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Application of Graphic Neuro-Fuzzy Designer in Energy Management

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ABSTRACT: The application of Fuzzy logic in the management of technological processes has given us better solutions compared to standard management techniques. Fuzzy logic makes it possible to build decision-making advisory systems based on the experience of operators and the results of experiments, and not just through mathematical models. To develop an information technology that allows the optimal planning process of any energy system to be carried out using Fuzzy logic and linguistic variables. For the modeling of the optimal solution of the Georgian electricity system management, special importance is attached to the operation of a new power plant that will cause less damage and pollution to the environment, while taking into account the justified volume of capital investments and operating costs. As the issue of harmonization of Georgia with EU laws is a priority, attention should be paid to the commissioning of new production facilities that will have a lower degree of environmental impact on air, water, and the environment.

KEYWORDS: Energy Management, MATLAB application, Fuzzy logic.

I. INTRODUCTION

The development of an electrical power system is accompanied by uncertainty, which complicates the use of widely used quantitative methods in practice. The implementation of fuzzy logic and fuzzy-management methods is adequate to solve this problem. Fuzzy Mathematics was founded by Lotfi A. Zadeh, a professor at the University of California, Berkeley. L.A. Zadeh assumed that the characteristic function of a set could take any value from an interval [0,1] and called such sets indistinct, or fuzzy sets. Lotfi A. Zadeh introduced linguistic variables and built an apparatus for describing an intellectual activity that shows the quantitative value of the result obtained [1].

II. RELATED WORK

Fuzzy logic is an innovative technology that has been used to develop engineering control. Fuzzy logic has great potential in energy capacity planning process management and automation applications, where it allows management system design to be developed directly based on expert experience and experimental results. These are the main methods of formalizing, processing, and using subjective, expert information. The system used performs operational analysis of information, assists in decision-making, and also makes a forecast of a controlled object. Fuzzy logic and linguistic variables are used to create this system [2]. Create a knowledge base and model that corresponds to the real object. This allows us to increase control over the effective management of energy system planning and reduce wrong decisions in complex processes involving certain inaccuracies and nonlinearity. The implementation of the structural model allows us to approach the object more realistically, determine the current state and make an effective management decision. The research aims to solve these problems, methods are used that process linguistic data, fuzzy sets, neural network theory, complex systems theory, chaos theory, and system analysis methods. Effective analysis of controlled data is possible when an intelligent data mining tool is developed that allows us to identify the structure of internal monitoring parameters. Creating similar intelligent systems and automatic analysis of controlled data improves the efficiency of the monitoring system and facilitates the efficient management of the technological facility. The methods of fuzzy logic are fundamental in this case, in particular, the linguistic rules of the issue "IF-THEN". The use

of these linguistic variables significantly reduces the demand for experimental data in qualitative identification. Nonlinear methods of identification use a fuzzy learning database that consists of two phases: the first is structural identification, that is, the formation of a learning database that roughly depicts the connection between incoming and outgoing data [3]. The second phase is parametric identification by extracting parameters of the detected dependencies from the learning base that reduce the model and experimental results deviation. A fuzzy controller is used to manage a process based on the use of fuzzy logic and fuzzy sets. It contains several parts:

- An interface is a set of tools designed to make two systems interact with each other;
- The fuzzy interface, which measures the values of variables, converts the input variables into the appropriate set and finally converts the data to the linguistic variables that are represented in the fuzzy indicators;
- The fuzzy interface contains a rule database that provides the necessary solution definitions that define the rules of linguistic control and data manipulation in the controller.
- Application knowledge of the field, decision-making system capable of simulating human decision-making, it is based on fuzzy concept and ability to infer fuzzy control action, using fuzzy influence and solution rules in fuzzy logic [4];
- Finally, the defuzzification interface converts the solution into a certain set. To control this process, too many controllers are created in different countries, which allows them to make optimal decisions. Mass controllers are called hybrid controllers. So genetic algorithms and neural network technology can be used in conjunction with physiology to achieve greater system performance and versatility. Probability fuzzy systems, which are a combination of fuzzy logic and probability, can be used to model and manage real systems that are random [5].

III. METHODOLOGY

In fuzzy sets, each element varies to $[0, 1]$ by a membership function: $\mu_A: x \rightarrow [0, 1]$, Where $[0, 1]$ means real numbers between 0 and 1 (including 0 and 1). The reference set X is a Universe of discourse for elements x , and the fuzzy-set A is defined:

$$A = \{(x, \mu_A(x)) | x \in X\},$$

Where $\mu_A(x)$ is called the Membership Function (MF) for the fuzzy-set A .

The value of the membership degree might include uncertainty [6]. If the value of the membership function is given by a fuzzy set, it is a type-2 fuzzy set.

Fuzzy sets are as follows: $A: X \rightarrow F([0, 1])$, where $F([0, 1])$: the set of all ordinary fuzzy sets that can be defined with the universal set $[0, 1]$. $F([0, 1])$ is also called a fuzzy power set of $[0, 1]$.

- A type-2 Fuzzy Logic System includes a fuzzifier, rule base, fuzzy inference engine, and output processor.
- The output processor includes a type-reducer and a defuzzified one that generates a type-1 fuzzy set output (from the type-reducer) or a crisp number (from the defuzzified) [7].
- A type-2 Fuzzy Logic System is again characterized by IF-THEN rules, but its antecedent or consequent sets are now type-2.
- Type-2 Mamdani Fuzzy System includes the fuzzification, fuzzy inference, type reduction, and defuzzification steps, the crisp inputs (X_n inputs), and one output (Y):

$$x_1 \in X_1, \dots, x_n \in X_n \text{ and } y \in Y. (1)$$

Fuzzy sets and FLSs have been used in decision-making, solving fuzzy relation equations, survey processing, time-series forecasting, and energy power system development decision as well. The Fuzzy logic algorithm can be formulated as follows show figure 1: Crisp Inputs (x) \rightarrow Fuzzy input sets \rightarrow Fuzzifier \rightarrow Rules \rightarrow Inference \rightarrow Type reduction \rightarrow Defuzzification \rightarrow Fuzzy Output sets \rightarrow Crisp outputs (y).

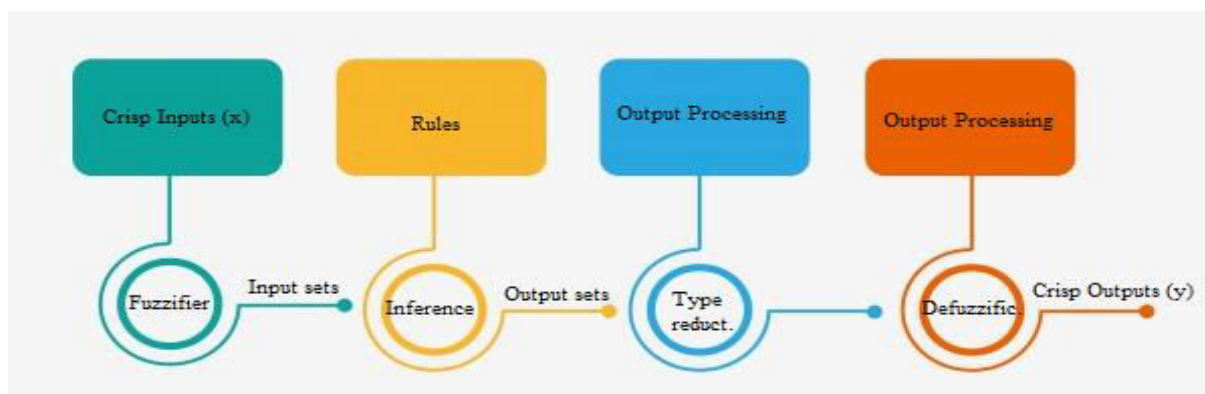


Fig.1. Fuzzy Logic Algorithm

Software Implementation

Now move on to the fuzzy rules. We have access to view and edit all the rules with the "Edit Rule" button. In the window that appears we see the terms of the rule (Source In 1, Source In 2, Source In 3). After selecting the linguistic variable, we select the operation that must be performed to satisfy the rule, in which case it is the "Equal" operator [8]. In the "Term" field we have a list of fuzzy terms. At the bottom of the interface are the parameters that the system will accept as a result of fulfilling each condition of the current rule. Creating a knowledge base is done by a person, who has to decide how many terms each linguistic variable will have [9]. The Mamdani type model considers an object $y = f(x_1, x_2, \dots, x_n)$ with $nX = (x_1, x_2, \dots, x_n)$ input and one solution y . The nonlinear relationship between incoming and outgoing data is described as a learning base: Calculating input and output values and their interrelationships are a function of the variable:

$IF(x_1 = a_{1j1}) AND (x_2 = a_{2j2}) AND \dots AND (x_n = a_{nj1})$
 $OR(x_1 = a_{1j2}) AND (x_2 = a_{2j2}) AND \dots AND (x_n = a_{nj2})$
 \dots
 $OR(x_1 = a_{1jkj}) AND (x_2 = a_{2jkj}) AND \dots AND (x_n = a_{njkj})$
 $THEN y = d_j, i = 1, m$

Where a_{ijp} - is a linguistic term that evaluates a variable in the string x_i whose number is jp ($p = 1, KJ$); KJ - is the number of connections in the string where the solution (y) is evaluated by the linguistic variable DJ ; m - is the number of linguistic terms we use to estimate of an output linguistic variable. The given reflection in the attribution functions of the input variables allows the program to determine what action to take based on the set of rules for each form [10].

IV. EXPERIMENTAL RESULTS

The task of the study is to find out what percentage would be appropriate to invest with less than 40% environmental impact and less than 100 million dollars in funding. For solving the problem used a type-1 fuzzy logic system [11]. There are variables: 2 inputs and 1 output. Each variable, Funding, Environmental Impact, and Investment have related terms (sets) (table 1).

Table 1. Input and output variables and related terms

Variables	T e r m s (sets)		
Funding	Cheap	Normal	Expensive
Environmental Impact	Light	Average	Huge
Investment	Desirable	Marginal	Undesirable

The Function of a set should take any value from an interval $[0,1]$:

Funding [Cheap, Normal, Expensive] $\{0, 0.5, 1.0\}$. Environmental Impact [Light, Average, Huge] $\{0, 0.5, 1.0\}$, Corresponding Matrix is done (table 2). In the next step we established rules:

Table 2. Input and output variables matrix [12]

Fund. \ Env.Imp.	Light	Average	Huge
Cheap	Desirable 1.0	Desirable 1.0	Marginal 1.0
Normal	Desirable 1.0	Marginal 0.5	Undesirable 0
Expensive	Marginal 0.5	Undesirable 0	Undesirable 0

1. If the Impact is light and funding is cheap then investing is Desirable;
2. If the Impact is average and funding is medium then investing is Marginal;
3. If the Impact is huge and funding is medium then investing is Undesirable;
4. If the Impact is light and funding is medium then investing is Desirable;
5. If the Impact is light and funding is expensive then investing is Marginal;
6. If the Impact is average and funding is cheap then investing is Desirable;
7. If the Impact is huge and funding is cheap then investing is Marginal;
8. If the Impact is average and funding is expensive then investing is Undesirable;
9. If the Impact is huge and funding is expensive then investing is Undesirable [13].

Chosen variables, terms, and parameters are presented in Tables 3-5.

Table 3. Environmental Impact (input variable) %, range [0 - 100], terms (light, average, huge)

Terms	Parameters			
Light	0	0	20	40
Average	20	50	80	-
Huge	60	80	100	100

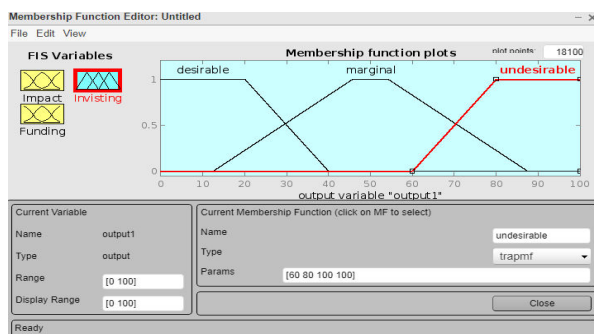
Table 4. Funding (input variable) Million \$, range [0 - 100], terms (cheap, medium, expensive)

Terms	Parameters			
Cheap	0	0	20	40
Medium	20	50	80	-
Expensive	60	80	100	100

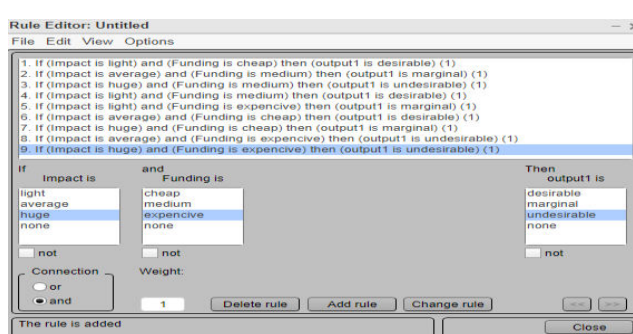
Table 5. Investing (output variable) %, range [0-100], terms (desirable, marginal, undesirable)

Terms	Parameters			
Desirable	0	0	20	40
Marginal	20	50	80	-
Undesirable	60	80	100	100

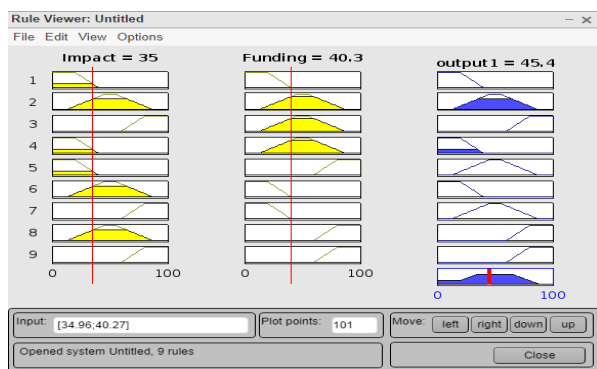
A Fuzzy Inference System was developed based on the MATLAB Graphic Neuro-Fuzzy Designer. Figure 2(a), (b), (c), and (d) shows trapezoidal type membership functions (MF) [14].



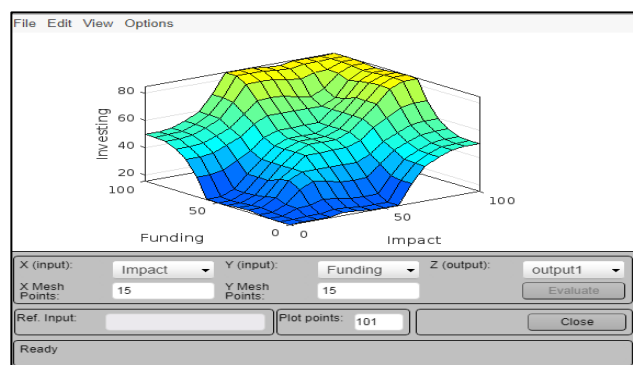
(a)



(b)



(c)



(d)

Fig.2.Trapezoidal type membership functions. Fuzzy Inference System (a), IF-THEN rules combinations (b), The output variable and the response (c), An output surface map for the system (d).

The design IF-THEN rules are presented by using all possible combinations of the values of the input parameters [15]. The input-output assessments are defined using expert knowledge. The task asks, in the conditions of a 35% impact on the environment and the case of a financial need of 40.3 million dollars, how much is it desirable to invest in the construction of a power plant [16]. The response of the output variable shows that under such conditions, investing in the construction of a power plant is desirable by 45.4%.

V.CONCLUSION

The article discusses the prospects for the development of energy capacities of a specific country (Georgia) based on the creation of relevant expert-objective knowledge bases using fuzzy logic [17]. The operational decision support system gives operators instant advice to make the right decisions taking into account various factors, which significantly improves the country's energy security that helps the country achieve its main goal. In addition, renewable energy use is coming to the forefront due to factors such as a limited supply of traditional energy resources, global warming, and an increase in energy consumption. Georgia is one of the richest countries in terms of renewable energy potential, especially hydropower, and the development of the renewable energy sector will allow it to meet the domestic demand of the country according to the population and the country's economy [18].

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