УДК 330.322.5:621.311

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ANNUITIES AS A TOOL OF INVESTMENT APPRAISAL CALCULATIONS OF STATIC PROJECTS IN ELECTRICAL GRIDS

Prokopenko, V. L. Annuities as a tool of investment appraisal calculations of static projects in electrical grids/ Vitaliy Leonidovych Prokopenko// Економічний аналіз: зб. наук. праць / Тернопільський національний економічний університет; редкол.: О. В. Ярощук (голов. ред.) та ін. – Тернопіль: Видавничо-поліграфічний центр Тернопільського національного економічного університету «Економічна думка», 2016. – Том 25. – № 1. – С. 190-199. – ISSN 1993-0259.

Abstract
Introduction. *The article is devoted to analysis of annuities as the computational tool that may ease discounted investment appraisals in electrical grids.*
Purpose. *The purpose is to study the possibilities of perpetual annuity, which is applied in a guiding industrial document for evaluation of static projects, to provide correct estimations of investments in electrical grids with time limited profitable periods of operation.*
Method (methodology). *The analysis is based on the concept of net cash flow which is traditionally applied in capital budgeting studies. Present value factor appraisal method is used to test annuities. Comparative method is applied to evaluate the relative error of NPV estimations based on perpetual annuity.*
Results. *It is shown that perpetual annuity arranges a coherent appraisal system of static projects combined of ordinary and discounted methods with contradictory methodological background. The resulting dependence of estimation period on the rate of discount is revealed to impede the simultaneous evaluations of projects in electrical grids with different functionality, terms of profitable operation, voltage levels and electricity transmission volumes. The application of perpetual annuity provides noticeable errors in the calculation of NPV leading to incorrect market-oriented evaluation of projects. The ranking procedures are affected further as well. The time-limited annuity is found out to be more consistent with these issues and may be recommended to ease the computations of discounted values without loss of accuracy. These findings can be helpful for grid operators in developing workable computational procedures of investment appraisals with relevance to new challenges of electrical grids and power industry in a changing market environment.*

Keywords: *investment appraisal; electrical grids; net cash flow; discounting; perpetual annuity; time-limited annuity; rate of discount; period of estimation.*

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АНУЇТЕТИ ЯК ІНСТРУМЕНТ РОЗРАХУНКІВ ІНВЕСТИЦІЙНОЇ ОЦІНКИ СТАТИЧНИХ ПРОЕКТІВ В ЕЛЕКТРИЧНИХ МЕРЕЖАХ

Анотація
Вступ. *Стаття присвячена аналізу ануїтетів як інструменту, який може полегшити розрахунки дисконтованих оцінок інвестицій в електричні мережі.*
Мета. *Мета полягає у вивченні здатності вічного ануїтету, який застосовується у керівному галузевому документі для оцінки статичних проектів, забезпечувати правильну оцінку інвестицій в електричні мережі з обмеженим у часі прибутковим періодом експлуатації. .*

Метод (методологія). *Аналіз базується на концепції чистого грошового потоку, яка традиційно застосовується в дослідженнях капітального бюджетування. Метод коефіцієнтів приведення до теперішньої вартості використано для оцінки ануїтетів. Метод порівняння застосовано для оцінки відносної похибки розрахунків чистої теперішньої вартості, які базуються на використанні вічного ануїтету.*

Результати. *Показано, що вічний ануїтет створює внутрішньо узгоджену оціночну систему для статичних проектів, яка поєднує методологічно несумісні прості та дисконтовані методи. З'ясовано, що зумовлена цим залежність оціночного періоду від норми дисконту не дозволяє виконувати одночасно оцінку проектів в електричні мережі з різною функціональністю, строками прибуткової експлуатації, рівнями напруги та обсягами передачі електричної енергії. Застосування вічного ануїтету призводить до суттєвих помилок в розрахунку чистої теперішньої вартості, у зв'язку з чим проекти отримують некоректну ринкову оцінку. Подальше ранжирування проектів також зазнає негативного впливу. Виявлено, що терміновий ануїтет краще підходить до цих оціночних задач та може бути рекомендований з метою полегшення дисконтованих розрахунків без зниження їх коректності. Ці результати можуть бути корисними для операторів мереж в розробленні ефективних розрахункових процедур оцінки інвестицій в контексті нових викликів розвитку електричних мереж та енергетичної галузі у змінному ринковому середовищі.*

Ключові слова: *оцінка інвестицій; електричні мережі; чистий грошовий потік; дисконтування; вічний ануїтет; терміновий ануїтет; норма дисконту; період оцінки.*

JEL classification: G31, L94

Introduction

During the last decades electrical power industry has been experiencing remarkable changes. All over the world electricity markets are continuously transforming their structure by integrating renewable energy generation facilities, promoting competition among producers and retail distributors, and rearranging governmental policies. Despite of being the natural monopoly segment of the industry electrical grids are in trends as well. In many countries this sector provides ample evidence of positive economic and social impact of Regulatory Asset Base (RAB) regulation policies aimed to give network operators some stake of freedom and a fair return on investments in exchange for intensive investing in modernization of electrical grids and improvement of the quality of electricity for consumers on retail markets. This innovative and unusually dynamic market environment necessarily incentivizes investment processes in the industry and challenges a lot of scientific and practical issues.

Capital-intensive nature of the industry has traditionally determined the magnitudes of invested capitals and relatively long, but not infinite, periods during which the returns are collected. Due to this specificity the discounted methods of investment appraisal such as net present value (NPV), internal rate of return (IRR), profitability index (PI) etc. are favored in domestic industrial studies [1; 2; 3]. However, seen from the point of computational techniques these methods appear to be quite complicated. As it goes on practice, a lot of factors contribute to multiply the complexity of this task. They are (1) alternative calculations for each project to find the best solution; (2) project ranking practices given there is an investment budget constraint; and (3) a wide range of electrical grid facilities that are needed to be appraised and invested in. Consequently, management and engineers in our country often become seriously puzzled with perception and application of these appraisals. Actually, along with relative lack of market-based investment experience this complicated practice develops strong incentives to use ordinary methods of payback period (PP), accounting value of project (AV), accounting rate of return (ARR) etc. which are customary and easy to compute and understand. Unfortunately, these methods are not well adjusted to investment appraisals in a spreading market environment because of ignoring the challenges of alternative opportunities for profitable application of private capitals, including demands on the capital market outside the power industry. Therefore promoting discounted appraisals in electrical grids and other sectors of industry seems to be relevant to ensuring successful investment decisions. For this purpose the article proposes a study of annuities as a tool that can be effectively applied to find a way to workable computational techniques. Both theory and practice of investment appraisals have a lot of relevant elaborations in this field that may be rightly addressed and developed with respect to new demands.

Investment feasibility studies often deal with ordinary annuities. They are the series of equal cash flows that are returned and capitalized annually at the end of each year. There are at least two ways to use annuities in the theory and practice of capital budgeting. Firstly, they are embedded in the structure of certain discounted methods. For example, it is a method of Equivalent Annual Cost (EAC) which is conventionally used in engineering. It is calculated by dividing NPV of the project by a present value factor of the annuity [4]. Ukrainian researchers name this method as Annualized Net Present Value (ANPV) [5, p. 186]. It is usable in comparing the projects with different estimation periods and variable cash flows. In this case time-limited annuities, which have specified periods of estimation, are applied.

Another way to use annuities in discounted calculations is to appraise future cash flows of equal size. Since the discounted methods has historically originated from appraisals of lifetime debts a perpetual annuity method, which was mainly used in these calculations, is successively mentioned in real capital budgeting studies as well [6, p. 82; 7, p. 343-344]. This annuity is a special case of ordinary ones provided that the estimation period tends to infinity. Its present value factor is inversely proportional to the rate of discount ($a_{\infty;E} = 1/E$) [6, p. 82; 8, p. 108]. It should be acknowledged that this simple formula certainly gives perpetuity a great head start in easing the computational techniques. When real investments, instead of financial ones, are considered this method would probably be an attractive appraisal tool for tentative estimations of long-lasting investments with generally defined goals and scope. Examples include preliminary investment decisions about starting private business, assimilation of new territories and development of communities and industrial clusters, mining operations under concessions etc.

With application to electrical power industry perpetual annuities may well correspond to the long-lasting perspectives of investment returns from the construction of energy generation facilities, the strategic development of interstate and national high-voltage power transmission networks, as well as the creation of energy clusters of industrial areas. After the invested facilities come up to full capacity the forecasts of variable cash flows for such investments irrationally complicate computations. Thus, it is convenient to treat such projects as static ones where perpetuities may be successfully applied in rough estimations. The industry guiding document, for example, suggests an approach that uses perpetual annuity method to build the complex evaluation system for the estimation of static projects [9].

With regard to local electrical grids the distribution network operators are recommended to use this approach to evaluate the efficiency of their construction and reconstruction when investment budgets are submitted for regulator's endorsement [10, p. 28-29]. However, unlike financial investments and real investments with general goal setting these investments being aimed to develop particular grid facilities in an economically and technologically innovative environment are virtually associated with time-limited profitable periods after which new investments is demanded again. Therefore it looks already transparent that there is a discrepancy between time-limited periods of collecting returns on such the real investments and the estimation of their feasibility by using perpetuities. As it appears on practice, the application of this guiding approach leads to estimations that are quite different from those calculated by applying conventional formulas.

The purpose of the article

The purpose of the article is therefore to answer the question whether perpetual annuities may be appreciated as really powerful tools in the estimation of investments in particular electrical grids assuming that their profitable operation is relatively time-limited within an observable perspective. If the result is negative, what kind of analytical tools of annuities may be applied to ease the discounted calculations in this segment of electrical power industry? For these purposes the guiding approach for the estimation of static projects in electrical power industry is scrutinized in this article.

Key research findings

To make the analysis clear and understandable it is appropriate at the beginning to give a more detailed description of this guiding approach [9]. It should be noted that the formulation which follows is partially adapted in the sense that unlike the original version all appraisal methods are described here using the same categories. For example, it is always net cash flow that is used to represent the annual returns instead of separately displayed net profits and depreciation of capital. Another easement is to eliminate the impact of elements of negligible value which are present in the original. It is meant here, for example, that liquid value of dismantled equipment is always subtracted from investments resulting in net investment as an operational category of this research. This adaptation allows drawing parallels with similar appraisal methods outside electrical power industry studies. At last the description is made to show the role of perpetual annuity in appraisal framework for static projects.

So, to begin with, the key method is assumed to be an Integral Effect, or Integral Discounted Net Income. This is the power industry's specific interpretation of a Net Present Value (NPV) method. So it is denoted here as NPV:

$$NPV = \frac{NCF}{E} - I \text{ or } NPV = NCF \cdot a_{\infty;E} - I \qquad (1) - (2)$$

where NCF denotes an annual net cash flow, which consists of a net profit and a depreciation used for renovation of capital assets, I – a net investment that is the invested capital reduced by liquid value of dismantled equipment, E – the rate of discount, $a_{\infty;E}$ – a present value factor of the perpetual annuity. If the value of project which is estimated the positive NPV shows that the project is feasible (NPV>0). Meanwhile ranking practices use maximum value of NPV to find the best solution among alternatives (NPV→max).

The second method is a Rate of Return on Investment (RRI) that describes a share of investment that is annually returned in the form of NCFs:

$$RRI = \frac{NCF}{I}. \tag{3}$$

This method is an ordinary one since the formula of IRR doesn't contain the rate of discount. This rate is a part of criterion for RRI instead. The project is assumed feasible if RRI is higher than the rate of discount ($R_i>E$, or $R_i>1/a_{\infty;E}$).

As it is stated in the document, for static projects RRI becomes equal to IRR [9, p. 9]. Indeed, if a traditional equation for IRR [11, p. 134; 12, p. 22] is thought for static projects with invariable annual NCFs it can be written as follows:

$$\sum_{t=1}^{T}(1+IRR)^{-T} = \frac{I}{NCF}. \tag{4}$$

The left part of the equation (4) is a present value factor of NCFs for the period of estimation T. Replacing it with the perpetuity where the rate of discount is the estimated IRR the expression which is identical to the equation (3) is logically obtained:

$$\frac{1}{IRR} = \frac{I}{NCF}\text{, from here } IRR = \frac{NCF}{I}. \tag{5) – (6}$$

The last appraisal method is a Payback Period (PP) which, as usually, shows how many times annual NCFs should return to investor to recover the costs of capital inputs. In this appraisal system PP is reversely proportional to RRI:

$$PP = \frac{1}{RRI} = \frac{I}{NCF}. \tag{7}$$

The project is believed to be feasible if PP is appraised less than the period of estimation (PP<T, or PP< $a_{\infty;E}$). And again the rate of discount serves as a part of criterion for the appraisal method instead of being included in the method's formula.

Thus, the appraisal system for static projects includes three interrelated methods which at the same time have obviously different methodological backgrounds. The first method is from the family of discounted methods. As it can be seen from the equation (1), due to the perpetuity it obtains a simplified description. While RRI refers to ordinary appraisal methods its application for static projects allows identifying it implicitly with the discounted method of IRR. Finally, PP being inversely proportional to RRI also falls into the field of twofold methodological interpretation. Nevertheless it is ambiguously reputed to be the ordinary method [6, p. 103; 11, p. 115; 12, p. 21]. As will be shown further, this uncommon combination of methods in a single appraisal system is provided by using the perpetual annuity.

The practice of applying these methods to the precise estimation of investments in construction and reconstruction of distribution networks with voltage 0.38-150 kV reveals that the estimation period for different real facilities becomes unreasonably dependent on the rate of discount in these calculations. To show this, the equation (1) should be rewritten for the positive value criterion as follows:

$$\frac{NCF}{E} > I \tag{8}$$

If the discount rate is taken, for example, at 10%, then the feasible investment should satisfy the condition of the inequality $10 \cdot NCF > I$. It can be seen that investments are compared with 10 annual NCFs. In other words, the calculation takes account of only the first 10 years of operation of grids. If the rate of discount is put down, for example, to 5%, the inequality will receive another expression, that is $20 \cdot NCF > I$. Now the evaluation of the project takes into account already 20 years of operation. Similar reasoning can be put forward for other different rates of discount resulting in different estimation periods.

It is clear that the integral effect, or NPV, of the projects cannot be calculated within this framework for the periods that are longer or shorter than those calculated inversely to the discount rate. The estimation period, thus, is strictly determined by the rate of discount. It is interesting that scientific papers in investment analysis provide some considerations that are obviously based on taking this relationship for granted. It is noted, for example, that the feasibility of the investment, if it is appraised using NPV method, is assumed reasonable when the period of estimation is no longer than the marginal period calculated inversely to the discount rate [13, p. 84]. Another author notes that the period of evaluation of investments should be consistent with the rate of discount [1, p. 11].

Still, the dependence of the estimation period on the rate of discount may hardly be justified for the exact evaluation of real investments in particular facilities. It should be frankly admitted that the specific recommendations concerning the duration of the estimation period are rarely provided. The solution usually depends on industry as well as the interests and rules of companies and outside investors. The general advice can be found in "Manual for the Preparation of Industrial Feasibility Studies" developed by UNIDO (United Nations Industrial Development Organization) in 1978. The authors have noted that the estimation period should be coherent with an economic life of the investment project. It is believed to be the period during which the investor collects profits. Its duration is assumed to be dependent on such factors as the technical life period of the project, the technological progress, industry life cycle, the opportunities of alternative investments, administrative constraints etc. [14, p. 365]. It is clear enough that after the economic life is over the losses are expected and new capital investments are demanded. Applying this guidance to electrical grids makes obvious that the estimation period for the investments should be derived from the analysis of technical side of the projects, the featured characteristics of the network which is constructed or reconstructed, the technology and profitability of network operation, general development trends of electrical power industry and electricity markets. It also follows that, seen from the point of computational procedure, the estimation period refers to the input data that shouldn't be derived during the project feasibility study but formulated before it is started.

On the other hand, the rate of discount is undoubtedly a market variable. Depending on the purpose of the analysis it reflects either the profitability of alternative capital inputs in other industries, regions and countries or the costs of credit repayment to finance the project. Economic analysis of discounting practices provides some theoretical evidence of this argument. One of the founders of modern neoclassical theory of interest, I. Fisher, has noted that "the rate of interest registers in the market the common marginal rate of preference for present over future income, as determined by the supply and demand of present and future income" [15, p. 121]. J. Hirshleifer has later interpreted fisherian theory using lending and borrowing rates as the indicators of opportunity costs of making real investments in a market economy [7, p. 330]. So when the rate of discount is considered there is only an issue of choice between different applications of capital to ensure future incomes as they are assessed with conformity to the mentioned rate of preference. It is clear as well that there is no close and direct relation of the rate of discount to the factors determining the economic life period of real investments and, respectively, the estimation period. It can be therefore concluded here that no causal relationship between these two categories can be coherently substantiated.

Nevertheless this "artificial" relation is featured in the guiding appraisal approach due to the use of perpetual annuity. It prevents the evaluation of projects with conformity to their economically reasonable estimation periods determined by the profitable operation of electrical networks. If for calculation purposes the rate of discount is taken, for example, at 8% the project evaluation can be performed for a period of 12.5 years. This period between two consecutive investments may be expected to be quite close to the feasible operation of some pieces of urban grids with voltage 0.38-10(6) kV that may serve a fairly localized in space and changing in time demand of electrical energy. Therefore with high probability they may face the unconformity to a spatial configuration of electrical load despite of being physically appropriate. However, most of investments will be undervalued since the profitable years of operation after 12.5 years are not taken into account. For example, the overhead lines with voltage 35-110(150) kV can be operated normally without forecasted economic losses up to 20-30 years. If, following the logic of the relation between the rate of discount and the estimation period, the former is put down to 5%, the latter will cover 20 years of the operation of high voltage transmission lines. It is virtually more close to their economic life duration. But, simultaneously, the application of this rate to estimate the investments in the mentioned above urban networks of 0.38-10(6) kV is very likely to undervalue these investments due to the unprofitable years of operation which will be probably included. The optional use of different rates of discount for technically different projects is inconsistent as well since they are estimated in the same economic environment. Thus, if the relation between the rate of discount and the estimation period remains in calculations it is impossible to obtain coherent estimations of investments in the electrical grids with different operational characteristics.

It is not less interesting a paradoxical, at a first glance, ability of the guiding approach to provide an absolutely coherent evaluation of projects. This is despite the fact that it combines ordinary and discounted methods of appraisal whose methodological background differs in the matter of recognizing the lessening value of more remote cash flows. It is obvious that in case of static projects the discounted methods should guarantee a more severe evaluation than ordinary ones because the weight of more remote cash flows is reduced through discounting regardless they are of equal nominal value. For such the cash flows the total discounted value is always obtained less than simple summation of their nominal values. It follows that the NPV value should not always be consistent with the values of RRI and PP. But as practice shows the guiding approach makes always possible to receive coherent estimations with the help of all three methods included.

To demonstrate how this result is achieved the feasibility criteria for all the mentioned methods should be rewritten in a way to formulate the requirements for the size of the annual NCF of the project. Considering the method of integral effect this requirement is observable from the equation (8):

$$NCF > E \cdot I \,. \tag{9}$$

For RRI it is derived from the equation (3) as follows:

$$\frac{NCF}{I} > E \text{, from here } NCF > E \cdot I \qquad (10)-(11)$$

And finally, from PP equation (6) it is obtained in a following way:

$$\frac{I}{NCF} < \frac{1}{E} \text{, from here } \frac{NCF}{I} > E \text{, therefore } NCF > E \cdot I \qquad (12)-(14)$$

As it can be seen from the inequalities (9), (11) and (14), all these methods have virtually the same criterion to evaluate the absolute efficiency of static projects. It actually requires that annual NCF must be greater than the share of investments, which is equal to the rate of discount expressed in relative units. In this case the project is assumed to be profitable while, otherwise, the project should be rejected. Thus is a background for the conformity of discounted and ordinary estimates. The usual and obvious inverse relationship between the feasibility of the project and the rate of discount additionally strengthens the signs of validity for this appraisal system. But the fact of the uncommon combination of discounted and ordinary methods still challenges it.

To understand the nature of this "trick" the common formula of NPV [12] can be used. The purpose is to write the equation for the total discounted value of NCFs for the estimation period taken as independent input data. This value is denoted here as Gross Present Value (GPV). The formula is as follows:

$$GPV = \sum_{t=1}^{T} \frac{NCF}{(1+E)^t} = \frac{NCF}{(1+E)} + \frac{NCF}{(1+E)^2} + \frac{NCF}{(1+E)^3} + \ldots + \frac{NCF}{(1+E)^T}, \qquad (15)$$

assuming that:

$$NPV = GPV - I \qquad (16)$$

After taking NCF outside the sign of summation the equation (15) can be rewritten as follows:

$$GPV = NCF \cdot \sum_{t=1}^{T} (1+E)^{-T}, \qquad (17)$$

Using a sequence of mathematical transformations described in [6, pp. 82-83], the equation (17) gets different expression:

$$GPV = NCF \cdot \frac{1-(1+E)^{-T}}{E} \text{, or } GPV = NCF \cdot a_{T;E} \qquad (18)-(19)$$

where $a_{T;E}$ is a present value factor of a time-limited annuity [8, p. 107].

At the same time the analogue of GPV for static projects designed with the help of perpetual annuity, as it goes from the equation (1), has logically the following expression:

$$GPV_{\infty} = NCF \cdot \frac{1}{E} \text{, or } GPV_{\infty} = NCF \cdot a_{\infty;E} \qquad (20)-(21)$$

The difference appears in present value factors. As it is noted in the literature, given long-lasting estimation periods, when $T \to \infty$, the component $(1+E)^{-T}$ in the equation (20) comes nearer to 0 and, thus, loses its weight. Therefore the present value factor of the time-limited annuity, which depends on the rate of discount and the estimation period, transforms to the present value factor of the perpetual annuity, which depends only on the rate of discount ($1/E$) [6; 8]. Indeed, for a period of 100 years and the rate of discount of 10%, the expression $(1+E)^{-T}$ will be equal to 0,00007. It is in fact of negligible value.

However, on practice the economically efficient operational period for most specific facilities of electrical grids, before the need for new investments is perceived, turns to be much shorter, mostly up to 30 years. Therefore, when NPV is calculated for real investments using perpetual annuity method the weight of the mentioned component becomes influential for the estimation of the present value of NCFs. Therefore the calculations made with the help of the guiding appraisal system lead to overvalued estimates of NPV. The relative size of an error can be determined by the following mathematical expression:

$$\Delta a = \frac{a_{\infty;E} - a_{T;E}}{a_{T;E}} \cdot 100\% \text{, or } \Delta a = \frac{1}{(1+E)^T - 1} \cdot 100\% \qquad (22)-(23)$$

Table 1 shows the results of calculations made with formula (23) for projects with the estimation periods of up to 30 years and the rates of discount from 5% to 15%.

Table 1. The relative error of estimation of GPV using the method of perpetual annuity

The rate of discount	Perpetual annuity present value factor	Time-limited annuity present value factor					Relative error, %				
		10 years	15 years	20 years	25 years	30 years	10 years	15 years	20 years	25 years	30 years
5%	20,0	7,72	10,38	12,46	14,09	15,37	159	93	60	42	30
10%	10,0	6,14	7,61	8,51	9,08	9,43	63	31	17	10	6
15%	6,7	5,02	5,85	6,26	6,46	6,57	33	14	7	3	2

As it can be seen from table 1, the relative size of the error increases as the rate of discount decreases and the estimation period shortens. Among values demonstrated in the table, perhaps, the errors of 2-3% received for the projects with 25-30 year estimation periods and 15% rate of discount may be ignored at most. All other errors are quite significant. However, the possibility of the scenario with 15% rate of discount is believed to be very small. If the rate of discount is taken on the level of average NBU (National Bank of Ukraine) bank refinance rates (in August 2016 – 17% [16, p. 3]) and the forecasted rate of inflation at a minimum level of 12% [17], than according to the formula [18, p. 13] the real discount rate can be computed as $(117/112-1)\cdot 100\% = 4{,}5\%$. Turning back to table 1 it can be seen that at a 5% rate of discount, which is close to this real value, the relative error in determining the GPV of the project is not less than 30% even for the estimation period of 30 years. This level of the error may certainly affect the estimation of NPV.

The analysis which is presented in this article shows that due to the perpetual annuity the guiding appraisal system ensures the artificial consistency of criteria for the evaluation of projects with the help of methodologically different methods. On the other hand, this system generates the substantial error of NPV calculations for most of real investments in electrical grids. Again, the reason is virtually the perpetual annuity method. The use of the time-limited annuity method could provide valid estimations of NPV for electrical grid facilities since this method perfectly meets the challenging issues of feasibility studies for the projects with a time-limited profitability. But in this case the estimated NPV would not correspond to the estimates of RRI and PP.

Strictly speaking, these differences would arise in the evaluation of each project. However, there are projects that meet feasibility criteria for simple methods of RRI and PP but don't achieve the true positive value of discounted integral effect. These can be the projects with the marginal efficiency when the net returns are closely over the threshold levels for ordinary methods. As a consequence, for such the projects the overall estimation would appear to be inconsistent: ordinary estimates say "yes" but discounted – "no". Eventually, the investor has no trustful value estimation of projects to make an efficient investment decision. The guiding approach hides this controversy.

To determine the interval of annual NCFs for which the appraisal is found to be contradictory, the following steps need to be done. Firstly, the inequalities (11) and (14) must be rewritten using perpetuity present value factor to obtain the inequality $NCF > I/a_{\infty;E}$. The right side of it may be denoted here as a perpetual annuity annual equivalent of investment. It sets the marginal efficiency of the projects according to the ordinary methods of RRI and PP.

Secondly, the combination of equations (16) and (21) with positive value threshold of integral effect leads to resembling inequality $NCF > I/a_{T;E}$. By analogy the right side of it may be denoted as the time-limited annuity annual equivalent of investment. It sets the marginal efficiency of the projects according to the discounted method of integral effect, or NPV.

After combining these inequalities the spacing of project's annual NCF for which the guiding appraisal approach hides a controversial estimation of investment can be provided as follows:

$$\frac{I}{a_{\infty;E}} < NCF < \frac{I}{a_{T;E}}. \qquad (24)$$

It should be noted that for projects with annual NCFs that are less than the lower threshold the negative estimation is always obtained with all the methods included. Oppositely, the projects that have annual net returns above the upper limit receive overall positive estimate. But in both cases the integral effect is overvalued due to the fallacy of the application of perpetual annuity. In case of positive estimation when projects may be further selected to form the investment budget of a company, inaccurate evaluation of the integral effect will certainly lead to erroneous ranking of investments.

Conclusions and prospects for further research

Due to the application of the perpetual annuity the guiding appraisal method for static projects in the electrical power industry provides an example of the unusual combination of ordinary and discounted methods. When this appraisal system is applied to evaluate the real investments in electrical grid facilities with relatively limited profitable operation the unjustified dependence of the estimation period on the rate of discount is revealed. This makes the appraisal system inappropriate for the simultaneous evaluation of projects in the electric grids with different functionality, terms of profitable operation, voltage levels and electricity transmission volumes. Perpetual annuity makes the estimates of feasibility of projects possible with a single criterion for the methodologically different methods. It allows the appraisal system as a whole to provide a coherent evaluation of static projects though it contradicts to the logic of these methods. Thereby a substantial error in the calculation of NPV is tacitly accepted when the static projects with time-limited profitable periods of operation are assessed with perpetuity. As a result, the projects with the marginal undiscounted level of efficiency are appraised positively while their real NPV may be negative. This causes inadequate ranking of the projects selected by the company in the market environment. The time-limited annuity is found to be more consistent with these issues and may be recommended to ease the computational procedures of discounted appraisals.

This study discovers the need to develop the appraisal methods for the static investment projects in the electrical grids with time-limited periods of profitable operation. Two basic principles of further research may be asserted by now. Firstly, the appraisal system should include methods of evaluation with the same methodological basis; secondly, the perpetual annuity should be replaced by the time-limited annuity in computations of discounted values. The relevance of such findings is viewed in relation to the conversion of distribution networks to the voltage of 20 kV and RAB-regulation of electrical network operators that are being launched currently by the national regulator. This initiatives need to be supported by the workable computational techniques of investment appraisal.

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Стаття надійшла до редакції 30.10.2016 р.