FUZZY MODELS AS DECISION-SUPPORT APPLICATIONS OF ELECTRICAL ENERGY TARIFFING

Viorel DUGAN, Razvan ŞOLEA, Daniela GHINIŢĂ

University “Dunărea de Jos”, Domnească 47, 800008 Galaţi,
viorel.dugan@ugal.ro, razvan.solea@ugal.ro

Abstract: The paper is a decision – support application which design and use two fuzzy models to estimation an electrical energy tariff, as it to be sell at consumers. The fuzzy tariff estimation model integrate not only the S.C Electrica S.A. rate position, but and some constraints/ compulsions of National Authority of Settlements from Energy (NASE), beginning with 1999, in this transition period from Romania.
The paper not refer to a price concrete case (internal tariff used in certain year, production price, transport price, distribution price, spot price, or an external price to be sold electrical energy – EE, etc). The paper shows how, by changing the parameters of S.C Electrica S.A and NASE, it is possible to can perform sensitivity tests on the tariff function model until we obtain an acceptable price. Much more: the two fuzzy models use different rules (conservative and aggressive, with hedge operators, respectively) for pricing.
Finally, the paper not finished all fuzzy possibilities (rules) which can influences the expected value of a some EE tariff but, can create a discussion base about the way of approximate/ fuzzy reasoning, as a decision-support application to find a new EE price.

Keywords: fuzzy models

1. INTRODUCTION

The estimation of an EE price, i.e. the price to produce, to transport or to distribute the EE, was always a major problem. In this aim, were used *modified forms* of the Black-Scholes formula to find a price (Carlsson and Fuller, 2001), the games theory (Maeda et al., 1992), models which use probability theory (Pereira et al 1992), Monte Carlo models (Baughman et al., 1992), fuzzy models (Cox, 1999; Wong, 1996; Yan et al., 1994), or even models in optimization methods (Wong, 1996) etc.

In any decision-support application is necessary to be considered many factors, which are different. These factors can be either heuristic, either can appear from numerical analyses. As a rule, the heuristic factors rise from the a priori experience of the decision factor; have a non numerical structure, and can be expressed better by linguistic values. But, for an EE price, the concrete situation is more complicated in a transition economy as in our country in these years, because: (i) not exists some EE tariffs, from more suppliers; (ii) not exists *a priori* knowledge of the demand and of the EE offer, as a price function; (iii) however, must equalize the demand with the offer of EE, and (iv), must keeping and the market discipline, indifferent of all professional, social and political constraints and objectives – just to name a few.

From these features, to find an EE tariff involve a critical mixture of many *vague* and *uncertain* factors, as the following: (1) the demand estimation, to be possible the knowledge of the EE offer (supply); (2) the competitive tariffation (pricing), when exists more offers; (3) the pricing strategies; (4) the market sensibility (industrial & domestic markets); (5) the cost of losses; (6) the demand peaks (daily, weekly, monthly, yearly); (7) the probable life cycle of the EE generators; (8) the legal national and departmental restrictions of capitalization; (9) the “oneness” EE product, i.e. the monopoly position (unique producer) of S.C Electrica S.A; (10) the social/or political restrictions, specifically the transition period above mentioned in Romania; (11) the time window and the update algorithm of the EE price etc. Additional, all these constraints and

This paper was recommended for publication by Sergiu CARAMAN

objectives have, clearly, more or less, some degree of *imprecision*.
Because these, and to understand easy the modality to obtain a fuzzy tariff for EE, both models from the paper, used only four rules, each. However, these few factors to establish a tariff for EE contain the following: (1) the S.C Electrica S.A must to be profitable while sustaining high sales kWh; (2) the average tariff of the competition's MWh in or/and near our market place (Ukraine, Bulgaria, Hungary, Moldavia); (iii) the cost to manufacture, transport and distribute the MWh.

We mention that "*to be profitable while sustaining high sales kWh*" is, simultaneously, and a constraint of NASE (*** Metodologia,…., ANRE 2003).
In the following, the section 2 is with the design of the fuzzy tariffing models. Here, the first model is one with a conservative/"quiet" attitude concerning the strategies for tariff estimating. Contrary, in the second model of price the approach is with some aggressive strategies, concerning all rules (level of tariff, manufacturing costs, and competition's price per MWh). How are used the fuzzy sets in the two fuzzy models is the content of the section 3, and, in section 4 is used the better defuzzification method. Both models are compared in the sections 4 and 5.

2. FUZZY TARIFFING MODELS DESIGN

As is above mentioned, *the first fuzzy model* has only four rules (Şolea, Ghiniţă, and Dugan, 2004):

[R1]: the EE tariff proposed by the S.C Electrica S.A must to be *high*.
[R2]: the EE tariff proposed by the S.C Electrica S.A and the NASE, must be *low*.
[R3]: the EE tariff proposed by the S.C Electrica S.A must be *approximately two times*costs* of EE.
[R4]: IF the competition EE tariff (from the neighbouring countries in the actual Romania, - i.e. Ukraine, Bulgaria, Hungary, Moldavia etc) it is *not very high*, THEN the EE tariff proposed by the S.C Electrica S.A, should be *approximately equal (or near*) the competition EE tariff.

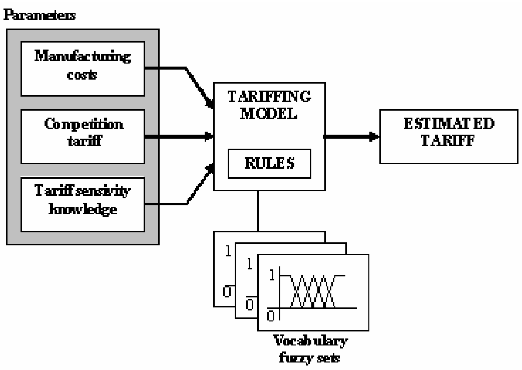


Fig. 1. The structure of the fuzzy model for electrical energy tariffing

From these rules we see that while the rules R1, R2 and R3 are non-conditional, the rule R4 is a conditional one (IF … THEN).

In *the second model,* were used the following aggressive rules:

[R1]: the EE tariff proposed by the S.C Electrica S.A must be *very high.*

[R2]: the EE tariff proposed by the S.C Electrica S.A and the NASE must be *relative/somewhat low.*

[R3]: the EE tariff proposed by the S.C Electrica S.A must be *greater/above approximately/around two times*costs* of EE.

[R4]: IF the competition EE tariff (from the neighbouring countries of Romania, – i.e. Ukraine, Bulgaria, Hungary, Moldavia) it is *not very low*, THEN the EE tariff proposed by the S.C Electrica S.A, must to be *approximately equal (or near, around)* the competition EE tariff.

The fuzzy model used below and proposed in Figure 1(Solea, Ghinita and Dugan, 2004), has ability to model *conflicting expert rules* from knowledge base (Cox, 1999; Lambert-Torres et al., 1998).

This feature of fuzzy system in the case of the first model, is that the first rule (R1) ensures profitability for S.C Electrica S.A, while the second rule (R2), ensures not only the social and political aspects of NASE and Government, respectively, but and a sufficient volume of EE (MWh) sales in the market area.

On the other hand, the third rule (R3) ensures that the tariff will cover the direct cost of manufacturing (generating, transport, and distribution), while the fourth rule (R4) says that as long as the tariffs of neighbouring countries are not considered very high, the tariff of S.C Electrica S.A can be close to that of competition (i.e. near).

3. THE USE OF THE FUZZY MODELS RULES OF EE TARIFF

Both models which were written in Matlab (were used standard functions as `trimf, pimfr, smf, max, interp1, defuzz` etc), shows how the base fuzzy sets are combined with fuzzy regions, regions created with the current data points from (***, Metodologia,…, ANRE, 2003). If the programs are running, the fuzzy models request the manufacturing costs and the competition's tariff, and, after they are executed, an estimated tariff is returned (Fig. 2a, only for the first model).

3.1 The fuzzy sets high and low of the EE tariff, shown in Figure 3, linear indicate what points are considered for EE to be a *high* tariff and a *low* tariff.

```
Introduceti costul de fabricatie
 [16...32]: 26

Introduceti tariful concurentei
 [32...72]: 53

Defuzzificare metoda centroidului
 52.1073   0.7284

Defuzzificare metoda maximului compus
 52.5000   0.7315
```

Fig. 2a. Execution of the first basic fuzzy tariffing model, Matlab writing

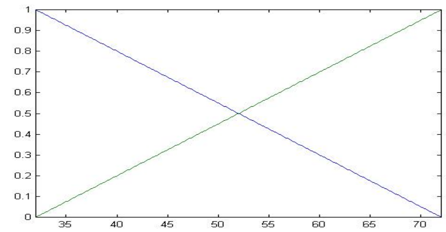


Fig. 3a. The price sensitivity fuzzy sets *high* and *low* for the tariff

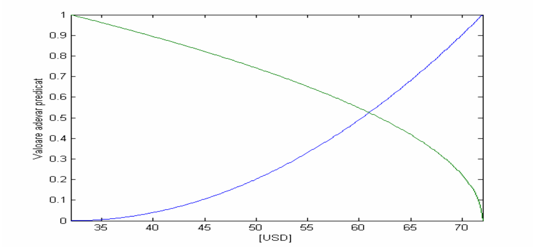


Fig. 3b. The tariff constraint fuzzy sets *very high* and *somewhat low* (obtained with *very* and *somewhat* edges)

For the second fuzzy model were used *hedge operators* (Beale, M et al, 1994; Cox, E., 1999 etc), which make possible to control the *restrictive* or *permissive* qualities of a fuzzy set: in this case, an aggressive attitude of Electrica SA toward market positioning. The hedges, which play the same role in fuzzy production rules that adjectives and adverbs in a natural language, are classified in two categories: *concentrators* (which make fuzzy sets more restrictive by raising grades to an exponent greater than 1.0 - e.g. *exactly*: exponent = infinity, *extremely* – exponent = 3, *very*- exponent = 2 etc), or diffusers/ diluters (which make fuzzy sets more permissive with exponents less than 1.0 – e.g. *somewhat*: exponent = 0.5, *slightly*: exponent = 0.25, *vaguely*: exponent = 0.03 etc). In our case, the fuzzy sets in Figure 3b are formed by the mixture of *very* and *somewhat* edges, with the base price sensitivity fuzzy sets *high* and *low* respectively, from Figure 3a. The *very* hedge intensifies the fuzzy set *high* (reducing the truth membership of values normally being *high*), while *somewhat* hedge dilutes/diffuses the fuzzy set *low* (increasing the truth membership of values normally being *low*), see the Figure 3b.

3.2 The model-base fuzzy sets from the figures 4a and 5a depend on the actual run-time data, because each new value of manufacturing costs and competition tariffs gives new fuzzy sets. As in other cases, the difference in the width of the fuzzy sets is because of the model semantics. The same fuzzy sets, but used in the second model are in Figures 4b, and 5b.

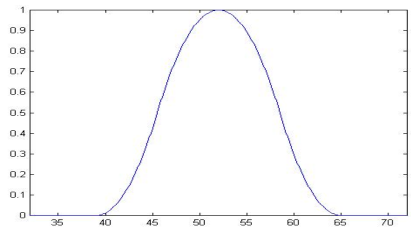


Fig. 4a. Fuzzy set of the *manufacturing costs,* the first model

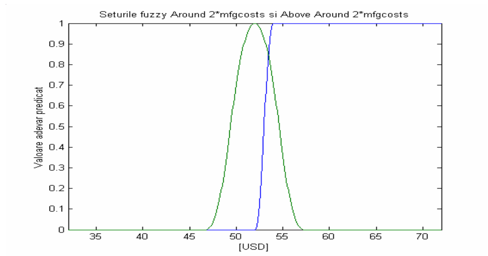
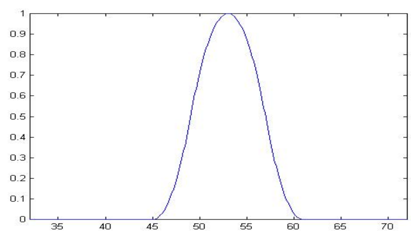


Fig. 4b. Fuzzy set of *around* and *above around* two times *manufacturing costs,* the second model

For example, the fuzzy set of the *manufacturing costs* (Figure 4a with a value of $52.00) has a 25% diffusion to account for a basic uncertainty, at this point, obviously for full manufacturing costs of EE, but, and for the degree to which we want this factor to contribute to the default tariff value (i.e. all 25%). By contrast, the fuzzy set *near competition's tariff* has a thinner diffusion (15%) to account for the model's assumption (i.e. the rule R4 with the S.C Electrica's tariff near/close to the competition's tariff). We recall that by changing the width of these dynamically created fuzzy sets (see Figures 4 and 5), can be obtained a modality to refine the precision of the fuzzy model (Shangvi, 1989; Cox, 1999; Yan et al., 1994).



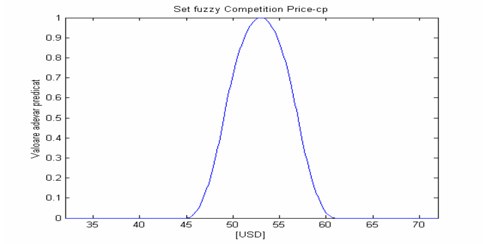


Fig. 5a and 5b: Identical fuzzy sets of the *near to competition's tariff* of the two models

3.3 The executions of the tariff estimation rules with the Matlab programs SNIA_BC1,2 are with linear and nonlinear fuzzy sets from Figures 3a *(high* and *low*) and 3b (*very high* and *somewhat low*), respectively. Both domains were between \$32.00 and \$72.00.

After evaluating and applying of the unconditional rules (R1) and (R2), the solution fuzzy sets are shown in Figures 6a, b, and Figures 7a, b, respectively.

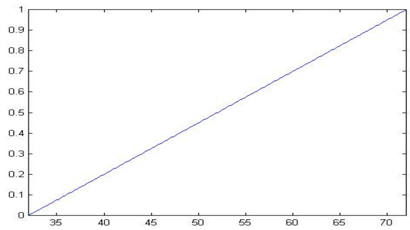


Fig. 6a: Fuzzy set of the *tariff* solution after executing rule [R1], the first model

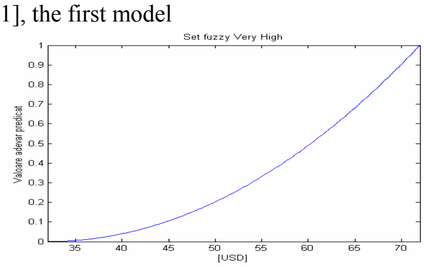


Fig. 6b: Fuzzy set of the *tariff* solution after executing rule [R1], the second model

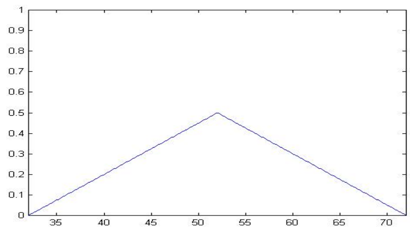


Fig. 7a: Fuzzy set of the *tariff* solution after executing rule [R2], the first model

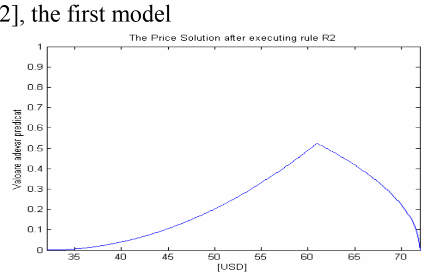


Fig. 7b: Fuzzy set of the *tariff* solution after executing rule [R2], the second model

When is executed a non-conditional proposition, the solution is generated by the intersection of the two sets (AND operation, Figures 7a and 7b). The equations which describe the formal actions for handling unconditional rules in the fuzzy models are below relationships (1) and (2):

$$\text{IF } (\forall \mu_{solution}[x]) = 0), \quad \text{THEN } \mu_{solution}[x_i] = \mu_{consequent}[x_i] \quad (1)$$

$$\mu_{solution}[x_i] = \min(\mu_{solution}[x_i], \mu_{consequent}[x_i]) \quad (2)$$

Eq. (1) shows the updating an empty solution fuzzy set with an unconditional rule, while eq. (2) shows the updating a working solution fuzzy set with an unconditional proposition. In Figure 7a, after the rules R1 and R2 execution, the model has a triangular fuzzy region with a μ[0.5] height, region obtained by the intersection of the (linear) *high* and *low* fuzzy regions. In Figure 7b, where are used the hedges *very* (high) and *somewhat* (low) and, as a result of these nonlinear and not completely symmetrical linguistic variables, the price fuzzy region it is not triangular, and the region is shifted to the right.

After the application of the rule R3, the solution fuzzy regions of the *tariff* are shown in Figures 8a and 8b.

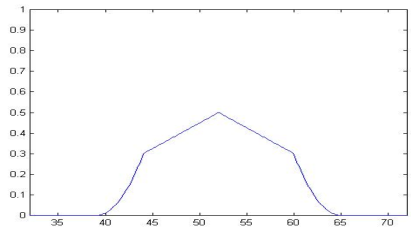


Fig. 8a: Fuzzy set of the *tariff* solution after executing rule [R3], the first model

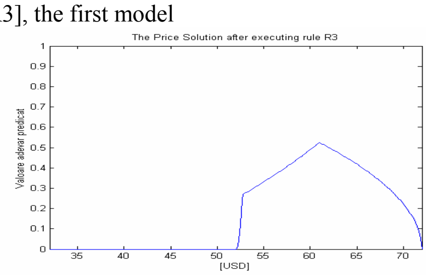


Fig. 8b: Fuzzy set of the *tariff* solution after executing rule [R3], the second model

Figures 8a and 8b are obtained because the rule R3 overlays the current working fuzzy regions with the bell-shaped fuzzy regions from Figures 4a and 4b respectively (*manufacturing costs*). R3 being an unconditional rule, obviously, is used the minimum operator (AND), to have the minimum of the solution fuzzy set and this consequent set.

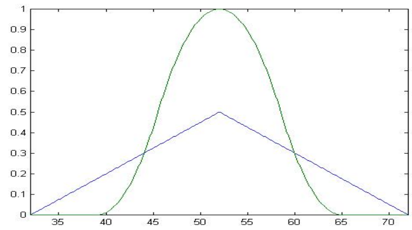


Fig. 9a: Fuzzy set of the *tariff* solution overlaid by the fuzzy set of the *manufacturing costs* (from Fig 4a)

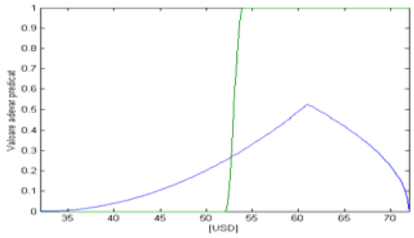


Fig. 9b: Fuzzy set of the *tariff* solution overlaid by the fuzzy set of the *more than/above around manufacturing costs* (from Fig 4b), before rule [R3] is executed.

The Figures 8a, b, and 9a, b, shows the solution fuzzy regions/ sets obtained with these rules, and the final fuzzy region obtained after applying of the AND operator for *tariff*, respectively.

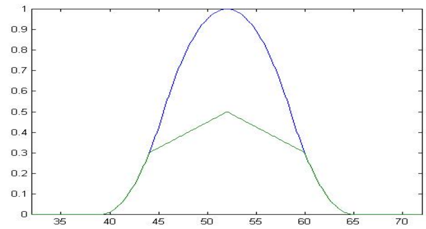


Fig. 10a: Fuzzy set of the *tariff* solution overlaid and restricted by the fuzzy set of the *manufacturing costs*

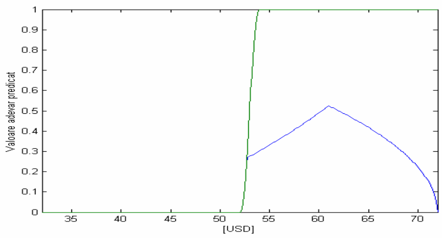


Fig. 10b: Fuzzy set of the *tariff* solution overlaid and restricted by the fuzzy set of the *more than/ above around manufacturing costs* (from Fig 4b), after rule [R3] is executed

In the same time, the Figures 9 and 10 shows that fuzzy regions are narrower fuzzy regions. However, with the same height of the peaks (µ[0.5] in Figures 9a and 10a), and a greater µ (in Figures 9b and 10b).

Both rules R4 are conditional rules (IF – THEN) and complex sentences, because here, the predicate fuzzy set, in the same time, is used also and as a consequent constraint fuzzy set. I.e., both rules R4 use a fuzzy linguistic variable in the predicate. To be more exactly: to evaluating and applying of the conditional rule R4, initially must create and evaluate the predicate linguistic variable, to be possible to determine the truth value from the following sentence(s):

```
. . . the competition price of EE
is not very high(low, in the second
model) . . .
```

To create the fuzzy region *very high* from Figure 11a, was incorporated the hedge *very* with the original fuzzy set *high* (see Figure 11a), and to obtain the linguistic variable (fuzzy region) *not very high* from Figure 11b, was applied the Zadeh standard complement *not* $(1 - \mu_A(x))$ to the fuzzy set *very high* (from Figure 11a). The same procedure was used and with the *very low* fuzzy region (hedge *very* to the *low* fuzzy set, Figure 12a): by applying the above standard Zadeh *not* $(1 - \mu_A(x))$ at fuzzy set from Figure 12a, was obtained the linguistic variable *not very low* (Figure 12b).

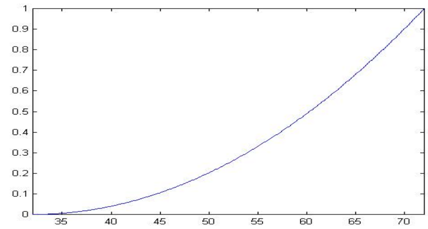


Fig. 11a: The fuzzy region *very high*

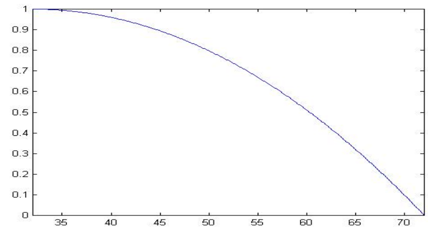


Fig. 11b: The fuzzy region of linguistic variable *not very high*

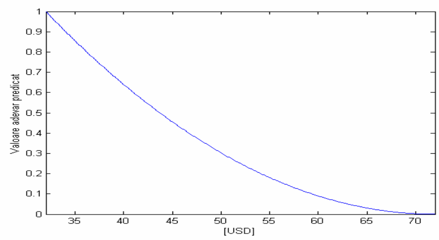


Fig. 12a: The fuzzy region *very low*

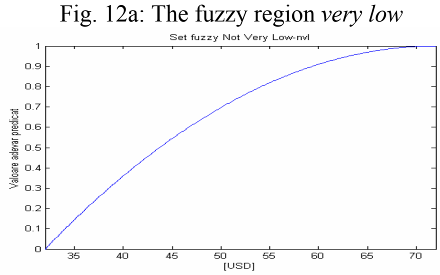


Fig. 12b The fuzzy region of linguistic variable *not very low*

From this moment we can determine the proposition's predicate truth by finding the membership competition's tariff (i.e. for $53.00). This has a truth value of [0.75] with the first model, so the consequent proposition:

`. . . the EE tariff proposed by the S.C Electrica S.A, must to be approximately equal (or near) the competition EE tariff,` can be evaluated, and the solution fuzzy set *tariff* can be updated.

The solution fuzzy set *tariff* after the evaluating and applying of the rule R4 can be see in Figure 13a for the first model, and in Figure 13b for the second model. With a truth value of [0.75] for the predicate, the minimum correlation process is applied to the fuzzy set *near the competition EE tariff* (see the Figures 5 and 2) and, as a result the consequent's height is diminished at [0.75] (Figure 13a). Recall that (Terano, Asai, and Sugeno, 1993; Cox, 1999; Yan et al., 1994; Beale and Demuth, 1994), the fuzzy conditional propositions update the solution fuzzy set by the union of the consequent set with the solution set (to be run the OR/ MAX operation). The below eqs. (3) and (4) are formal relations to be applied the conditional fuzzy rules (where: ⊗ Pr is the Cartesian product).

$$\mu_{consequent \otimes Pr}[x_i] = \mu_{consequent}[x_i] \times \mu_{premise} \quad (3)$$

$$\mu_{solution}[x_i] = \max(\mu_{solution}[x_i], \mu_{consequent \otimes Pr}[x_i]) \quad (4)$$

Eq. (3) is for the correlation process, and eq. (4) shows the update mode of a working solution fuzzy set with a conditional proposition. Both models are now complete.

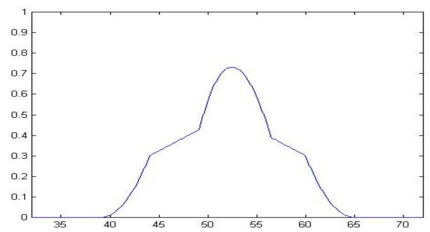


Fig. 13a The final fuzzy set of the *tariff* solution after executing rule [R4], first model

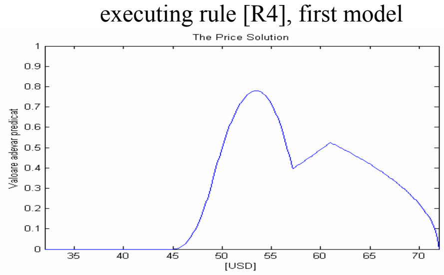


Fig. 13b: The final fuzzy set of the *tariff* solution after executing rule [R4], second model

3.4 To find the expected tariff value is necessary to be defuzzify the solution fuzzy set, which is a fuzzy space representing the combined knowledge of the four rules R1 … R4. This space contains the tariff fuzzy set.

4. CHOICE OF THE DEFUZZIFICATION METHOD

Defuzzification is the final phase of fuzzy reasoning. The fuzzification method used is a critical factor at any fuzzy model design. By defuzzification we select the expected value of the solution variable from the consequent fuzzy region. This is a value that best represents the information contained in the consequent (solution) fuzzy set.

In the fuzzy models, there are several methods of determining the expected value of the solution fuzzy region (Cox, 1999; Yan et al., 1994; Beale and Demuth, 1994). These are *methods of decomposition* (also called *methods of defuzzification*), and they describe the ways we can derive an expected value for the final fuzzy state space.

From the literature above mentioned, the *centroid (*or *center of gravity* technique, or *composite moments* technique) finds the "balance" point of the solution fuzzy region, by calculating the weighted mean of the fuzzy region. Centroid defuzzification finds a point representing the fuzzy set's center of gravity and is the most widely used technique because it has several desirable properties: (1) the defuzzified values tend to move smoothly around the output fuzzy region; that is, the changes in the fuzzy set topology from one model frame to the next usually result in smooth changes in the expected value; (2) it is relatively easy to calculate; and (3), it can be applied to both fuzzy and singleton output set geometries.

Because these features, in our paper firstly was used the *centroid* defuzzification method to defuzzify the *tariff.*

The Figure 13a shows the final fuzzy set and the defuzzification results with first model, which include a recommended *tariff* of $52.10 with a high degree of compatibility. The selection of defuzzification methods in a fuzzy model depends how we want to be the value of the result. As we mentioned above, the composite moments technique (centroid) allows a mixture of both conditional and unconditional rules (R1 – R4) into a solution result which move smoothly around the output fuzzy space as the model parameters change (see the Tables 1).

Other method, *the composite maximum method* (also called *maximum height*), closely related with *average maximum* and *center of maximus* methods, should be sensitive to the proposition that has the greatest degree of truth (for example, rule R4). In this case, such decisions (defuzzifications) about tariff are (or can be) usually discontinuous; in other words, a class of tariffs (values, prices).

If the truth of the R4 rule is greater of the unconditional R1, R2, R3 truths, the *tariff's* value is based only this rule.

If the truth of the R4 rule is less of the R1, R2, R3 truths, the *tariff's* value is based on the unconditional R1, R2, and R3 mixed rules.

These differences between the estimation tariffs by the two defuzzification methods (centroid & composite maximum) for different competition tariffs (50 lines) are in the Tables 1a and 1b. E.g., in the Table 1a, the manufacturing costs, from (***, Metodologia,…, ANRE, 2003), are always, as value, $26.00.

The Table 1a shows an atypical defuzzification behaviour, respectively as the competition tariff increases (between $46.00 . . . $70.50), the truth of the rule [R4]'s predicate decreases. It can be seen that at the competition tariff of $46.00 (line 1, i.e. L1 in Table 1a), the tariff of $49.9625 is considered *not very high*, but at the competition tariff of $70.50 (line 50, i.e. L50 in Table 1a), the tariff of $53.9269 is, as value, *very high.*

As a conclusion, *the centroid technique* "consider" the effects of the unconditional rules and "retain the tariff" in a region towards the center of the unconditional rules regions.

Table 1a

No.	Pret conc.	Gr.ap.	Pr(Centroid)	Gr.ap	Pr(Maxim)	Gr.ap
1	46.0000	0.8775	49.9625	0.4491	45.8000	0.8795
2	46.5000	0.8686	50.2300	0.4558	46.3000	0.8708
3	47.0000	0.8594	50.4875	0.4622	46.7000	0.8618
4	47.5000	0.8498	50.7242	0.4681	47.2000	0.8526
5	48.0000	0.8400	50.9285	0.5192	47.7000	0.8430
6	48.5000	0.8298	51.0909	0.5763	48.2000	0.8331
7	49.0000	0.8194	51.2346	0.6266	48.7000	0.8229
8	49.5000	0.8086	51.3699	0.6684	49.1000	0.8125
9	50.0000	0.7975	51.4969	0.7017	49.6000	0.8018
10	50.5000	0.7861	51.6160	0.7265	50.1000	0.7908
11	51.0000	0.7744	51.7277	0.7430	50.6000	0.7795
12	51.5000	0.7623	51.8321	0.7513	51.0000	0.7679
13	52.0000	0.7500	51.9299	0.7516	51.5000	0.7561
14	52.5000	0.7373	52.0213	0.7439	52.0000	0.7440
15	53.0000	0.7244	52.1073	0.7284	52.5000	0.7315
16	53.5000	0.7111	52.1883	0.7054	52.9000	0.7189
17	54.0000	0.6975	52.2649	0.6751	53.4000	0.7059
18	54.5000	0.6836	52.3381	0.6377	53.9000	0.6927
19	55.0000	0.6694	52.4086	0.5937	54.3000	0.6793
20	55.5000	0.6548	52.4776	0.5433	54.8000	0.6656
21	56.0000	0.6400	52.5460	0.4905	55.2000	0.6516
22	56.5000	0.6248	52.6470	0.4838	55.7000	0.6374
23	57.0000	0.6094	52.8537	0.4787	56.1000	0.6229
24	57.5000	0.5936	53.0609	0.4735	56.6000	0.6082
25	58.0000	0.5775	53.2601	0.4685	57.0000	0.5933
26	58.5000	0.5611	53.4510	0.4637	57.5000	0.5782
27	59.0000	0.5444	53.6330	0.4592	57.9000	0.5628
28	59.5000	0.5273	53.8056	0.4549	58.4000	0.5473
29	60.0000	0.5100	53.9684	0.4508	58.8000	0.5315
30	60.5000	0.4923	54.1207	0.4470	59.2000	0.5155
31	61.0000	0.4744	54.2619	0.4435	52.0000	0.5000
32	61.5000	0.4561	54.3913	0.4402	52.0000	0.5000
33	62.0000	0.4375	54.5080	0.4373	52.0000	0.5000
34	62.5000	0.4186	54.6112	0.4347	52.0000	0.5000
35	63.0000	0.3994	54.6999	0.4325	52.0000	0.5000
36	63.5000	0.3798	54.7733	0.4307	52.0000	0.5000
37	64.0000	0.3600	54.8307	0.4292	52.0000	0.5000
38	64.5000	0.3398	54.8715	0.4282	52.0000	0.5000
39	65.0000	0.3194	54.8919	0.4277	52.0000	0.5000
40	65.5000	0.2986	54.8906	0.4277	52.0000	0.5000
41	66.0000	0.2775	54.8681	0.4283	52.0000	0.5000
42	66.5000	0.2561	54.8249	0.4294	52.0000	0.5000
43	67.0000	0.2344	54.7623	0.4309	52.0000	0.5000
44	67.5000	0.2123	54.6818	0.4330	52.0000	0.5000
45	68.0000	0.1900	54.5852	0.4354	52.0000	0.5000
46	68.5000	0.1673	54.4744	0.4381	52.0000	0.5000
47	69.0000	0.1444	54.3514	0.4412	52.0000	0.5000
48	69.5000	0.1211	54.2178	0.4446	52.0000	0.5000
49	70.0000	0.0975	54.0756	0.4481	52.0000	0.5000
50	70.5000	0.0736	53.9269	0.4518	52.0000	0.5000

Table 1b

No.	Pret conc.	Gr.ap.	Pr(Centroid)	Gr.ap	Pr(Maxim)	Gr.ap
1	46.0000	0.5775	56.1737	0.3652	46.6000	0.5878
2	46.5000	0.5936	56.2236	0.3667	47.1000	0.6034
3	47.0000	0.6094	56.2910	0.3688	47.6000	0.6188
4	47.5000	0.6248	56.3769	0.3714	48.1000	0.6339
5	48.0000	0.6400	56.4819	0.3746	48.6000	0.6486
6	48.5000	0.6548	56.6069	0.3784	49.1000	0.6631
7	49.0000	0.6694	56.7463	0.3827	49.5000	0.6773
8	49.5000	0.6836	56.8935	0.3873	50.0000	0.6912
9	50.0000	0.6975	57.0483	0.3921	50.5000	0.7048
10	50.5000	0.7111	57.2104	0.3972	51.0000	0.7181
11	51.0000	0.7244	57.3795	0.4026	51.5000	0.7310
12	51.5000	0.7373	57.5553	0.4082	52.0000	0.7437
13	52.0000	0.7500	57.7376	0.4140	52.5000	0.7561
14	52.5000	0.7623	57.9262	0.4201	53.0000	0.7681
15	53.0000	0.7744	58.1207	0.4264	53.5000	0.7799
16	53.5000	0.7861	58.3209	0.4330	54.0000	0.7913
17	54.0000	0.7975	58.5266	0.4398	54.4000	0.8025
18	54.5000	0.8086	58.7375	0.4468	54.9000	0.8133
19	55.0000	0.8194	58.9535	0.4831	55.4000	0.8239
20	55.5000	0.8298	59.1743	0.5476	55.9000	0.8341
21	56.0000	0.8400	59.3998	0.6057	56.4000	0.8441
22	56.5000	0.8498	59.6296	0.6577	56.9000	0.8537
23	57.0000	0.8594	59.8637	0.7042	57.4000	0.8630
24	57.5000	0.8686	60.1029	0.7455	57.9000	0.8720
25	58.0000	0.8775	60.3457	0.7820	58.4000	0.8807
26	58.5000	0.8861	60.5698	0.8161	58.9000	0.8890
27	59.0000	0.8944	60.7742	0.8471	59.3000	0.8971
28	59.5000	0.9023	60.9637	0.8741	59.8000	0.9049
29	60.0000	0.9100	61.1430	0.8964	60.3000	0.9124
30	60.5000	0.9173	61.3176	0.9136	60.8000	0.9196
31	61.0000	0.9244	61.4923	0.9256	61.3000	0.9264
32	61.5000	0.9311	61.6724	0.9326	61.8000	0.9330
33	62.0000	0.9375	61.8606	0.9353	62.3000	0.9392
34	62.5000	0.9436	62.0583	0.9340	62.8000	0.9452
35	63.0000	0.9494	62.2677	0.9295	63.3000	0.9508
36	63.5000	0.9548	62.4921	0.9224	63.7000	0.9561
37	64.0000	0.9600	62.7378	0.9136	64.2000	0.9611
38	64.5000	0.9648	63.0283	0.9057	64.7000	0.9659
39	65.0000	0.9694	63.3046	0.8951	65.2000	0.9703
40	65.5000	0.9736	63.5539	0.8804	65.7000	0.9744
41	66.0000	0.9775	63.7752	0.8609	66.2000	0.9782
42	66.5000	0.9811	63.9676	0.8359	66.7000	0.9817
43	67.0000	0.9844	64.1285	0.8043	67.2000	0.9848
44	67.5000	0.9873	64.2556	0.7648	67.6000	0.9877
45	68.0000	0.9900	64.3515	0.7169	68.1000	0.9903
46	68.5000	0.9923	64.4190	0.6599	68.6000	0.9926
47	69.0000	0.9944	64.4601	0.5933	69.1000	0.9946
48	69.5000	0.9961	64.4764	0.5166	69.6000	0.9962
49	70.0000	0.9975	64.4690	0.4370	70.1000	0.9976
50	70.5000	0.9986	64.4387	0.4348	70.6000	0.9986

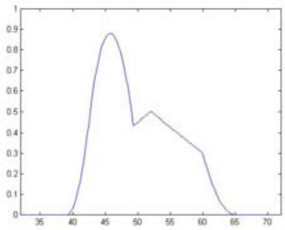


Fig. 14a.L1

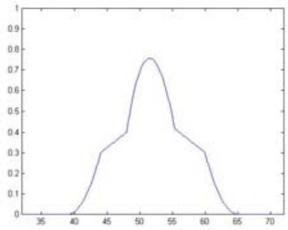


Fig. 14a.L13

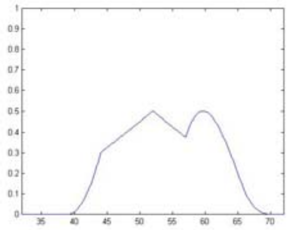


Fig. 14a.L31

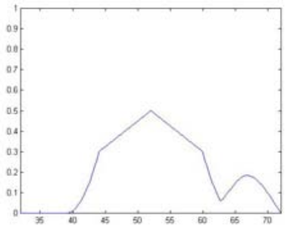


Fig. 14a.L50

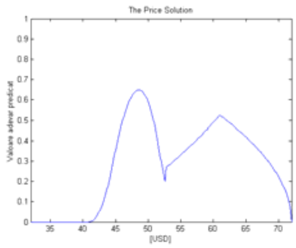


Fig. 14b.L1

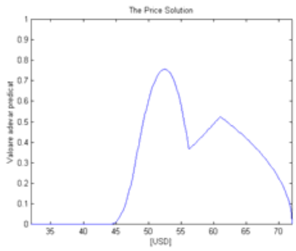


Fig. 14b.L13

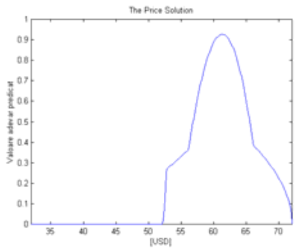


Fig. 14b.L31

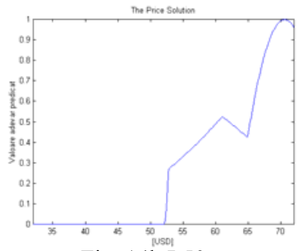


Fig. 14b.L50

The *composite maximum method* follow very closely the competition tariff between the lines 1– 30, in Table 1a. But, as soon as the importance (surface) of output fuzzy region defined by the rule R4 is less that the importance (surface, strength) of the output fuzzy region formed by the unconditional rules R1, R2, R3, the conditional rule R4 no controls the fuzzification result. The results, in our case, are the maximum region defined by the intersection of the unconditional rules that have a constant height of ≈ [0.5] in the output fuzzy set. This thing is at the line 30, where, with this method, the tariff jumps from \$59.20 back to \$52.00 and remains at this value, although the competition tariff rises.

The Figures 14a, b.Li (i = 1, 13, 31, 50) are the executions of the tariff models associated with the charts shown in the Tables 1a, 1b; more exactly, the graphs associated only with the lines i (i = 1, 13, 31, 50) from the Tables 1a, 1b.

5. CONCLUSIONS

The paper considers two fuzzy models to obtain a tariff (price) for EE in our country. In the fuzzy models were considered some objectives of SC Electrica SA, a restriction of ANRE (***, Metodologia…., ANRE, 2003), and a rule IF-THEN (conditional), concerning the competition (with the countries near our country, to avoid a competition war).

All fuzzy rules used (conditional and unconditional) are a mixture of many vague and uncertain factors, with a more or less of imprecision degree. But, the first model has conservative rules, while the second model is with a more aggressive strategy (rules) concerning the EE price.

However, using only four rules and a fuzzy reasoning method, were discussed two basic tariffing models for EE.

Because fuzzy logic provides a sensitive approach to obtain a tariff for EE, we believe that in the future this approach can be refined by (i) use of more conditional and unconditional rules, with more sophisticated linguistic variables, and (ii), by exploring the effects of moving the unconditional sentences from the front to the end of the model (i.e., here, R1 will be R4 and vice versa), etc.

REFERENCES

Baldick, R. et al. (1992). *Electricity Tariffs Under Imperfect Knowledge of Participant Benefits*, IEEE Trans. on PWRS, No. 4, Nov., pp. 1471-1482

Baughman, M.L. et al. (1992). *Monte Carlo Model for Calculating Spot Market Prices of Electricity*, IEEE Trans on PWRS, pp 584-590

Beale, M. and Demuth, H. (1994). *Fuzzy Systems Toolbox for use with MATLAB*. Boston, MA, USA: HP – PWS PC.

Carlsson, C. and Fuller R. (2001). *On Optimal Investment Timing with Fuzzy Real Options.*Proc. of the EUROFUSE 2001 Workshop on Preference Modelling and Applications, 235-239, and on http://www.abo.fi/~fuller/afuse01.pdf

Cox Earl (1999). *The Fuzzy Systems Handbook*: 2nd Edition, NY, USA: Academic Press.

Dougherty C. (2002). *Introduction to Econometrics,* 2nd Edition, NY, USA: OUP Inc.

Ghajar R., and Billinton R. (1993). *Comparison of Alternative Techniques for Evaluating the Marginal Outage Costs of Generating Systems*. IEEE Trans on PWRS, 4, pp 1550-1556

Hanselman D., and Littlefield B. (2001). *Mastering MATLAB 6. A Comprehensive Tutorial and Reference.* Upper Saddle River, NJ, USA: Pearson Education International.

Kahraman C. (2001). *Fuzzy Versus Probabilistic Benefit/Cost Ratio Analysis for Public Work Projects*. Int. J. Appl. Math. Comput. Sci., No.3, pp 705-718, and on http://www.cs.berkeley.edu

Lambert-Torres et al (1998). *A Fuzzy-Logic Tool to Support Medium and Long-Term Decision-Making Planning.* International Journal of Power and Energy Systems, No. 3, pp 167-175

Maeda, A. et al (1992). *Game Theory Approach to Use of Non-commercial Power Plants under Time-of-Use Pricing.* IEEE Trans on PWRS, pp 1052-1059

Pereira, M.V.F. et al (1992), *Integrated Analysis of Generation and Transmission Systems in Terms of Chronological Probabilistic Production Costing and Wheeling Calculations,* IEEE Trans on PWRS, pp 885-891

Shangvi A.P. (1989). *Flexible Strategies for Load/Demand Management Using Dynamic Pricing,* IEEE Trans on PAS, 1, pp 83-93

Şolea, R, Ghiniţă, D., and Dugan, V., *A fuzzy model for Electrical Energy Pricing,* Proc. of the 12th Symposium on Modelling, Simulation and Identification Systems, SIMSIS12, Galaţi, September 2004, pp

Sugeno, M. (1992). *Industrial Applications of Fuzzy Control.* 3rd Ed., NY, USA: Elsevier Science Publishing Co. Inc.

Terano T., K. Asai, and M. Sugeno (1993), *Fuzzy Systems Theory and its Applications.* San Diego CA, USA: Academic Press Ltd.

Wong, K.P., and Wong Y. W. (1996): *Combined Genetic Algorithm/Simulated Annealing/Fuzzy Set Approach to Short-Term Generation Scheduling with Take-or-Pay Fuel Contract.* IEEE Trans. on PWRS, No. 1, pp 128-136

Yan, I. et al (1994). *Using Fuzzy Logic. Towards Intelligent Systems.* NY, USA: Prentice Hall.

*** *Metodologia de Stabilire a Tarifelor Specifice pentru Serviciul de Distributie a Energiei Electrice*, 2003, in Cod: 0-032.5.3131.0.00, ANRE Bucuresti, si in MO Nr. 573/29.06.2004