °C to +70 °C.

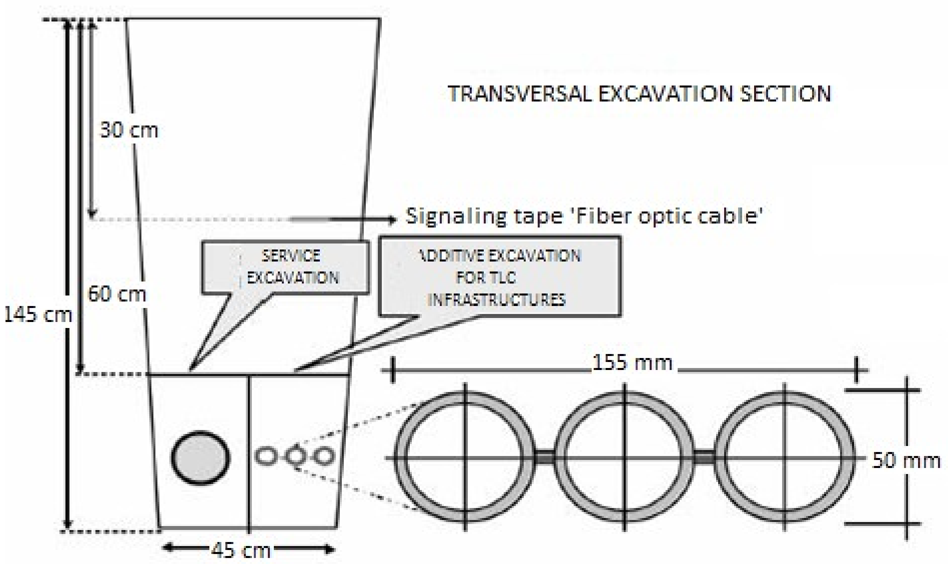


Fig. 1.12. *Transversal section*

The maximum load factor allowed by the cable must not exceed 50%. The bending radius should not normally be less than 8 diameters.

In environments with the possibility of collecting water or outside buildings, the pipes must not be a way to convey water to the electrical equipment.

The completion of the cable ducts covers the use of fittings, derivation boxes (condulet), couplers, nipples, reductions in glass and nipple, nuts and locknuts, locking joints and/or drainage. The ducts are laid at a depth of 60 cm with path near and parallel to the structures, with supports at intervals such that any bending of pipes and still spaced over a length not exceeding 2.5 m. The width of the trench depends on the number and diameter of the cable ducts.

In order to allow an easy laying of cables is provided the installation of wells in CLS provided with ductile iron manhole positioned along the pipe (at a mutual distance of up to 30 meters in straight line), in the changes of direction and in correspondence of light centers leads.

The wells should be large enough to allow the insertion of cables complying with the minimum bend radius allowed (at least 12 times the diameter of the cable). The dimensions of the wells depend on the sections of cable used.

The cables must be routed so as to be protected from damage under normal conditions of operation. As far as possible, the high-voltage cables must be laid in such a way as to be separated from low voltage and control cables, and those at low current.

The cable lines directly buried must have mechanical strength adapted to the nature of the mortar bed.

In the absence of the protective tube, the burial depth must be:

- at least 0,4 m for low-current cables;
- at least 0,6 m for low voltage cables;
- at least 0,8 m for high voltage cables.

Where the burial depth can not be met, additional protective measures should be taken, particularly against mechanical damage.

The protection of the cables at high current must be covered in each case by a layer of soil at least equal to 0,4 m. The metal conduits must be grounded.

The low voltage cables laid on the surface in power installations must not have conductor casings. The inclusion of low voltage signaling, measurement and control wires, within the high-voltage cables is allowed if a sufficient isolation is guaranteed and if these elements do not provide an important protection and safety function.

The distances between the wires and the other lines (electric and non-electric) must be designed in such a way as to preclude any mutual interference and to be able to carry out the work on a line without serious disturbance in the others.

1.3.5.1 Interference of power lines with other underground networks

It is necessary to avoid or limit proximities, parallelisms and intersections of power lines with other systems: it is preferable an arrangement so that the lines and plants can not be damaged or influence each other in an inadmissible manner and so as not to hinder mutual operation and maintenance.

The metal housing of the cable lines that run parallel or cross can come in contact with each other only if the lines are connected to the same grounding system.

In the soil, the cable lines with lower voltages should be arranged above those with higher voltages. Exceptions are permitted by mutual agreement between the operators of the two lines.

The single core cables of a three-phase system arranged parallel to each other are treated as a single cable line. In these cases, the protective tubes of ferromagnetic material are only allowed if all the single-core cables are laid in the same tube.

The connections in parallel of more cables downstream of the same organ of overcurrent protection are only allowed if the cables are routed so that their impedances are approximately equal. In the parallels and intersections of cables for the transport of energy measures have to be taken against the possible damage due to heat accumulation; further measures are taken against the spread of fire along cable lines or channels.

The cable lines for plants with important functions of protection or safety shall not be placed in the same duct or shaft parallel to the cable lines for the transport of energy, or cross the same.

The lines in high voltage cable with high-power short-circuit between phases or ground can not be laid parallel to other lines in the same cable or cross; exceptions are allowed if the arrangement or protective measures are able to prevent the endangerment of people or property.

Among the high current cable lines, low current that cross or run parallel, the following minimum distances have to be respected:

- in buildings or in cable ducts: 0,005 m for each kV of rated voltage, but at least equal to 0,1 m horizontally, or vertically to 0,2 m;
- in the ground: 0,3 m.

If the minimum distances cannot be respected, fire resistant shielding and electrically non-conductive are necessary between the cable lines, while if the cable lines are subjected to the same operator or if the operators concerned have agreed in writing on the construction, operation and maintenance of cabling, the parallels and intersections are allowed, without screening and without the minimum clearances given:

- inside buildings intended only for electrical systems function, for cable lines belonging to the enterprise and not used for installations with important functions of protection and safety;
- in parallelisms of lines in high-voltage cable with a length not exceeding 50 m;
- in parallelisms of cable lines of high and low voltage, when the line in the low voltage cable serves solely to the transmission of measurement signals and control of secondary importance;
- cable lines for low voltage and low current system joined together at the same ground system;
- for the lines in the low voltage cable whose outer shell is made of plastic or metal casings when all the cables are connected together and grounded.

1.3.5.2 Nearby, parallelisms and intersections of power lines with the national highways and other roads

The power lines must be designed and constructed so as not to hinder the already planned expansion of national highways.

Nearby, in the parallelisms and intersections with roads (roads, bridges, tunnels, etc..), cable lines must not be damaged by vibrations and shocks. They should also have sufficient flexibility in the presence of structural elements hinged (bridges).

The cable lines for systems with critical security features and safety devices must be constructed so as not to suffer mechanical damage caused by oil, gasoline or other liquids or corrosive in flames as a result of breakdown or traffic accidents; furthermore cable lines inside the channels must be designed and arranged so as not to endanger the traffic in case of a cable fire: channels for cables laid inside tunnels must not contain materials that can produce large amounts of smoke.

The steps of cables in tunnels, sheltered in the way of traffic and electrical systems and that can propagate fire, must be shielded with fireproof material.

Chapter 2

Magnetic fields

The electric and magnetic fields are different physical quantities, but interact with each other and depend on each other to the point of being considered dual manifestations of a single physical phenomenon: the electromagnetic field.

The magnetic field can be defined as a perturbation of a certain spatial region determined by the presence in the neighborhood of a distribution of electric current or magnetic mass, where the unit of measure is the Ampère [A/m]. The electric field can be defined as a perturbation of a certain spatial region determined by the presence in the neighborhood of a distribution of electric charge, where the unit of measure is volt [V/m]. The magnetic field is hardly shieldable and decreases only away from the emission line. Electric field is instead easily shieldable by materials such as wood or metal, but also trees or buildings. These fields are linked to each other in space to determine the propagation of a called electromagnetic field (EMF). The key features that distinguish the electromagnetic fields and determines the properties are the frequency [Hz] and the wavelength [m], which express inter alia the energy content of the field itself.

The term electromagnetic pollution refers to interactions between non-ionizing radiation (NIR) and matter. Fields NIR low frequency are generated by transport and distribution of electricity at high, medium and low voltage, and from household appliances and electrical devices in general. With specific reference to the lines of electricity transport by manufacturers to users, is possible to distinguish different types of power line, according to the supply voltage:

- power lines to transport high-voltage (380 kV): connect the power plants to the primary stations where the voltage is lowered from the value of transport to the distribution networks (field super regional);
- distribution power lines or high voltage sub-transmission lines (132 kV and 220 kV): start from the primary power stations and supply large users or the primary substations, the

originators of the medium-voltage distribution lines;

- medium voltage distribution power lines (15 kV): start from the primary substations and feed substations and medium-sized industrial and sometimes particular users;
- power lines distribution at low voltage (220-380 V): start from secondary substations and feed users in the area.

For low-frequency fields (power lines, electrical appliances) measures taken are the intensity of the electric field [V/m] and the magnetic induction ([T], but generally in thousandths of Tesla, mT, and millionths of a Tesla μT). The growing demand for electricity and communications has produced in recent years a considerable increase in the number of power lines and base stations for mobile phones: this has resulted in an increase of EMF in our environment and therefore public exposure to electromagnetic radiation.

2.1 Theory on electromagnetic fields

The power line during its normal operation generates an electric field and a magnetic field. The first is proportional to the voltage of the line itself, while the second is proportional to the current that circulates. Both decreases very rapidly with distance as shown by the following graphs. However in the case of underground cables, screen presence and the relative proximity of the conductors of the three electrical phases actually makes the electric field zero everywhere, therefore accordance with local regulations at the sensitive receptors is guaranteed regardless of the their distance from the power line.

As regards to the magnetic field it is noted that the greater proximity of the conductors of the three phases between them compared to the aerial solution makes the field negligible already a few meters from the axis of the power line. Below is shown the trend of the maximum magnetic field along the path of a buried line at 20 kV.

The connection line generates, with radial trend compared to the cables, the electromagnetic fields due to the passage of the current and which is proportional to it. In the air, the performance of this range as a function of the distance from the cable is proportional to the inverse square of the distance, ie it strongly decreases its intensity moving away from the source. The presence of insulation coatings and metal shields will further limit the intensity. The electric field is produced by a poly phase system and is associated to the charges involved, and hence the voltages, and is therefore present as soon as the line is placed under tension, regardless of the fact that it transports or less power.

The magnetic field B is instead associated with the current (and hence power) carried by the line, which disappears when the line is only "live" but does not carry energy.

Electromagnetic fields, according to their frequency, can be divided into:

- ionizing radiation waves (IR): high frequency waves so called because they are able to modify the molecular structure by breaking the atomic bonds (the most recurrent example is that of X-rays) and therefore carcinogenic;
- non-ionizing waves (NIR): of which are still ongoing numerous studies aimed to test the effects on humans. This type of waves includes, between the various frequencies, microwaves, radio frequency fields and extremely low frequency (ELF - Extremely Low Frequency 0 to 10 kHz). Among these low frequency fields (ELF) is also included the electricity transmitted at a frequency of 50 Hz.

The variables that determine the intensity and distribution of the magnetic field in the surrounding space of a buried line are basically:

1. intensity of the line currents;
2. distance from conductors;
3. insulation, shielding and burial depth of the cable;
4. arrangement and distance between conductors.

To mitigate the magnetic field generated by an electric line is necessary to act on one or more of the quantities listed above, since the shielding by materials with high permeability and / or conductivity is not a feasible way. The influence of the various factors can be seen immediately from the Biot-Savart law: the magnetic field is directly proportional to the intensity of the current and is inversely proportional to the distance from the source:

$$B = \frac{\mu_0 \cdot I}{2\pi R} \tag{2.1}$$

The fourth factor, comes into play if the transmission system is three-phase, that is composed of a triad of currents of equal magnitude but out of phase in time. As the magnetic field at each point of the surrounding space is given by the vector composition of the contributions of the individual alternating currents, there arises an effect of mutual compensation of such contributions greater the closer together are the sources, to obtain a total compensation if the three currents were concentric. For overhead lines, the minimum distance between the conductors is limited to the necessary distance between the stages and depends on the operating voltage, while for the lines in cable this distance may be of the order of 20-30 cm with a substantial reduction of the field Magnetic already within reach. As it has been more and more frequently, medium voltage lines are no longer built by over head line, but buried in order to drastically reduce the effect due to electromagnetic radiation attenuated by the soil that acts as a "natural shield ", lowering the intensity of these emissions to values even lower than the most common everyday appliances. The calculation was carried out in compliance with the CEI Norm, n. 211-4.

2.2 Normative references

Guidelines for Limiting Exposure to electric and magnetic fields that vary over time and exposure to electromagnetic fields have been shown in 1998 by the ICNIRP.

On 07/12/99 the Council of the European Union issued a Recommendation to Member States aimed at creating a framework for protecting the population against electromagnetic fields, which is based on the best scientific data existing; in this respect, the Council endorsed just the ICNIRP guidelines. Subsequently in 2001, following a recent analysis conducted on the scientific literature, a committee of experts of the European Commission has recommended to the EC to continue to adopt such guidelines.

Then it took place, with the purpose of reorganization and improvement of the legislation in force, the Law 36/2001, which identified three levels of exposure and entrusted the government responsibility to determine and periodically update the exposure limits, the attention values and quality objectives, in relation to the plants likely to cause electromagnetic pollution. Article. 3 of Law 36/2001 established exposure limit value of the electromagnetic field to be observed in order to protect human health from acute effects; the amount of attention were defined as the value of the electromagnetic field to be observed as a measure of caution for the purposes of protection from possible long-term effects; finally, the objective quality criterion were defined as local and urban standard, as well as the value of the electromagnetic field for the progressive minimization of exposure.

The Italian framework law (36/2001), as mentioned always by the aforementioned Committee, was enacted despite the recommendations of the Council of European Communities of 12.07.99 sustain the member States to use international guidelines set by ICNIRP; all European Union countries, have accepted the opinion of the Council of EC, while Italy has adopted more stringent measures than those indicated by international organizations. In execution of that Act, it was in fact issued the DPCM 8.7.2003, which set the exposure limit 100 microTesla for magnetic induction and 5 kV/m for the electric field;

the act has established the attention value of 10 microTesla, by way of caution to protect against possible long-term effects in the play areas for children, in residential areas, in school settings and in places where people stay for more than four hours per day; an objective quality has been set, to be observed in the design of new power, the value of 3 microTesla. It was also explicitly clear that these values are intended as median value over 24 hours, in normal operating conditions. It is not therefore correct to refer to the maximum value of current possibly bearable by the line. It is noted that the values of care and quality objectives are established by the Italian Legislator of 10 and 33 times lower than international ones. In this regard, it should also be remembered that, in relation to electromagnetic fields, health protection is implemented – in the entire country - only through respect for the limits prescribed by the DPCM 8.7.2003, which can only be an useful reference. In fact, the Ministerial Decree of 29.05.2008, which defines the method for calculation of buffer zones of power lines, reproduces Article. 6 of that D.P.C.M..

2.3 Effects on health of electromagnetic fields

All effects, which may be of short term or long term, derived from the induction of electric currents in the body, in various organs and tissues of exposed persons. Regarding the short term, several studies have shown that exposure to high intensity of electric and magnetic fields can cause visual sensations in humans, micro shocks, vibration of hair or down and effects on the nervous system . The man is able to sense the presence of an electric field to the threshold levels that average are placed between 2 and 10 kV/m. In the case of patients of which has been implanted with a pacemaker, the electric field may interfere negatively on the normal operation resulting in extreme cases even the cessation of the stimulation. Also the magnetic field causes dysfunctions that are particularly strong on some models of pacemakers. The most studied long-term effects concern non-tumor and tumor cells. Among the not carcinogenic effects have been reported neurological and circulatory disorders, sleep disorders, irritability and decreased libido. In particular, a survey conducted by the Department of Public Health of the United States has found an increased incidence of depression and headaches of 400 individuals resident in buildings placed in the nearby of power lines and exposed to a magnetic field of 0,2 microTesla. The main concerns of the population, however, regard the possibility, suggested by a number of epidemiological studies, that chronic exposure to electromagnetic fields, which occurs for those who live in the vicinity of power lines, can produce long-term effects, and in particularly encourage the development of tumors. Epidemiological investigations are studies that aim to establish a posteriori the causal link between the diseases and chronic exposure to electromagnetic fields, in order to check the difference that exists in comparison with control groups. Further studies are carrying out about the causal association between exposure to electromagnetic fields with very low frequency and the increase of the risk of leukemia and tumors of the nervous system in children living in homes near high voltage power lines: confirmed initial studies indicate an increased risk of leukemia and brain tumors in children living in homes with induction levels above 0,2 and 0,4 microTesla . It was found an increased risk of leukemia for workers of three power companies with exposure average levels of magnetic induction greater than 0.2 microTesla. All authors agree that the health effects are attributed to the component of the magnetic fields of the field, because the electric component is easily screened. As regards the biological mechanisms of action of the fields, has been demonstrated by several researchers an influence of EMF on the production of night-time levels of melatonin in animals, that is to be reduced. This may lead to a decrease in immune response.

2.3.1 Concluding remarks of the Institute of Health

Basing on a critical evaluation of the scientific evidence it is considered credible a causal interpretation between childhood leukemia and exposure to magnetic fields at 50/60Hz, even whether problems of interpretation related to the numerical dimensions of the available studies and the possible confounding variables. Contributes to admit character of probability and not of certainty to the etiologic role of the fields magnetic induction of tumors, the fact that there is still no agreement on the possible biological mechanism of the fields themselves. Exposure limits may be based at the present time only on the acute effects of exposure because only of these is adequately documented the relationship with the intensity of external fields. ompliance with the exposure limits provided by the Italian law must therefore be considered a minimum requirement that must be supported an overall goal of a reduction in exposure, where technically possible and with reasonable terms. t is therefore necessary that the projects of new power plants provide the objective of reduction of exposure to electric and magnetic fields, including the adoption of new technological solutions. In particular, the containment of exposure appears priority for kindergartens, schools and other indoor and outdoor environments aimed at children. Regarding the existing facilities, appears a priority to plan interventions of reducing the levels of exposure in homes, schools and workplaces, prove far superior to those average found in similar environments .

2.3.2 Concluding remarks of the technical and scientific commission

Epidemiological studies suggest that the electric and magnetic fields at low frequency (50/60 Hz) should be classified as "probably carcinogenic" although the positive association between exposure to these fields and certain types of cancer, such as childhood leukemia and, in some studies, brain tumors and of mammary in males, appears modest in size and it is not sufficient to establish a causal link between exposition and pathogen effect. Even in the absence: of definitive epidemiological demonstrations, of adequate experimental confirmation; of knowledge on the mechanism of oncogenic action that gives biological plausibility of the association; of knowledge of the exposure-response relationship, from which is possible to derive the unit of carcinogenic risk and the exposure limits related to certain excesses f carcinogenic risk, it may suggest, in the spirit of the precautionary principle, the following recommendations relating to the intensity of the fields.

2.3.2.1 New buildings or residential areas near power lines or plants for the electricity distribution

It is suggested to tend, as far as possible, to minimize the values of the magnetic field taking, as precautionary measures, a reference value for the upper limit of the magnetic induction the interval from 0,1 to 0,3 microTesia, regarded as provisional and indicative only based on the current knowledge . To be consistent with these suggestions should be adopted certain techniques rules of caution: • change the method of construction of housing and allocation of domestic sources of electricity; • change the methods of construction and distribution lines; • it should be a good procedure to allocate the new medium-low voltage substations outside the buildings.

2.3.2.2 Existing buildings or power lines

If the structures are (if different from schools or other public or private places where children stand for long hours in the day, for which are valid the limits recommended for new buildings) It is necessary the remediation of the most compromised territorial situations.

2.4 Electric and electromagnetic fields in over head power lines

In the case of a power line the lines of force of the electric field starting from the electrical cable and end to the ground. The intensity of the field depends on the distance from the line and the height of the conductors. A shielding effect of the electric field on the ground is produced by trees, buildings and fences. The electric field levels will be reported, below power lines to a simple triplet , obtained resorting to some models of computation. These values are reported under unperturbed field conditions and with conductors at the minimum height from the ground permitted by Italian law.

• 380 Kv line from 7000 to 8000V/m • 220 Kv line from 2000 to 3000 V/m • 132 Kv line from 1000 to 2000 V/m • 15 Kv line from 100 to 150 V/m

Several instrumental surveys, carried out by various institutions in homes built in the nearby of high voltage power lines and in the center of each room, have highlighted of the electric field levels between 1 and 5 V/m .

The magnetic field of a power line varies throughout the day depending on the demand of energy; the minimum is reached during the night hours. Its level is below the maximum line and decreases moving away from the same.

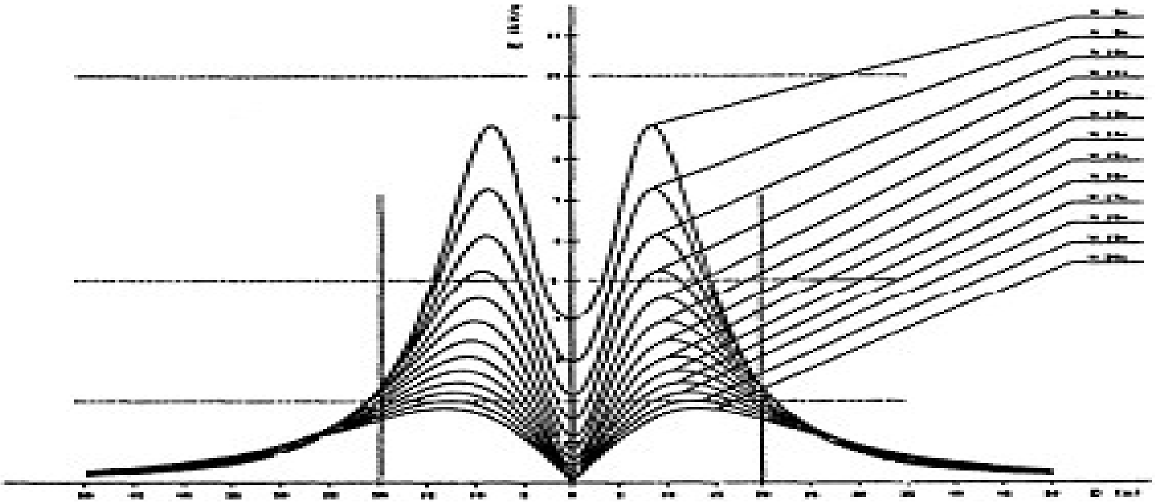


Fig. 2.1. *Diagram of the electric field intensity under an high voltage line. The electric field depends, in each point, on the contribute of each cable. The intensity, as it is clearly evidenced, decreases rapidly with the distance from the electricity pylon*

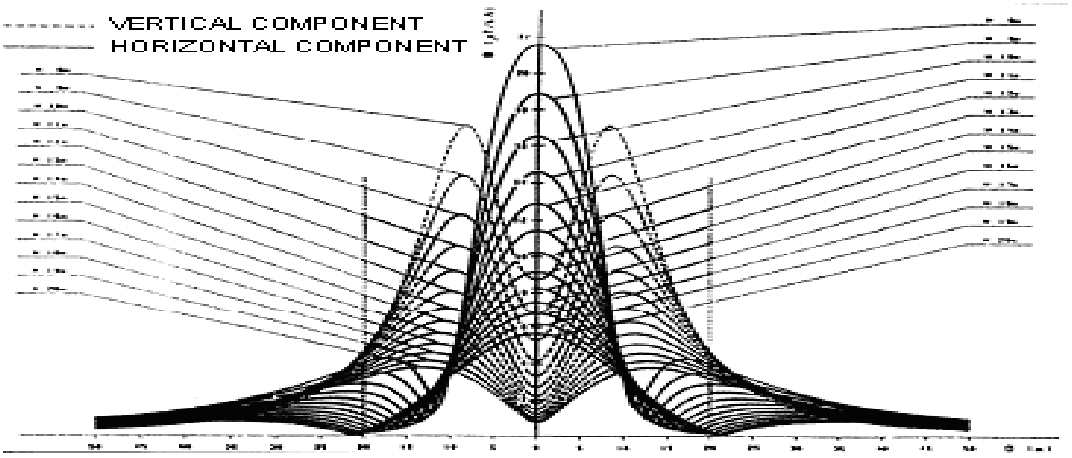


Fig. 2.2. *Analogous diagram to the previous, regarding the magnetic field*

The magnetic field also depends on the height and arrangement of the conductors; contrary to the electric field it is not shielded by objects and buildings present in the vicinity. Even for the magnetic field levels below electrical lines of simple triad are showed, obtained by resorting to some models of computation and with reference of conductors located at the minimum height from the ground allowed by Italian standards , and passed through the maximum provided load current for each type of line.

- 380 Kv line from 20 to 22 microTesla
- 220 Kv line from 16 to 18 microTesla
- 132 Kv line from 14 to 16 microTesla
- 15 Kv line from 1 to 3, 5 microTesla

2.5 Electromagnetic fields in underground MV conduits

In line with the provisions of art. 4 of DPCM 08/07/2003 of Law. n ° 36 of 22/02/2001 the tracks must be carried out taking into account the quality limit of magnetic fields, fixed by that legislation to 3 μT. Two possible types of ducts present are:

1. ducts in which cables are helicoidally laid;
2. ducts in which single-core cables are laid

In the first case, conduits in which cables are helicoidally laid, applies as reported in CEI 106-11 and CEI 11-17.

In fact, as shown in CEI 106-11 the reduced distance between the phases and their continuous transposition, due to stranding, causes that the quality objective of 3 μT, even in the limit conditions of conductors with larger section and relative " rated capacity ", is reached already at a very short distance (50 to 80 cm) from the axis of the cable.

It should be noted in this regard that even the recent decree of 29.05.2008, on the determination of buffer zones, MV underground lines cable and/or aerial helicoidal cables were exempted from the calculation procedure, so for these purposes is considered as valid the concepts shown in the above mentioned law. It follows that in all sections made by the use of helicoidal cables is possible to consider that the amplitude of the compliance zone is equal to 2 m, straddling the axis of the conduits, equal to the band of enslavement of the line.

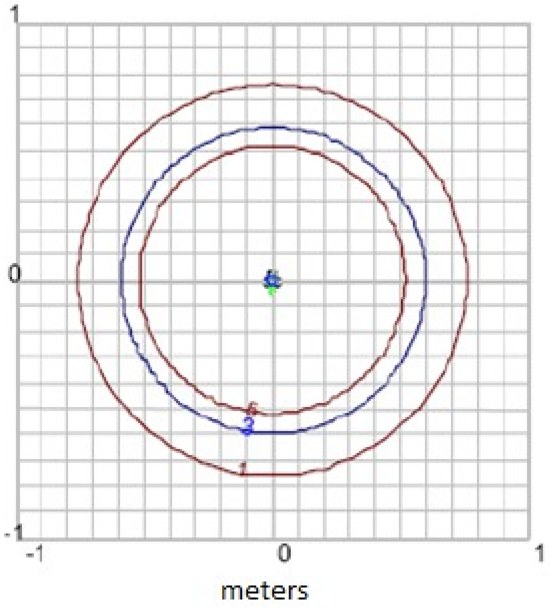


Fig. 2.3. *Curves with equal level for the magnetic field of a MV underground line in helicoidal cable (by CEI 106-11)*

2.5.1 First case: conduits in which only helicoidal cables are laid

In this paragraph, a calculation will be made of electromagnetic emission of a main conduit that collects cable ducts from four groups (A, B, C, D), this conduit arrives directly within a station of user. All cable ducts of the individual groups using a system of helicoidal cables such a system as mentioned above is advantageous from the electromagnetic impact point of view. To be specific, in the calculated section 4 lines are present at a minimum depth of laying of 1.5 meters, the sections are respectively: 600, 480, 370, 600 mm^2, on each line has been supposed a real flux, for the groups (A, D) is equal to 547 A, for groups (B, C) is equal to 456 A.

The following diagrams are obtained by the calculation software "CalcoloElf_versione 1.0", the most significant diagrams were calculated on two levels at zero from the ground, and at +1 meter above the ground, in accordance with current regulations, for the calculation of the effects of long exposure to sensitive receptors.

On y-axis of the diagrams is exposed the value of magnetic field strength expressed in microtesla (μT), on the x-axis is exposed the distances in meters (m).

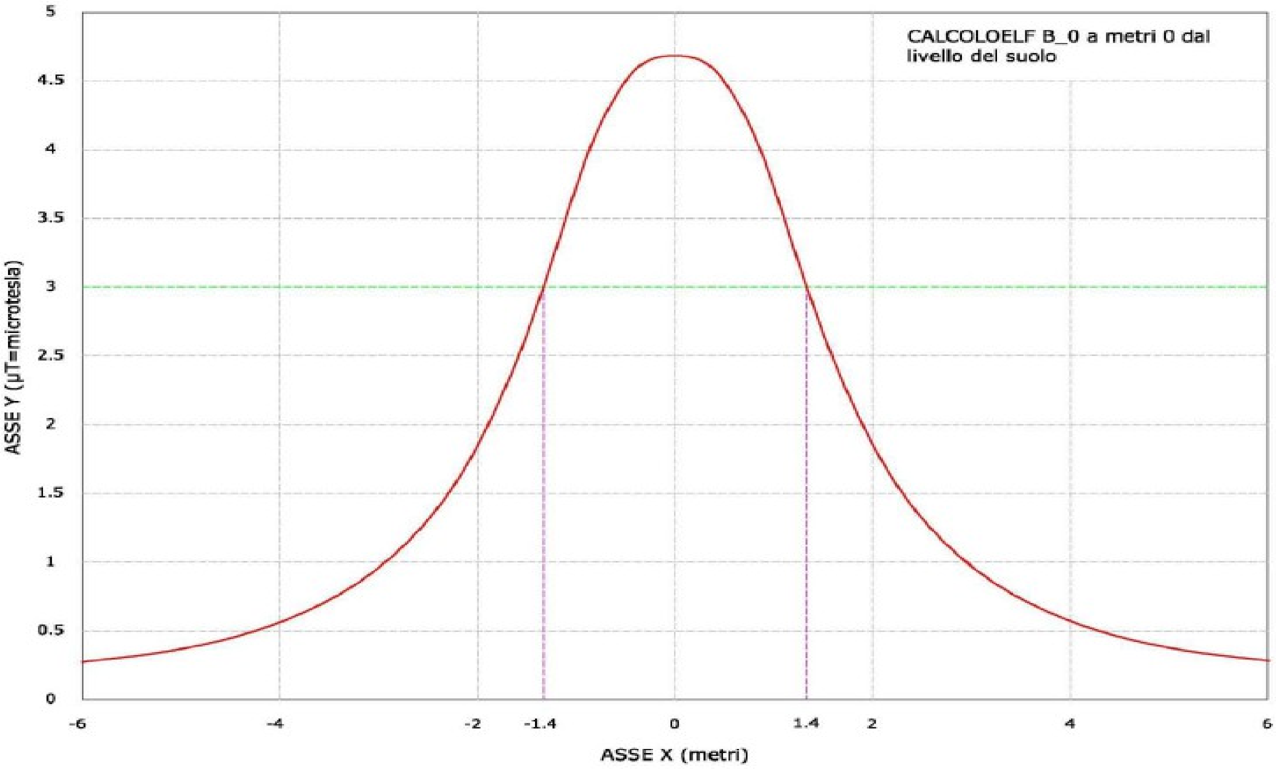


Fig. 2.4. *Diagram of the magnetic field of MV underground lines in an helicoidal cable at an altitude of 0 m above the ground*

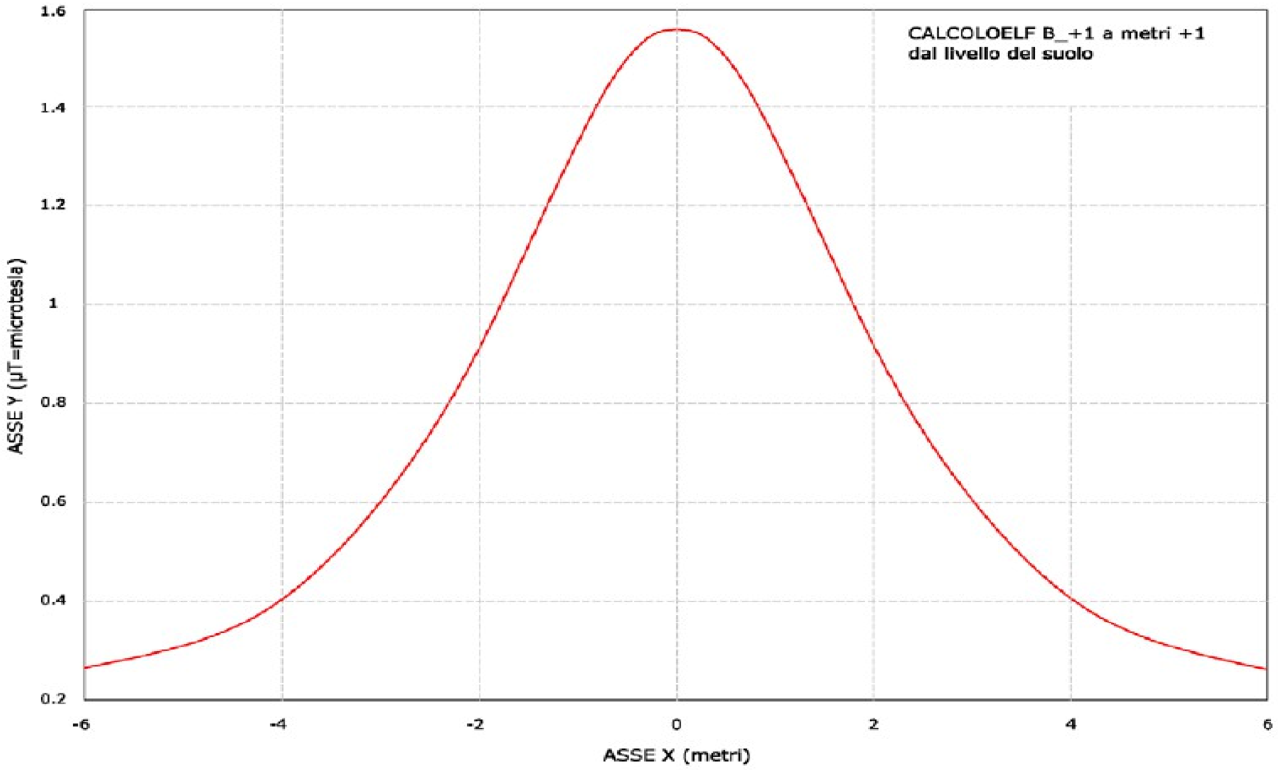


Fig. 2.5. *Diagram of the magnetic field of MV underground lines in an helicoidal cable at an altitude of + 1 m above the ground*.

Therefore, as regards the calculation of the magnetic field lines is, in MV underground lines, identified as respect volume relative to the volume MV underground conduits in axis with the cylindrical conduit with a radius of 1.4 meters and as respect band its projection to the ground. It is clear from the following image that the cylindrical respect volume does not cross the zero level and then there is no interaction with receptors sensitive so there is full compliance with the limits in force. The calculation of the electric fields has not been conducted since all cables in medium voltage employed are equipped with metal reinforcement connected to the ground, which shields the effect of the electric field, thus the external electric field to the screen is zero.

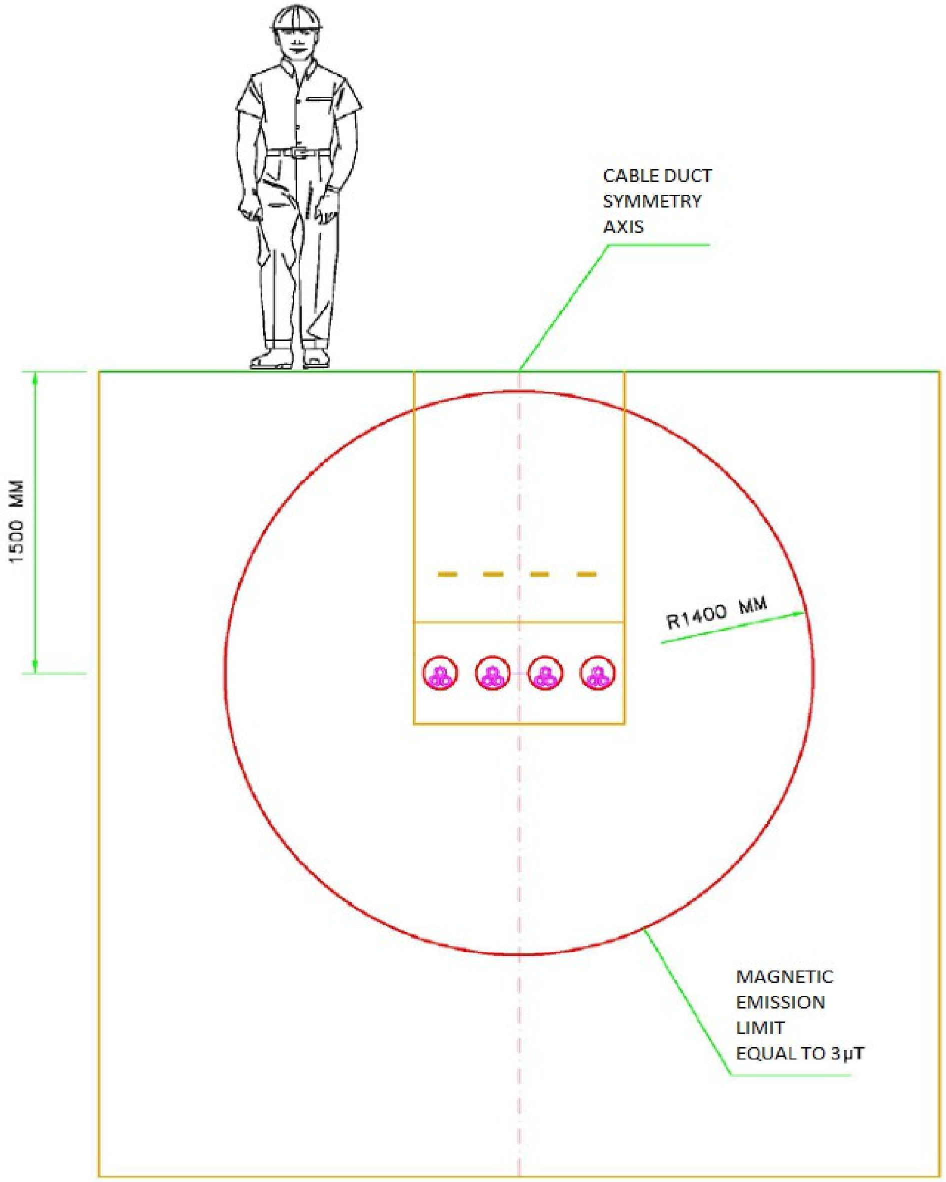


Fig. 2.6. *Respect volume of magnetic field in MV helicoidal underground cable lines*.

2.5.2 Second case: conduits in which single-core cables are laid

In this case it was considered the situation of ducts within the power station. Entering the specific section calculated are 4 lines to a depth of 1.5 meters laying of the sections are respectively 600, 480, 370, 600 mm^2, on each line was considered the real scope, for the groups (A, D) is equal to 547 A, for groups (B, C) is equal to 456 A. The distance between the backhoe is 20 cm and the installation depth is 1.5 m, the distance between each set of triples is about 1.5 m.

According to the Prime Ministerial Decree of 8 July 2003 in force since 13/09/03 regarding the Line underground cable with single-core cables laid in the floor, the formula to be applied may be the same as that used for overhead lines in plan:

$$B = \frac{P \times I}{R'^2} \times (0{,}2 \times \sqrt{3}) \tag{2.2}$$

Where P [m] is the distance between the adjacent conductors (in case of different distances, P becomes the average of the distances between the outer conductors and the central one), I [A] is the current, symmetrical and balanced, which crosses the conductors , R' [m] is the distance of the conductors at which calculate the magnetic induction B.

In such a configuration has been carried out the calculation of the magnetic induction field as required by the CEI 211-4 "Guide to the methods of calculation of electric and magnetic fields generated by power lines."

This rule considers the line infinitely long and allows to calculate the electromagnetic fields according to a cross section of the line itself. The calculation software "CalcoloElf_versione 1.0" used processes the vertical and horizontal components of the magnetic field produced by the individual conductors, taking into account their phase shifts, combining the various components, and outputs the main effective value of the resulting magnetic field. The following diagrams were obtained by the calculation software "CalcoloElf_versione 1.0", the most significant diagrams were calculated on two levels at zero from the ground, and share +1 meter above the ground, in accordance with current regulations, for the calculation of the effects of long exposure to sensitive receptors.

The y-axis of the diagrams shows the value of magnetic field strength expressed in microtesla (μT), the x-axis show the distances in meters (m).

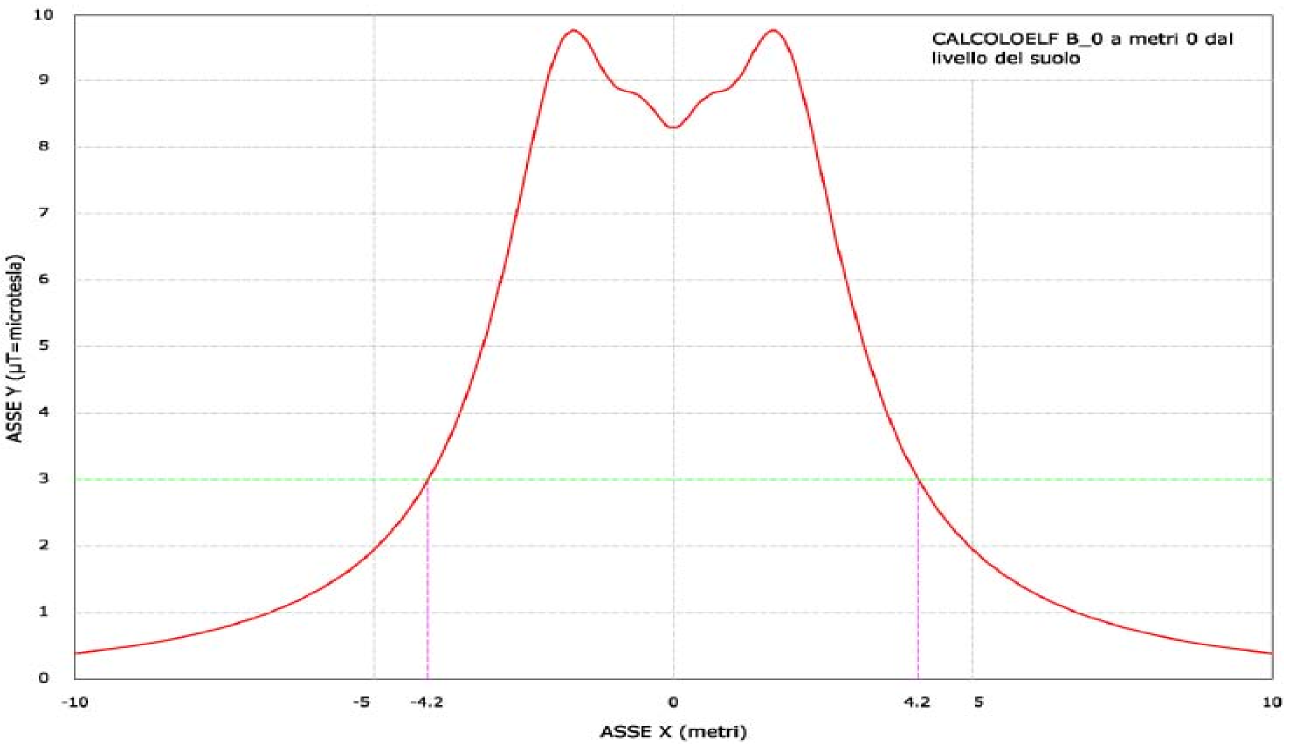


Fig. 2.7. *Diagram of the magnetic field in MV underground lines in single-core cable in the vicinity of the cabin at an altitude of 0 m above the ground*

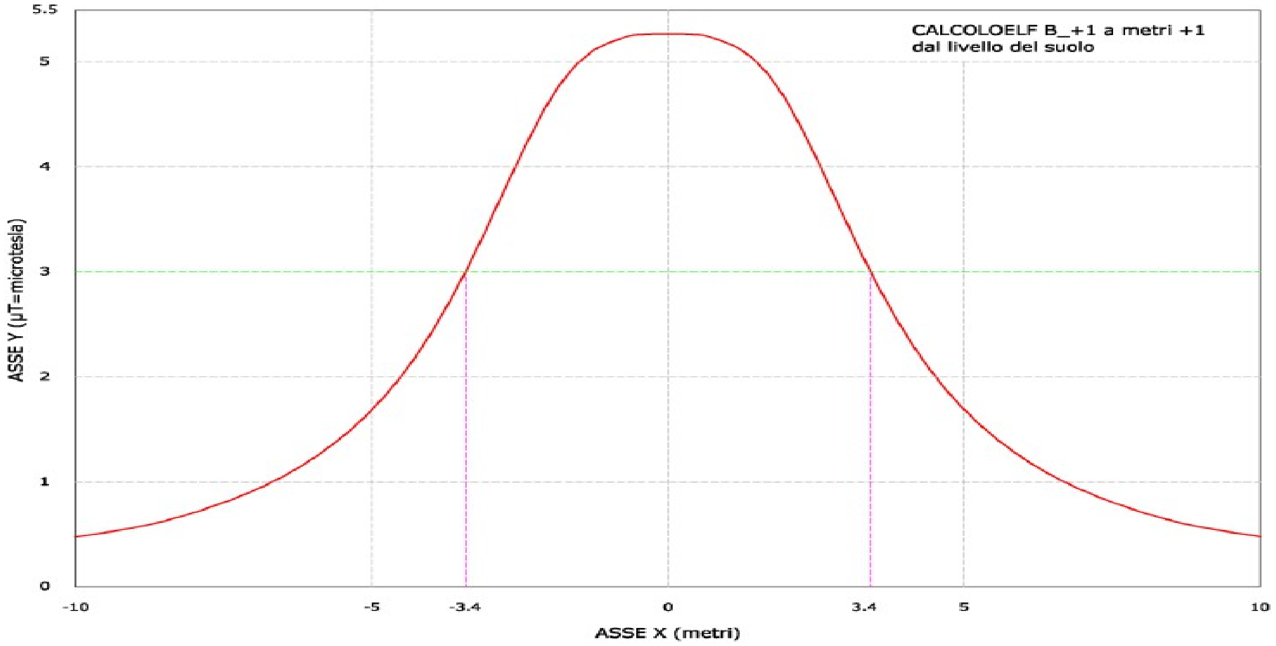


Fig. 2.8. *Diagram of the magnetic field in MV underground lines in single-core cable in the vicinity of the cabin altitude +1 m above the ground*

In addition, according to the recent decree of 29.05.2008, on the determination of buffer zones, is possible to consider that the width of the buffer zone in the latter case is approximately 8.4 m (4.2 +4.2 m above symmetry axis of the conduit).

The calculation of the electric fields has not been conducted since all cables in medium voltage employed are equipped with metal reinforcement connected to the ground, which shields the effect of the electric field, thus the external electric field to the screen is zero.

2.5.3 Conclusions

In the first case, that relative to the magnetic field of the main conduit that collects all the conduits from the groups (A, B, C, D), this conduit arrives directly inside the station user. It identifies as its volume compared to the volume MV underground conduit axis with cylindrical conduit with a radius of 1.4 meters and as a buffer zone of its projection on the ground. It is clear from the image that the volume of cylindrical respect does not cross the zero level and then there is no interaction with sensitive receptors therefore there is no danger to human health, in accordance with statutory limits.

In the second case of the cable ducts in MV, in the worst condition, namely that inside a cabin of delivery, the buffer zone, as required by the Decree of the MATTM of 29.05.2008, rides on the cable ducts to 'internal station user charge is equal to 8.4 m (4.2 +4.2 m above symmetry axis of the conduit). Within the buffer zone defined above should not exist sensitive receptors (structures inhabited by people for more than 4 hours), also in this area will be allowed only the presence of personnel who will carry out the sporadic and maintenance operations carried out in a modest time.

It can be concluded that in such examples there is no danger to human health.

Moreover, the calculation of the electric fields for both cases was not conducted because all the cables in medium voltage employed are equipped with metal reinforcement connected to the ground, which shields the effect of the electric field, thus the external electric field to the screen is null.

Chapter 3

Risk reduction solution and discussion

For several years, the conductors of the low-voltage lines are exclusively made with insulated wire over head lines or landfilled. Some old lines, however, have not yet replaced, using bare conductors and insulators on concrete piles, metal or wood. The incidence of death by electrocution on these lines is still significantly lower than that determined by the average voltage also by virtue of the low proportion of LV lines to bare cables. Consider that about 84% of the lines of LV Enel Distribution is underground or overhead cables. Due to the low incidence of mortality due to electrocution in LV lines, in the following paragraphs will be indicated risk reduction solutions exclusively for MV lines.

Excavation performed up to the depth of 60 cm from the floor except in the case of conduits of connection between the primary station and that of delivery to final consumers that will be executed at 100 cm of depth; on the bottom is laid a layer of sand of about 10 cm on which the pipes are laid, then covered with dry material such as crushed stone or similar, then it will be executed a “tomb” until full settlement of the material removed, while discharges will be removed. The excavations open and non-seated need to be reported in accordance with the law. For all cases that may arise in the course of the excavations and for which it was not possible to reach the depth of 60 cm (crossings of sewers, manholes and chambers of other public and private services), is necessary to be adopt steel pipes thickness less than 4 mm of 10 cm diameter, which if conditions permit, must be coated laterally with cement mortar. Inside the excavation, during the filling must be placed a PVC tape with the word "cables". The material obtained from the excavations of which makes it unnecessary to re-use for backfilling shall be transported in areas of the landfill where not create hindrance to the movement of vehicles. The solution of a power line underground cable is usually a specific niche use in cases of crossing urban and semi-urban areas and in areas of high ecological and environmental interest. In general the use of air electrical power allows for greater reliability in terms of safety and availability of the power line, since it does not encounter the problems of technical origin arising from the use of cables; in fact, the last choice includes: • construction works and linear excavations (underground installation of two sets of cable for each set of three airline for the 380 kV level); •possible imbalances in the flow of power due to the alternation of airlines and cable lines, with possible overloads in the parts where the cables are inserted; • problems related to the criteria of fast/slow closure due to malfunction with transitory nature on the cable conduit; • the problem of the compensation of the reactive power produced by the cables and the consequent insertion of shunt reactors, with the realization of clearing stations along the path to locate a function of the network topology; • presence of joints required to realize the various sizes (500-600 m) which, being critical points, reduce the overall reliability of the connection; • in case of failure you require additional site work and excavation for service restoration of the power line underground cable. An underground cable power line involves high investments, compared to the solution of a power line in over head solution and with reference exclusively to the cost parameters of the work (the sources consulted estimated cost values greater than the underground work of the airline in an order between 2 and 5 times higher) as the environmental parameters are definitely in favor of the buried solution (and do not take into account the savings in the operation of the underground solution than air). A correct "Cost - benefit analysis" allows greater information than the economic parameters underlying the different design alternatives: it is necessary to consider a Regional Spatial Plan which require the concentration of traffic flows and energy along the main existing highways. The process of negotiation and coordination that has to accompanied a project is fully integrated in the objectives of the Strategic Environmental Assessment, which was introduced in the European Community by Directive 2001/42/EC as an innovative tool that tends to integrate, in an earlier stage instances through territorial and environmental sustainable means of participation, negotiation and consultation, extended to the stakeholders. The Legislative Decree No. 152 of April 3, 2006 "Environmental Regulations" has also implemented the Directive mentioned at the national level: it is therefore important to compare and analyze on a base of a parameters set, with Technological, Economical, Social, Environmental and Territorial nature. The "Zero Option" is the alternative hypothesis that involves the renunciation of the implementation of the provisions of the intervention. Cost - benefit analysis carried out by comparing the set of estimated costs of undertaking the work (CAPEX) and operating and maintenance costs (OPEX) of the new facilities, with the aggregation of the main quantifiable benefits and monetized that are believed to arise from 'entry into service of the new link. The summations of the costs and benefits were discounted and compared in order to calculate the profitability index of the work (IP), defined as the ratio between the discounted benefits and discounted costs, and highlight its economic sustainability (the IR must be greater than 1). The analysis horizon (Duration) in the case of electric energy distribution is set conservatively to 20 years, value from a smaller side of the technical life of the media elements of the transmission network, the other equal to a significant limitation to the reliability of the estimates. The building up of aerial energy distribution network involves issues of land management and negative consequences as follows: 1. changes in cropping systems that need to move from work-intensive activities, because they require regular host more than 4 hours, low labor intensity. Substantially shift from specialized crops such as vineyards, orchards, and horticultural crops in greenhouses, to arable crops in open fields, grasslands and pastures; 2. inability to practice of valuable cultivation: eradication of vineyards and orchards, greenhouses divestment and loss of investment on horticultural lands are the consequences; 3. the impossibility to carry out intensive activities means loss of value of the interested lands and the residual ones; 4. the visual disturbance of the pylons and wires affect the recreational potential in areas affected by interfering on the development of certain economic activities connected such as tourist accommodation, educational farms, horse stables, etc.. The negative economic impact on farming is obvious and can be summed up in the loss of income, employment and wealth. Analyzing the economic loss this is essentially the depreciation of the value of agricultural land following the amendment of the addresses in the bands upcoming network, and the visual impact to the surrounding surfaces. Objectives of continuity, reliability, security and lower cost of electric service should be the driven forces of the choice.

3.1 Vegetation mitigation

In the decision discussion of such operas it is important to consider the visual and environmental impact, trying to rispond to this question: what is the goal of the project? In the following paragraphs mitigations of overhead distribution networks will be discussed: it is important to evidence the care and the men kind of the possible measures to take care, but: are they feasible or respected in the reality?

3.1.1 Nature of mitigation measures

As for the definitions of works of mitigation and compensation are briefly recalled the main criteria for implementation of mitigation and compensation linked to the achievement of certain infrastructure projects in the area. Nevertheless, as the alternative with lower impact has been chosen and the optimization of individual design elements has applied, residual impacts are impossible to avoid. There are some most common types of residual impact that have to be mitigated too: • physical-territorial (excavations, report, morphological changes, stripped of lithology, soil impoverishment and destruction in general); • nature (reduction of vegetated areas, wildlife habitat fragmentation and interference with, disruption and impoverishment of ecosystems in general and ecological networks); • anthropogenic - public health (pollution from noise and air pollution, pollution of aquifers vulnerable, functional interference, urban, commercial, etc.); • landscaping, as the sum of the above, together with the visual impact of the work.

3.1.2 Methodological considerations-applications

Often the term "mitigation works" implies different categories of interventions, which comprehend the real works of mitigation that is, those directly related to the impacts eg. reconstruction of wooded areas or of natural meadows eventually caught by the realization of the power line in the construction phase of the "optimization" of the project and not necessarily associated with a possible impact on existing vegetation, such as creating belts of vegetation masking of power stations, construction of shrubby areas within the brackets in the agricultural zone to improve the ecological network and implement biodiversity, etc.

3.1.3 Recovery of ecological network elements in the agriculture field

This phase implies the measures necessary to convert network to “green”, in order to reduce the visual impact of the opera, such as:

• reintegration landscape and nature of the power station by means of new construction: bands, hedges and/or wooded perimeter embankments; • planting of shrubs onto brackets. These actions are to be considered: minimal cost, given the type of intervention (sowing and planting of native shrubs) that do not subtract agricultural land, as the areas inside the base of support is still lost from the agricultural point of view; reconstruction of precise elements of the ecological network (approximately 10 x 10 m^2) which in agricultural areas crossed acquire a considerable ecological significance (refuge of wildlife species, the presence of local species of plants, etc.). The possibility of reconstruction of areas of valuable ecosystem can be traced back to the cases described below. The most frequent types of support and planting station are taken into account, although not identified with precision at the current level of definition of the project: • traditional support pylon with double circuit; • support pylon with double circuit and insulating brackets; • standard electrical stations. In lowland areas, references to potential vegetation and re vegetation measures to be proposed, are summarized in the diagram below.

n.	TYPOLOGY	NATURAL VEGETATION	RE-CONSTRUCTION
1	Pylon with double circuit	WOOD	GRASS PASTURE
		GRASSLAND	SHRUBS
2	Pylon with double circuit	WOOD	GRASS PASTURE
		GRASSLAND	SHRUBS
3	Single support with double circuit and insulating brackets	WOOD	GRASS PASTURE
		GRASSLAND	SHRUBS
4	Electric station		WOOD

Table 3.1. *Re vegetation strategies*

In the design phase of reconstruction of the elements of the ecological network and into the landscape and nature of the power stations for the area under consideration it is proposed to adopt the following procedure:

- adopt methodologies of Naturalistic Engineering through the exclusive use of native species of shrubs and trees of species that refer to the dynamic range of the potential natural vegetation of the site;
- create wooded bands, partially uplifted, in other to improve perspective, the masking effect, consistent with the limits imposed by the plant safety (maximum heights of 5-6 m below the input lines). The following types of intervention have been identified:
- power stations in the uplifted forest zone realized through plantations of tree and shrub species of small embankments (h_{max} 3-4 m) to ensure the rapid effect of visual masking, which improves over time as the individual plants grow (medium term) ;
- forest buffer zone realized by simple planting of trees and shrubs in the sections where there is the possibility of the embankments;
- tall shrubs accomplished by simple planting shrub species for functional limitations of the system in case of input - output lines;

- support pylon with double circuit and insulating brackets: clean up and restoration of vegetal ground, seeding, and shred species grow up.

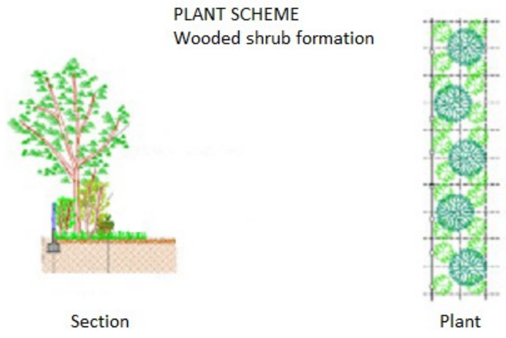


Fig. 3.1a. *Wooded shrub formation; section and plant*

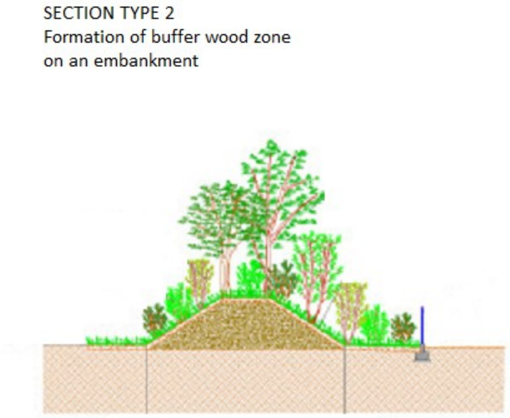


Fig. 3.1b. *Formation of buffer wood zone*

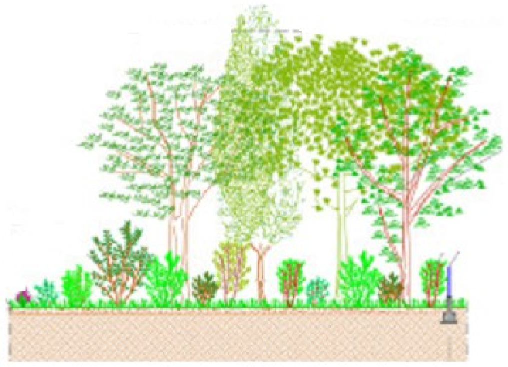


Fig. 3.2a. *Formation of buffer wood zone*

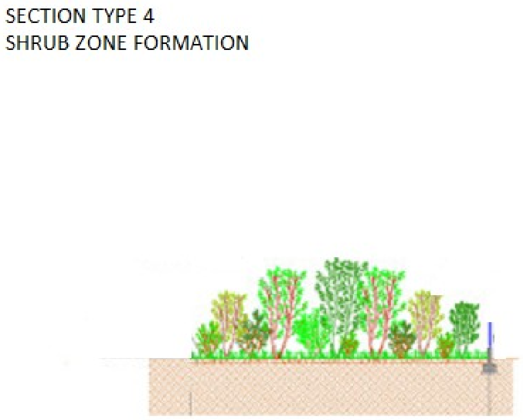


Fig. 3.2b. *Formation of shred zone*

3.1.4 Considerations in planning mitigation works

The shrubs around the leg to be understood only in the areas of natural beauty, unless interference with the elements of the eco planning (eg. Shrubs should not be planted on the lawns where it is stable if anything conceivable to perform transplants in sod turf from the original).

Fig. 3.3. *Sections of support re-vegetation support*

3.1.5 Choosing the best technological solution

The national electricity transmission grid, based on the criteria of functioning and exercise, mainly consists of power lines in the over head typology, with different structural characteristics in relation to the different needs of realization and voltage levels of the Italian electricity system. The solution of a power line underground cable is usually a specific niche use in cases of crossing urban and semi-urban areas and in areas of high ecological and environmental interest. Until the 90s was also used in oil-filled cable technology (OF), which had technical characteristics that further limited the scope of application: the cables into OF, in fact, require oil supply tanks at predetermined intervals also to ensure, in function of the gradients, an internal pressure adequate, therefore, with a constraint on the characteristics of the path dictated by the height differences to be overcome.

To reduce the magnetic field, at the same current, it can intervene on the arrangement of the conductors and groped to 'shrink' the line, reducing the distance between the phases, with supports in insulating brackets. This solution involves a reduced occupation of space and, therefore, lower supports.

The possibility of using supports in insulating brackets, compared to conventional lines, however, entails a mechanical and electrical nature which does not allow an extensive use of these lines, in complete replacement of traditional technology,

in addition to the fact that the current maintenance procedures under tension power lines are not applicable to compact lines. Also, along the route of the line is not possible to install the same angles that are present in the traditional lines, due to the reduced distance between the phases and the different mechanical performance of the supports.

The tubular supports allow to reduce both the visual impact, being thinner, both the electromagnetic field, thanks to the reduced distance between the conductors in the three phases.

These supports allow to reduce from about 10 to 2.5 m the base of the tower, with a considerable saving in terms of subtraction of soil. By contrast, the reduced mechanical performance of this type, considerably restrict the field of use (short spans, reduced deflection angles of the line, reduced unevenness) are the reasons why it is not possible to adopt this type of support in all cases.

3.2 Environmental framework

The following paragraph summarizes what inferred from studies conducted in the Environmental Impact Study for each environmental component potentially caught by the project due to a new electric network, with aerial or buried cables.

3.2.1 Atmosphere and air quality

Air is one of the four essential elements of the earth, breathed continuesly in each day, fundamental for each aerobic process; it is not a case that the first impact considered it is about it...

3.2.1.1 Summary report of the impacts

As regards the assessment of impacts, for the construction phase are revealed as only possible critical points resulting from the dissemination of dust, especially in times of particular climate and drought, related to the handling of the material of the excavations and the traffic generated by the construction activities.

These problems are of a decidedly limited, and mitigated with appropriate measures aimed at containing diffusion phenomena such as a careful material handling and a regular cleaning of roads of the construction site. Regarding the operating phase, given the type of intervention in the project, there are no particular criticality related to the operation of the works in the project.

Even the phase of end of life disposal of entities is less important than the implementation phase.

3.2.1.2 Mitigation actions

In order to reduce the phenomenon of lifting of dust, will be taken of the techniques of proven efficacy, flanked by a few simple steps and behavior of common sense shown schematically in the following table:

Phenomena	Mitigation actions
Dusts uplift from temporary deposits of excavation and construction materials	• reduction of the exposure time of stocked material to the wind; • localization of deposit area not affected by turbulence; • watering of stocked loose material: the moisture content of deposits, has an important influence in the determination of the emission factor. Due to “WRAP Fugitive Dust Handbook”, this technique guarantees the 90 % of dust dejection
Dust uplift due to the earth movement in the construction site **Phenomena**	• movement of scarce heights and with low exit velocity; • coverage of fine inert charges which can be dispersed during transportation • reduction of collection works of loose material **Mitigation actions**
Dust uplift due to the earth movement in the construction site	• watering of the material: this technique, which due to the “WRAP Fugitive Dust Handbook” guarantees a reduction of almost the 50% of the emissions, does not show potential impacts on other environmental sections. It can represent a variable from the economic point of view, due to the possible high amounts of water requested to avoid the dust uplift
Dust uplift due to the circulation of vehicles inside the construction site	• watering of the ground, more intense in hottest seasons and in windy periods. It is possible to stop this action after rainfalls. It is also suggested to improve watering on the area mostly subjected to traffic, by a preventive analysis of transit ways;

	• low circulation velocity of vehicles; • coverage of vehicles • realization of pavements inside the construction site, as first phase
Dust uplift due to the circulation on streets and without pavement	• watering of the ground • low vehicles velocity • vehicles coverage • disposition of mobile barriers in the vicinity of residential centers and near the accesses of the construction site
Dust uplift due to the circulation of vehicles on pavement roads	• realization of trenches for wheels clean up • low velocity of vehicles circulation • coverage of vehicles
Other	• actions of grass filling and recovery of areas without pavement in order to reduce dusts due to wind, also after the end of construction site.

Table 3.2. *Mitigation of dusts*

3.2.2 Aquatic environment

What about surface water and the water bed? It is necessary to consider the permeability of the site soil of the zone interested by the intervention and the water flux, the preexisting water corses, such as streams, rivers and so on.

3.2.2.1 Summary Report of the impacts

In the case of interventions in hilly and mountainous areas, there could be no interference with the internal water circulation. Most of the rocks have a secondary permeability (due to fracturing), while some are almost impermeable (silty shales and sandstones, clays).

On these formations excavations of limited depth, such as those in the project, will not cause any change in hydrogeological.

In the case of low depth to some of the supports of the track in the project, will have the foundation beneath the surface of the average excursion of soil, or will be interested by seasonal fluctuations.

In order to avoid failure, it will always be necetssary, beyond where possible, lay the foundation plane below the line of least excursion flap, so that the foundation remains always "give up" and is not subject to fluctuations in piezometers.

Regarding environmental impacts, will be sufficient to pay attention during the construction phase, so that, given the action under the water table, do not lead to accidental spills and contamination.. In the case of a tower which falls within an alluvial area with a determined return period of the stream under consideration, is necessary to consider the possibility of a flooding of the base of the tower.

3.2.3 Soil and subsoil

Soil is the solid matrix which substain the human activities, it is fundamental to guarantee its stability during and after the intervention, in order to have a successfull long time life of the opera.

3.2.3.1 Summary Report of the impacts

From the point of view of geological and geomorphological aspects, in the absence of intervention, for the area of interest is expected the natural morphological evolution in relation to exogenous agents that normally act on the territory concerned.

On the other hand also as a result of the realization of the power line is not expected to have a significant impact to the geological structure, in particular for the underground excavation activities and earthwork related to the construction of the foundations are of a size that does not alter the state of this sub-component.

For the same reasons there are no even significant physical and chemical interactions with the circuits of movement of groundwater. It is necessary to consider the rock formations in order to draw up a proper analysis of slope stability with a consequent choice of the most suitable route in order to avoid geomorphological problems: example is that of areas with presence of turbidites, subject to phenomena of dripping and sliding surface. It is therefore essential for a correct geomorphological analysis the study of the geological map, attached to the study of environmental impact.

3.2.4 Vegetation and flora

Sustainability in my opinion is the equilibrium between what's new and the preexisting elements of a determined system: mitigation is the mutual dialogue, but it has to be reinforced by conoscence. Flora and fauna are the live elements before humans, and it is important to establish a conitinuity of the natural evolution.

3.2.4.1 Summary Report of the impacts

The impacts to the component are mainly attributable to the construction phase, because of the actions in the project related to the erection of the trusses and the stringing of the cables of the power line. Possible actions that could have an impact borne by the component are as follows: opening of the construction site, transportation, openings of tracks access, preparation of pitches for the realization of the supports, foundation work and installation of supports, cutting plants and finally, stringing of conductors and guard cable. During the exercise the only impacts are attributable to the pruning of tree species in order to ensure the safety distance from the cables of the power line. As regards the impact associated with the removal of the plant cover, the prerequisite for the evaluation of interference is represented by the design effort that is necessary to minimize the cutting of the vegetation below the line.

During processing for the installation of supports and the stretching of the conductors may result in damage to the vegetation left standing in the surrounding areas and along the service roads, as they may manifest as sores on the trunks or damaged branches, barking trees, broken branches, trampling, soil compaction, direct disturbance resulting in open wounds that open the way to pathogens.

These risks of impact will be minimized by adopting appropriate measures in the construction phase, in order to avoid excessive interference with the arboreal species arranged in the vicinity of machining operations.

3.2.4.2 Mitigations

In the design phase, the distribution of the supports on the territory has to be made, as far as possible, keeping the bottom of the power line conductor at a height such as to prevent any cutting of the vegetation.

Similarly, as regards the opening of slopes and pitches for the construction of the supports, the area of cleaning of vegetation has to be limited to that actually required on manufacturing needs. The pose and the stringing of the conductors has to be done avoiding the cutting and damage to the vegetation, thanks to the use of the helicopter and of a winch and a brake.

At the end of activities is necessary the cleaning and restoration of all areas caught during the construction phase.

If the interference with the vegetation is unavoidable, special precautionary techniques will be implemented to run the cut: they consist in limiting the cut at the top of the plants that actually interfere with the line (topping), to the benefit not only of the vegetative component, but also the landscape, with the reduction of the perception of the intervention.

An important mitigation is also represented by the use of tubular piles where technically possible to substantially reduce the overall dimensions of the supporting structures of the line.

Additional mitigations have also to be taken during construction to limit interference with the vegetation near the construction site:

- the site area has to be fenced and perimetrate in order to minimize the killing, or the interference of individual trees in the vicinity;
- the soil adjacent to the tree species has not to be compacted: is necessary to provide an area of respect around the trees bordered by a special fence
- near trees the transit of vehicles has to be limited at the minimum
- site installations will be avoided in the vicinity of individual trees
- protections will be taken around the trunks with wooden planks, of adequate height to the possible interference and also large enough to protect the crown.

3.2.5 Fauna and ecological networks

A lot of activities can be done - for free - by animals, such as the guard against rodents by cats, the fundamental action of pigeons against insects and louses: the food chain has to be preserved!

3.2.5.1 Summary Report of the impacts

The main potential for interferences related to the construction and operation of power lines are:

- the risk of collision of birds against the guard cable during operation;
- the disturbance potentially caused to wildlife by noise during the construction phase.

Below, applying the methodology and parameters of evaluation exposed in the SIA, shows that the evaluation was carried out in function of the characteristics of the specific territorial areas caught.

Regarding the interference in avifauna, especially compared to the risk of collision, it is necessary to identify the area involved in the project, and the ecosystem characteristics.

3.2.5.2 Mitigations

Following the valuation analysis made in the areas of intervention can be identified possible mitigation actions to be implemented along the route of the planned work to minimize the potential impacts described.

As for the construction phase, interference with wildlife, due mainly to the acoustic impact of the construction site, can be limited to the maximum thanks to the adoption of the normal operating devices, which are described in the section on mitigation.

Concerning instead the operating phase, in order to reduce the possible risk of collision of birds with the conductors may be fitted, in areas where such collisions can occur, visual warning systems.

In particular, it will have on the rope guard, at varying distances depending on the risk of a collision, the spirals of colored plastic (usually white and red) arranged alternately. The dash lines on which to install such systems may be those with medium to medium high impact. It should be noted, moreover, that these bollards are particularly effective because in addition to their physical presence, thanks to their obvious coloration, produce noise audible only from fauna making the work for the latter distinguishable even in poor visibility conditions.

3.2.6 Noise

Acoustic pollution is a contingent effect related to human activities: what's about the construction site and the strategies of prevention? Visual advertisement can be considered limited to a specific zone of interest, while noise interest the environment subjected to the action of the acoustic wave, with the risk to involve who is not interested in.

3.2.6.1 Summary Report of the impacts

With regard to the construction phase, the main emission factors are linked to the activities of the means of construction, to working and induced traffic, which given the type of work, will not include activities particularly emissive.

Although at this stage were not reported particular problems is useful include the use of mobile barriers height of 3 meters that define the site area, mainly in the areas most populated, designed to decrease levels of impact on the buildings next to areas of intervention.

As for the operating phase, it is assessed on the basis of the technical characteristics of the works in the project, the potential disruption caused by the crown effect. Analyzes carried out have shown that at the reference distance of 15 m from the nearest conductor, technical data from standard reference books indicate that the noise level induced falls on the 40 dB. These levels are broadly compatible both with respect to the indications given from law and also with the comparison to the distances of buildings, including blocks, in the immediate vicinity of the works in the project. On the basis of the above consideration it is considered that the level of impact on the component is absolutely irrelevant, and this consideration has to be verified for each element of the project.

3.2.6.2 Mitigations

The predictions of the impact point to the possibility that occur during construction noise conditions that would require mitigation measures to contain them as much as possible. Priority action must aim at cutting emissions at source, with interventions both on equipment and facilities, both managerial.

In general terms, whereas there is the problem and the need to comply with national legislation on limits of exposure of workers will certainly be preferable to adopt appropriate technical and management solutions able to limit the noise of the machines and machining cycles.

The reduction of emissions directly on the source of noise will be obtained through a proper choice of machines and equipment, with appropriate procedures for maintenance of vehicles and equipment, and finally, intervening whenever possible operational modalities and the predispositions of the construction site.

Therefore, in the planning and realization of the site, is necessary to put in the devices listed below in the form of a check-list, for the limitation of noise emissions.

Selection of machines, equipment and performance improvements:

- selection of machines and equipment approved in accordance with European Union directives and subsequent national implementations;
- use of construction equipment and operators focusing on the tires rather than the undercarriage;
- installation, if not already provided, of silencers on discharges;
- use of soundproof generators and compressors.

Maintenance of vehicles and equipment:

- reduction of friction through lubrication operations;
- replacement of worn parts;
- control and joints tightness;
- balancing of rotating parts to prevent excessive vibration;
- test the tightness of the closing panels of the engines;

- carrying out of maintenance to roadways internal to the site areas while maintaining the road surface level to avoid the formation of holes.

Operational Mode and preparation of the construction site:

- choice of a suitable ground for the storage of materials and the shelter of the means necessary for the construction;
- supply for working stages and in subsequent times so as to limit the size of the area and to avoid storage for long periods;
- orientation of the plants that have a directional emission in a position of minimal interference;
- location of the fixed noisiest at the maximum distance from the critical receptors or the most densely populated areas;
- exploiting the potential shielding of fixed structures in the site with careful design of the layout;
- use of anti-vibration bases to limit the transmission of vibrations to the floor;
- limitation to the necessary activities in the first / last hours of the daytime period (6 ÷ 8 and 20 ÷ 22);
- imposition of directives to operators such as to avoid unnecessarily noisy behavior (avoid dropping materials from excessive heights or drag them when they can be raised ...);
- prohibition of misuse of horns, replacing them when possible with warning lights.

The site operations will be carried out basically by limiting the noise disturbance to the population, preferring weekdays and daytime hours. With regard to the transit of heavy vehicles have to avoid the transit of vehicles in the early hours of the morning and during the night.

All mitigation must be calibrated in relation to:

- the final layout of the site;
- equipment that will be used;
- authorization and exemption requirements of ARPA.

The second type of intervention concerns hoc measures designed to prevent the propagation of the noise generated by construction activities in order to protect any receptors which might be affected by excessive noise levels. Within this type of assistance is to deploy mobile barriers at the edge of the sites, the construction or even better at the minimum distance from sources of noise technically feasible. The Mobile noise barrier able to fulfill the above requirements can be realized in metal (aluminum or steel), with the supporting structure to "L" in steel.Although the simulations have shown levels of impact within the legal limits, it will be useful to foresee the use of a mobile barrier with a height of 3 meters, for use in the construction site in the areas mostly populated. The benefits produced by these barriers have been tested with simulations dedicated.

With regard to the possibility that, in spite of the mitigations and attention on environmental display, exceedances can be checked, it highlights the need to apply to operate in derogation of the terms of the second law when required by national legislation (pursuant to Article . 6 paragraph 1 letter h of Law no. 447/95) and in the manner prescribed by the concerned municipalities.

3.2.7 Landscape

Landscape represents the overall picture, the simplest view from a certain distance, the whole system seen in an unique picture, where details are represented by the elements involved, which can determinine an increase or a depreciation of the interest of a location.

3.2.7.1 Summary Report of the impacts

A long study of the area and consultation with the local regulatory authorities and local communities concerned is necessary, in order to guarantee a diffuse and shared information and partecipation. Municipalities have to be involved, in order to have a complete knowledge of area interested and the respect of the original landscape.

3.2.7.2 Mitigations

The reduction of the environmental impact of an infrastructure such as a power line is an operation that takes full advantage of proper planning, careful to consider the multiple aspects of reality environmental and land concerned. Therefore, it is at this stage that occurs already put in place a series of measures to streamline the operation.Further measures are applicable during construction, operation and demolition of the power line. For the latter phase are valid criteria similar or symmetrical to those of realization. The criteria that guided the selection phase of the track can be useful to locate the path that interferes less with the structure of the landscape. In addition to the obvious criterion to limit the number of supports to those technically indispensable, can be applied to other relating to the choice and placement of supports, and some of these were a direct application of the criteria of good practices:

- containment of the height of the supports to 40 m, also in order to avoid the necessity of signaling for the safety of low-altitude flight which would make particularly visible the power line;
- the location of the supports in areas without vegetation or where it is more sparse when the track passes through wooded areas;
- the location of the supports in order to reduce visual interference especially in populated areas or with historical and cultural heritage;
- optimization of the positioning of the support in relation to land use and its fragmentation, such as positioning, where possible, the boundaries of the property or in correspondence of country roads.
- compliance with the bands of protecting river (150m), small streams, by placing the pylons out of them;
- possible adoption of a mimetic paint for backups, taking into account the specific relationships between support and background. During the design will perform the appropriate color choices so as to harmonize the integration of support depending on the characteristics of the landscape traversed;
- any use of green isolators in woodland areas that may be, in this context, less visible than white glass normally used.

During operation the main impacts on the landscape mainly concern the the perception of new infrastructure. This is also the greater impact that generates the work as a whole. The works of minimization envisaged can be framed in the following areas:

1. typological selection of supports;
2. painting of the pylons;
3. creation of buffer zones;
4. works of restoration and landscape restoration;
5. night lighting of the works.

3.3 Conclusions

The Environmental Impact Study is the culmination of a long process of consultation and sharing between the promoter of the complex and difficult project, the relevant local authorities and local communities concerned.The SIA, environmental study impact, takes into account the characteristics of the territories concerned.

Therefore, these supplements analyzes covered the same time the project is currently in process, and all the alternatives being proposed procedure by the various local communities and the Technical Board Interregional set up ad hoc.

It was found in general that the suggestions of local stakeholders and the relevant local authorities are more responsive to the unspoken "expectations and vocations" environment. In fact, as can be seen in detail the results of the all Alternative, compared with the respective solutions of the project process, improvements were globally and therefore to be included in the project. In fact, these variations, each in its specific relation to the territory concerned, have to be assessed as an improvement over the original proposal.

Therefore the findings of the environmental study impact is a project based on the basic choices of the company integrated with the alternatives of local realities, including the alternative proposed by the Interregional Technical Board, involving the movement of new whether in areas far from the villages, makes the most environmentally compatible, and on it is possible proceed to a detailed development aims to solve any problems on time remaining with appropriate mitigations.

The long study of the area and consultation with the local regulatory authorities and local communities concerned, has the aim to produce positive results as mainly dependent on the new power can not occur particularly critical impact situations, despite the worst situation in which it through a set of territories and landscapes strongly characterized and also significantly protected both by the natural characteristics for both their specificity landscape of this land border between two different regions steeped in history.

First of all the stretches where the replacement of the existing with the new power line follows the existing route, then in the sections in which no particular territorial variations are produced, there are no additional impact situations, for the persistence of a condition already known and in somehow already metabolized within existing landscape.

Chapter 4

The comparison

At the end, common place to argue that in a power cable is preferable to a plane: it is not always true. Decisive parameter for this purpose is the nominal operating voltage (maximum effective value of the electric potential difference between two conductors of the power line), which in turn is closely linked to the power to carry:

- the low voltage (less than 1 kV, the standard value in Europe is 400V, for power up to hundreds of kW) the use of the cable, with current technology, it is certainly preferable from the point of view of economic, environmental, are used for the distribution of electrical energy, have a short length (on average, a few hundred meters) and do not pose any particular problems of exercise;
- for medium voltage (1-36 kV for power up to a few MW), although, with the current technology;

The most expensive of the over head lines, are used heavily in urban distribution and that of industrial plants as the higher cost is offset by the lower space required (valuable element in highly structured area), have limited length (up to several kilometers) and most reactive power required compared to the airline is low, allowing an exercise substantially similar to that with airlines.

For a correct comparison between the two technologies, aerial and underground cable, it is necessary to consider the following aspects:

- technical - functional and exercise;
- environmental impact;
- economical,

below are examined in more detail each of them.

4.1 Technical-functional and exercise aspects

A power line is characterized by several parameters, related to the type of technology and the technique of installation, of which the main ones are those which express the electrical equivalent circuit as responsible of the electrical balance that is reached during the transmission of the required power. They are:

- the resistance, depends on the section of the conductor, the type of material (usually copper or aluminum) and the length of the power line, responsible for the loss of power due to the passage of current: between the two technologies (if the power line is properly sized) there is a substantial difference;
- the inductance, depends on the distance between the conductors of the three phases (increases as the distance) and the section of the conductors themselves, it is responsible for the energy stored in the magnetic field that is generated with the passage of current: it is greater in the airlines compared to those in the cable, because the distance between the phases is much greater in the first;
- the capacity, also depends on the distance between the conductors of the phases (increases with decreasing distance), from the section of the same and the material used for insulation; it is responsible for the energy stored in the electric field that is generated with commissioning of the power line voltage: it is much greater in cable lines that in those routes.

In summary, a cable has, with respect to the airline, a greater capacity and a lower inductance. In terms of exercise:

- a greater capacity leads to a higher reactive power required to keep energized the cable (keep in tensi oter transmit the active power required by the user).
- a lower inductance leads to a higher fault current, which implies, in turn, the need for a more costly dimensioning of connected equipment such as circuit breakers, disconnectors, transformers, etc. This diversity of parameters between the two solutions has other implications on the exercise, the main of which is that of voltage regulation which is more difficult in the case of the cable with respect to the airline.

Aspect of fundamental importance in the exercise of a power line is its unavailability, ie the probability to not be able to carry the required power in a given period of time (normally one year). It depends on two factors: the probability that a failure occurs and the average time required to restore the functionality of the power line as a result of failure.

The over head power lines have a number of faults per kilometer on average higher than those in underground cable, but most are transient faults (the 90% found in the statistics of failures of the Italian lines coincides with that found at the international level), and are solved by the system automatic protections, in a time of a few seconds, or by means of quick operations in remote control, in a recovery time of a few minutes, and, overall, have little weight on availability.

Considerable weight on the unavailability him instead the permanent faults, ie those involving permanent damage to the structure of the power line and require the intervention of special teams of operators which, when you find the point where the failure occurred, they must proceed by the appropriate instrumental to the restoration of the structure of the power line damaged.

This type of failure is more common in average power lines than in aviation. An in-depth study (mention publ. CIGRE) shows:

- faults on high-voltage 132-150 kV airlines are 1.7 per 100 km of line in a year, of which 10% ie permanent, therefore 0.17 per 100 km per year,
- faults on power lines (as always said permanent) 1.6 per 100 km per year if oil-insulated and 0.35 per 100 km per year if made of plastics,
- the average time to repair a permanent fault on airlines was 7 hours, while the cables in oil of 220 hours and for cables with synthetic insulation of 100 hours.

All this leads to the conclusion, as was observed statistically (cite CIGRE), an unavailability:

- for airlines of 0.02%/100km on an annual basis, that is about 2 hours per year per 100 km of line;
- for cable lines of 3.9%/100km on an annual basis for those in oil and 0.39% /100km on an annual basis for those with synthetic material, that is, to the cable, the unavailability is 20 to 200 times greater than that of the airlines.

In the case of suburban path, not easily accessible, is necessary to predict repair times longer than the average, since this is a reputable unavailability greater than at least 30 times that of the airline.

4.2 Aspects of environmental impact

About the environmental impact it is possible to identify two components:

- the global component,
- the local component.

The global component is made up of all the resources (materials and energy) needed for the construction, operation throughout the useful life of the work, the dismantling and recycling at end of life.

This type of analysis is very complex, to give a first rough idea can be seen as follows:

- an airline uses materials such as aluminum (conductor), steel (wires and supports), glass (insulators), concrete (foundations), all materials (except cement) are easily recoverable, have an energy content per unit of mass not high, the manufacturing process has an environmental impact not high per unit mass;
- a cable line (with reference to plastic insulated cable) uses aluminum and / or copper (conductor and shield), girdles of semiconductor material, plastic materials for the insulating layer, outer sheath of thermoplastic material, cement and steel for construction of the seat of pose, almost all materials are more difficult to recover (in practice, the materials semiconductors and insulating those must be destroyed with little environmental impact) and whose production processes are energetically more costly, the amount of cement required in addition, to equal path, is higher compared to that of the airline.

Furthermore the operation of an underground cable is energetically much more costly than in the case of the airline. All this leads to the conclusion, as also demonstrated by studies in the field of CIGRE and IEC, that the overall environmental impact of a power line underground cable is greater than that produced by the same airlines.

For the local impact, with specific reference to the case in question, it is in the first place be noted that the construction of a power line in the high voltage cable requires the excavation of a trench of about 1 m to 1.8 m for the whole length of the track with the need to create a path along the area of accessibility of at least 6 m to allow the use of excavating machines and trucks for the removal of the excavated material in excess and for the supply of that necessary to the construction (sand, artifacts of cement, cable etc..). In addition, the exercise of the power line needs to have the accessibility of the entire process to be able to intervene to repair any faulty conditions: this requires the maintenance of a strip of land of 6 m wide free and the affixing of appropriate signage, for safety reasons. It is obvious that all this constitutes a significant environmental and landscape impact in particular in those areas where there is the presence of a large and varied vegetation: it is certainly more impactful a deep and very long cut compared to airlines that can be raised compared to the existing vegetation and insist on the ground on few m^2.

About irreparable it has also to be noted that currently, both in Italy and in other countries, is in course the dismantling of old power planes making available the floor surface restoration or other uses, while, with regard to underground cables , the process require to replace the old cable with a new one, but with no demolition of the cable ducts which are therefore becoming permanent structures.

4.3 Economic aspects

The cost of a high voltage underground cables are always much higher than those of airlines. In particular:

- the cost of building an underground cable ranging from about 3.6 to 16 times (average 7 times) those of an overhead power line,
- operating costs are from tens to hundreds of times higher than airline cable (in relation to the cost of primary energy and labor),
- the costs of dismantling and recovery in the cable are almost double those for the airline.

An additional, but not least, the economic aspect to consider is the value of the areas concerned by the work, in order to define a possible purchase and estimate the diminution in value to compensate.

The economic value of exchange is defined by the Land Registry or that resulting from recent sales contracts carried out in the area under consideration, any other value would be pure fantasy.

The area affected by the power airline plane of the compact type is estimated to be about 25 m wide, while for a possible underground cable should be about 6 m.

In the present case there is no need to consider a wider area due to the magnetic field to the ground because the value of the current maximum provided during the useful life of the work is much less than the nominal flow rate: in the case of high voltage distribution, about 100 A against 300A flow (in the case of the cable the current would be a bit higher because of necessary component to most reactive power required for the energization as stated above).

For the diminution in value should be noted that the airline, having the wires very high compared to the ground, allows the unfolding of agriculture and forestry and natural with no modifications (as can be easily seen, by everyone in the land underlying the overhead electrical high voltage existing), not just for the cables having to leave accessible for repairs the strip of ground above: in the case of the cable, therefore, the loss of value of the land is greater than in the case of over head cables.

The solution with the power line underground cable is definitely and unequivocally, much more costly than with similar over head cables.

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