ROMAI J., **5**, 2(2009), 49–58

A FUZZY ALGORITHM FOR RELIABILITY SIMULATION OF AN ELECTRIC STATION

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Abstract In this paper we present an applied study of reliability simulation for an electric station, based on a soft computing simulation method, namely using a fuzzy algorithm in MATLAB environment. This study revealed that the values of reliability obtained through this method is accurate compared to the values obtained by Monte Carlo method or by direct computation.

Keywords: failure tree, reliability, fuzzy simulation, electric station (ES).
2000 MSC: 03E75, 93C42.

1. INTRODUCTION

The soft computing paradigm is based on fuzzy logic and is tolerant to imprecision, uncertainty, partial truth, and approximation. Fuzzy logic represents an extremely useful tool in modeling the behavior of electrical equipment. Fuzzy set theory is using multi state systems and multi criteria decisions, forming a mathematical instrument which is flexible and easily adaptable to reality. This theory is useful for modeling electromagnetic systems and also for energy equipment reliability evaluation [1, 10]. In reliability studies a bivalent operational evolution mode is generally accepted: normal operation state and failure state. In reality transitions between states are not swift, which implies a nuanced expression of system's performance (very good, good,..., medium, poor). This paper presents the development of reliability simulation software for electric stations. The software is based on failure trees method and is using fuzzy logic in the MATLAB environment. The MATLAB programming environment has predefined functions for development of fuzzy computing steps (fuzzyfication, inference, defuzzyfication) [6, 8]. These functions are linked to 2 external C++ modules, the "inference system" and the "fuzzy engine". Typical structures of fuzzy inference systems can be represented by a model which reveals a correspondence between: crisp input value - membership functions

- inference rules output characteristics - output membership functions - crisp output values. Similar studies and program variants are presented in [3] and [4]. In Section 2 we describe the development of a computer simulation program for the study of complex electric system's reliability, fuzzy algorithms, definition of asymmetric Gauss input and output membership functions, rule sets and result display methods. The third Section is focused on a case study for the electric station in Voivozi, (Bihor county) using the developed simulation program under MATLAB environment. Section 4 presents the conclusions, showing the importance and efficiency of fuzzy modeling in reliability analysis by comparing fuzzy and Monte Carlo methods also shown in equivalent reliability diagrams and highlighting the contribution of the authors.

2. DEVELOPMENT OF THE SIMULATION SOFTWARE USING FUZZY LOGIC

A frequently used analysis method in a system's reliability study is based on failure probability evaluation. In this method the crisp values of failure probabilities for electrical components are generally used in order to compute the system's reliability, based on equivalent reliability diagrams [2,3,4,6,8].

2.1 Definition of the input membership functions

No.	Linguistic variable	Acronym	Value
1.	Not acceptable	NA	0
2.	Almost acceptable	AA	0.167
3.	Close to acceptable	CA	0.333
4.	Acceptable	A	0.5
5.	Good	G	0.667
6.	Almost very good	AVG	0.833
7.	Very good	VG	1

Table 1.

The developed software is using Gaussian membership functions. For this kind of function the mean and the standard deviation (σ) must be specified. So for every component of the system seven degrees were defined (see Table 1), on a linear interval of failure and repair intensity values, and then the function values were established (λ and μ).

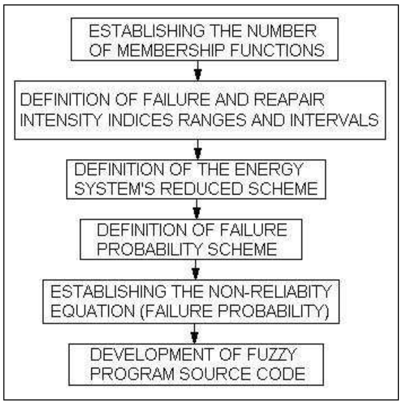

Fig. 1. Schematic function blocks for fuzzy analysis set up.

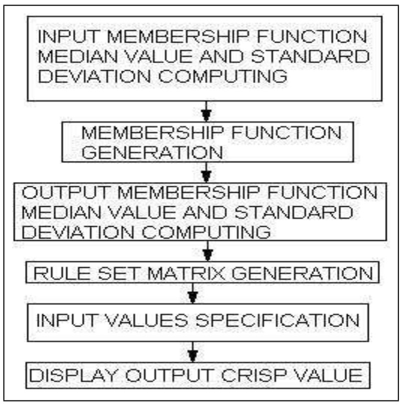

Fig. 2. Flowchart of the fuzzy program.

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 Figure 2.

All program functions are launched from the "d.fuzzy.m" module. The Graphical User Interface (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 input system equation is introduced from the "d.param" module and the input λ and μ are instantiated 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 op-

Fig. 3. Main program GUI (Translation: Fuzzy simulation...; Data; Inputs; Fuzzy simulation; Decision surfaces; Exit).

tional names. The saved data can be reloaded in a separate interface from their files which contain all system parameters and also the system equation. Once established the input system parameter values for specific runs can be instantiated from the "d.param.intr.m" module.

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

$$F_i = \frac{\lambda_i}{\lambda_i + \mu_i}, \tag{1}$$

where i =1...7, is the number of the membership function according to the earlier defined grade. The standard deviation (σ) is computed with an asymmetric Gauss function based on the relations:

$$\sigma_{i,1} = \frac{|F_{i-1} - F_i|}{3}, \tag{2}$$

$$\sigma_{i,2} = \frac{|F_i - F_{i+1}|}{3}. \tag{3}$$

After the introduction or reload of data from saved files, we can reenter the main module which gives us two options: fuzzy simulation or decision surfaces display. After computing the input membership functions parameters for each system component the program generates these functions. The decision surface display facilitates the evaluation of the fuzzy outputs.

2.2 Definition of the 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 the 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 elem1 is VW and elem2 is W and elem3 is A then the system is W.

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 we want to represent can be selected in the program interface.

2.4 Simulation results

After generating the membership functions and the 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 the inputs are specified and the "evalfis" function is used for the computation of the crisp output values. The program displays this value in a separate window.

3. CASE STUDY VOIVOZI ELECTRIC STATION

Case study is performed for the normal form of Electric Stations (ES) Voivozi, Bihor County scheme. The evaluation of reliability is realized considering the Padurea Neagra user, positioned on BC1- 20kV collector bar and the study criteria is considered in the absence of the consumer. Analyzing the operative mono cable 110 kV scheme of the Bihor County energy system, it can be concluded that Suplac is considered output and Oradea Vest and Marghita are considered inputs.
Using statistical data representing median values of reliability indicators for the equipments in ES and also using the equivalent reliability diagram we have reduced the ES Voivozi scheme to an Equivalent Reliability Diagram (ERD) presented in Figure 7. This diagram was used to formulate the system of equa-

Fig. 4. λ and μ parameter editing window for ES Voivozi.

tion for the fuzzy simulation. The reduction of normal scheme has been made by transposing it in a scheme in which the elements are connected in series or parallel considering the dimensioning and the connection of elements. All feeds for Padurea Neagra consumer, on all path, from the source have been considered.

In Figures 4-5 input data of analyzed electric station are presented. In Figure 6 the obtained membership function diagram are presented for ES Voivozi. Similarly we have representations of last nine elements of ERD. For computing output membership functions we start from the system scheme from which the failure tree is generated - Figures 7, 8.
The characteristic equation of the system is deduced from the schemes presented in Figures 7, 8 and is given by relation

$$F_{VOI} = 1-(1-F_1F_2)(1-F_3)(1-F_4F_5)(1-F_6F_7)(1-F_8)(1-F_9)(1-F_{10}) \quad (4)$$

Relation (4) is used by the program to generate the output membership function presented in Figure 9. In Figure 10 is presented, for example, a decision surface. The program displays the obtained output values in a separate window presented in Figure 11.

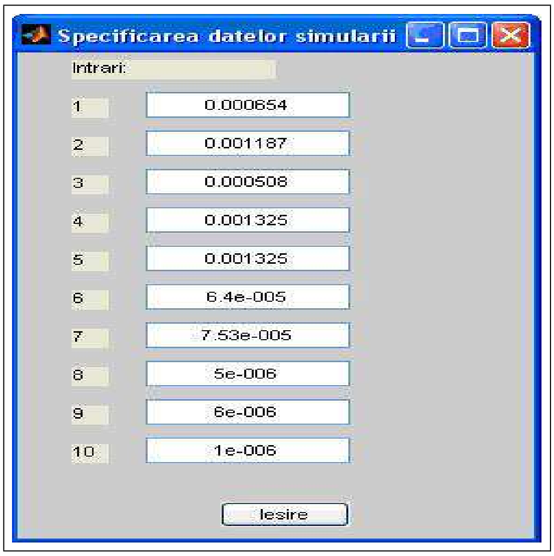

Fig. 5. Simulation data editing window for ES Voivozi.

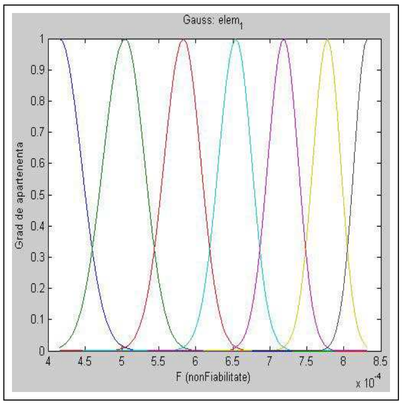

Fig. 6. Membership functions for element 1.

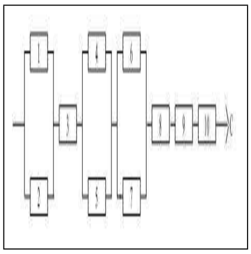

Fig. 7. The reduced scheme for ES Voivozi.

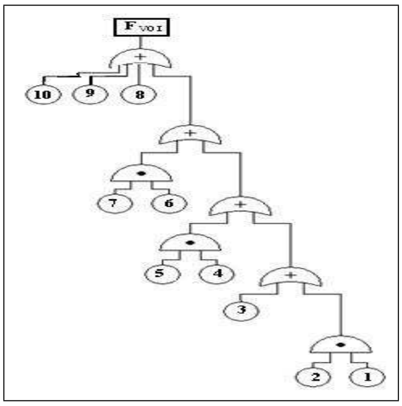

Fig. 8. The failure tree for ES Voivozi.

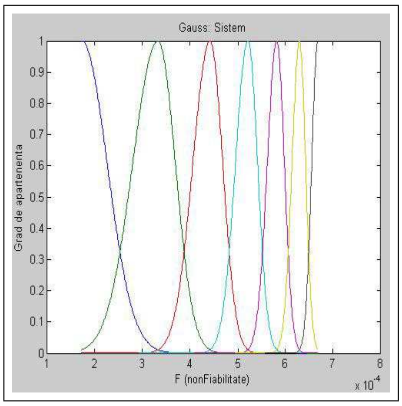

Fig. 9. Output membership functions generated for the analyzed system.

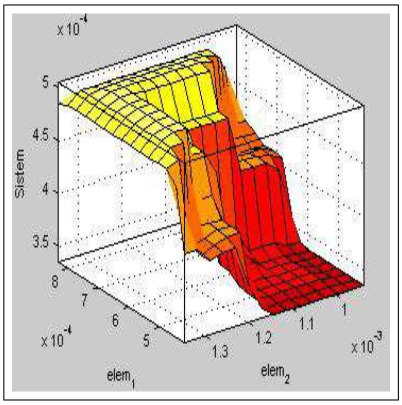

Fig. 10. Output values for inputs 1 and 2.

Fig. 11. Reliability output window for the reliability of ES Voivozi.

4. CONCLUSIONS

The use of fuzzy sets theory in the study of the reliability of the electric energy systems and equipments is justified by the possibilities offered by the quantification and the modeling of the qualitative enounces - incomplete and altered information, subjective appreciations - in flexible forms, more close to the way of thinking that 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 the reliability of the system can evolve. In Table 2 we can see that the realized evaluations, obtained with the ES reliability fuzzy simulation program, are accurate, in comparison with the values obtained by Monte Carlo method and the direct ERD computation [2, 4].

ES/R	FUZZY	MONTE CARLO (10.000 sim.)	ERD
VOIVOZI	0,99942759	0,99951	0,99947

Table 2.

The development of ES fuzzy reliability simulation program by using the MATLAB programming environment, based on the failure tree method, application of this program for ES Voivozi, Bihor County, and the comparative evaluation with the Monte Carlo simulation method results and with the ERD analytical method results, are the contributions of the authors in this article.

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