ASSESSMENT OF INVESMENTS IN LOCAL DISTRIBUTION SYSTEM USING COST-BENEFIT ANALYSIS

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Abstract: This paper demonstrates the possibility of using cost-benefit analysis to evaluate investments in the development of local distribution systems, specifically the modernization of distribution transformers. The article interprets the results of the analysis of three investment variants of a specific company operating a local distribution system in the Czech Republic.

Keywords: LDS, CBA, transformer, investments, assessment.

1 INTRODUCTION

The local distribution system (LDS) is being used to connect end-users to the electricity network. Through this system, the supply of electricity for the customer and his delivery point is ensured. All rules for the operation of LDS are set out in the Energy Act and the relevant implementing regulations. The minimum technical, planning, operational and information requirements for the connection of users to distribution networks are set out in the Distribution System Operation Rules, which are approved by the Department of Energy.

This paper presents the principle of assessing investment in the construction of a new transformer station in LDS. To demonstrate the method, the real intention of the company operating the LDS is used. The economic side of a new project is always the main indicator of the suitability of a variant solution, but not the most important. Non-monetary pros and cons can have a greater impact on decisions. Both of these aspects are taken into account in a cost-benefit analysis (CBA), supplemented by static and dynamic monetization methods.

2 CURRENT STATUS OF SOLVED LDS

Two 22/0.4 kV air-cooled transformers, each with an apparent power of 630 kVA, are located in the low-voltage substation of LDS. One of these transformers is permanently maintained as a backup. The second of the transformers is operated with only a third load, so the current state of LDS is on the verge of profitability. The aim of the intended investment is to reduce the operating costs of the LDS while keeping a sufficient power reserve for the implementation of other investments proposed in [1] - in particular, the construction of charging stations for electric vehicles.

3 DESCRIPTION OF INVESTMENT OPTIONS

The reference variant (state without project implementation) in this case is to keep the current state as it is today. Of the two 630 kVA transformers, only one will continue to operate, both of which will remain at the current site of the current substation. The substation will continue to operate without modernization of the equipment.

3.1 OPTION 1

Investment variant 1 assumes the installation of a new oil transformer with a nominal output of 630 kVA in a new kiosk station. The kiosk will be located outside the existing substation.

3.2 OPTION 2

Investment variant 2 assumes the installation of a new oil transformer with a nominal output of 400 kVA in a new kiosk station. The same placement as for investment variant 1 is assumed, so the only different factor between investment variant 1 and 2 is the rated power of the transformers used.

3.3 OPTION 3

The third investment option involves the construction of two kiosk transformer stations, each at one of the considered locations specified in more detail in [1]. The transformer located on the northeast corner of the area would have a rated output of 250 kVA and would serve to cover its own consumption inside the complex. The second of the transformers, located in the southwest corner of the complex, near the building of the existing substation, would be used to power the land outside the company's premises. This kiosk would also be used as a substation for possible photovoltaic power plant proposed in [1].

4 COST-BENEFIT ANALYSIS

The essence of the method is to analyze the investment impact on actors, quantification of the identified effects, and conversion to a common numeric (ideally financial) unit. Then we can use the indicators of criteria of net present value, internal rate of return of economic CF, profitability index, and payback period.

The advantage of CBA is that the benefits, but also the costs do not need to be expressed in monetary terms necessarily. It can be alternatively expressed in other ways (for example, in socioeconomic, environmental, or qualitative terms). However, it is important that it always needs to be expressed in a meaningfully measurable way.

4.1 CONVERSION OF QUANTIFIED BENEFITS INTO CASH FLOWS

The evacuation of the premises of the current substation will bring a usable area of approximately 200 m^2, which can be used directly for the purposes of the company or offered for rent. After analyzing the market for renting production premises, we can consider the rental price for 1 m^2 of approximately 100 CZK per month. The stated price is the median of the prices offered for production premises, taking into account the concerned locality. The freed-up area would therefore bring savings of approximately 20000 CZK per month, on which we can further calculate. Compared to the need to provide production space differently, the savings would be significantly higher.

We will quantify the lower no-load and short-circuit losses using data on the annual electricity consumption and the nameplate values of the new and current transformer. The total electricity losses for a given period are determined according to the relation [2]:

$$\Delta W_T = \Delta W_0 + \Delta W_z = (\Delta P_0 + k_\Delta \cdot \Delta Q_0) \cdot T + (\Delta P_k + k_\Delta \cdot \Delta Q_k) \cdot \left(\frac{P_{max}}{S_n \cdot cos\varphi}\right)^2 \cdot T_\Delta \qquad (1)$$

where ΔW_z are the annual losses of electric energy due to the transformer load (kWh), ΔP_k are the active short-term transformer losses (kW), ΔQ_k are the short-circuit reactive losses of the transformer (kVAr), S_n is the apparent transformer power (kVA). ΔW_0 are the annual no-load losses of the transformer (kWh), ΔP_0 are the active no-load losses of the transformer (kW), ΔQ_0 are the no-load losses of the transformer no-load (kVAr), T is the time the transformer is in operation for the given period (h).

A detailed calculation is realized in [1]. The total electricity losses of the existing transformer are ΔW_T = 25571.25 kWh, for the new transformer with an apparent power of 630 kVA, ΔW_T = 17140.86 kWh and for the new transformer with the apparent power of 400 kVA ΔW_T = 7753.39 kWh.

To economically quantify the losses, we will use the actual price of the electricity consumed. In general, we divide the price of electricity into two parts. The first part is the price for power electricity. It consists of the amount of active electricity consumption and electricity tax. The second part is the payment for distribution. The distribution price consists of fixed charges which are derived from the reserved power input and do not change with the amount of energy consumed, and charges which are derived from the amount of energy consumed. The total variable costs (sum of the price of power electricity and the variable part of the price for distribution) per 1 MWh of electricity for the given company were set in [1] at 1594.68 CZK. The cost of electricity loss $N_{\Delta T}$ for the first variant is then 40777.96 CZK per year, for the second variant 27334.19 CZK per year, and for the third variant 12364.18 CZK per year.

4.2 ECONOMIC LOAD OF THE TRANSFORMER REGARDING LOSSES

The average annual value of the load β of the currently used transformer is approximately 6.3%. The economical load of the transformer is the load at which the total losses of active power caused by the transformer are minimal. To determine the optimal load of the transformer, specific losses are used, i.e., losses per unit load. To calculate the economic load, we use the relation derived in [2].

$$S_h = S_n \cdot \sqrt{\frac{\Delta P_0 + k_\Delta \cdot \Delta Q_0}{\Delta P_k + k_\Delta \cdot \Delta Q_k}} \tag{2}$$

The calculations show that the economical apparent power that would be appropriate to load a 630 kVA transformer is 286.58 kVA. The economical apparent power with which it would be appropriate to load this 400 kVA transformer is 142.21 kVA. This value is close to the maximum quarter-hour maximum for 2019 in the solved LDS, which was 123 kW. Neglecting the possibility of a significant increase in consumption in the future, we can consider it more appropriate from the point of view of the economy to use a transformer with a lower apparent power.

4.3 ECONOMIC LOAD OF THE TRANSFORMER

The procedure of the previous subchapter is limited to losses only and does not take into account the purchase price of the transformer and its depreciation. From an economic point of view, it is therefore more accurate to speak of annual production costs, which include both losses, expressed in terms of loss costs, and costs derived from the cost of the transformer, using the relation [2]:

$$S_{he} = S_n \cdot \sqrt{\frac{N_{iT} + (\Delta P_0 + k_\Delta \cdot \Delta Q_0) \cdot n_\Delta^0}{(\Delta P_k + k_\Delta \cdot \Delta Q_k) \cdot n_\Delta}} \tag{3}$$

The calculated value of the economic load from the economic point of view (S_{he} = 1144.28 kVA) is well above the rated power of the transformer (S_n = 630 kVA). This value is, of course, nonreal. The result can be interpreted as the chosen transformer is very good for this use.

4.4 DETERMINATION OF THE DISCOUNT RATE

Determining of the discount rate is important for calculation by dynamic methods. In our case, we will apply only the dynamic method for evaluating investments – the net present value of *NPV*. The discount rate can be considered 2 % p.a., which is the inflation targeting of the Czech National Bank for this year. If the maximum social permissible rate is up to 5.5 %, we can consider a discount rate of 5 % p.a. This value will be used in the calculations.

4.5 CALCULATION OF ECONOMIC INDICATORS

- Payback time

The payback period of an investment is an important and frequently used investment valuation indicator that gives a rough idea of the time after which the returns on the initial investment will exceed the value of the investment itself. The method is static and is an expression of the so-called simple payback period. The calculation of the simple payback period is based on a formula [3]:

$$TN_P = \frac{IN}{CF} \tag{4}$$

where *IN* is the cost of investment (investment expenditure) (CZK), *CF* is the annual cash flow (annual income - cost savings due to the investment) (CZK).

- Return on investment

The return on investment (ROI) compares the net accounting profit to the size of the investment, or the volume of total assets and liabilities. Simply put, we can define *ROI* as the ratio of money earned to money invested. It therefore indicates the return on the amount spent as a percentage. We calculate it according to the relation [3]:

$$ROI = \frac{return}{investment} \cdot 100 \tag{5}$$

- Net present value method

The last method that will be used to assess individual investment options will be the *NPV* method. The main advantage of this method is the consideration of the time factor. We calculate the net present value according to the formula [3]:

$$NPV = \sum_{n=0}^{20} \frac{CF}{(i+i)^n} \tag{6}$$

where *CF* is the cash flow (CZK), *i* is the interest rate (-), *n* is the number of years we have to wait for income (-), *IN* is the initial investment (CZK).

Calculations of economic indicators for individual investment variants are summarized in Table 1.

Investment option	Payback period (years)	ROI (%)	NPV (CZK)
1	7.10	281.60	1 665 369.79
2	6.41	312.11	1 974 362.60
3	11.92	167.83	380 739.24

Table 1: Economic indicators for particular investment variants

5 CONCLUSION

Compared to the reference variant, all three considered investment variants are preferably considered an economic comparison. It should be mentioned that in the calculation of economic returns and other indicators, the possibilities of selling the current equipment of the substation and transformers were not considered, which would increase the profitability of the investment. After making a comparison from a noneconomic point of view, we identified this investment option as the least meaningful, and we were able to move on to deciding between options 1 and 2. Figure 1 shows comparison between the reference variant and investment options 1 and 2. The third investment option is on the verge of profitability, as we can see in Table 1.

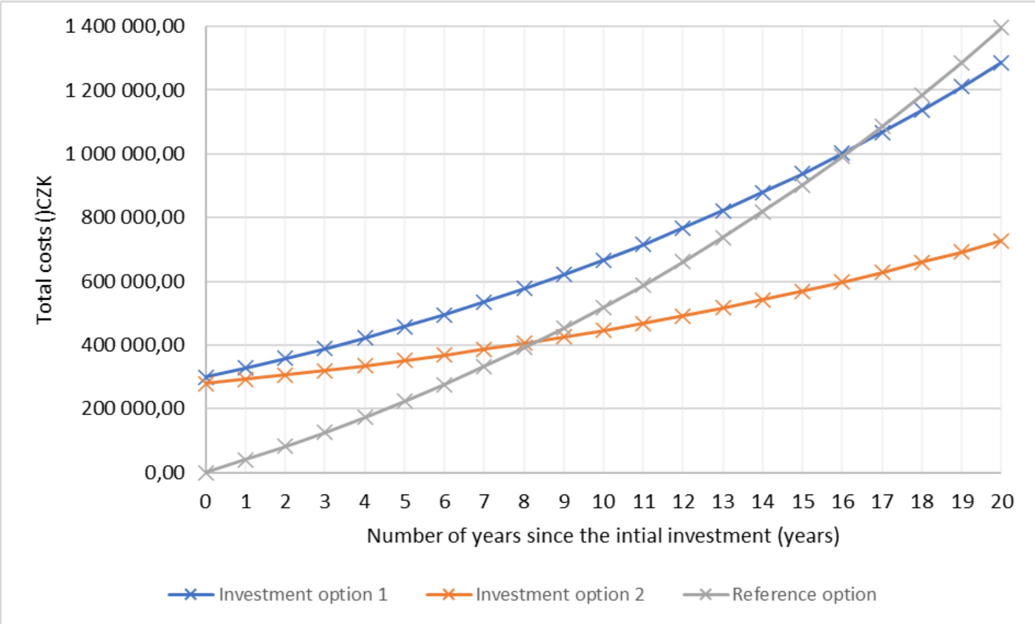

Figure 1: Cost comparison taking into account the growth of electricity prices

In general, we can say that while maintaining the current state, it pays off to invest in a transformer with a nominal output of 400 kVA. With increased consumption in the future according to the planned intention, it is a reasonable choice to invest in a higher rated power of the transformer, despite the slightly higher purchase price and higher operating costs.

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