# TECHNICAL-ECONOMIC ANALYSIS OF THE SOLUTION FOR MODERNIZING LOW VOLTAGE DISTRIBUTION ELECTRICAL NETWORKS

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**Abstract - In recent years, the need to modernize low-voltage electricity networks, especially those that supply electricity to rural areas, has become increasingly important. The paper aims at the technical-economic analysis of such a solution with two working scenarios. These involve on the one hand the emergence of new electricity networks and on the other hand the redistribution of consumers. This ensures the quality parameters imposed in the electricity supply of consumers as well as the optimal scenario from an economic point of view.**

**Keywords: electricity, networks, consumers, modernization, economic efficiency, economic indicators.**

## 1. INTRODUCTION

The transfer of electricity from one source to consumers is done through electricity networks. The organization and coordination of these networks determines their structure, a structure that strongly influences the economy and operational safety of the power system [1],[3].

The low voltage network to be analyzed is the network that supplies electricity to a rural locality. The low voltage electrical network is in aerial construction made using classic AL conductors that are powered by two 20 / 0.4kV transformer substations connected radially from the medium voltage overhead power line that leaves the 110 / 20kV distribution station and stretches length of 14.3 km.

Figure 1 and Figure 2 show two overhead substations, PTA 1 and PTA 2, respectively, in the existing operating situation. The two substations have a 20 / 0.4kV 100kVA transformer and supply PTA 1 a number of 179 consumers (169 single-phase consumers and 10 three-phase consumers) and PTA 2, a number of 116 consumers (111 single-phase consumers and 5 consumers phase). The low voltage overhead network has a total length of 3.65 km and 2,003 km, respectively, both made of wired ropes OL-AL 50 / 8mmp that required multiple repairs.

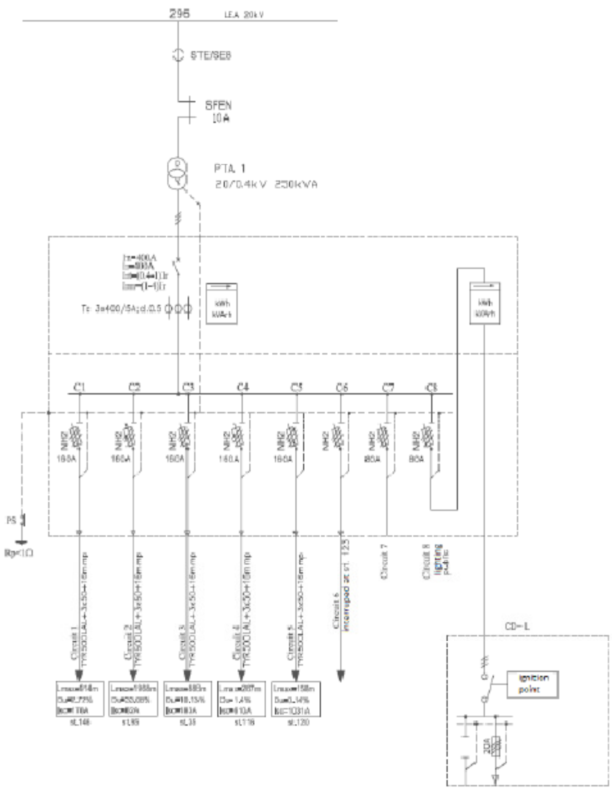



**Fig. 1. One-line diagram scheme PTA 1 - existing situation**

The low voltage network is made of concrete columns, vibrated or centrifuged, partially inclined and cracked. Local consumers are part of the household consumer class with an installed household power of 6kW and a calculated household power of 1.6kW. The power factor is cosφ = 0.85. Transformer loads do not meet current and projected electricity consumption. To ensure proper electrical parameters, the low voltage line is dimensioned so that the supply voltage of the receivers falls within the permissible limits.

The medium voltage network is made on vibrated-prestressed concrete pillars planted along the roads.
The electrical network is characterized by electrical conductors made of OL-AL with a section of 70 $mm^2$.

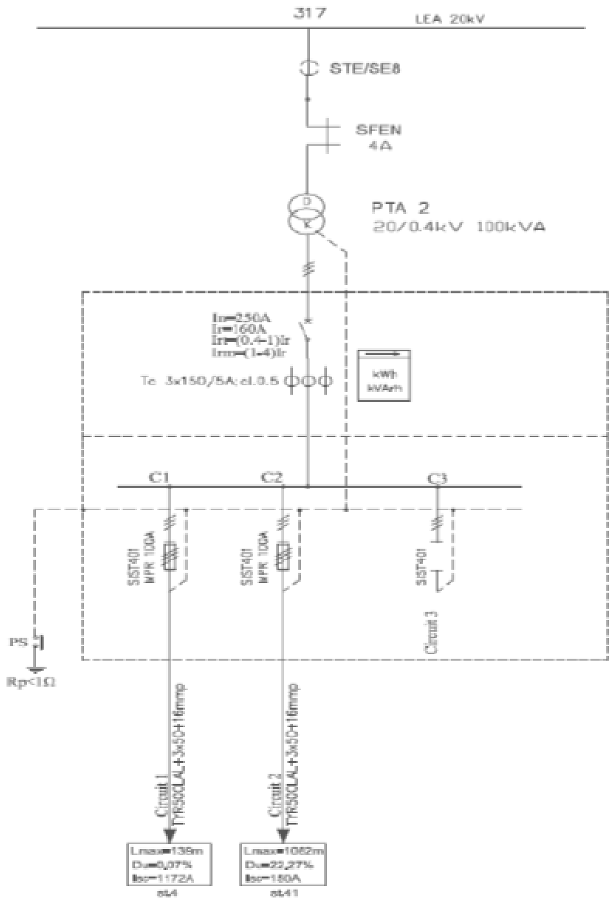



**Fig 2. One-line diagram scheme PTA 2 – existing situation**

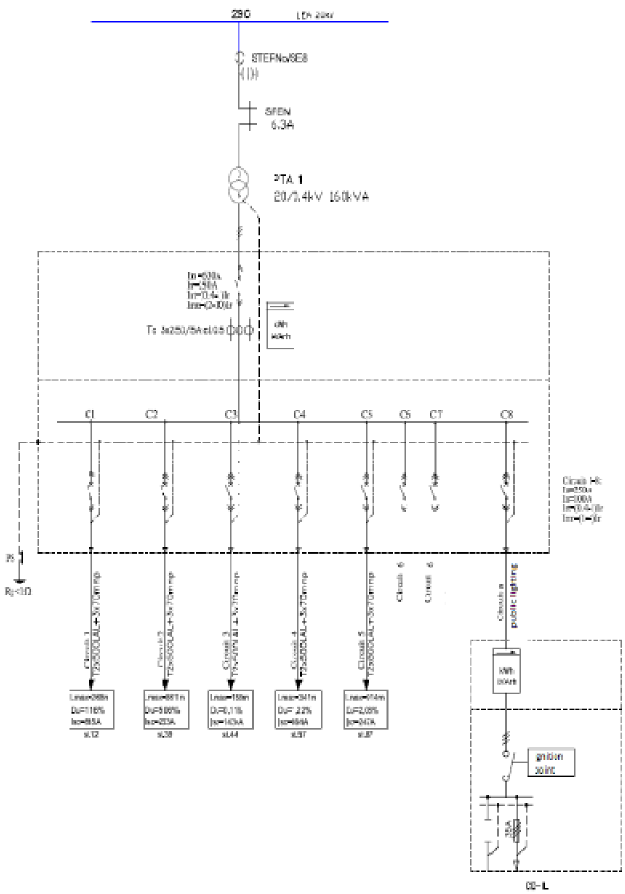



**Fig. 3. One-line diagram scheme PTA 1 - proposed solution**

## 2. CASE STUDY

Considering that in the existing situation the quality parameters of the electricity do not comply with the legislation in force, two possible scenarios will be analyzed through which the aim is to bring them within the imposed limits.

It was studied the possibility of placing new 20/0.4kV transformer substations that will be supplied from the medium voltage electrical distribution network through connections in OHL (LEA) and/or 20kV SLE(LES). The new substations will aim to reduce voltage drops at the end of the network and increase short-circuits currents to ensure the operation of the protections.

Figures 3 and 4 show the proposed operating solutions for the two overhead substations, PTA 1 and PTA 2.

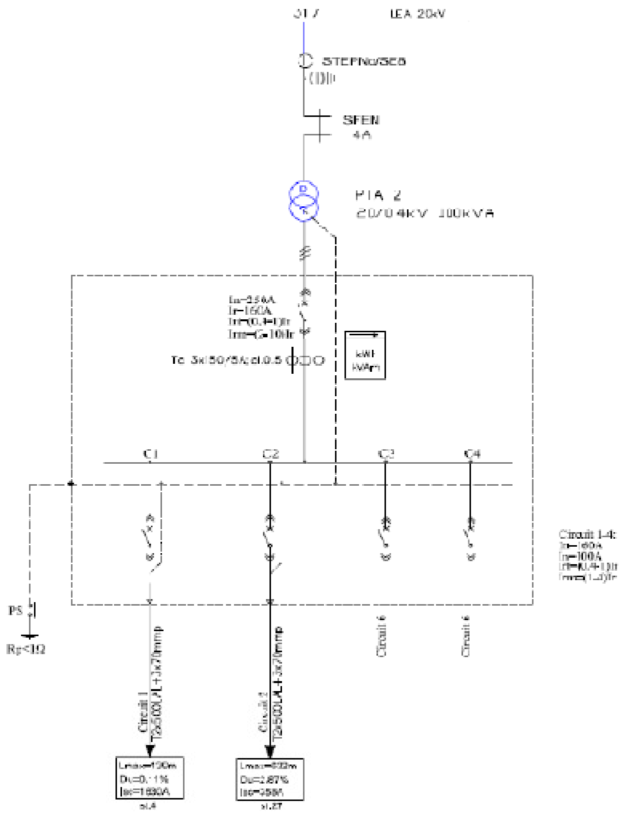



**Fig 4. One-line diagram scheme PTA 2 – proposed solution**

Consumers will be redistributed on existing stations and designed to obtain optimal loads of 20/0.4kV transformers and thus their own technological consumption as low as possible.

The scenarios analyzed, with the emergence of new energy installations, also aim to ensure continuity in the supply of electricity to consumers, including in cases of failure or maintenance, which is not possible in the current configuration of the low voltage distribution network.

Thus, it will be analyzed the possibility of modernizing the connections in BMPM / BMPT solution and CCBYY 2x10 and TYIR3x16 + 25mm$^2$ AL conductors, at the property limit with access from the public domain to eliminate own commercial technological consumption, installation of separation boxes and selectivity, replacement integral of the conductors of the classic Al network with a network made with twisted conductors, the separation of the public lighting network, as well as the possibility of eliminating the section of the common MEDIUM VOLTAGE/LOW VOLTAGE network in order to comply with the coexistence conditions imposed by legislation [5],[6],[7].

**Table 1. Centralization of subscribes – the existing situation**

| PT | Subscribes | |
|---|---|---|
| | Single Phase | three phase |
| PTA 1 | 169 | 10 |
| PTA 2 | 111 | 5 |
| Total | 280 | 15 |

The energy sold in the existing situation is 273MWh / year.

**Table 2. CPT Centralization– the existing situation**

| Technical CPT | MWh |
|---|---|
| Network | 17.1491 |
| PTA 1 | 9.15000 |
| PTA 2 | 4.47300 |
| Total | 30.7721 |
| % | 10.1 |

The own technological consumption (CPT) represents the electricity losses registered by the distribution operator. The CPT presented is purely technical and does not include the commercial part. Table 2 summarizes the CPT of the studied low voltage electrical network (in MWh / in the present - compared to the calculated sold energy).

Network CPT is the consumption caused by the transport of electricity from the power supply to the consumer. Its value is obtained by summing its own technological consumption related to each section of the low voltage electrical distribution network and multiplying this value by the unit of time (3000h).

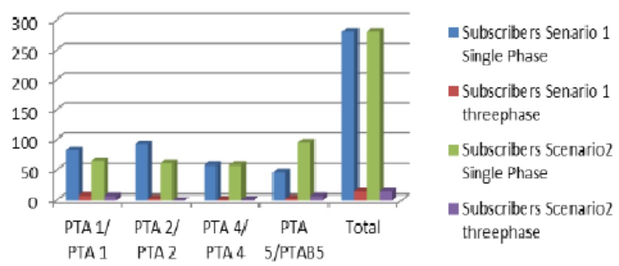



**Fig. 5. The subscribers centralization depending on the scenario (1,2)**

The energy sold in the two analyzed scenarios has the same value as in the existing situation, keeping the number of both single-phase and three-phase subscribers, of 273MWh / year.

The electricity losses registered by the distribution operator in the projected situations are totaled in table 4 (in MWh / in the present - compared to the calculated sold energy) and are, from a value point of view, lower than in the existing situation.

**Table 4. CPT Centralization**

| Technical CPT | MWh | |
|---|---|---|
| Network | 7.6557 | 6.79389 |
| PTA 1 | 4.83900 | 4.15900 |
| PTA 2 | 3.81100 | 3.41700 |
| PTA 4 | 3.09500 | 3.09500 |
| PTA 5 | 2.79400 | 3.84100 |
| Total | 22.1947 | 21.3059 |
| % | 7.5 | 7.2 |

## 3. TECHNICAL-ECONOMIC ANALYSIS

The economic analysis, involving the calculation of financial indicators, used the updated financial flow method, in accordance with internationally accepted standards. For the calculation of performance indicators, the discounted financial flow also includes the value of the investment.

The criteria (methods) for evaluating project performance are discounted net income (VNA); internal rate of return (RIR) and the updated period of return on invested capital (Ta).

The discounted net income (VNA) is calculated on the basis of the annual financial flow (At), which takes into account investment expenses, operating expenses and income. The future annual flows, generated by the investment, are updated at the time of commissioning (PIF) of the new installations.

The viability of the project is determined if the VNA, calculated over the entire analysis period (t), is positive for a considered discount rate (a).

The relationship for VNA estimation is:

$$VNA = \sum_{t=1}^{n} \frac{A_t}{(1+a)^t} \quad (1)$$

Were: At – represents the amount of money for the year t;

$1/(1+a)^t$ – discount coefficient;

a- discount rate;

The criterion also allows the selection of the optimal solution from several analyzed variants, the optimal variant having the highest value of the updated net income.

The value of discounted net income is influenced by several factors:

- How to make the investment. In order to accurately calculate the present value of the investment, it is important to know the distribution of the investment during the project. This is quite difficult assuming complicated calculations and for this reason a uniform distribution of the investment for the realization period can be considered;

-Installed production capacity. If several objectives with different production capacities are compared, their equivalence is necessary;

- Equipment life time;

- The value of the discount rate greatly influences the value of the discounted net income;

By reporting the VNA made within the project to the updated investment, the "VNA Rate" is obtained, expressed in USDVNA / USDinvestment.

This efficiency indicator allows both the appreciation of the project itself (for which it is recommended as RVNA> 1), and the comparison of several technical and economic variants (maximum RVNA) that involve significantly different investment costs[2],[5].

$$R_{VNA} = \frac{VNA}{\sum_{t=1}^{PIF} \frac{CI_t}{(1+a)^t}} \qquad (2)$$

Where: C- operating cost;

I – investment costs;

The internal rate of return (RIR) is also based on the discounted cash flow and represents that "discount" rate for which the VNA becomes zero.

The calculation relation for determining the RIR is:

$$\sum_{t=1}^{n} \frac{A_t}{(1+RIR)^t} = 0 \qquad (3)$$

The project is accepted if RIR> a.

For the equation written above we can have several solutions, from a mathematical point of view all the solutions are correct but from an economic point of view only the smallest value is correct.

There are situations in which the internal rate of return cannot be calculated, especially in the case of large investment projects in which a very long study period is chosen, in which case all capital flows become positive or negative (for example in the case of loans leasing or other form of loan).

The updated recovery time (Ta) is a superior VNA concept.

The method updates the net income, recorded year by year, determining the recovery period of the invested capital. It is a clear criterion for accepting projects. The acceptability criterion is that the recovery period is less than the normal duration of use. This period corresponds to the time when the cumulative discounted net income becomes zero:

$$\sum_{t=1}^{T_a} \frac{A_t}{(1+a)^t} = 0 \qquad (4)$$

Internal capital accumulation rate.

This criterion is defined by the relation:

$$R_c = \frac{V_{inact} - C_{act}}{I_{act}} = \frac{1}{n} \qquad (5)$$

Where: act shows that the amounts are updated;

Vinact – income from recipes;

Cact- updated costs;

Iact – updated investments;

n - duration of capital recovery.

The criterion is very important in providing information on how profitable a project is for the study period.

Updated total expenditure criterion:

The criterion is applied for choosing the optimal option from several variants of the project when we do not know the level of revenues. The optimal variant will have the minimum value of the updated total expenses:

$$CTA = \sum_{i=1}^{n} \frac{(C_i + I_i)}{(1+a)^t} = \min \qquad (6)$$

Were: Ci – investments costs;

Ii – investments funds;

t- period of time.

The application of this criterion has two impediments:

- It cannot be used to establish the eligibility of the investment project;

- Because the revenues from revenues are not taken into account, it is mandatory to equate the projects in terms of production capacity and useful annual effects.

For projects involving low investment, empirical economic evaluation criteria can also be used in which capital flows are no longer updated. The most used empirical criteria are the recovery term and the profitability of the project [5].

Recovery term:

Represents the number of years in which the relationship is fulfilled:

$$\sum_{i=1}^{t} Vin_i - C_i - An_i - I_i = 0 \qquad (7)$$

$$t = \frac{I}{Vni - C} \qquad (8)$$

Where I is the value of the investment;

Vni - total income from receipts;

C - investments costs.

It is noted that this criterion is similar to the duration of capital recovery except that the amounts are no longer updated.

Profitability of the project

It is determined by the relation:

$$R_p = \frac{Vni - C}{I} = \frac{1}{t} \qquad (9)$$

Eligibility condition: Rp>1

The criterion allows the rapid elimination of the weaker variants of the project [2].

**Table 5. Calculation of the investment in the scenario1**

| No. crt | Works total evaluation / transformation stations | Value without VAT | | | | |
|---|---|---|---|---|---|---|
| | | LEI | | | | EURO |
| | | C+I | LU | MU | Total | Total |
| 1 | Works total evaluation - EL 1.1. - PTA 1 | 473698 | 65739 | 12204 | 551641 | 113250 |
| 2 | Works total evaluation - EL 1.2. - PTA 2 | 386131 | 35315 | 7063 | 428509 | 87971 |
| 3 | Works total evaluation - EL 1.3. - PTA 4 designed | 285431 | 42377 | 8003 | 335812 | 68941 |
| 4 | Works total evaluation - EL 1.4. - PTA 5 designed | 200613 | 42377 | 8003 | 250993 | 51528 |
| TOTAL without VAT | | 1345873 | 185809 | 35274 | 1566956 | 321690 |
| VAT ( 20 % ) | | | | | 313391 | 64338 |
| TOTAL with VAT | | | | | 1880347 | 386028 |

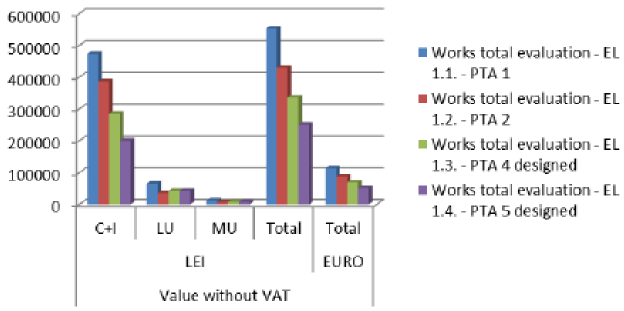
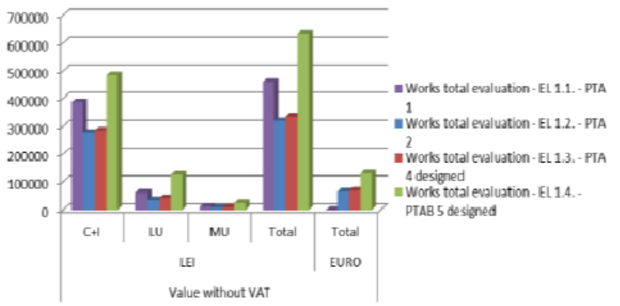



**Fig. 6. The variations of the investment in scenario 1**

**Table 6. Calculation of the investment in the scenario2**

| No. crt. | Works total evaluation / transformation stations | Value without VAT | | | | |
|---|---|---|---|---|---|---|
| | | LEI | | | | EURO |
| | | C+I | LU | MU | Total | Total |
| 1 | Works total evaluation - EL 1.1. - PTA 1 | 386874 | 61438 | 11344 | 459656 | 94365.83 |
| 2 | Works total evaluation - EL 1.2. - PTA 2 | 277406 | 35315 | 7063 | 319784 | 65650 |
| 3 | Works total evaluation - EL 1.3. - PTA 4 designed | 285431 | 42377 | 8003 | 335812 | 68941 |
| 4 | Works total evaluation - EL 1.4. - PTA 5 designed | 484679 | 125117 | 24552 | 634348 | 130229 |
| TOTAL without VAT | | 1434391 | 264248 | 50962 | 1749600 | 359187 |
| VAT ( 20 % ) | | | | | 349920 | 71837 |
| TOTAL with VAT | | | | | 2099520 | 431024 |

Where C + I represents the costs of construction works and installations; LU - equipment costs (equipment list) and MU equipment assembly costs (equipment assembly).




When calculating the investment, the legal provisions of the Instruction of July 2, 2008 (issued by the Ministry of Development, Public Works and Housing and published in M.O. I no. 524 of July 11, 2008) of application of some provisions of H.G.R. 28 / 09.01.2008, published in M.O. of Romania, part I, no. 48 of 22.01.2008, as well as the structure and methodology for elaborating the general estimate for investment objectives.

The cost of the works is estimated and was calculated at the exchange rate of 4.871 lei / euro.

The calculation relationships (1) - (9) were used to determine the values presented in table 6 and 7.

**Table 7.Economic performance indicators**

| Economic performance indicator | Value | |
|---|---|---|
| | Option 1 | Option 2 |
| The value of investment works, lei | 1,566,956 | 1,749,600 |
| Construction and assembly value, lei | 1,381,147 | 1,723,172 |
| Annual cots, lei | 105,048 | 115,330 |
| Total updated costs, lei | 652,621 | 599,089 |
| Internal rate of return,% | 10.0 | 9.02 |
| Updated net income, lei | 414,509 | 258,237 |
| VTA/CTA ratio | 4.69 | 5.11 |
| Profitability threshold: | | |
| - in percent, %: | 21.31 | 19.57 |
| - in physical values, MW: | 59.77 | 54.83 |
| Updated recovery time, years | 17 | 19 |
| Specific investment / consumer, lei / client | 5,311 | 5,930 |
| CPT in the projected situation,% | 7.5 | 7.2 |

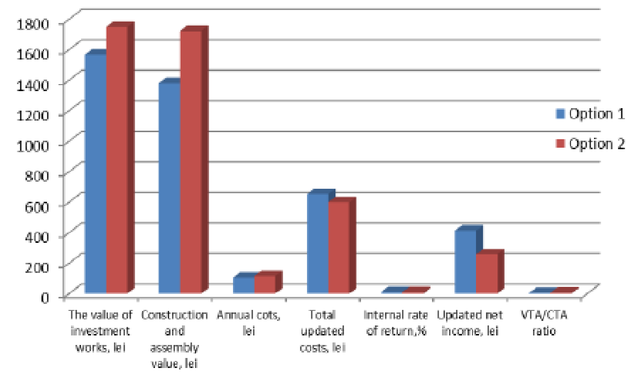



**Fig 8. Economic performance indicators**

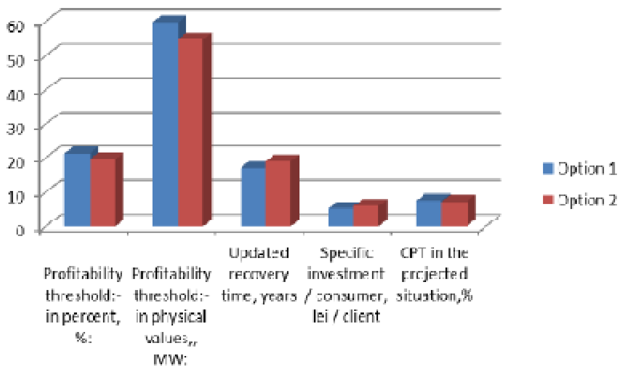



**Fig 9. Profitability threshold**

## 4. CONCLUSION

From a technical point of view, both technical scenarios propose power injection works by installing new 20 / 0.4kV transformer substations and redistributing between PTs the modernized low voltage electrical network. In the first case, the two designed 20 / 0.4kV substations and the related medium voltage connections are in aerial construction, and in the second variant, an underground medium voltage network is chosen to supply the medium voltage distributor of the transformer station 5.

Compared to the value from the existing situation (30.77MWh; 10.1%), the own technological consumption is reduced to 22.19MWh (7.5%) by implementing the first proposed solution or to 21.31MWh (7.2%) if the second solution is chosen. From an economic point of view, the first proposed solution has a lower investment cost. Economic indicators reveal that the first option is a better investment.

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