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A FUZZY LOGIC MODE TO ESTIMATE THE AVAILABILITY LEVEL OF ELECTRICITY FROM RENEWABLE ENERGY CONVERSION

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Abstract: In the paper, the authors suggest a way of assessing the level of availability of electricity that comes from renewable energy sources based on fuzzy logic. The modeling is done with the support of the Fuzzy Toolbox in the Matlab computer software. Based on the electricity level, decisions can be made to control the components of the sources so that the availability is increase. Thus the energy sources will operate optimally. The proposed model is applied in the paper for the following categories of renewable energy resources: biomass, hydraulic energy, photovoltaic solar energy and wind energy.
Keywords: renewable energy sources, Matlab computer software, fuzzy logic

1. INTRODUCTION

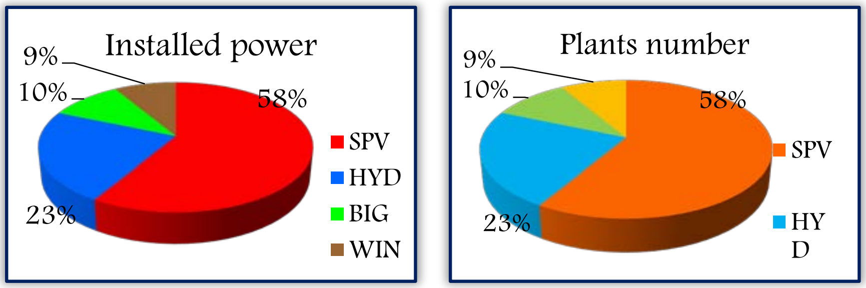
Renewable energy sources (RES) can be converted into electricity, the power installed in such plants depending on several parameters such as entering the primary natural energy potential [1].

Consecrated as a result of the activity of Professor L. Zadeh, who established his mode of operation, Fuzzy logic, was established as one of the most widespread techniques in decision making in automation processes, where based on the input variables, the variables of optimization can be optimized output [2]. This is also the case for systems for converting renewable energy into electricity. These renewable sources (RES) installed in power plants, are or are expected to be automated to increase the availability of energy. Thus, based on the model proposed by the authors in the paper, one can control on the one hand the internal components of the RES, to increase the continuity in the electricity supply of the consumers and on the other hand, the passage through controlled orders, on the external components, that is to say to those belonging to the regional Power System (PWS) of interconnection.

2. ABOUT RES. CASE OF BIHOR COUNTY

In Bihor County there are a number of 102 RES operators which are authorized to operate [7]. Examples with these are given in table 1. The centralization of powers by categories of RES is presented in table 2.

The situation of the powers and the number of production units on primary energy sources are presented in the graphical representations in figure 1.



(a) (b)

Figure 1. Installed powers (a) and number of power plants (b)

Due to the non-finalization of the methodological norms regarding the electricity settlement provided in the network, some small power plants currently operate under self-production mode even if they have obtained the approvals of connection to the public power grid.

Table 1. An overview on the situation of power plants with RES in Bihor County

No.	Company	Type of plant	Place	Installed power [MW]	Connection substation	U_n [kV]	Year of work
1	Global Alternative	Hydro power – Poiana 1	Poiana	0,53	Băiţa	20	-
2	Global Alternative	Hydro power– Poiana 2	Poiana	0,237	Băiţa	20	-
3	Alesis S	Hydro powerValeaBistrei	Popeşti	0,71	Voivozi	20	-
4	Infradoors	Photovoltaic plant	Oşorhei	2,73	Oradea-Sud	20	-
5	Transgex SA	Geothermal plant	Oradea	0,05	PTab, 400 kVA	0,4	2013
6	Resident solar	Photovoltaic plant	Nojorid	2,975	Oradea Sud	20	2012
7	SEZ Trade	Photovoltaic plant	Popeşti	2,95	Voivozi	20	2013
8	GeenTehnic	Photovoltaic plant Salonta 2	Salonta	4,49	Salonta	20	-
9	Delalina	Photovoltaic plant	Gepiu	2,74	Salonta	20	2013
10	Green Electrovest	Photovoltaic plant	Mădăras	2,55	Salonta	20	2013

The total power of these installations with RES for Bihor County, at the level of August 2019, by resource categories, according to the reports of PWS Operator - Transelectrica and Energy National Regulator - ANRE [6] [7], is given in table 2.

Table 2. Total powers by RES categories from the power plants in Bihor County(2019)

Type of RES	Power by ATR [MW]	Power by CR [MW]	Total capacity [MW]	Power with PIF [MW]	Power by DEN [MW]
Biogas	0,000	1,754	1,754	0,498	0,498
Biomass	0,000	5,500	5,500	0,500	0,500
Wind	0,000	21,500	21,500	11,500	11,500
Photovoltaic	1,951	90,633	90,611	68,239	68,936
Geothermal	0,000	0,050	0,050	0,050	0,050
Hydro	0,215	11,949	11,164	12,124	12,678

Based on the assessment of the energy potential of the RES in Bihor County, levels and thresholds of influence on the availability of the electricity generated by the RES will influence the power transit in the regional PWS.

3. APLICATION

A fuzzy system works with membership functions of several forms, the values given to the variation intervals of the input parameters are not usually fixed, and the evaluation of the results is done through vague states, formulated through inference rules with the use of variables linguistic variables [2].

As an application, this chapter presents the fuzzy modeling of the availability of electricity at the output of the photovoltaic power plant. The passage between the controllable inputs of the adopted photovoltaic systems model, as is the case of accumulators, reserves or inclination of solar panels, is controlled according to the level of the input variables independent of the human will. The decision can be taken, for example, when the availability of solar radiation is low. For wind systems, the decision can be made in case of lack or reduced wind speed

For the PWS Bihor case, fuzzy logic can be used for SRE power plants, in three hypotheses as follows:

- Hypothesis 1: Fuzzy analysis of a power station with four categories of RES: photovoltaic, micro-hydro, biomass and wind, considered connected to the public electricity grid to establish the availability of electricity at the record point or to the consumer;
- Hypothesis 2: The fuzzy analysis of the automatic control of the processes constituted as input variables in the system by evaluating the levels of the characteristic parameters of the RES based on which the decision of adjustment, compensation or switching between the component elements that have weight in increasing the availability of electricity to the consumer is based;
- Hypothesis 3: evaluation of the parameters of the continuity in the electricity supply from the SRE of the consumers for several interconnection scenarios.

For the proposed variants, the parameters necessary to establish the optimum power supply variant of the consumers are calculated, which are transposed with the help of fuzzy logic in the input and output variables with thresholds and levels in accordance with the values obtained by calculation and the initial data chosen [5]. for the power stations with the RES analyzed the adjustment limits and therefore the levels chosen for the characteristic parameters that are constituted in the input or output variables, the energy data from the specialized literature and the technical prescriptions specifying the maximum level of the obtained under the current operating conditions are used [5].
The input variables in the fuzzy system for the analyzed cases are:

- For wind power plants: wind speed, wind duration, turbine orientation, turbine height, reserve, energy accumulation, inverter efficiency, rotor diameter, blade surface;
- For photovoltaic power plants: radiation intensity, irradiation duration, panel orientation, shading, reservation, energy storage, inverter efficiency;
- For micro-hydroelectric plants: fluid flow, operating time, drop, reserve, turbine-generator output;
- For biomass power plants: heat power, biomass humidity, storage, generator efficiency, turbine efficiency.

The fuzzy intermediate data for the adopted model, the fuzzy rules and the output fuzzy rules of the fuzzy system are introduced in correlation with the analyzed SRE characteristics. The fuzzy toolbox from Matlab is used for modeling and simulation, as indicated in [3] and [4].

The membership function is triangular, the logic type "Mandani" and the number of inference rules created is 10. Four input parameters are considered: irradiation, inclination of photovoltaic panels, reserve and accumulation of energy in batteries. Output parameter is considered the availability of electricity to the consumer at the interconnection point of RES with PWS. The linguistic variables that characterize each level of the input and output parameters are: little, average and big or small, medium and maximum.
Tables 3 and 4 show the results obtained for the sets of two input variables combined. As combinations (C1 and C2) of the input parameters in tables 3 and 4 are: P_1 - intensity of solar radiation [W / m^2], P_2 - angle of photovoltaic panels (PVP), P_3 - number of batteries.
The logic diagram for testing and adjusting the availability of electricity for a photovoltaic power station connected to the zone SEE, with the interconnection of the components on which it is operated, is shown in figure 2.

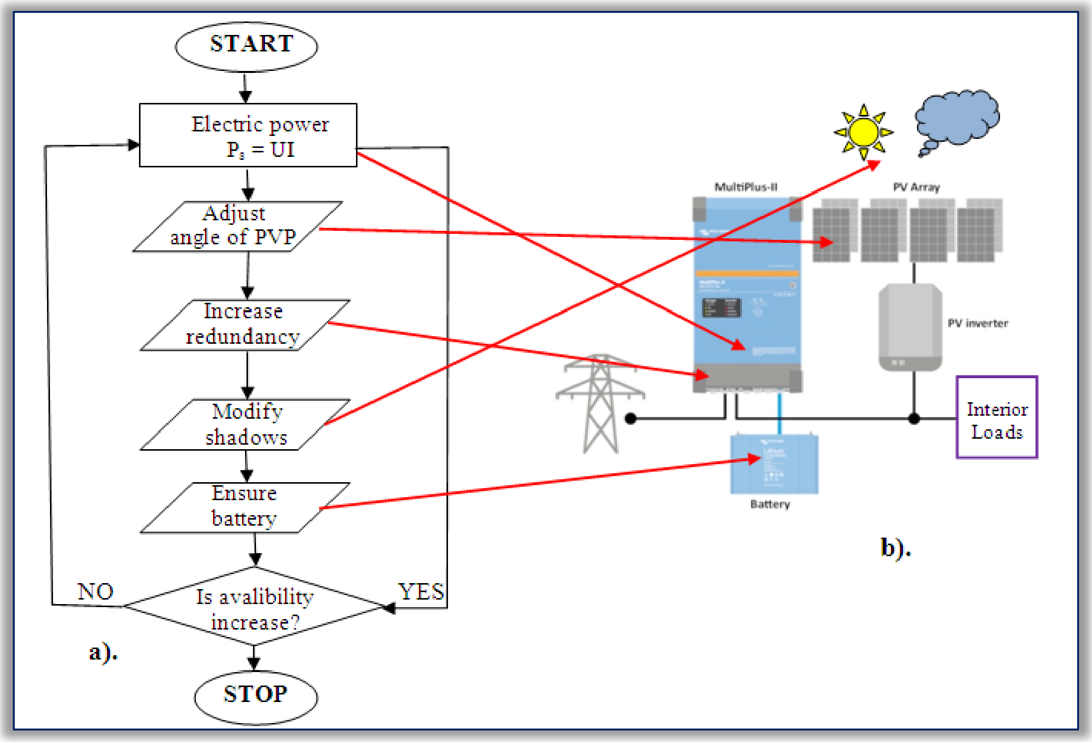


Figure 2. Logical diagram of the adjustment of the parameters necessary to increase the availability of electricity (a) and the principle diagram with the interconnection of the components (b)

Table 3. Thresholds and levels of input and output parameters for photovoltaic plants – C_1

Irradiation degree	Variation range P_1	Inference rules P_1	Angle of PVP	Variation rangeP_2	Inference rules P_2	Availability level	No of appearances
small	900-1100	3	little	0-30	2	reduce	2
medium	1101-1300	4	medium	30-60	5	median	5
big	> 1300	3	high	60-90	3	high	3

Table 4. Thresholds and levels of input and output parameters for photovoltaic plants – C_2

Redundancy degree	Variation range P_1	Inference rules P_1	Battery level	Variation range P_3	Inference rules P_3	Availability level	No of appearances
small	900-1100	3	little	0-1	4	reduce	4
medium	1101-1300	5	medium	2-5	5	median	5
big	> 1300	2	high	5-10	1	high	1

Figure 3 shows how to choose the input and output variables and in figure 4 the inference rules.

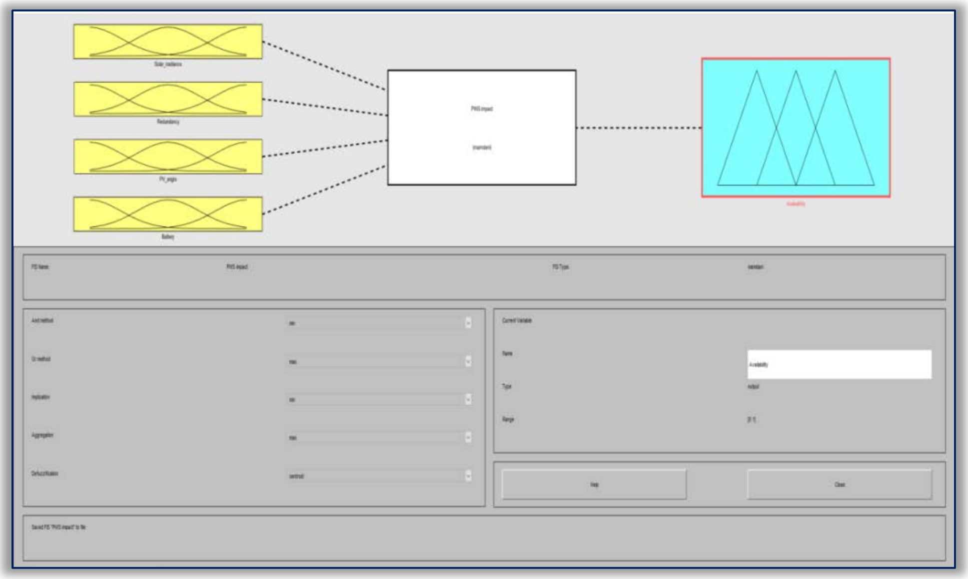


Figure -3 Capture about establishing the input and output variables and entering the data to evaluate the impact on the regional PWS of photovoltaic power plants

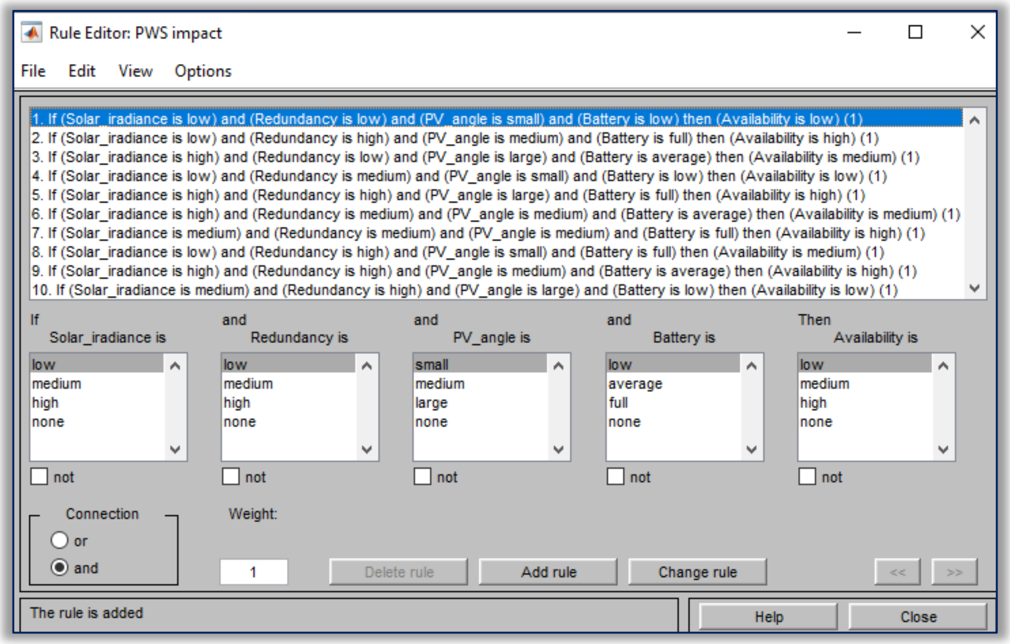


Figure – 4 Capture about establishing inference rules for photovoltaic power plants

The reference levels and the ranges of values for the input variables are presented in figure 5 and in figure 6 the values of the output variable are given: availability of electricity.

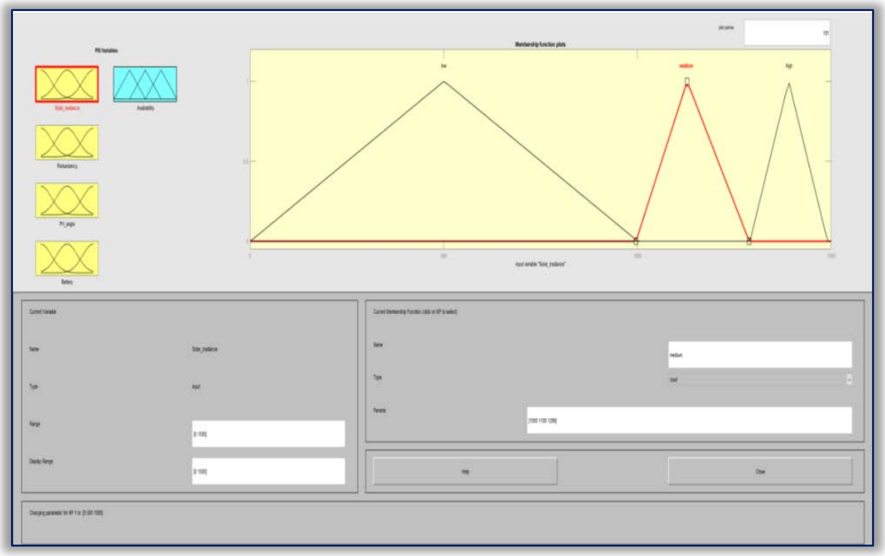


Figure 5. Capture about establishing numerical and linguistic values for the input variables

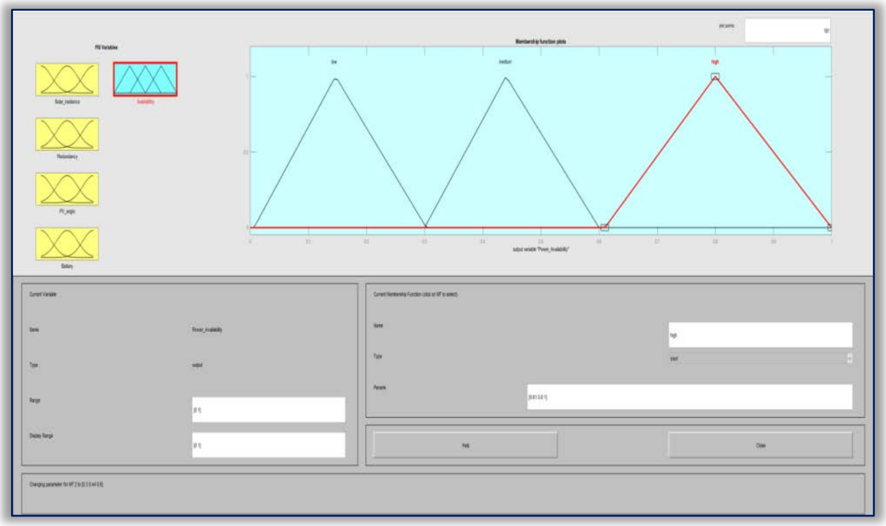
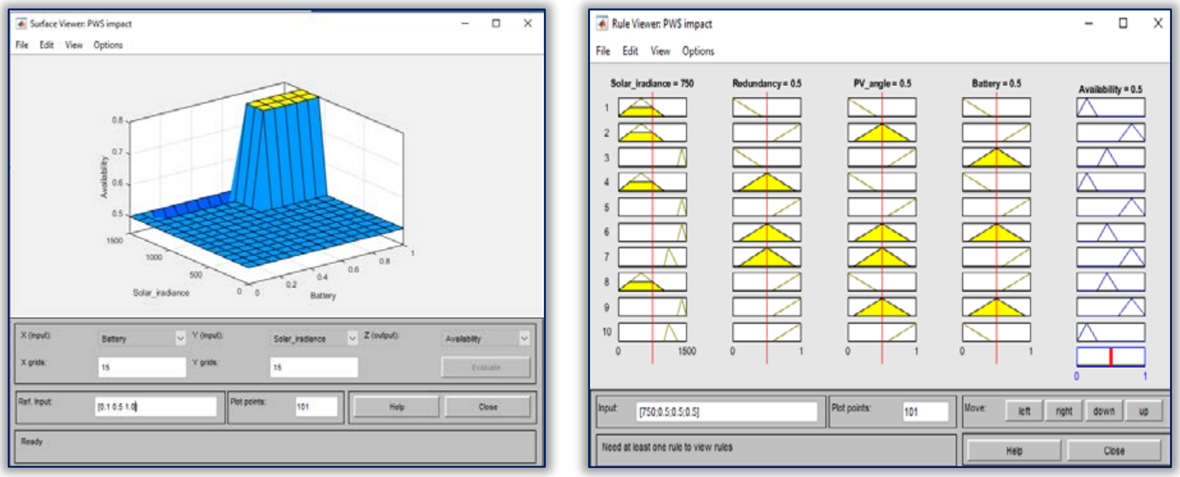


Figure 6. Capture about establishing numerical and linguistic values for the output variable

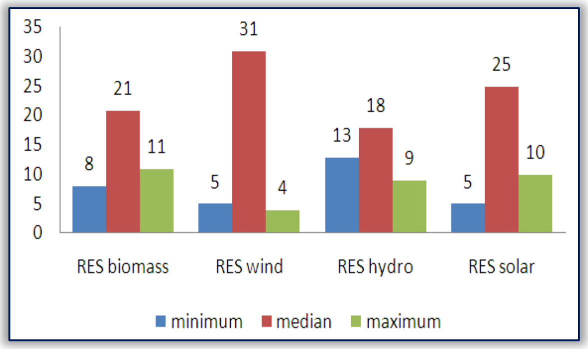
Figure 7 shows the decision surface obtained (a), respectively the inference graphs (b).



(a) (b)

Figure 7. Generation of the decision surface (a) and the inference graphs (b,) for analyzing the availability of electricity from the photovoltaic power plant

Applying the same working principle, but with the specific input variables, the authors also modeled a biomass power plant, a hydroelectric power station and a wind power farm. The centralization of the results obtained by fuzzy modeling, for the analyzed cases, is shown in Figures 7 and 8.



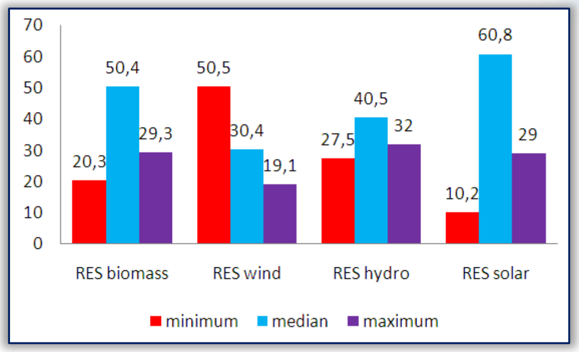


Figure -7.Number of availability casesFigure -8Percentage of availability cases

4. CONCLUSION

As authors, we can make the following observations: the more the number of inference rules is extended, the more accurately the input parameters can be adjusted in order to obtain the optimal output parameters, as desired in the operation of the RES power plants. Even if it is obvious to the connoisseurs of fuzzy systems this, only by repeated simulations and by introducing the intervals of variation for the parameters analyzed with wide range of values, the desired results can be obtained. For the 10 rules formulated by the authors, however, one can appreciate the impact of the input parameters on the availability of electricity at the connection point between RES and the regional power systems. We recommend, due to the variability of the natural parameters of the RES, such as wind speed or solar irradiation, the realization of power plants with renewable energy resources, of distributed type, that is to say the adaptation of the resources with the place of energy consumption.

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