CONDITIONS FOR EFFICIENT USE OF THE 1000 V ENERGY DISTRIBUTION

Gheorghe HAZI, Aneta HAZI

University of Bacău, Romania - gheorghe.hazi@ub.ro, ahazi@ub.ro

***Abstract* – This paper provides an analysis about the conditions in which using the 1000 V overhead system is efficient compared to the classical 400 V overhead system. The efficiency is established through a technical and economical calculus using the net present value indicator. The paper shows the results obtained for the current conditions in Romania.**

Keywords: *efficiency, net present value, low voltage systems, optimal solution.*

1. INTRODUCTION

In Romanian, there are insulated villages, monasteries, areas with insulated dwellings. Power demanded in the same situations doesn't exceed some scores of kW. Using of 0.4 kV power lines for distances longer than 1 km call forth problems due to values of lines voltage drops. Aggrandizement of medium voltage network, usually 20 kV, demands high investments. Therefore, 1 kV distribution is interesting apparently. Advantage of this network, at least for the overhead line (OHL), is that investment is the same with 0.4 kV distribution. For the same current, delivered power increases of 2.5 and line voltage drops are meaning smaller. Disadvantage of this network is that it demands two energy transformations: from 20 kV to 1 kV and from 1 kV to 0.4 kV.

In this paper, authors establish conditions when 1 kV network is better than 0.4 kV network. The study is made for different values of power and distances. Note, that for the certain distances and power it can be also solutions, [3].

2. SOLUTIONS ANALYZED

Variants analyzed are following:

- Supply with OHL three-phase 20 kV and transformer substation 20/0.4 kV placed on the consumer (figure 1)
- Supply with 1 kV OHL three-phase and transformer substation 20/1 kV placed on the source and transformer substation 1/0.4 kV placed on the consumer (figure 2).

Variants analyzed and solutions offered take account by the following assumptions and conditions for calculus:

- The supply source is an 20 kV overhead line that has a sufficient capacity for taking over insulated consumption. Its power demanded is 3-54 kW.
- Consumer is concentrated or it is place on the limited area.
- Demanded power of the consumer do not vary in time, power factor is 0.9 and use period of maxim load is 3500 hours/year.
- Consumer use only 0.4/0.231 kV voltage mono-phase or three-phase.
- Supply network must observe technical constrains. These are referring to the minimal voltage in the delimitation point, to the admissible currents on the elements of the network and to the suitable working of the protections in case of faults in the network. In case of 20 kV source voltage, the minimal voltage in the delimitation point was by $0.95 \cdot 400/\sqrt{3}=219.5$ V

3. ASSESSMENT OF COSTS FOR SOLUTIONS ANALYZED

For assessment of better solution depending on power and distance, it is compared technical – economically

Figure 1
Solution 1 – Supply with 20 kV OHL kV and PT 20/0.4 kV

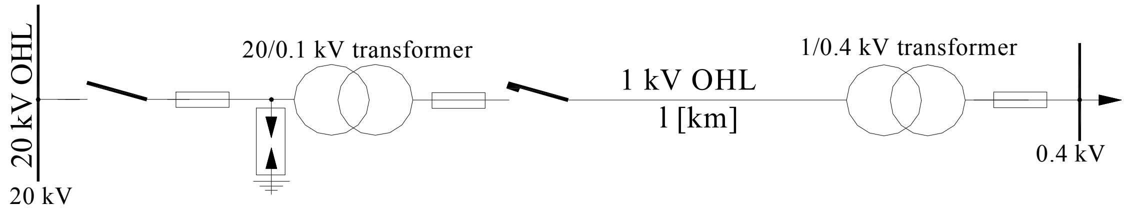

Figure 2. Solution 2 – Supply with 1 kV OHL, PT 20/1 kV and PT 1/0.4 kV

the classical solution with solution proposed, using NPV indicator.

Expression of NPV, [lei] depending on the demanded power P [kW] and on the distance l [km], is:

$$NPV(P,l) = I(l) + \sum_{j=1}^{T_s} Cex(l)\cdot(1+a)^{-j} + \sum_{j=1}^{T_s} C\Delta Wp(P,l)\cdot(1+a)^{-j} + \sum_{j=1}^{T_s} D(P,l)\cdot(1+a)^{-j} - \frac{CLEA\cdot l}{2}\cdot(1+a)^{-Ts} \quad (1)$$

where:

T_s – period of investigation that is 20 years.

I(l) – value of investment, [lei], depending on the line length. This comprises value of transformer substation (value of transformer substations for the solution 2), (CPT, CPT1, CPT2) and value of 20 kV or 1 kV line, (CLEA·l):

$$I(l) = CLEA\cdot l + CPT \quad (2)$$

for the classical solution,

$$I(l) = CLEA\cdot l + CPT1 + CPT2 \quad (3)$$

for the variant with 1kV OHL.

$$Cex(l) = CLEA\cdot l\cdot\frac{\beta LEA}{100} + CPT\cdot\frac{\beta PT}{100} \quad (4)$$

are working costs, [lei/an] for classical solution

$$Cex(l) = CLEA\cdot l\cdot\frac{\beta LEA}{100} + (CPT1 + CPT2)\cdot\frac{\beta PT}{100} \quad (5)$$

for the variant with 1kV OHL.

For the working costs rate there were considered constant values βLEA=4% for the 20 kV lines, βLEA=4.5% for the 1 kV lines and βPT=3.5% for the transformer substations, [1]. The working costs are considered constant in time.

$$C\Delta Wp(P,l) = \Delta Wp(P,l)\cdot c_w \quad (6)$$

cost of energy loss per year [lei/an], ΔWp – value of energy loss per year [kWh/an], c_w [lei/kWh] – unitary cost of energy loss.

Calculus of energy loss is based on the iterative calculus of working regimes for a load P and for a distance l. It was imposed load consumer by $\underline{S}$=P+jQ and line voltage of source by $\underline{U}=20000\cdot e^{j0}$. For that, transformers was modeled by scheme π, line 20 kV by scheme π and lines 1 kV by impedance $\underline{Z}_l=R_l+jX_l$.

$$D(P,l) = W_n(P,l)\cdot D_{sp} \quad (7)$$

where D(P,l) [lei/an] is probable damage, W_n [kWh.an] - undelivered probable energy and D_{sp} [lei/kWh undelivered] – specific damage.

$$W_n(P,l) = \frac{P\cdot TSM}{8760}\cdot T_{ran}(l) \quad (8)$$

where P·TSM is delivered energy per year to consumer, T_{ran} unsupplied average period per year of consumer, [h/an] due to supply coupling. T_{ran} it was established using reliability indicators calculus:

$$T_{ran}(l) = N_r(l)\cdot T_r(l) \quad (9)$$

N_r – yearly mean number of breaks removed by repairs [breaks/an];

T_r – mean period of break [h/break]

Value of D_{sp} is equal with monomial tariff for the domestic consumers. It must be specified that upstream network isn't considered in the probable damages calculus. This isn't change conclusions because damages due to this network have the same value for all solutions and variants.

The last term from relation (1) is remanent value of 20 kV or 1 kV line. Line has a life normal period by 40 years that mean double of period of investigation Ts.

It was establishing a minimal number of subvariants for establishing of NPV for solutions. There were considered only variants that observe technical conditions:

$$NPV_i(P,l) = \min_j\left[NPV_{ij}(P,l)\right] \quad i = 1..4 \quad (10)$$

Subvariants result from combination of transformers power and conductors section of overhead line. Thus, for every power and distance it is selected a solution dimensioned economically both in variant 1 and in variant 2.

Finally, establishing of optimal solution is realized by establishing of minimum between solutions:

$$NPV_{opt}(P,l) = \min_i\left[NPV_i(P,l)\right] \quad i = 1..4 \quad (11)$$

It was calculated NPV_{opt} for the power P=3..54 kW (with step by 3 kW) and l=1...18 km (with step by 300 m). It was resulted a high number of variants.

4. RESULTS OBTAINED

For an easy assessment, results are shown as graphics for different values of power and distance. In the figures, decreasing to 0 of NPV shows violation of one technical constrains.

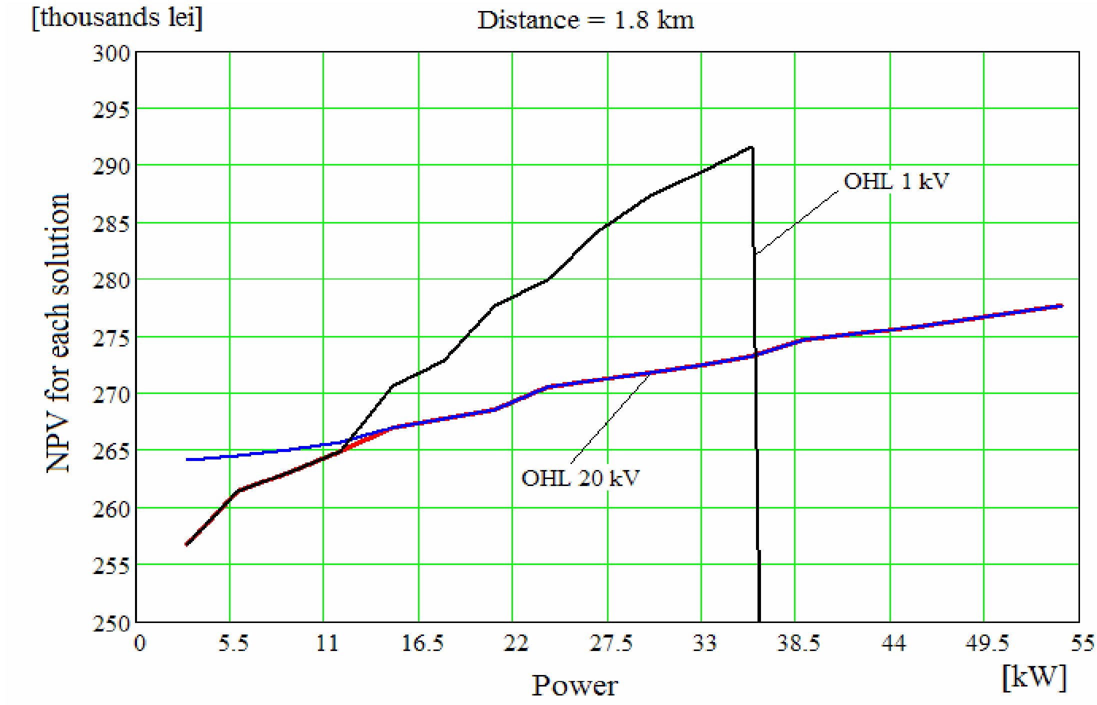

Figure 3. Values of NPV for l=1.8 km and variable power

Values of NPV obtained for different distances are shown in the figures 1, 2 and 3. For low distances, up to 1,5 km, using of 1 kV OVH is inefficient due to transformer substations 20/1 kV and 1/0.4 kV, that are at the low distances. For the bigger distances, 1 kV distribution is efficient. Thus, for 1.8 km distance (figure 3) solution is efficient for power up to 12 kW. For 3 km distance (figure 4), solution is efficient for power up to 30 kW.

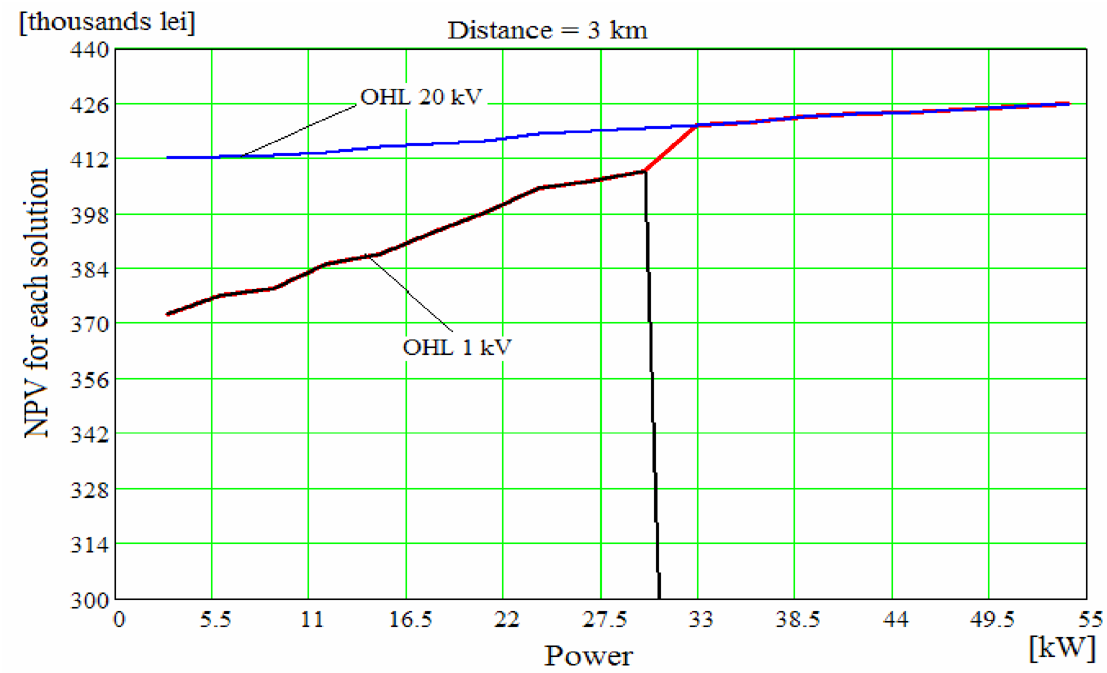

Figure 4. Values of NPV for l=3 km and variable power

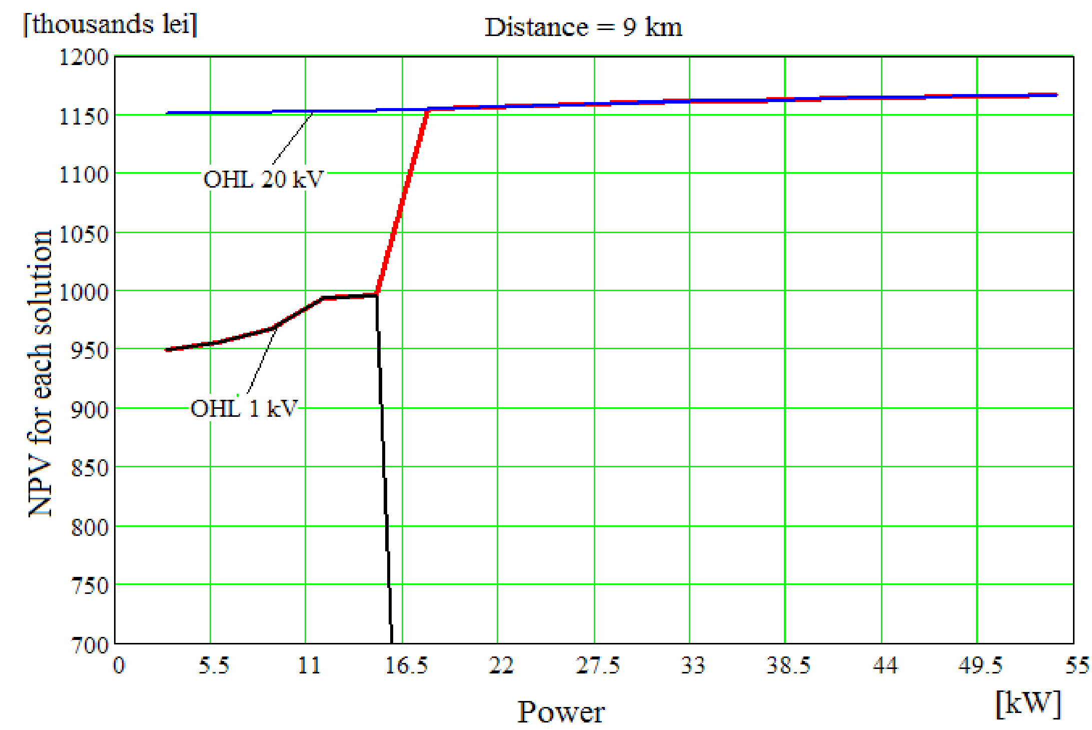

Figure 5. Values of NPV for l=9 km and variable power

For 9 km distance (figure 5) solution is efficient for power up to 15 kW. In the figures 6, 7 and 8 it is shown variation of NPV depending on distance for a constant demanded power.

For a 3 kWdemanded power (figure 6) solution is efficient for distances longer than 1.5 km.

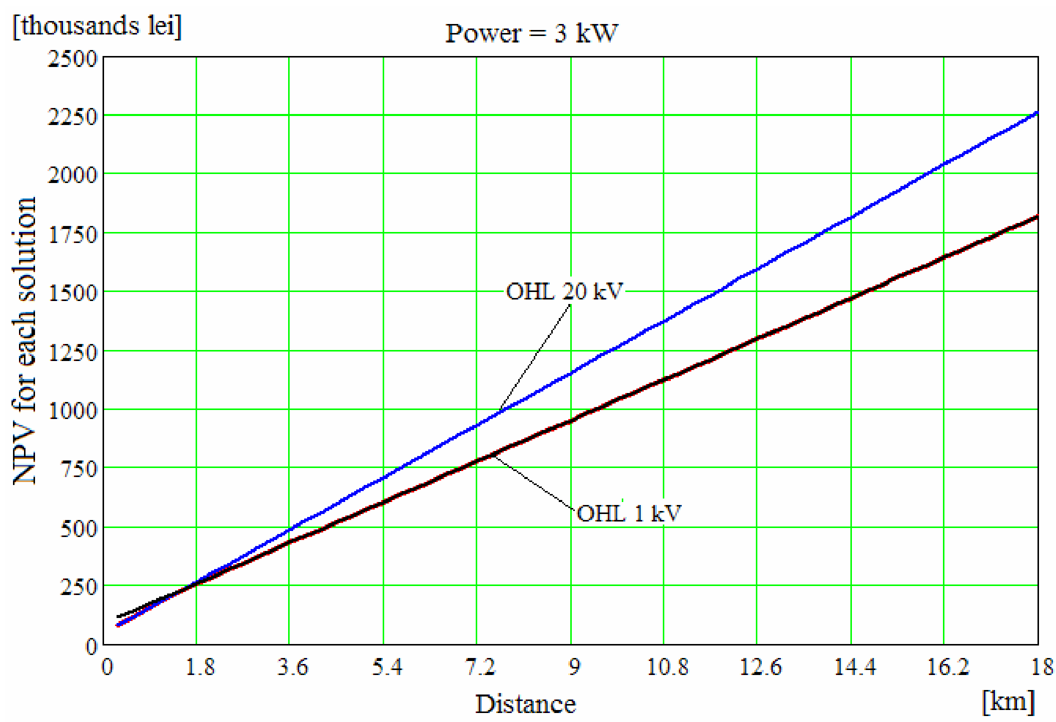

Figure 6. Values of NPV for P= 3 kW and variable distance

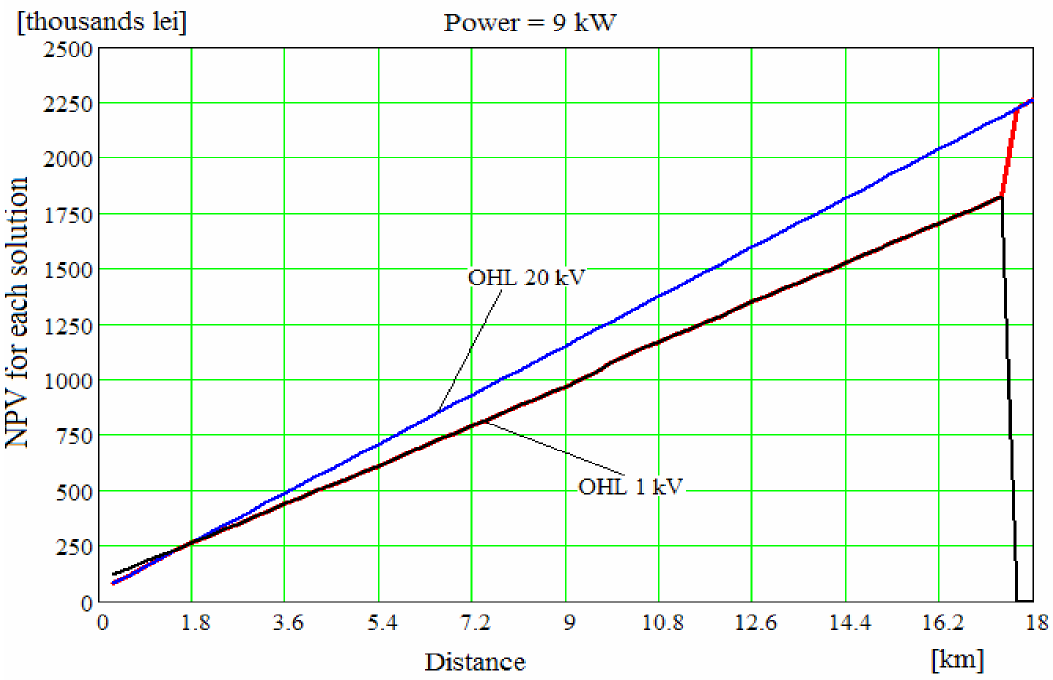

Figure 7. Values of NPV for P= 9 kW and variable distance

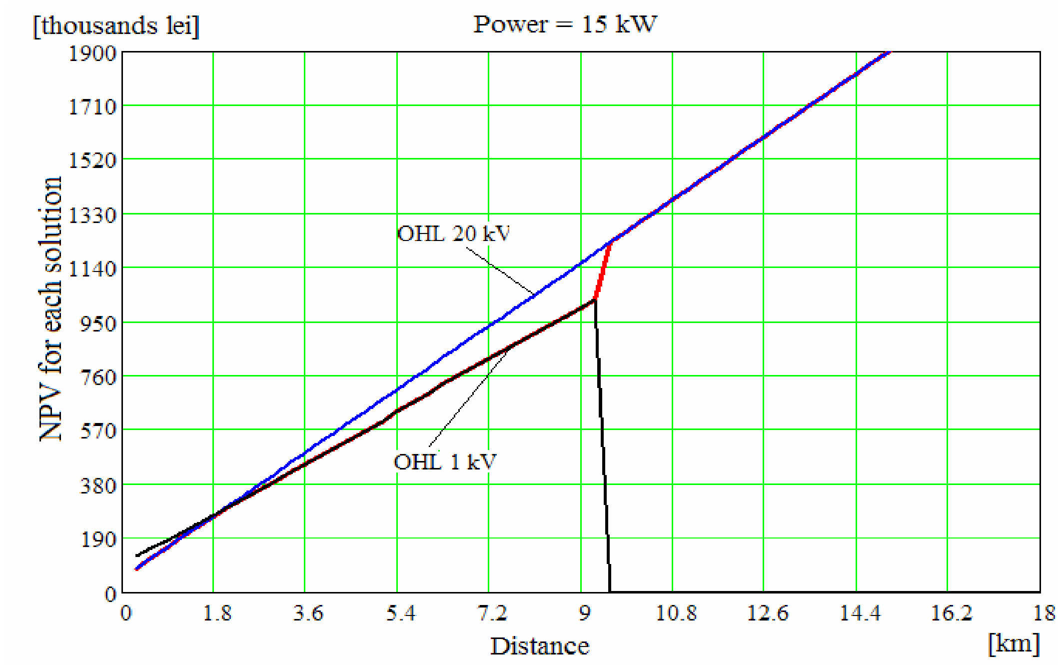

Figure 8. Values of NPV for P= 15 kW and variable distance

5. CONCLUSIONS

- Using of 1 kV network for supply of insulated areas, with low energy consumption, is efficient for distances longer than 1.5 km
- Maxim distance of efficient solution for the different power is following:
  - 3-6 kW – 18 km
  - 12 kW – 12 km
  - 21 kW – 5.7 km
  - 27 kW – 3.6 km
- When power increases, then minim limit of efficient solution increases:
  - 3-6 kW – 1.8 km
  - 12 kW – 1.8 km
  - 21 kW – 2.4 km
  - 27 kW – 2.7 km

References

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