Fuzzy Concept for Projects Evaluation in Power System Utilities

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Abstract--**This paper presents a new fuzzy concept for project evaluation in Power System Utilities which uses fuzzified economic criteria. For this purpose the classical economical criteria for accepting/rejecting a project are modified and upgraded in a fuzzy sense. The Investors point of view for successful project is modelled by triangular fuzzy number.**

Developed model is extension of the classical deterministic model and enables possibilities to perceive influence of the specific parameters and uncertainty to the rate of investment in specific project.

Index Terms- **Project evaluation, Decision-making, Engineering economy, Fuzzy logic, Power system utilities.**

I. INTRODUCTION

Power systems projects, especially construction of new power plants and high voltage transmission lines are complex, occurring as unique projects undertaken to achieve exactly defined goals. They have to be finished in specified period, with limited budget and with guaranteed quality.

The projects in power system utilities are characterized with relatively long period of construction, intensive investments at the beginning of the project and many participants from different profiles and specialities. Within these projects a great number of parameters and indexes are necessary to be conducted the analyses with high degree of uncertainty and impreciseness. In the analyses of the technical and economical aspects of the power system project (that usually are in exploitation more than 20 years) it's unavoidable to use data, which have a high degree of uncertainty and impreciseness [4]. Therefore, studying, analyzing and energetic-economical valuation of such projects means a complex process which requires knowledge and experience in modelling and a vision of upbringing the correct decision.

The typical sequences in the projects in electric power utilities consist of an initial investments followed by operation and maintenance costs and returns in later years. The evaluation of these projects and investments are complicated by the fact that there are usually costs and benefits associated with an investment occurring at different points of time [1].

However, in many practical situations it is not possible to ignore the fact that the vagueness has an important role in the technical and economical valuation of the power system project evaluation [6, 7]. Thus, many essential project parameters such as:

– Price of electricity during the exploitation period of the power system project,
– Discount rate, that intends to capture the time value of the money,
– Time of construction of the project,
– Life-cycle of the project, etc.

may confuse the investors in power system utilities in an uncertain economic environment.

These variables are non-random and hence, not suitable for modelling by probabilistic theory. The next important issue is that these variables are unknown, but *bounded variables*. In order to take into account this uncertain future situation, imprecise character and vagueness, those variables could be modelled by fuzzy numbers [3, 9]. Thus, the expected discounted benefits of the undertaken power system project (**B**), as well as the discounted costs (**C**), are represented rather as fuzzy numbers than as ordinary crisp numbers [5].

II. MODIFIED FUZZY ECONOMIC CRITERIA FOR PROJECT EVALUATION

The most important and most used economical parameters for project evaluation [1] are:

- Net Present Value (NPV),
- Profitability Index (PI) and
- Internal Rate of Return (IRR).

Net Present Values means difference between discounted benefit and discounted cost of the project. In accordance to the classical terminology: if NPV > 0, project is economically acceptable. On the contrary, if NPV < 0 then the investments will not meet the desired results or, in other words the investments for the project will not be retrieved.

Profitability Index (PI) of the project is a ratio between the benefit and cost of the project, discounted on the base year [1]. Thus, if the ratio: PI=Benefit/ Cost >1 the project is acceptable for investment, but if the ratio PI=Benefit/Cost <1 the project is not acceptable from an economical point of view.

An investment's Internal Rate of Return (IRR) is defined as discount rate at which the investments NPV equals zero. The corresponding acceptance which to compare the IRR is the opportunity cost of capital to the company [1]. Thus, if the investment's IRR exceed the opportunity cost of capital, the investments is attractive from economic standpoint.

The main questions, in modelling the Investor standpoint in the decision making process, are:

Which NPVmin > 0 will be satisfactory for the investor, thus when NPV > NPVmin, the project will be accepted for investment?

Which value for B/C>1 will be acceptable, or which value will be satisfactory for the Investor? Would the investor for

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other reasons invest in a risky project with Benefit/Cost ratio lower than one?

Which is the minimal acceptable rate of return (MARR) which will satisfy the requirements of the investors in power system utilities, considering profit, risk and uncertainty?

When economic parameters of the projects are expressed by crisp number, the operation of ranking and ordering of the projects is well defined and clear. However, when the calculations of the Benefit and the Cost of the project are realized with fuzzy numbers, calculated Net Present Value (NPV) and the Profitability Index (PI), as final results, are fuzzy numbers [4-6]. In this case, checking of the fulfilment of the economic criteria needs applying the efficient method, which will compare a fuzzy number with a crisp number?

If the fuzzy logic concept is used for evaluation of the investments in the undertaken power system project, the basic economic parameters, as NPV, PI and IRR are not yet the crisp numbers, but the fuzzy numbers defined by theirs membership function. The procedure of evaluation of the projects with fuzzy economical parameters is more complicated and not always unique. Therefore, it's much more appropriate to calculate degree of plausibility in which the project A is much more worthwhile then project B, or equivalently, degree of plausibility that fuzzy economic parameter of project A is greater/lower than fuzzy economic parameter of project B. Moreover, modelling of the subjective Investor's point of view for successful project may be also realized in fuzzy sense by appropriate fuzzy number.

Following the advanced engineering logic in a fuzzy sense, the further modification of the economic criteria for acceptance of the project will be done. That way, the Investors point of view in a decision making process (with include accepted level of risk) will be expressed by fuzzy numbers.

Thus, the fuzzified economic criteria for project evaluation in power system utilities shall be:

$$\mathbf{NPV = B - C > Fuzzy\_Zero} \quad (1)$$

$$\mathbf{PI = B / C > Fuzzy\_One} \quad (2)$$

$$\mathbf{IRR > Fuzzy\_IRR} \quad (3)$$

where:

Fuzzy_Zero - fuzzy number for defining of the criteria for accepting the project according to the NPV method.

Fuzzy_One - fuzzy number (fuzzy one) for defining of the criteria for accepting the project according the Benefit/Cost method.

Fuzzy_IRR - fuzzy number which defines the minimal (fuzzy) acceptable rate of return (**MARR**) of the project.

Each of this numbers is subjective and intuitive. Construction of the fuzzy numbers is in whole depending on the way of reasoning of the decision maker. One possible graphical presentation of the fuzzy numbers **Fuzzy_Zero** and **Fuzzy_One**, with their corresponding membership functions are shown on Fig.1. and Fig. 2. Similar presentation could be done for fuzzy number **Fuzzy_IRR**.

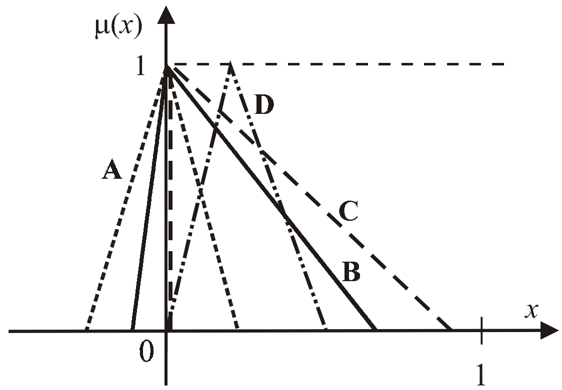

Fig.1. Possible presentation of the fuzzy number **Fuzzy_Zero** with triangular fuzzy numbers

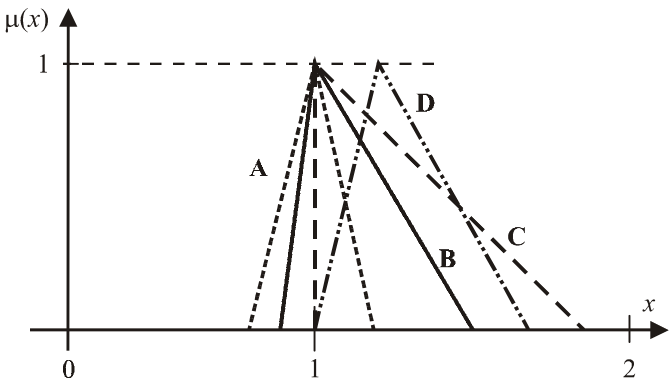

Fig.2. Possible presentation of the fuzzy number **Fuzzy_One** with triangular fuzzy numbers

Designed fuzzy numbers with triangular membership functions, shown on Fig. 1 and Fig. 2 could have the following *linguistic* description:

Fuzzy number **A** – accepting of the symmetrical risk in the project;

Fuzzy number **B** – accepting of the minimum risk with domination of the benefit from the project;

Fuzzy number **C** – zero risk and higher benefit;

Fuzzy number **D** – full rejecting of the risk with sure benefit for successful project.

III. RANKING THE FUZZY NUMBERS WITH SATISFACTION FUNCTION

Since the fuzzy numbers are described with a corresponding membership function, it is possible that the fuzzy numbers overlap, which makes the procedure of determining which fuzzy number is greater or lower than the other more difficult [4]. For example (Fig. 3), it is easy to conclude that fuzzy numbers **B** and **C** are larger than fuzzy number **A**. Otherwise, the comparison between fuzzy numbers **B** and **C** (Fig. 3) which are overlapping is not easy to perform and that is the reason why an appropriate procedure to work out a final decision is needed. Moreover, since two fuzzy numbers may overlap each others (like fuzzy numbers **B** and **C**), it is much more appropriate to talk about the degree of satisfaction of the fuzzy economic criteria than for strictly satisfaction of the economic conditions in classical form [4, 6].

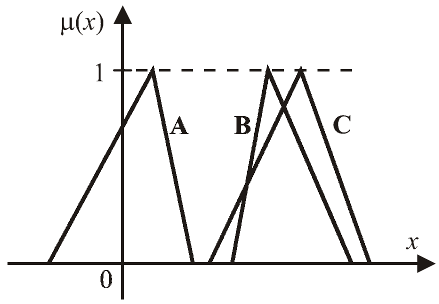

Fig. 3. Comparison between fuzzy numbers **A, B** and **C**

One of the most appropriate methods for comparison of two fuzzy numbers is the method based on the satisfaction function (SF) [2]. It determines the degree of satisfaction that fuzzy number **A** is greater than fuzzy number **B.** Thus, degree of satisfaction (degree of plausibility) that project (A) whose economic parameter is fuzzy number **A** is less worthy than project (B) described by fuzzy number **B** is:

$$S(\mathbf{A} < \mathbf{B}) = \frac{\int_{-\infty}^{\infty}\int_{-\infty}^{y} \mu_{\mathbf{A}}(x) \circ \mu_{\mathbf{B}}(y) \mathrm{d}x\mathrm{d}y}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \mu_{\mathbf{A}}(x) \circ \mu_{\mathbf{B}}(y) \mathrm{d}x\mathrm{d}y} \quad (4)$$

Similarly, degree of satisfaction that project A is much more worth than project B (the fuzzy number **A** is greater than fuzzy number **B**) may be calculated by the following formula:

$$S(\mathbf{A} > \mathbf{B}) = \frac{\int_{-\infty}^{\infty}\int_{y}^{\infty} \mu_{\mathbf{A}}(x) \circ \mu_{\mathbf{B}}(y) \mathrm{d}x\mathrm{d}y}{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \mu_{\mathbf{A}}(x) \circ \mu_{\mathbf{B}}(y) \mathrm{d}x\mathrm{d}y} \quad (5)$$

In above equations " $\circ$ " is sign for T -norm operator, usually multiplication.

In cases where comparison between fuzzy and crisp number shall be performed, this formula have to be transformed. Thus, plausibility that the fuzzy number **A** is less than the crisp number k is given by:

$$S(\mathbf{A} < k) = \frac{\int_{-\infty}^{k} \mu_{\mathbf{A}}(x) \mathrm{d}x}{\int_{-\infty}^{\infty} \mu_{\mathbf{A}}(x) \mathrm{d}x} \quad (6)$$

while, plausibility that fuzzy number **A** is greater than crisp number k is:

$$S(\mathbf{A} > k) = \frac{\int_{k}^{\infty} \mu_{\mathbf{A}}(x) \mathrm{d}x}{\int_{-\infty}^{\infty} \mu_{\mathbf{A}}(x) \mathrm{d}x} \quad (7)$$

IV. Linguistic interpretation of satisfaction function for projects evaluation

Depending on the value of satisfaction function, which is used for comparison of the calculated economical parameter **A** of the project and adopted fuzzy number **B** for modelling the Investor's expectation for successful project, the following linguistic description could be suggested:

– If $S(\mathbf{A} > \mathbf{B}) < 0.15$, the project A is *significantly unsatisfactory* for investment;
– If $0.15 \le S(\mathbf{A} > \mathbf{B}) < 0.30$, the project A is *very unsatisfactory* for investment;
– If $0.30 \le S(\mathbf{A} > \mathbf{B}) < 0.45$, the project A is *unsatisfactory* for investment;
– If $0.45 \le S(\mathbf{A} > \mathbf{B}) \le 0.55$, the project A is *on the boundary* for profitable acceptance;
– If $0.55 < S(\mathbf{A} > \mathbf{B}) \le 0.70$, the project A *is favourable* for investment;
– If $0.70 < S(\mathbf{A} > \mathbf{B}) \le 0.85$, the project A is *very favourable* for investment; and
– If $0.,85 < S(\mathbf{A} > \mathbf{B}) \le 1$, the project A is *significantly favourable* for investment

V. Case Study: Project HPP St.Petka

Proposed approach for fuzzy evaluation of the hydroelectric project will be applied on the hydro project St. Petka (Republic of Macedonia). HPP St.Petka will be on the river Treska and it will be located between the HPP Kozjak (in construction) and the existing HPP Matka.

The main data of the HPP St.Petka are:
– Number of units 2
– Water discharge through turbines 2 x 40 m^3/s
– Net head 38.7 m
– Average water inflow in accumulation 21.89 m^3/s
– Average yearly production of electricity 60.27 GWh

Calculation of the expected yearly production of electricity from HPP St.Petka, is performed by a computer program based on the principle of a dynamical programming. It takes into account all relevant data and facts available in design phase [8], such as: design concept of the dam and machine hall, cascade type of system HPP Kozjak - HPP St.Petka - HPP Matka, irrigation and environmental limitations, characteristics of the units, friction losses, etc.

Construction costs are estimated on 30 millions $, and they are divided equally on the foreseen n-years for construction of the HPP St Petka.

For calculation of the fuzzy economic parameters of the project, discount rate is modelled by triangular fuzzy number $\mathbf{d} = (0{,}04; 0{,}05; 0{,}06)$, while the market price of electricity is $\mathbf{c}_1 = (0{,}035; 0{,}040; 0.045)$ \$/kWh. It is considered that, the exploitation cost is 15% from the benefit obtained from electricity production.

Fuzzy economic parameters are calculated by methodology presented in [4]. Derived fuzzy economic parameters, for Net Present Value (**NPV**), Profitability Index (**PI**) and Internal Rate of Return (**IRR**) of the specified project, are shown in Table1.

TABLE.I.
FUZZY ECONOMIC PARAMETERS OF THE HYDROELECTRIC PROJECT ST.PETKA DEPENDING ON THE YEARS OF CONSTRUCTION

Years of construction	Economic parameter		
	NPV	**PI**	**IRR**
3	[-4,08;3,14; 12,81]	[0,76; 1,10; 1,55]	[4,15; 5,23; 6,27]
4	[-4,62; 2,33; 11,78]	[0,74; 1,07; 1,54]	[4,11; 5,17; 6,20]
5	[-5,11; 1,57; 10,79]	[0,71; 1,05; 1,53]	[4,06; 5,12; 6,13]

Evaluation of the project parameter will be performed according calculated fuzzified Net Present Value, Profitability Index and Internal Rate of Return. In Tab.2 are shown results for project evaluation, when satisfaction function is calculated by (7). In this case fuzzy economic parameters are approximated by triangular fuzzy numbers.

TABLE II.
EVALUATION OF THE ECONOMIC PARAMETERS OF HYDRO PROJECT ST.PETKA DEPENDING ON THE YEARS OF CONSTRUCTION

Years of construction	Economic parameter		
	S (**NPV** > 0)	S (**PI** > 1)	S(**IRR** > 5%)
3	0.850	0,775	0,685
4	0.795	0,731	0,640
5	0.750	0,689	0,601

Presented results in Tab.2 show that according NPV and PI criteria hydro project St.Petka is a very favourable one for investment. According assumed value for IRR=5% the project belongs to the class of favourable projects for investment.

Next examples will ilustrate the concept in which the investor's point of view is modeled by triangular fuzzy number. Profitability Index of hydroelectric project St.Petka, given by triangular fuzzy number: $\mathbf{PI} = [0{,}76;1{,}10;1{,}55]$ will be compare with the fuzzy numbers which modeled the way of reasoning of the investor for:

- Accepting of a symmetrical risk (**PI_Inv_1**),
- Null risk and sure benefit (**PI_Inv_2**)
- Null risk and as much as bigger benefit (**PI_Inv_3**)

Calculated values for satisfaction function in these three cases are:

$$S(\mathbf{PI} > \mathbf{PI\_Inv1}) = \mathbf{S}\{[0{,}76;1{,}10;1{,}55] > [0{,}9;1;1{,}1]\} = 0{,}779$$

$$S(\mathbf{PI} > \mathbf{PI\_Inv2}) = \mathbf{S}\{[0{,}76;1{,}10;1{,}55] > [1;1{,}1;1{,}2]\} = 0{,}639$$

$$S(\mathbf{PI} > \mathbf{PI\_Inv3}) = \mathbf{S}\{[0{,}76;1{,}10;1{,}55] > [1;1{,}2;1{,}5]\} = 0{,}282$$

VI. CONCLUSION

In the proposed study fuzzufied economic criteria for evaluation of the investment in power system utilities are developed.

Investor's way of reasoning is modelled by fuzzy numbers: **Fuzzy_Zero**, **Fuzzy_One** and **Fuzzy_IRR**, depending on the specified economic criteria (NPV, PI or IRR) consequently. Each of this fuzzy number is subjective, intuitive and its definition is an attempt for modelling human decision making process. Depending on the value of the satisfaction function, linguistic descriptions for level of acceptance of the project is suggested.

Developed model is extension of the classical deterministic models and enables possibilities to perceive influence of the specific parameters and uncertainty to the rate of the undertaken project in power system utilities. It enables to perform simulation of various type of scenario which may include some external factors of the project, which could not be monetary quantified, or included in analyses in classical way.

The application of fuzzy-logic concept in model for energetic-economical evaluation of project in electric utilities, gives a special contribution to the up-to date engineer's upbringing, while making analyses without relevant data with multiple meaning.

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