JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA

FUZZY SIMULATION IN RELIABILITY ANALYSIS

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Abstract:
In the first part of this paper we present an introduction of fuzzy logic application in power systems and equipments reliability analysis. The second part considers the development of a computer simulation program for complex electric system's reliability study fuzzy algorithms, definition of asymmetric Gauss input and output membership functions, rule sets and results display methods. The third part is focused on the development of a case study for the electric station in Tileagd, Bihor County using the developed simulation program in the Matlab environment. The fourth part emphasis on the conclusions which show the importance and efficiency of fuzzy modeling in reliability analysis by comparative evaluation of fuzzy and Monte Carlo methods also shown in equivalent reliability diagrams, highlighting authors contributions. The last part of the paper presents the references which were consulted.

Keywords:
failure tree, reliability, fuzzy simulation

1. INTRODUCTION

Fuzzy logic represents an extremely useful tool in modeling the behavior of electrical equipment. Fuzzy set theory considers multi state systems and multi criteria decisions, the mathematical instrument is flexible and easily adaptable to reality. This theory is useful for modeling of power systems and equipment reliability evaluation [1, 9].

In reliability studies it is generally accepted a bivalent operational evolution mode: normal operation state and failure state. In reality the transition between states is not sudden, which implies a nuanced expression of system's performance (very good, good,..., median, poor). In this paper there is presented the development of reliability simulation software for electric plants based on the method of failure trees using fuzzy logic in the MATLAB environment. [2,6,8]

2. DEVELOPMENT OF SIMULATION SOFTWARE USING FUZZY LOGIC

A frequently used analysis method in a system's reliability study is based on the evaluation of failure probability. In this method the crisp values of failure probabilities for electrical components are generally used in order to compute the systems reliability, based on equivalent reliability diagrams. [5,7]

2.1. Definition of input membership functions.

The developed software is using Gaussian membership functions. For this kind of function the mean and standard deviation (σ) must be specified.

So for every component of the system 7 grades were defined, on a linear interval of failure and repair intensity values (λ and μ) and then the function values are established.

Not acceptable	N	0
Almost acceptable	AN	0.167
Close to acceptable	PS	0.333
Acceptable	S	0.5
Good	B	0.667
Almost very good	AFB	0.833
Very good	FB	1

The fuzzy method is presented schematically in figure 1. The fuzzy analysis program generates input membership functions (on basis of specified failure intensity λ and repair intensity μ) and then generates the output membership functions and the rule set. The flowchart of the algorithm is presented in fig. 2.

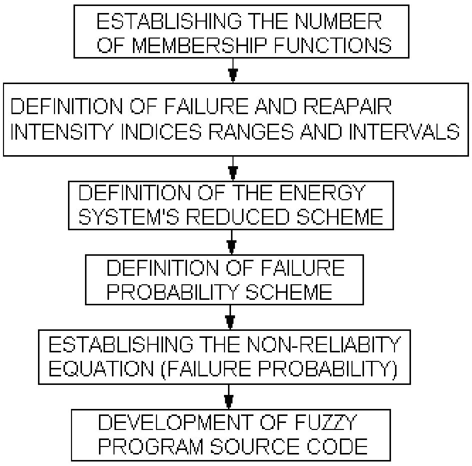


Figure 1. Schematic function blocks for fuzzy analysis set up

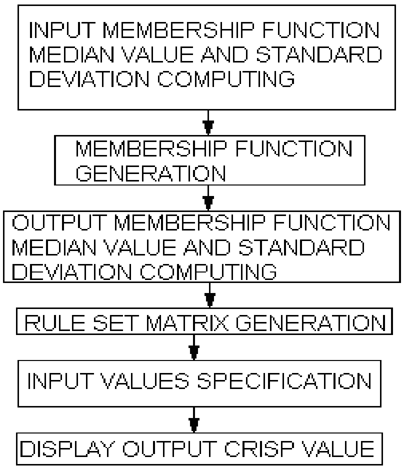


Figure 2. Flowchart of the fuzzy program

Figure 3. Main program GUI

All program functions are launched from the „d_fuzzy.m" module. The GUI window is presented in figure 3.

The „d_date.m" module is launched on action of „Input data" button. The simulation data input includes λ and μ specification, data saving and data reload.

The system equation is input from the "d_param" and λ and μ are input from a separate window which allows as many parameters as many components were specified. The program also allows data saving (the data are saved in a .mat type file) in files with optional names. The saved data can be reloaded in a separate interface from their files which contains all system parameters and also the system equation. Once established the system parameter values for specific runs can be input from the "d_param_intr.m" module.

Mean values for membership functions are computed on basis of the relation:

$$F_i = \frac{\lambda_i}{\lambda_i + \mu_i} \qquad (1)$$

where i = 1...7, is the number of the membership function according to the earlier defined grade.

Standard deviation (σ) is computed with asymmetric Gauss function based on relations (2):

$$\sigma_{i,1} = \frac{|F_{i-1} - F_i|}{3}, \qquad \sigma_{i,2} = \frac{|F_i - F_{i+1}|}{3} \qquad (2)$$

After the introduction or reload of data from saved files, we can reenter the main module which gives us two options:

- fuzzy simulation
- decision surfaces display

Choosing "Fuzzy simulation", after computing input membership functions parameters for each system component, the program generates these functions. Decision surface display facilitates the evaluation of the fuzzy outputs.

2.2. Definition of output membership function

In order to compute the output membership functions we start with the reduced system schematics from which the failure tree is generated. From the flowchart we can derive the system's characteristic equation and then the program generates the output membership function.

2.3. Definition of the rule set

The rule set of the fuzzy inference system defines the way in which the inputs and outputs are linked. The rules are described in form of logical relations having as variables linguistic degrees of the inputs and as operators the "and" and "or" logical operators. An example of fuzzy rule is:

If $elem_1$ is FB and $elem_2$ is B and $elem_3$ is S than the system is B.

After the establishment of the rule set, the program can generate inference surfaces in the input-output space which are in fact the values of the outputs for the whole range of given inputs. Due to the limitations of 3D representation, these surfaces can be represented only as 2 inputs simultaneously, the remaining inputs being considered static for that case. The 2 inputs which are wanted to be represented can be selected in the program interface.

2.4. Simulation results

After generating the membership functions and rule sets the program also generates the so called "fuzzy inference system" information structure. If this structure is used for a single run, then the crisp values of inputs are specified and the "evalfis" function is used for the computation of crisp output values. The program displays this value in a separate window.

3. CASE STUDY. TILEAGD ELECTRIC STATION (SE) [2].

In [2] the normal form of SE Tileagd, Bihor County scheme is presented. Evaluation of reliability is realized considering the Săcădat user, positioned on BC - 20kV collector bar and the study criteria is considered in the absence of the consumer.

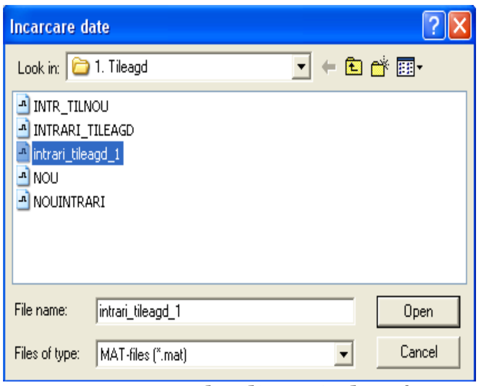


Figure 4. Data loading window for SE Tileagd

Using statistical data representing median values of reliability indicators for the equipments in Electric Stations (SE) and also using the equivalent reliability diagram we had reduced the SE Tileagd scheme to an equivalent reliability diagram (DEF) presented in figure 14 a. This diagram was then used to formulate the system equation for the fuzzy simulation. The reduction of normal scheme had been made by transposing it in a scheme in which the elements are connected in series or parallel considering the dimensioning and connection of elements. All feeds for Săcădat consumer, on all path, from the source had been considered. In figures 4-7 input data of analyzed electric station are presented.

In figures 8 -13 the obtained membership function diagrams are presented for SE Tileagd.

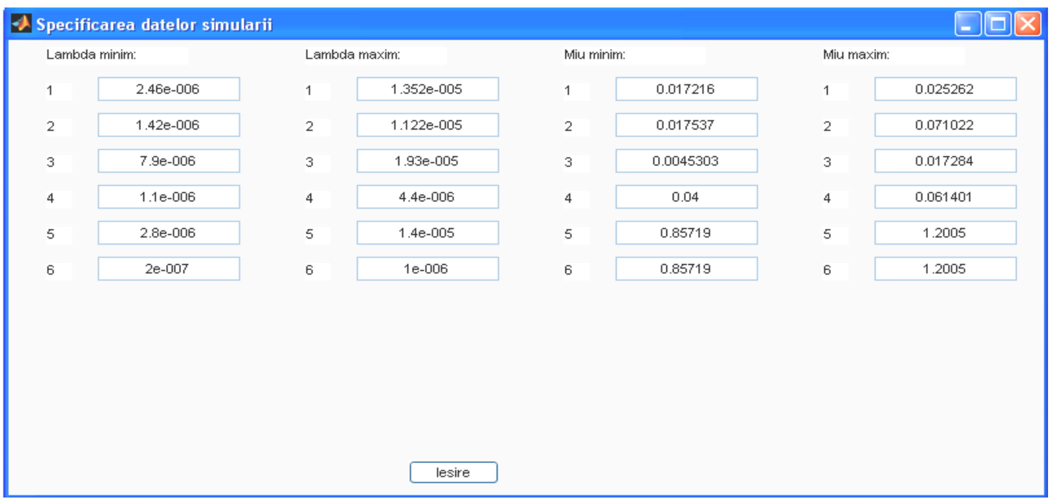


Figure 5. λ and μ parameter editing window for SE Tileagd

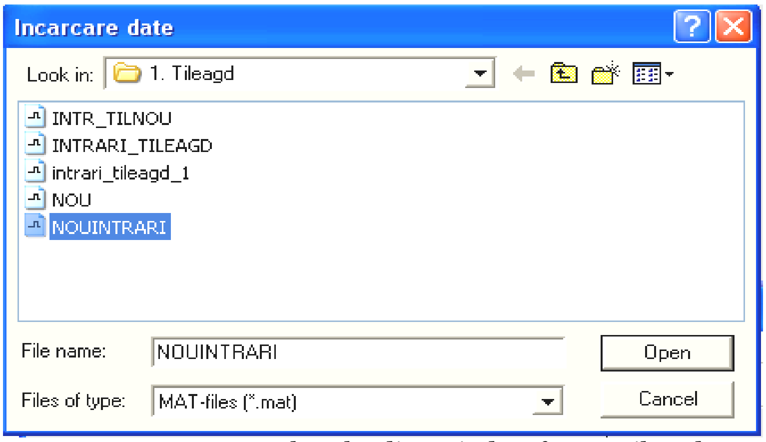


Figure 6. Input values loading window for SE Tileagd

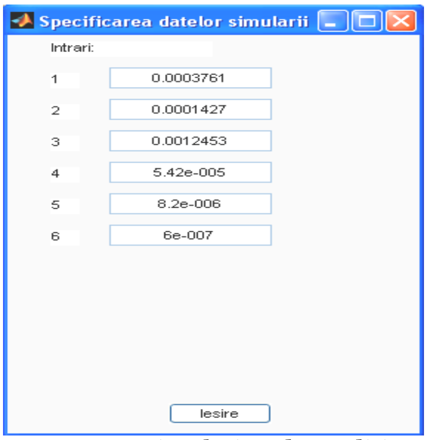


Figure 7. Simulation data editing window for SE Tileagd

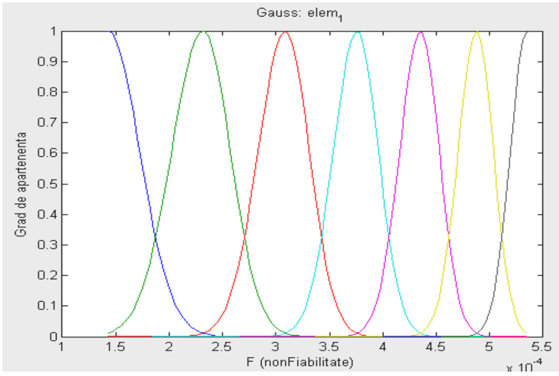


Figure 8.
Membership functions for element 1

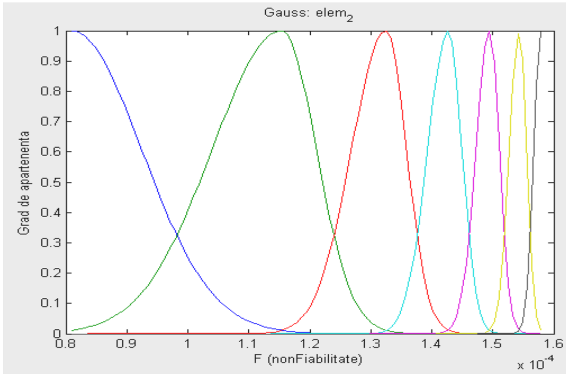


Figure 9.
Membership functions for element 2

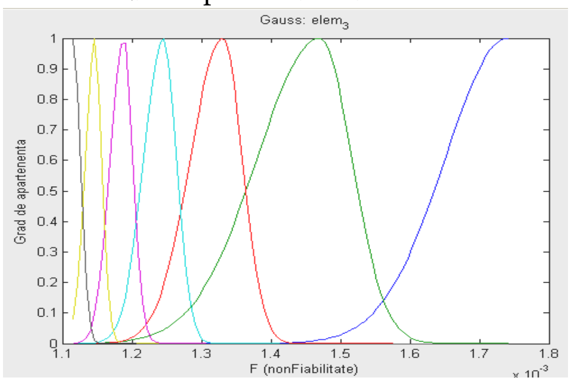


Figure 10.
Membership functions for element 3

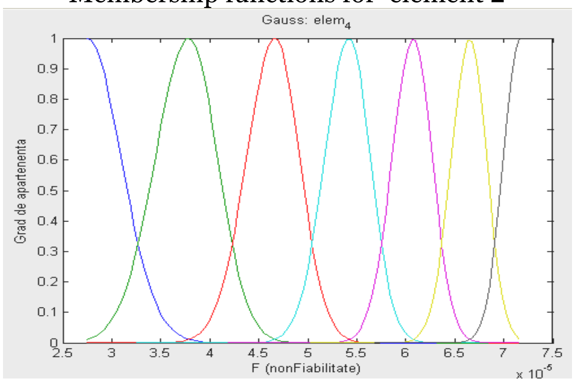


Figure 11.
Membership functions for element 4

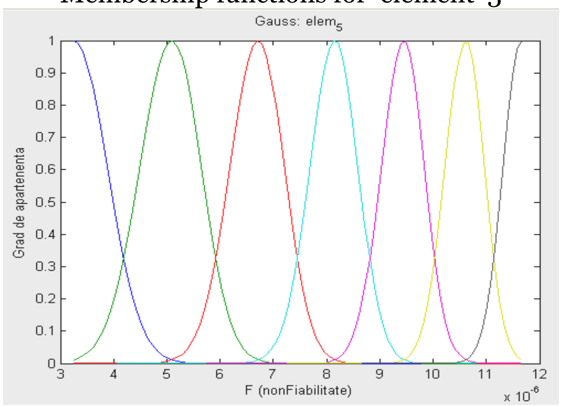


Figure 12.
Membership functions for element 5

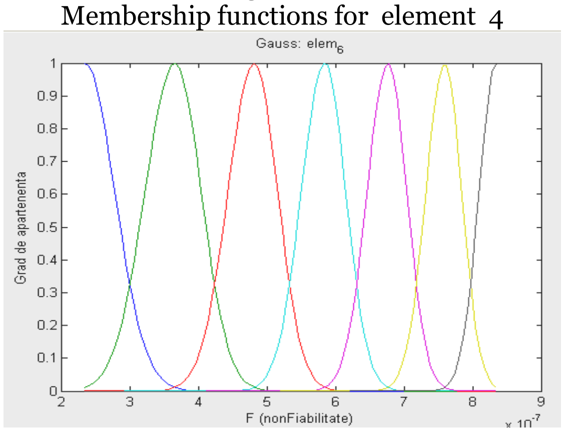
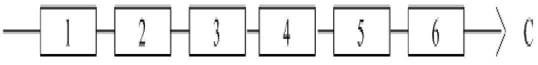
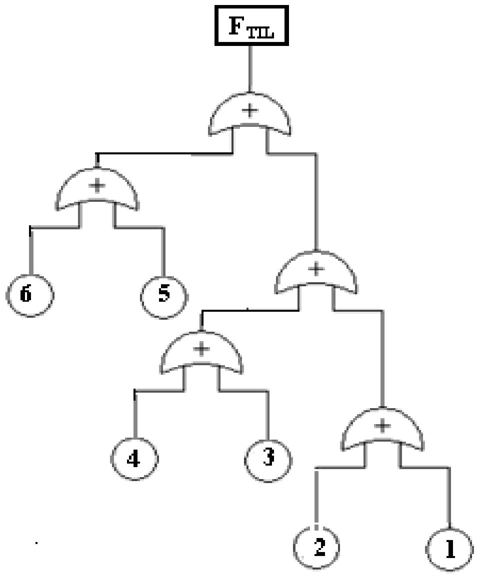


Figure 13.
Membership functions for element 6



a)



b)

Figure 14. Reduced scheme (a) and scheme of system for SE Tileagd (b)

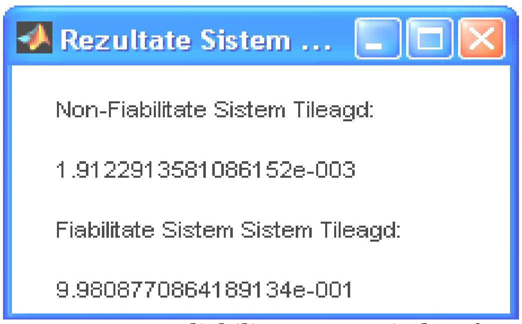


Figure 16. Reliability output window for SE Tileagd

For computing output membership functions we start from the system scheme from which the failure tree is generated - figure 14.

Characteristic equation of the system is deduced from the schemes presented in figure 14 and is given by relation (3):

$$F_{TIL}=1-\prod_{i=1,6}(1-F_i)=1-(1-F_1)(1-F_2)(1-F_3)(1-F_4)(1-F_5)(1-F_6) \quad (3)$$

Relation (3) is used by the program to generate the output membership function presented in figure 15.

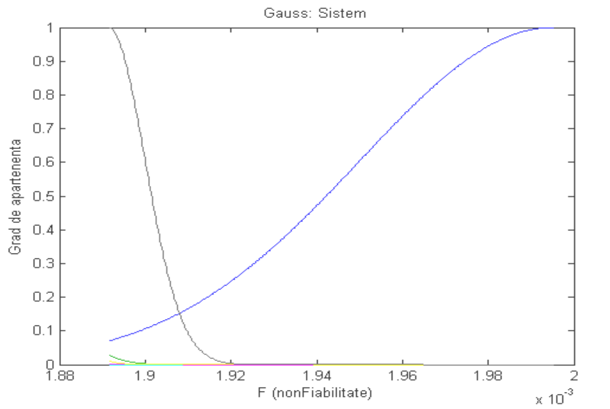


Figure 15. Output membership functions generated for SE Tileagd

The program displays the obtained output values in a separate window presented in figure 16. In figures 17 and 18 some decision surfaces are presented.

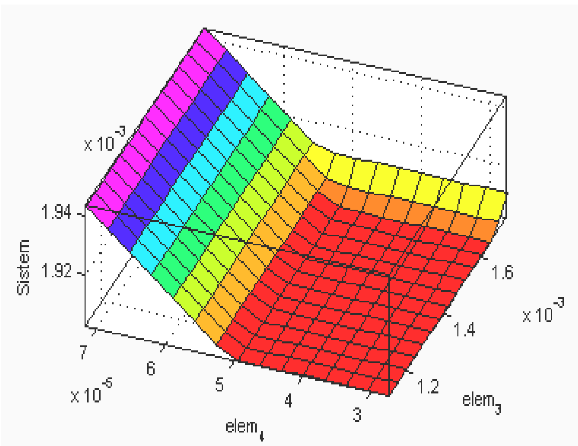


Figure 17.
Output values for inputs 4 şi 3

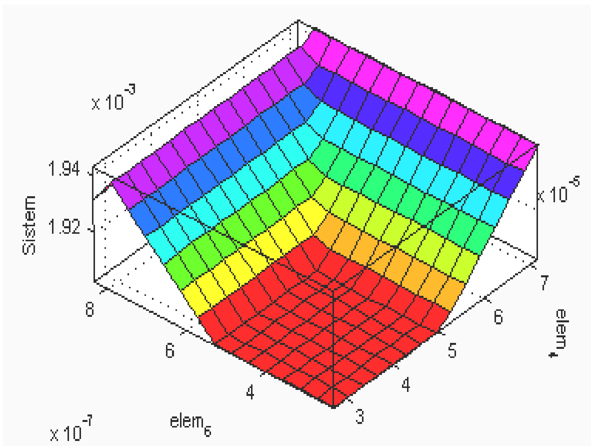


Figure 18.
Output values for inputs 6 şi 4

4. CONCLUSIONS

The use of "fuzzy sets theory" in the study of reliability of electric energy systems and equipments consists in the possibilities offered by quantification and modeling of qualitative enounces – incomplete and altered information, subjective appreciations – in flexible forms, more close to the way of thinking the engineers operates with.

The program developed under MATLAB environment for the fuzzy simulation of reliability of electrical equipments permits the step by step definition of the fuzzy model and it is realized in a versatile manner, object oriented and modular. The program can make diverse simulations, in small times, for a given scheme, in the analyzed fuzzy intervals making possible the visualization of values range in which the non-reliability and reliability of the system can evolve.

The realized evaluations, obtained with the SE reliability fuzzy simulation program, are accurate, in comparison with the values obtained by Monte Carlo method and direct DEF computation [2, 4].

Comparative results for fuzzy, Monte Carlo and DEF methods

SE \ R	FUZZY	MONTE CARLO 10000 simulări	DEF
TILEAGD	0,99808771	0,99822	0,99808

Development of SE fuzzy reliability simulation program using the MATLAB programming environment, based on failure tree method, application of the program for SE Tileagd, Bihor County, and comparative evaluation with the Monte Carlo simulation method results and with DEF analytical method results, are contributions of the authors in this article.

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