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EVALUATING INVESTMENT PROJECTS IN ENERGY INDUSTRY

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Abstract *The investment objectives of electrical and heating industry are subject to technical, economic and financial assessments, highlighting their effectiveness considering several variants. It is also essential to examine the technologies and the technical solutions, adopted equipment, distribution and use of electricity, the location of the plant, saving conventional energy, the use renewable resources etc.*

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1. Characteristics of the electricity production and the impact on investment

Electrical activity presents some particularities that cannot be ignored when analyzing issues of risk and return on their investment.

a) In the field of electricity there is no possibility of storing output, since size is subject to momentary demand of consumers of electricity. This application is different during the day and to respond to this, production capacity must exist to cover the maximum level. The electrical energy produced by a power plant or energy system according to consumer demand momentum is called dynamic loading. The variation of this power over a period of time (day, week, month and year) is represented by the diagram called load curve. In a power system, a load curve or load profile is a chart illustrating the variation in demand/electrical load over a specific time.

Daily load curve is as follows (Figure 1.1):

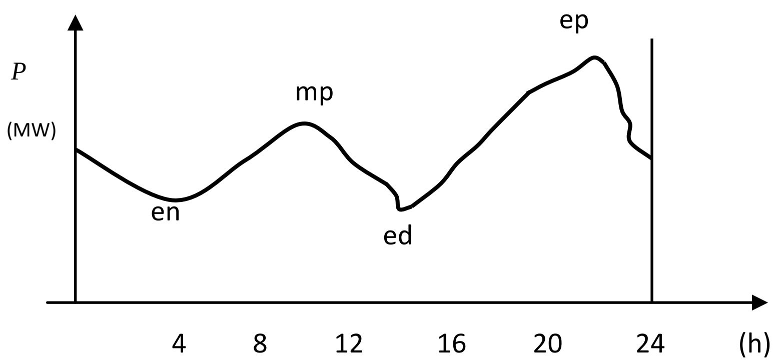


Figure1.1. Daily load curve.

Notations on the curve have the following meanings: en - empty night, mp - morning peak, ed - empty day, ep - evening peak.

b) Installations for the production, transmission and distribution of electricity throughout the country are interconnected, forming the national energy system.

The advantages of interconnected operation of power plants are:

- Possibility to use rationally the country's primary energy by building large power plants adapted to the size of the resource and not to local consumption;

- Using the power reserve of an existing power plant elsewhere

The electricity supply chain begins in power stations where electricity is generated. Electricity generators use either fossil fuels, such as coal and gas, or renewable energy sources, such as wind, water or the sun. Electricity is transported over long distances from power stations through high voltage transmission power lines (110 kV, 220 kV and 400 kV) carrying enormous powers. At these stations is achieved the interconnection between power plants. The electricity is then transformed to lower voltages (20 kV or 6 kV, and at 0.4 kV) before being distributed to residences and businesses (Figure 1.2).

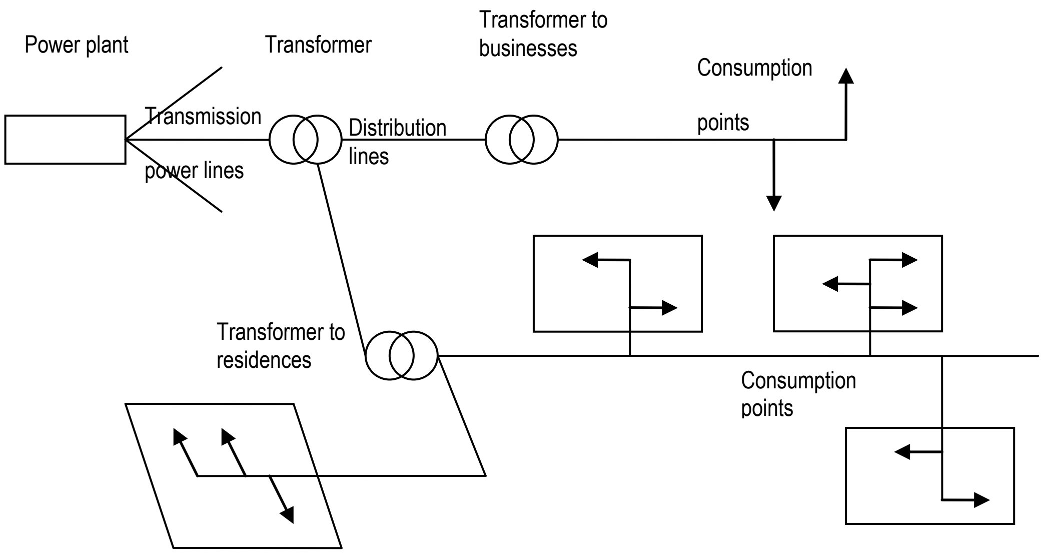


Figure 1.2. Electricity transmission and distribution scheme

Electricity can be provided to the consumer in one or more supply points of power installations. These feed points can be different, so that in the event of a loss of voltage at a point to provide power to the consumer through the other point. Such supply points through independent pathways are: two different plants or power stations; two distinct bar sections within the same power plant or station.

If more consumers that are fed from a power station or some shared facilities, the share of investment or production costs falling upon these consumers, is fixed in proportion to the powers requested by them.

c) Coverage of the load curve is done by affecting plants of different categories of electricity – base, semi top and top - using economic criteria and safety in operation. Electricity production from base load is ensured by nuclear power plants, hydroelectric power plants (HPP) built on the river, thermal power plants (TPP), mainly those using coal, power plants with large groups. Covering loads during peak hours is from hydroelectric reservoirs or hydroelectric reservoirs and pumped storage (HPSS) because they have a power reserve maneuver through hydraulic energy stored in the lakes; top curve can be covered also by the gas turbine plants. Electricity from semi top curve is covered either with semi top HPP character either with power plants or district heating condenser.

d) Variants of development of power system are based on data on the consumption of electricity and heat dynamics produced by heating, the evolution of the shape of the load, the maximum primary energy resources that can be allocated for this purpose, the situation of existing facilities for production, transmission and distribution of electricity etc.

It should be taken into account the characteristics of different types of power plants to calculate investment expenditure, operating costs, operating times etc.

e) Different types of power plants are distinguished by life span, duration of planned repairs, machinery and equipment reliability etc., issues to be quantified in technical and economic calculations, applying the equivalence solutions. For example, a hydroelectric plant life is greater than a thermal power plant. For equivalence, at the thermal power plant is taken into account replacement investment, which is considered equal to the initial investment and the same echeloning in time.

f) If some equipment, facilities or equipment will be decommissioned at a certain time, it is necessary to calculate their residual value and also the residual value of the materials that can be capitalized.

Residual value of the plant is calculated for the end of the study, based on the not depreciated value with the relation:

$$W_n = \frac{a(D + d - D')\cdot I}{100} \qquad (1.1)$$

Where:

d – represent the execution period;
D – the useful life of the plant;
D' – the study period (conventional period established for calculations, considered at the beginning of the execution period of the plant);
a – normal rate of depreciation;
I – the purchase price of the machine or plant decommissioned.

If some equipment is decommissioned before the end of the study period, on the ground that changes the grid load in the electrical network, in the transformer station, etc., shall be counted as time worked (t) instead of D '.

g) Damage to consumers, due to interruptions in the power supply, is an operating expense, which highlights distinct solutions just to differentiate between them in terms of quality of supply of electricity or heat. Thus, it may be established the best solution from the point of view of economy and from the point of view of safety in operation.

h) Electrical networks are often subject to separately economic analysis. Among several variants (solutions) of new electricity networks, the most economical choice should take into account the degree of operational safety.

i) Some hydro power facilities are designed for complex use with multiple advantages on water management, irrigation, economic and social development of the area etc. In case of the hydropower plants, the investment will only comprise energy investment, determined by regulations.

j) In the production of electricity and heat arises with particular urgency the need of energy conservation by replacing higher calorific primary resources (gas, oil) with solid fuels that have low calorific value (lignite, oil shale).

Because energy is a key factor of economic progress, it is necessary to provide both increasing energy resources and saving and efficient use of these resources. Thus, we consider the following: electricity production to take place concurrently with the supply of heat; exploitation of new energy sources and renewable resources; enhancement of technical hydropower potential, arranged by micro hydro power; reducing specific fuel consumption etc.

2. The economic criteria used in evaluating investment alternatives in energy industry

An important element that differs in energy field from one investment objective to another is the size of the investment and operating costs, according to the type of power plants. For example, such a difference is typically between thermal power plants and hydropower plants, the first having lower investment costs and higher operating expenses.

Differences in spending are also between thermal power plants. Therefore, the economic evaluation of investment programs and projects in this branch uses indicators (criteria) that cumulate both investment expenditure and operating. Such indicators are used particularly in profile and location studies, or in any preliminary phase of economic and technical documentation.

2.1. Equivalent costs

Different investment variants can be evaluated by summing the costs of investment and operation, as equivalent costs indicator:

$$K = I \cdot E_n + C$$

or (2.1)

$$K = I + C \cdot T_n \rightarrow \text{min}$$

where:

K – equivalent costs indicator;
I – total investment;
C – annual production costs;
En – standardized coefficient of economic efficiency;
Tn – standardized payback period.

If the annual production volume is different from one investment alternative to another (depending on the type and mode of operation of the power plant),then there are calculated specific equivalent expenses (per unit of electricity delivered) i.e.:

$$k = \frac{I \cdot E_n + C}{q} \qquad (2.2)$$

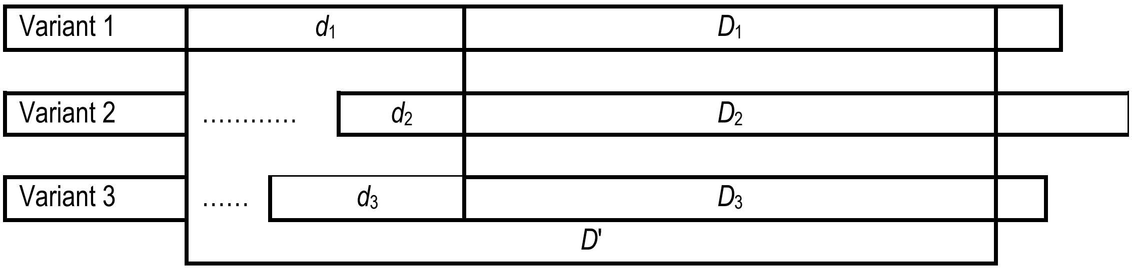
Or $$k = \frac{I + C \cdot T_n}{q \cdot T_n}. \quad (2.3)$$

The alternative with the lowest equivalent costs is the best solution that should be adopted.

2.2. Discounted total costs (DTC)

The discounted total costs include construction costs and operation costs of the project and at the same time the equivalence costs needed to compare the alternatives. Also it should be taken into calculations, where appropriate, the remaining residual value of equipment and facilities.

Discounting should be considered at the beginning of execution of investment. If the variants to be compared have different execution times, the discounting will be for all at the same time, namely at the beginning of the highest execution time, so that commissioning should be on the same date for all variants (see chart below):



where:

d1, d2, d3 is the execution period;

D1, D2, D3 - life span of the equipment per variants;

D '- the period of study.

If we analyze the various projects dealing only with actual investment and operating costs(not the case for equivalence in terms of installed capacity and energy production, and no disused equipment), the discounted total costs formula would be:

$$DTC = \sum_{h=1}^{d} \frac{I_h}{(1+a)^h} + \sum_{h=d+1}^{D'} \frac{C_h}{(1+a)^h} \quad (2.4)$$

where:

I_h – the annual investment cost;

C_h – annual operating expenses (without depreciation);

a – the discount rate.

If the annual production costs are equal in time we are using the relationship:

$$DC = C_h \left(\frac{(1+a)^{D'} - 1}{a \cdot (1+a)^{D'}} \right) - \left(\frac{(1+a)^{d} - 1}{a \cdot (1+a)^{d}} \right) \quad (2.5)$$

the terms in brackets expresses the sum of discount factors:

$$\left(\frac{1}{1+a} + \frac{1}{(1+a)^2} + \ldots + \frac{1}{(1+a)^{D'}} \right). \quad (2.6)$$

Among the variants compared, the most effective is that to which the discounted total costs are minimal.

The DTC criterion is used to assess energy investment projects, taking into account the problems of equivalence, i.e. costs that would be required to produce equal effects and also the decommissioning of machines, whose value is subtracted from the total.

Thus, various projects are equated considering:

- The production capacity (electric power and / or heat flow installed): calculating the investment related to the difference of power for lower power variants;

- The quantity of electricity and / or heat produced: calculating the cost of the difference of energy for the variants with lower power quantities;

- The time interval that produces economic effects and consumes resources: considering either the lifetime of each variant or the study duration(which may occur in relation to decommissioning); a single discount time for all variants which determines introducing in calculus residual values of equipment (with greater duration than the study duration)and also residual values of equipment scrapped before the expiry of study duration etc.

The present value of the investment of equivalence (I_h) and annual cost for equivalence (C_h)is obtained in the same way as for the actual costs.

The methodology for calculating the energy investment has established two types of plants standard (reference) for equivalence:

- Plants that use fuel oil and lignite for power plant producing based on the load curve;

- Plants with gas turbines, for those producing for peak load.

Equivalence of solutions on installed power and quantities of energy produced aims to boost the use of inferior coal and eliminate as possible hydrocarbon, valorization in increasingly harnessed hydropower potential etc.

Discounted residual value of installations to be decommissioned in several successive years is given by:

$$\sum_{h=d+1}^{D'} W_h \cdot (1+a)^{-h}. \qquad (2.7)$$

If decommissioning of equipment or facilities shall be made at the end of the study period, the discounted residual value will be determined as follows:

$$W_n \cdot (1+a)^{-D'}. \qquad (2.8)$$

The residual value of an installation k is calculated using the formula:

$$v_{rk} \cdot (1+a)^{-D_k}. \qquad (2.9)$$

If you have multiple installations with lifetimes different of the project, the amount of the residual value will be discounted:

$$\sum_{k=1}^{n} v_{rk} \cdot (1+a)^{-D_k}. \qquad (2.10)$$

Losses (expenses) damages due to the discounted value of damages are calculated with the formula:

$$\sum_{h=1}^{D'} P_h \cdot (1+a)^{-h}. \qquad (2.11)$$

After choosing the most favorable project on the grounds of the discounted total costs, this will be compared with the power plant taken as a standard, whose technical economic indicators play the role of normative values.

If there is only one option, we compare it with standard plant.

Please note that in case of thermal power plant,the economic analysis is made compared to the standard plant consisting of:

- A thermal power plant or complex of thermal power plants providing the same amount of heat, placed by the consumer and running on the same fuel;
- A power plant condenser, providing the same amount of heat and electricity production, located at the mouth of the mine and operating on the same fuel.

3. Indicators of financial and economic evaluation of energy investments

3.1. Specific investment

This indicator is calculated using the relationship:

$$s = \frac{I}{P} \qquad (3.1)$$

wherein:

s – the specific investment;
I – investment cost;
P – installed power in MW or kW.

Specific investment size varies from one type of plant to another. At the thermal power plants operating with gas, specific investment values are between 700-1800 Euro / kWe installed; at power plants using coal, this indicator reached between 1700-3400 Euro / kWe installed, due to the collateral investments (that involves household coal including unloading system, transport, milling storage of coal and ash evacuation system); specific investment at hydropower reached between 1000-9000 Euro/kW installed, due to engineering works (dams, reservoirs, forced pipe, tunnel excavation etc.).

In order to assess the specific investment level as acceptable or not, it is compared with standard power plant specific investment.

3.2. The production cost of a kWh

This indicator is calculated using the relationship:

$$C_e = \frac{C_{an}}{E_L} = \frac{C_{an}}{E_B (1-\varepsilon)} \quad lei/kW \qquad (3.2)$$

where:

C_{an} – represent total annual production costs;
E_L – electricity supplied;
E_g – energy of generators at the terminals of;
ε – consumption of domestic services.

a) The cost of the power plant unit

It highlights the main structure of the primary elements of cost, for more rigorous assessment of energy investment projects, per variants. The calculation formula is as follows:

$$C_{kWh} = \frac{a \cdot s}{T_u} + \frac{b}{\eta} + z \qquad (3.3)$$

where:

a – annual rate of depreciation of plant,
s – specific investment;

Tu – installed power usage time, in hours;
b – specific cost of fuel (lei / kWh);
η – the overall yield of the investment, ranging from 0.36 to 0.39;
z – other expenses (salaries, current maintenance costs, etc.).

In a thermal plant that uses oil or lignite, we see that fuel costs are predominant (80-85%) of the total annual cost, while being proportional to the duration of use of installed power during the year. Instead, a number of other operating expenses are equal to different operating durations ,during the year (3500 ... 6000 hours). Fixed expenses are independent of the annual duration of operation of the plant.

b) The unit cost in the energy system

Expenses for a kWh of electricity consumed (c) sent from the terminals of the power central may be determined by highlighting the variable and fixed costs, using the following formula:

$$c = a + \frac{P \cdot \Pi_{max}}{P_{max} \cdot (1 + e_n^{'} \cdot i_p)} \quad {}^{lei}\!/_{kW} \qquad (3.4)$$

where:

a – variable costs of the energy system relative to a kWh electricity (equal approximately to those of fuel);
P – coefficient of installed power system backup (P = 1.15 -1.20);
Π_{max} – the participation of consumers in the maximum load of that system;
Pmax – Uneven load chart of the consumer;
b – constant annual costs in energy system relative to 1 kWh electricity produced (all expenses are approximately equal to the energy system, without the cost of fuel);
e' – normal coefficient of economic efficiency in energy branch (electricity production);
ip – investment expenditure for 1 kw installed capacity of the power system.

Determination of the two categories of costs - variable and fixed - is done in order to trace the influence of the share of fixed costs on the total cost, under a certain installed capacity and a certain time of use.

The share of fixed costs (f) in the cost of electricity delivered is dependent on installed capacity and power usage time , being inverse proportional to their sizes, i.e.:

$$\varphi = \frac{CF}{P \cdot T_u} \qquad (3.5)$$

It means that with the reducing the duration of annual power usage, the share of fixed costs in the total cost increases.

The share of fixed costs for a given value of T_u depends upon the type of the power plant.

Denoting by x the share of fixed costs for T_u = 6500 h / year ($x = \frac{\varphi}{C_{an} \cdot 6500}$) , this has the following values:

x = 0.2 ... 0.4 in power plants with conventional fuel;

x = 0.6 ... 0.85 in nuclear power plants;

x = 0.85 ... 0.95 in hydro power plants;

We emphasize also that the annual level of variable costs is influenced by the operating mode of various plants, especially at the large and medium hydroelectric power. Their commissioning cause changes in the variable costs of power plants with which they are working in the load curve.

4. Evaluation of renewable energy projects

The principal technologies used to extract energy from the various natural processes

generated from the radiant energy of the sun include: solar photovoltaic, solar thermal, wind, biomass, hydropower.

For a renewable energy project, the feasibility study should document the evaluation of the following :technology, financial and economic conditions, infrastructure, risk, sensitivity analysis. The economic and financial evaluation is based on cost benefit analysis, using the following indicators:benefit cost ratio, payback period, net present value,internal rate of return etc.

The benefit cost ratio (BCR) is the ratio between discounted total benefits (V) and discounted total costs (C):

$$BCR = \frac{\sum_{h=1}^{n} V_h \frac{1}{(1+i)^h}}{\sum_{h=1}^{n} C_h \frac{1}{(1+i)^h}}$$

For a project to be acceptable,this ratio sould have a value of 1 or greater than 1.Considering mutually exclusive projects,the rule is to choose the project with the highest benefit cost ratio. The payback period (T) is the length of time required to recuperate the investment costs through the net profit after tax adding financial cost and depreciation i.e.net cash flow (CF)

Going from the relationship:

$$\bar{I} = \frac{CF}{(1+i)^d}\left[\frac{(1+i)^T - 1}{i(1+i)^T}\right]$$

we reach the formula:

$$\bar{T} = \frac{\log\left[\frac{CF}{CF - i\bar{I}(1+i)^d}\right]}{\log(1+i)}$$

Since the payback period is the time period required for the amount invested in a project to be repaid by the net cash outflow generated by the project,it can be calculated by simply cumulating the discounted net cash flows until it reaches the amount invested.

The net present value (NPV) of a project is defined as the value obtained by discounting for each year, the difference of all cash outflows and inflows throughout the life of a project at the firm's cost of capital.

The discount rate or cut-off rate should reflect the opportunity cost of capital i.e. the possible return on the same amount of capital invested else where, or the minimum rate of return expected by the investor. If there are several investment proposals, the project with largest NPV should be selected.

$$\text{NPV} = \sum_{h=1}^{n} CF_h \frac{1}{(1+i)^h} - \text{I}$$

where CF is the cash flow of a project in years 1, 2, 3,..., n and I is the investment cost.

5. Conclusions

The disadvantage of the NPV is the difficulty in selecting the appropriate discount rate and consequently it doesn't show the exact profitability rate of the project. Therefore the financial evaluation of the investment projects uses also the internal rate of return.

The internal rate of return (IRR) is the discount rate at which the present value of cash inflows is equal to the present value of cash outflows, the benefit cost ratio is 1 and the net present value is zero. The IRR method assumes that the project's annual cash flows can be reinvested at the project's IRR.

IRR indicates the maximum interest rate that could be paid without any losses for the project. The investment project is accepted if the IRR is greater than the cut-off rate. If there are more investment proposals, the project with the highest internal rate of return will be selected.

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