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# Variation of Life Cycle Cost of Overhead Transmission Line and Underground Transmission Cable

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**Abstract: This paper compares the Variation of Lifecycle Cost of Overhead Transmission Line (OTL) and Underground Transmission XLPE Cable (UTC) of three different Italian AC voltages (380kV, 220kV, 132kV). This article uses annuity for calculation of present value of periodical maintenance, loss of energy and dismantling cost of transmission lines. The entire procedure is shown by carrying out on average market value of cable and overhead lines. All the major cost component is converted into Million Euros per Kilometer for easy comparison. In addition to the economic costs, this article also quantifies the environmental costs of a transmission facility, in terms of the burden on territory. The presence of an electro-magnetic field exceeding the value set by national Laws (or Rules or Standards) may create a quarantined area of land unavailable for human activities or development. Further, Replacement Model is applied to OTL and UTC for evaluating the compensation factor for Right of Way at three different voltages in terms of Euros/sq. meter. Nonetheless, the method is generalized and may be widely applied to any type of OTL and UTC comparison.**

**Keywords: Annuity, Replacement Model, Transmission Lines, Underground Transmission Cables, Overhead Transmission Lines, Economic comparison, Lifecycle cost, Power Transmission Economics.**

## I. INTRODUCTION

From last two decade, XLPE UTC and accessories with silicone rubber insulation bodies were used for Power Transmission. There is continuous improvement in XLPE insulated cable technology which re-focused attention towards the installation of underground HV and EHV transmission lines. The deregulation of energy market and the need to connect new power plants to the existing grid has further stimulated the growing requirements to install a significant quantity of underground cables. In the near future, in order to sustain the transmission grid development, a comparative economic analysis of innovative and traditional transmission lines will be essential. The planning choices will have to be consistent with safety, reliability and operation constraints, taking into account the transmission costs. With the market introduction of cross-linked polyethylene (XLPE) extra-high voltage (EHV) cables, the high investment costs of HV and EHV Underground Transmission XLPE Cable (UTCs) (which can be increased by shunt reactive compensation) were often taken as an argument to prefer an OTL “a priori,” without consideration of the sensibly different economic burden brought about by OTLs. Meaningful differences concern the impact of a new line on territory and the energy losses over the lifetime. The role of these factors has gained importance in recent years because of safety and ecological increasing constraints on territory and more stringent grid energy-efficiency requirements. Consequently, suitable criteria were introduced into the economic analysis in order to evaluate costs and benefits emerging from these issues for the two alternatives. Below shows the major cost component over the entire service life of transmission lines. Capital costs, UTC shunt compensation investment cost, Loss energy costs, Burden on territory, Dismantling costs, Operation and maintenance costs.

The choice between the two solutions AC OTL and UTC is merely driven by technical, environmental, and economic considerations. In this article, the analysis has been focused on and restricted to AC underground transmission cables and overhead transmission lines. The article compares costs of overhead lines and underground XLPE cables, both being possible options for the construction of new lines in existing grids. All operating costs over the life of the asset can be converted into an equivalent capital sum at the start of the project life and so these costs can be added to the capital cost of the investment. In addition to the economic costs, this article also quantifies the environmental costs of a transmission facility, in terms of the burden on the built/developed/occupied land or territory. The presence of an electro-magnetic field exceeding the value set by national Laws (or Rules or Standards) may create a quarantined area of land unavailable for human activities or development. The economic impact (€/$m^2$) to the land crossed by a transmission line can be estimated taking into account the loss of value of the rights-of-way. The methodology can be applied, modifying its constituent parameters, to many different configurations and countries.

## II. UNDERSTANDING MAJOR LIFECYCLE COST COMPONENT OF TRANSMISSION LINES

For an OTL, the number of conductors per phase, the type of conductor and the type, size and height of tower, depend on technical requirements and geographical factors that perhaps vary from country to country [2]. In order to show the application of the present comparative procedure, a real example has been chosen but the procedure can be applied to any configuration. Therefore, the economical comparisons have been computed for the HV and EHV voltage levels. Fig. 1 shows the standard towers at 380 kV, reporting clearances of the conductor spacing necessary for positive-sequence(inductance and capacitance) parameter computation and the minimum clearances above ground $H_{min}$ used in computation of rights-of-way (with reference to a given target of quality of magnetic induction level and rms current value). In general, each country has its own $H_{min}$ it is around 7.78 - 8 m for 380 KV OTL. In this article, the traditional towers only are considered even if an overhead line could be erected with more innovative design.

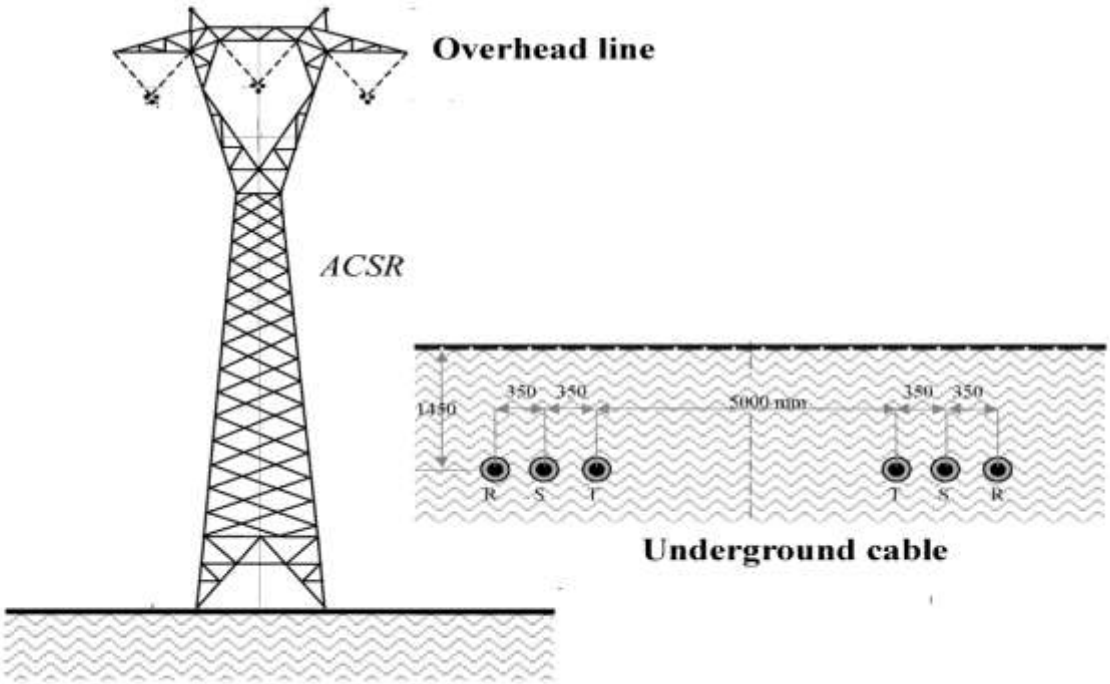


Fig. 1 shows the 380 kV OTL & UTC

For the EHV level of 380 kV, the OTL is equipped with the same phase conductor ACSR Φ=31.5 mm (3 sub conductor) as it appears suitable for a new line. With regard to the 380 kV cable system, Fig.1 also shows the typical underground installation of a double-circuit UTC with 2500 $mm^2$ copper conductors, necessary to transmit the same ampacity of a single-circuit OTL 3x585 $mm^2$. In fact, the last row of Table I report the ampacity for OTL i.e. the thermal limiting current of a line. The 380 kV UTC configuration is usually flat type (even if trefoil ones are usually adopted) where the spacing and burial depth (from cable axis) reduces to 165 mm. IEC 287-3-1 reports the different country standards but the values do not differ significantly from those chosen. Table I reports positive-sequence parameters per unit length in order to compute the steady-state regime and power losses of the distributed parameter line. These losses are the sum of Joule and shunt conductance losses. In the sinusoidal regime, the OTL conductance is usually neglected but in this case consideration is taken of the corona losses and the insulators leakage currents. Both types of loss depend upon the prevailing weather conditions (dry or rainy) and, for instance, 90 rainy days per year have been considered. The per unit length resistance of OTL has been computed at 75°C, conductor temperature when operated at the thermal limit (depending upon room temperature and wind conditions, etc). The electrical parameters of the cables have been computed by means of IEC 287 assuming perfect cross-bonding (i.e. no induced current) at a given spacing, which determines both the inductance and the apparent resistance parameters and consequently all the transmission constants. It is worth noting that the cable ampacity evaluation is performed according to the thermal study affected by, beyond the cable spacing, soil (ρ=1.0 K·m/W for other country's values refer to IEC 287-3) and cable thermal resistivities as well as the burial depth.

TABLE I

| OVERHEAD # | | | | | CABLE # | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Voltage level | 380 kV | 220 kV | 132 kV | | Voltage level | 380 kV | 220 kV | 132 kV | |
| Conductor diameter | ACSR 3 sub-cond. Φ=31.5mm | ACSR Φ=31.5 mm | ACSR Φ=31.5 mm | $mm^2$ | Cross-section | Φ = 2500 Cu | Φ = 1600 Al | Φ = 1000 Al | $mm^2$ |
| Resistance at 75°C (50 Hz) | 23.10 | 69.3 | 69.3 | mΩ/km | Apparent resistance at 90°C (50 Hz) | 13.3 | 32.6 | 42.5 | mΩ/km |
| Per unit length series inductance | 0.858 | 1.282 | 1.213 | mH/km | Per unit length inductance | 0.576 | 0.480 | 0.500 | mH/km |
| Per unit length shunt Leakance (50 Hz) | 10 | 20 | 40 | nS/km | Per unit length shunt Leakance (50 Hz) with tanδ = 0.0007 | 51.5 | 53.0 | 55.4 | nS/km |
| Per unit length capacitance | 0.0133 | 0.00894 | 0.00947 | µF/km | Per unit length capacitance with $\varepsilon_r$=2.3 | 0.234 | 0.241 | 0.252 | µF/km |
| Ampacity | 2955 | 905 | 870 | A | Ampacity | 1788 | 1089 | 893 | A |

### *A. OTL AND XLPE UTC CAPITAL COSTS (I)*

The uncertainties associated with capital costs of innovative technologies does influence the comparative evaluation results. The necessity to adopt a methodology that takes into account the technical, environmental and social aspects involved in new line realization should be noted. The choice of parameters can vary country by country but the methodology and approach remain the same. The UTC capital cost includes the burden for excavation and installation, whereas in the case of OTL the cost burden of the wayleave is considered. The investment costs of UTC are not proportional to line length due to the fix costs of terminal stations. The line lengths in the article are typically longer than 5 km and hence capital cost can be considered a length linear function. The capital expenditure (*Capex*) for a new transmission line can be assigned to one or more construction years, preceding the start of circuit operation. In the present case, it has been assumed that all investment costs (I) were sustained in the construction year 0.

The main cost components are:

• cost for acquisition of rights of way (*ROW*s);
• cost for acquisition of further portions of land (e.g., for location of substations) from land owners;
• cost of purchase of all pieces of equipment from manufacturers;
• Costs for transportation of materials;
• Costs of onsite civil and electrical works for equipment installation;
• cost of civil works (for example: towers foundations and trench excavation);
• Costs for swathe reinstatement at the end of construction works;
• contingency costs, which account for the risk of sustaining extra costs not precisely identifiable in the project economic appraisal;
• Engineering and project-management costs.

It is worth noting that the cost figures used in the following calculations are rough approximations and do not refer to any specific project. They represent mean reference values resulting from worldwide industry surveys: the actual costs for each particular project can change sensibly with local market situations and commercial agreements. The following *Capex*s have been assumed for the transmission lines in Fig. 1.

TABLE II

| | **Capital cost of OTL (I) (M€/Km)** | **Capital cost of UTC (I) (M€/Km)** |
|---|---|---|
| **At 380 KV** | **0.600** | **3.500** |
| **At 220 KV** | **0.385** | **2.200** |
| **At 132 KV** | **0.295** | **1.875** |

Ratio of UTC/OTL = 5.83, 5.71, 6.36 for three different voltage level of 380 kV, 220 kV, 132 kV respectively. Therefore capital cost of UTC is approx 6 to 7 times compared to the OTL.

### *B. THE COST OF REACTIVE COMPENSATION (C)*

In the case of construction of long UTCs, an additional cost for the provision of reactive power compensation must be accounted for. In the proposed cable circuit, two shunt reactors, one at each cable end, must be foreseen for 380 KV line and one reactor is foreseen at 220KV and 132KV Transmission Line . The suitable value of the compensation degree is equal to 0.53 is taken through out in this article [6]. The investment costs for reactive power compensation include:

- The acquisition costs of the land where each reactor (usually three phase with unchained magnetic flux) and its dedicated surge arresters, circuit breakers, earth switches, and disconnecting rods will be located;
- The costs for site preparation and other civil works;
- The supply capital cost of the aforementioned equipment;
- The equipment installation work costs.

One part of the investment cost must be sustained regardless of the amount of inductive reactive power needed; it represents the constant portion of the reactive compensation capital expenditure. The remaining part is variable and mainly linked to the size of reactors. It may be assumed proportional to the provided MVaRs. The entire compensation power needed for the double-circuit UTC for 380 KV line and single circuit for rest 220 KV, and 132 KV (with compensation degree 0.53), can be calculate is given below and cost arising after compensation is given in Table III for UTC.

$Q_c = w \times C \times U_m^2 = 2 \times 3.14 \times 50 \times 0.234 \times 380^2 = 10.61$ MVaR/Km;
$Q = K \times 10.61 \times L = 0.53 \times 10.61 \times 2 \times 10 = 112.466 =$ approx. 120 MVaR.;
Where K is compensation factor, w is angular frequency, $U_m$ is nominal voltage;
(Q) = (120 × 17.5)/10 = 0.210 M€/Km.
Similarly, for 220 kV (Q) = 0.035 and for 132 kV line 0.013.

TABLE III

| | Capital cost of OTL (M€/Km) | Capital cost of UTC (M€/Km) |
|---|---|---|
| **Investment Cost At 380 kV** | **0.600** | **3.500** |
| **Compensation cost** | **NIL** | **0.210** |
| **Investment Cost At 220 kV** | **0.385** | **2.200** |
| **Compensation cost** | **NIL** | **0.035** |
| **Investment Cost At 132 kV** | **0.295** | **1.875** |
| **Compensation cost** | **NIL** | **0.013** |

### *C. POWER LOSSES EVALUATION ((E))*

The economical assessment of the power losses plays a significant role in the overall cost evaluation during the operational life of a transmission line. The load diagram of a line is strictly linked to its typology. There could also be cross-border interconnections, connections between power plant and grid [1] or lines in the meshed transmission network. With regard to the latter, the load diagram presents great fluctuations both on a daily and monthly basis. By analyzing some HV line load diagrams, an equivalent operation at the maximum power with cos $\phi$ =0.98 for 350 hours a year has been considered. If the line is directly linked to a power plant, the load profile depends upon the power generation profile (base load and peak load power plants). In these cases, the power loss economic evaluation can play a more relevant role [1]. Therefore, it is possible to compute the energy losses for two different transmission technologies with the same length **L** and the corresponding actual costs in the following hypotheses. Table IV shows the Power Loss of Transmission Line.

Line lifetime = 40 (years);
Real rate of interest (discount rate) = 5%;
Loss energy cost = 40 (€/MWh).

TABLE IV

| | Power Losses of OTL (E) (W/m) | Power Losses UTC (E) (W/m) |
|---|---|---|
| **At 380 kV** | 606 | 187 |
| **At 220 kV** | 171 | 81 |
| **At 132 kV** | 158 | 96 |

Therefore Annual Energy Loss (AEL) = actual loss (W/m) × 365 × 24 × *l* & discounted values (annuity) is given by

$$((E)) = \frac{(1+i)^n - 1}{i(1+i)^n}(AEL \times cost\ of\ power)/l \quad [8].$$

Where i = 5% & N = 40 years therefore calculating, we have ((E)) = **3.6436, 1.0282, and 0.9500** (M€/Km) for three different voltages of 380 KV, 220KV and 132 KV respectively for OTL while ((E)) = **1.1243, 0.4870, and 0.5770** (M€/Km) for three different voltages of 380 KV, 220KV and 132 KV respectively for UTC. Where cost of power taken as 40 Euros/MWh & *l* = length of line. Similarly, cost for 220 kV and 132 kV can be calculated and given in the table V as:

TABLE V

| | **Power Losses of OTL ((E)) (M€/Km)** | **Power Losses UTC ((E)) (M€/Km)** |
|---|---|---|
| **At 380 kV** | **3.6436** | **1.1243** |
| **At 220 kV** | **1.0282** | **0.4870** |
| **At 132 kV** | **0.9500** | **0.5770** |

*D. THE BURDEN ON TERRITORY OR LAND (T)*

The actions of each country to mitigate against exposure to electromagnetic fields differ. For example, the framework law has imposed a general discipline devoted to protection from electromagnetic field exposure [3]. Conservatively, it is possible to determine a right-of-way, where any building activity is interdicted to extended residence, along the entire AC transmission line route, having a width F depending upon current, voltage limit and line arrangement. The right-of-way is wider or shorter as a function of the magnetic induction limit of exposure and hence of the maximum current. Usually for existing lines, there is a value of attention of 10 µT whereas for new lines a target of quality of 3 µT. It is noted that the magnetic field as well as the right-of-way for UTC perhaps be reduced by the phase cable arrangement and/or screening. In order to quantify the cost burden of land or territory due to the installation of a new line, UTC and OTL are considered to be erected on the same route and on land that has not been developed/built in but with a "buildability" similar to that of the area adjacent to Right of Way. It is necessary to evaluate the loss of value of the land due to difficulty or prohibition of future development as a result of the presence of the transmission line. To this end, it is proposed that a suitable building coefficient "ed" be assumed that is determined and is consistent with adjacent area to new line right-of-way. The parameter ed ($m^3/m^2$) is highly variable as a function of geographic situation and means the average ratio, in a given area, between building volume and surface of area itself; it ranges between 3-4 in urban area and 0.8 - 1 in suburban area. In order to evaluate the variation of value of land located in the rights-of-way, it is necessary to know some parameters depending upon the land kind. Therefore, every square-meter of land located in the "rights-of-way" would lose: $w_x = k \cdot ed$ (€/$m^2$), where k (Euros/$m^3$) is strongly dependent on the local real estate market. Hence, the burden on an area of extension F {1000 sq. meter}, (that is, the width of the no-build band multiplied by an unitary kilometric length of "corridor") can be written as

$$\mathbf{(T) = F \times 10^{-3} \times w_x}$$

In the OTL case, with the value 48m and for UTC it is just 4m, resulting from electromagnetic-field (EMF) calculations and compliance with the quality target limit along different Europe countries, it yields

$$\mathbf{(T) = 0.014 \times w_x\ \{M€/km\}\ for\ 380\ kV\ UTC}$$

$$\mathbf{(T) = 0.100 \times w_x\ \{M€/km\}\ for\ 380\ kV\ OTL}$$

TABLE VI

| | **Burden On Territory For OTL (T) (M€/Km)** | **Burden On Territory For UTC (T) (M€/Km)** |
|---|---|---|
| **At 380 kV** | **$0.100 \times w_x$** | **$0.014 \times w_x$** |
| **At 220 kV** | **$0.048 \times w_x$** | **$0.004 \times w_x$** |
| **At 132 kV** | **$0.039 \times w_x$** | **$0.003 \times w_x$** |

*E. THE VISUAL IMPACT*

The economic evaluation of visual impact is extremely complex owing to its strongly subjective nature (as the value of the landscape is something very specific and a function of local views and preferences). Not withstanding the ambiguity, when a new line must be installed, this aspect could be evaluated. In this respect, the advantage of UTC is understandable.

*F. DISMANTLING COST ((D))*

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A comprehensive analysis of a transmission line must take into account the end of life i.e. the dismantling phase of the line. This operation foresees some costs in order to restore the place at the end of line life, with a considerable delay with respect to the investment and a subsequent lower burden [1]. Dismantling & decommissioning cost is taken as 5 % of total cost of investment for OTL & UTC. Table VII shows the present value of cost of dismantling a transmission line.

For UTC

$$((D)) = \frac{0.05 \times 3.71}{(1 + i)^n}$$

For OTL

$$((D)) = \frac{0.05 \times 0.6}{(1 + i)^n}$$

Where i = 5% & N = 40 years life, hence calculating for 380 kV, we have **((D)) = 0.02635 (M€/Km)** for UTC while ((D)) = **0.00426 (M€/Km)** for OTL. Similarly for 220 kV and 132 kV line cost is given in Table VII.

TABLE VII

| | DISMANTLING COST OTL ((D)) (M€/Km) | DISMANTLING COST UTC ((D)) (M€/Km) |
|---|---|---|
| **At 380 kV** | **0.00426** | **0.02635** |
| **At 220 kV** | **0.00273** | **0.01587** |
| **At 132 kV** | **0.00209** | **0.01341** |

*G. OPERATION AND MAINTENANCE ((OM)) COSTS*

The operation and maintenance of a line, during its life, implies some costs. They must be considered in the overall cost analysis. The evaluation of OM refers to investment cost per kilometer the following values represent the annual cost to pay per kilometer of line as a percentage of investment cost as sown in table VIII. For an OTL, the maintenance costs are between 0.7 and 1% a year (with respect to investment costs) and depend upon the weather conditions. The OTL operation ranges between 0.8 and 1%. The OTL OM (flat installation with low salt pollution) can range between 1.5 and 2%. These values must be considered as an average indication and can rise in cases of extraordinary environmental occurrences. With regard to UTC, once installed, they do not need particular maintenance due to the absence of atmospheric external situations. In any case, their burdens are negligible considering that in [4] it has been reported a non-availability of 0.126 hours per year per circuit of OTL whilst 3.4 hours per year per circuit of UTC. The procedure does not take into account the different failure repairing times of OTL and UTC and their influences on the system costs.

TABLE VIII

| Table (OM) cost of UTC & OTL [5], [7] | | |
|---|---|---|
| | OTL | UTC |
| Operation | 0.8 – 1.0% | 0.1 - 0.3% |
| Maintenance | 0.7 – 1.0% | 0.1% |
| Operation & Maintenance cost | 1.5 – 2.0% | 0.2 – 0.4% |

For UTC

$$((OM)) = \frac{(1+i)^n - 1}{i(1+i)^n}(OM)$$

For OTL

$$((OM)) = \frac{(1+i)^n - 1}{i(1+i)^n}(OM)$$

TABLE IX

| | OPERATION AND MAINTENANCE ((OM)) COSTS of OTL (M€/Km) | OPERATION AND MAINTENANCE ((OM)) COSTS of UTC (M€/Km) |
|---|---|---|

| | | |
|---|---|---|
| **At 380 kV** | **0.051477** | **0.0350131** |
| **At 220 kV** | **0.033031** | **0.0210928** |
| **At 132 kV** | **0.025310** | **0.0253100** |

Where i = 5% & N = 40 years and (OM) is taken 1% and 0.1% for OTL and UTC respectively, hence calculating for 380 kV, we have **((OM)) = 0.0350131 (M€/Km)** for UTC while **((OM)) = 0.051477 (M€/Km)** for OTL. Table IX shows the present value of the operation and maintenance cost of transmission line for different voltages.

## III. TRANSMISSION LINE COST ANALYSIS

From Table X, XI, and XII (reporting all of the aforementioned cost components), it can be seen that the proportion between the ratio involving only the initial investment costs for the UTC and the OTL cases i.e., Ratio of UTC/OTL = 5.83, 5.71, and 6.36 for three different voltage level of 380 kV, 220 kV, and 132 kV respectively and that embracing, instead, the whole of life costs (yet leaving out the cost components (T) for OTL and UTC), ratio of lifecycle cost of UTC and OTL is 1.028, 1.904, and 2.06 decreases by a factor of 4.802, 3.806, and 4.3 respectively for three different voltage level shown in Fig. 5 and Fig. 6. Savings from lower UTC energy losses chiefly contribute to this change.

TABLE X

| | **OTL {M€/Km} at 380 kV** | **UTC {M€/Km} at 380 kV** |
|---|---|---|
| **CAPITAL COST (I)** | **0.600** | **3.500** |
| **COMPENSATION COST (C)** | **0.0** | **0.210** |
| **POWER LOSSES ((E))** | **3.6436** | **1.1243** |
| **BURDEN ON TERRITORY (T)** | **$0.100 \times w_x$** | **$0.014 \times w_x$** |
| **DISMANTLING COST ((D))** | **0.00426** | **0.02635** |
| **OPERATION AND MAINTENANCE ((OM)) COSTS** | **0.051477** | **0.0350131** |
| **(∑) Total (Approx.):** | **$4.763 + (0.100 \times w_x)$** | **$4.896 + (0.014 \times w_x)$** |

TABLE XI

| | **OTL {M€/Km} at 220 kV** | **UTC {M€/Km} at 220 kV** |
|---|---|---|
| **CAPITAL COST (I)** | **0.385** | **2.200** |
| **COMPENSATION COST (C)** | **0.0** | **0.035** |
| **POWER LOSSES ((E))** | **1.0282** | **0.4870** |
| **BURDEN ON TERRITORY (T)** | **$0.048 \times w_x$** | **$0.004 \times w_x$** |
| **DISMANTLING COST ((D))** | **0.00273** | **0.01587** |
| **OPERATION AND MAINTENANCE ((OM)) COSTS** | **0.033031** | **0.0210928** |
| **(∑) Total (Approx.):** | **$1.449 + (0.048 \times w_x)$** | **$2.759 + (0.004 \times w_x)$** |

TABLE XII

| | **OTL {M€/Km} at 132 kV** | **UTC {M€/Km} at 132 kV** |
|---|---|---|
| **CAPITAL COST (I)** | **0.295** | **1.875** |
| **COMPENSATION COST (C)** | **0.0** | **0.013** |
| **POWER LOSSES ((E))** | **0.9500** | **0.5770** |
| **BURDEN ON TERRITORY (T)** | **$0.039 \times w_x$** | **$0.003 \times w_x$** |
| **DISMANTLING COST ((D))** | **0.00209** | **0.01341** |
| **OPERATION AND MAINTENANCE ((OM)) COSTS** | **0.025310** | **0.0253100** |

| | | |
|---|---|---|
| (∑) Total (Approx.): | 1.272 + (0.039 × $w_x$) | 2.621 + (0.003 × $w_x$) |

The other, potentially relevant, factor further lessening the proportion between overall UTC and OTL costs is the lighter economic burden on territory imposed by the installation of a cable as an alternative to an overhead line. If there are restrictions of land use because of local laws, the amount of these compensation costs (T) (appearing in Table VI as a function of $w_x$) depends on the market value of the land crossed by the link. In the hypothesis of build-prohibition all over the width of the corridor where the magnetic field magnitude exceeds 3μT, Fig. 2, 3, 4 shows the Lifecycle costs and as a function of $w_x$. The intersection point between (∑) of UTC and OTL (whose abscissa $w_x$ = 1.5465, 29.7727, and 37.4722 Euros/$m^2$) is the point of economical indifference.

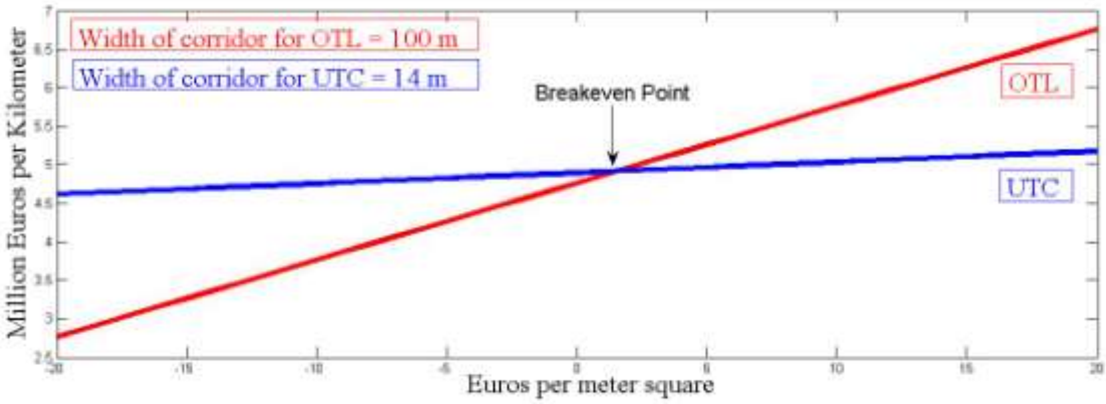


Fig. 2 Lifecycle cost per kilometer as a function of $w_x$ for **380 kV** (“quality target” = 3 μT), Breakeven Point = 1.5465

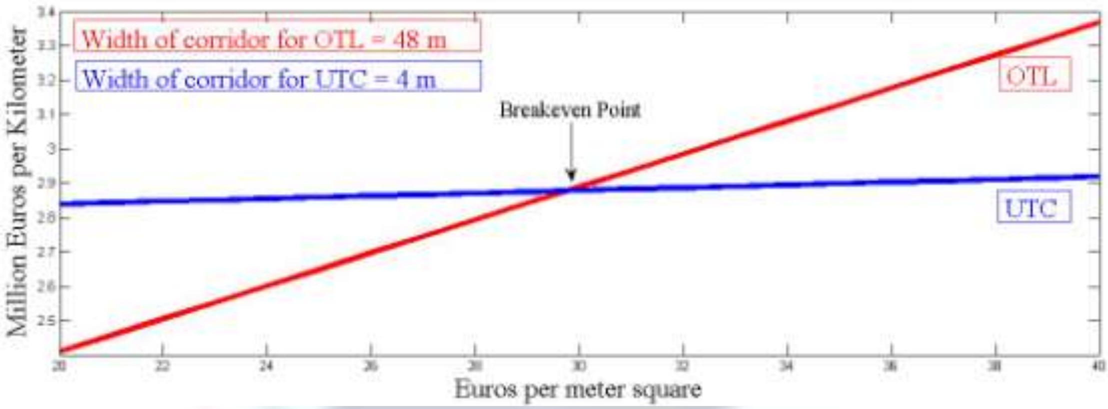


Fig. 3 Lifecycle cost per kilometer as a function of $w_x$ for **220 kV** (“quality target” = 3 μT), Breakeven Point = 29.7727.

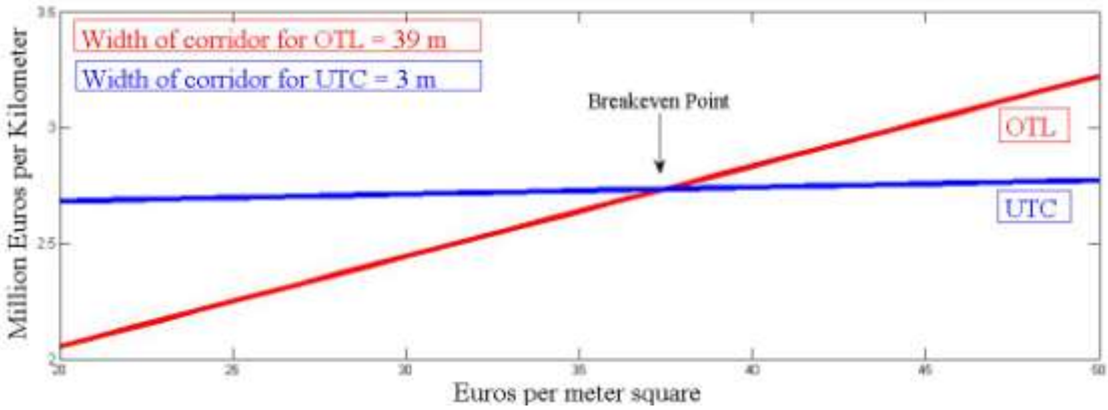


Fig. 4 Lifecycle cost per kilometer as a function of $w_x$ for **132 kV** (“quality target” = 3 μT). Breakeven Point = 37.4722.

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Above figure shows the value of compensation factor for replacement from OTL to UTC when $w_x$ = 1.5465, 29.7727, and 37.4722 Euros/$m^2$ are Breakeven values as shown. Application of replacement Model clearly indicates the replacement of existing system (OTL) to New Transmission System (UTC) by using breakeven values. Further, it is clearly seen from Fig. 7 that failure of UTC occurs at the start of the Lifecycle of Transmission Line. This failure occurs mainly due to poor workmanship or mostly unintentional third party damage.

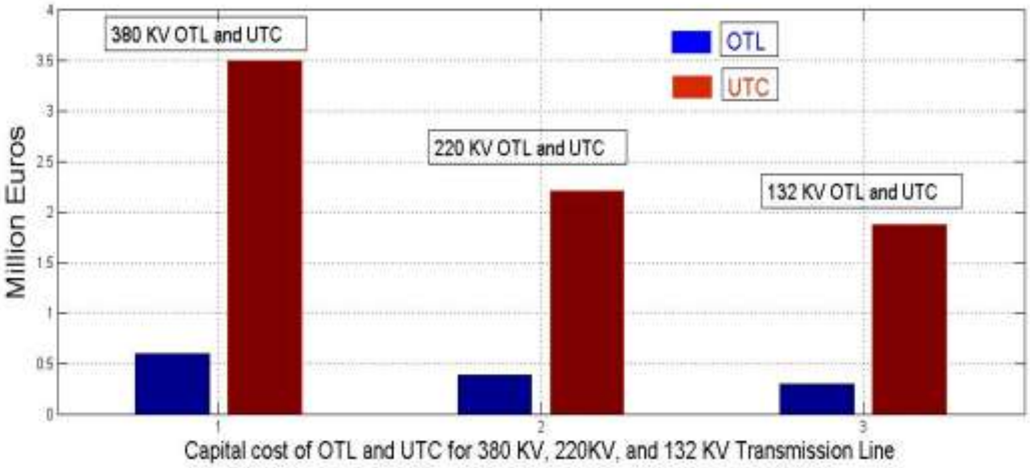


Fig. 5 Capital cost of OTL and UTC for three different Voltages (380KV, 220KV, and 132KV)

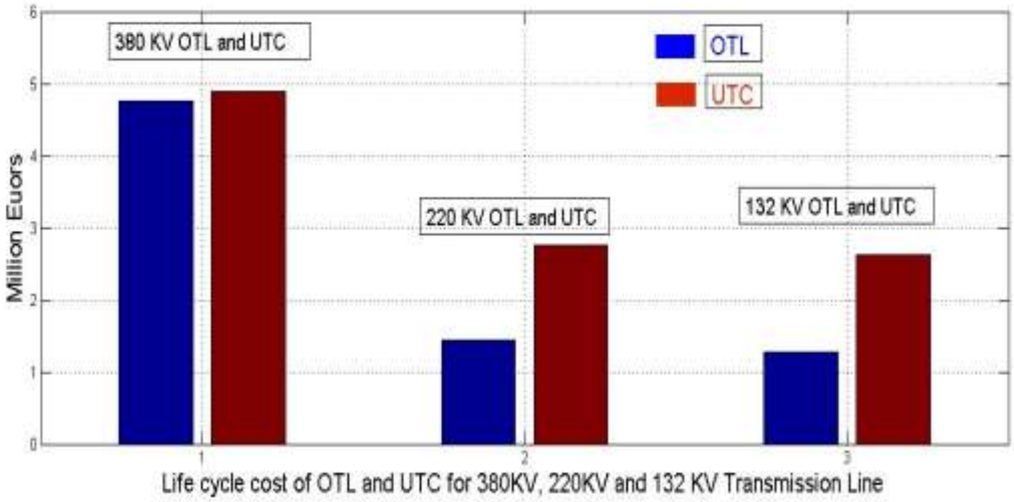


Fig. 6 Lifecycle Cost of OTL and UTC for 380KV, 220KV and 132KV Transmission Line

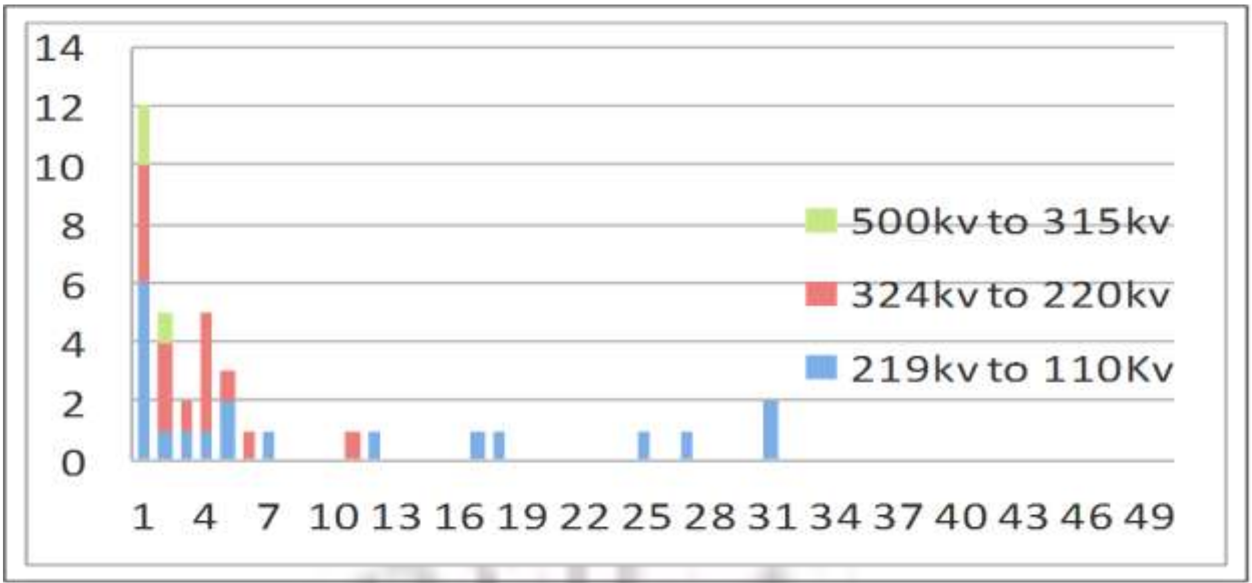


Fig. 7 Trend in AC EHV XLPE Internal Failure [9]; horizontal axis represents years while vertical axis represent number of faults.

## IV. CONCLUSION

This article presents a unique method for the identification and calculation whole of life cost of OTLs and of XLPE UTCs, Whereas overhead lines have been the selected solution, extra high voltage cables have made a breakthrough with the introduction of XLPE insulation reducing dramatically the losses whilst maintaining an excellent level of cable system performance. From an overall cost standpoint and not from a mere investment cost standpoint, the cost gap between UTCs and OTLs is strongly reduced due to UTC energy loss savings and a lower impact on territory. One another aspect of this article is compensation for acquiring right of way for transmission line can be easily obtained for three different voltages level of 380 KV, 220 KV and 132 KV. Failure for Voltage level 220 kV and above mostly occurs at the start of the lifecycle. Mostly cause of failure is workmanship and Unintentional third party damage.

Ensuring reliable and economic connections and respecting the environment is a crucial task, often requiring innovative solutions. In spite of the low investment cost of overhead lines, UTCs have other important tangible benefits as well as some advantages which are less tangible. This paper makes a detailed technical and economic assessment of these two different technological solutions. The model however can be applied to any country with its own specific transmission standards, rules and/or laws. Drawing some general conclusions, it is apparent that where land has already been developed for residential purpose or where development potential is very high, underground cables are preferred option having less environmental impact even if there are higher capital costs. Conversely, in low value territory, transmission technologies with higher territory impact and fewer capital costs are preferable. In conclusion, overhead lines and cables have been debated as competitors often without stating precise criteria. From an overall cost standpoint and not from a mere investment cost standpoint, the cost gap between UTCs and OTLs is strongly reduced due to UTC energy loss savings and a lower impact on territory. One another aspect of this article is compensation for acquiring right of way for transmission line can be easily obtained. For the sake of simplicity, the procedure does not take into account the costs due to undelivered energy nor the congestion and re-dispatching costs arising from the differences in UTC and OTL failure repair times.

## REFERENCES

[1] R. Benato, D. Capra, R. Conti, M. Gatto, A. Lorenzoni, M. Marazzi, G. Paris, F. Sala: "Methodologies to assess the interaction of network, environment and territory in planning transmission lines," Proc. of CIGRÉ 2006, Paper C2-208, September 2006.

[2] ICF Consulting: "Unit Costs of constructing new transmission assets at 380 kV within the European Union, Norway and Switzerland," Final Report, October 2002.

[3] Framework Law n. 36/2001 on the protection against exposure to electric, magnetic, and electromagnetic fields. Italy.

[4] ICF Consulting: "Overview of the Potential for Undergrounding the Electricity Networks in Europe". Final Report, February 2003.

[5] Joint Working Group 21/22.01. "Comparison of high voltage overhead lines and underground cables," CIGRÉ Brochure 110, December 1996.

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Vol. 2 Issue 6, June-2013, pp: (1-4), Available online at: **www.erpublications.com**

[6] R. Benato, M. Del Brenna, C. Di Mario, A. Lorenzoni, E. Zaccone, "The rule of XLPE cables in the EHV electric energy transmission," Proc. of AEIT-CIGRÉ, Padova, 18 February 2005.

[7] R. Benato and A. Paolucci, EHV AC Undergrounding Electrical Power. Performance and Planning. New York: Springer, 2010.

[8] P. Chandra, Investment Analysis And Portfolio Management. Third Edition. New Delhi: Tata McGraw-Hill, 2008.

[9] CIGRÉ Tech. Brochure # 379, “Update of service experience of HV underground and submarine cable systems,” 2009.