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Fuzzy Model for Estimating the Power Consumed in a Transformer Station

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***Abstract* – The paper studies the implementation of a new transformer station in a network designed to take over some of the existing consumers, to provide the necessary energy for a number of new consumers and a reserve for future new connections to the electricity grid. By creating a fuzzy model, a number of rules have been created to highlight the power consumtion regimes, manifested at the level of the transformer station. Also, the possibility of optimizing and taking over from existing clients was created so that a balance and an optimization can be created regarding the disposition of the consumers on each station.**

Cuvinte cheie: *bare încapsulate, curenţi mari, model magnetic, model termic în regim staţionar,probleme cuplate.*

Keywords: *encapsulated busbars, high currents, AC magnetics model, steady-state heat transfer model, coupled problems.*

I. INTRODUCTION

The major changes in the structure of electricity networks illustrate the decentralization of these systems and generate a huge amount of data, which must be processed efficiently. The management of these networks begins by processing-more and more in real time the information provided from the field. [2].

The use of artificial intelligence in the energy field can be found in studies on the integration of production from renewable sources, forecasting of electricity conversion and their price, power quality control, improving the stability of electricity systems.

The paper is intended to be a way to present the advantages of using computer algorithms or even artificial intelligence in the process of managing electrical networks.

The analysis in this paper is based on a hypothetical study, for an electrical network that supplies both household and non household consumers, single-phase and three-phase, as well as prosumers with photovoltaic panels, which will generate only during the day and for which the weather conditions were neglected. Thus, a generalized, optimal regime was analyzed, which theoretically applies in ideal conditions manifested daily.

The main objectives pursued were:

- defining the area of interest;
- creation of rules for highlighting the power consumption regimes manifested at the level of the transformer stations;
- establishing the time intervals in which the analysis was carried out;
- graphic highlighting by variation of the input data, of the different operating regimes for the electrical network.

II. TRANSFORMER STATION

Among critical electrical assets, the power transformer is probably the most representative [2]

A substation is a downstream transformer substation with a power of up to 2500 kVA, designed to supply low voltage (up to and including 1 kV) to consumers.

A substation consists of MV connection equipment (20 or 6 kV), one or more MV/LV transformers and LV switchboards, [7].

In relation to the grounding, the transformation stations can be divided into three categories, namely:

a. Overhead substations mounted on concrete (rarely wooden) poles, with relatively low power transformers, usually between 20 and 250 kVA and usually intended to supply low voltage consumers in rural areas.

b. Above ground transformation stations; this positions are performed in the following variants:

b.1. substations in metal cabins, prefabricated, usually used for temporary supply, site (rarely for normal urban supply), with powers between 100 and 1000 kVA;

b.2. transformation stations in above ground rooms, realised in specially built wall cabins or on the ground floor of apartment blocks in some rooms specially reserved and arranged for the transformation station or in specially reserved rooms in the technological premises of industrial enterprises.

c. Underground transformation stations, built in an underground construction, in places where for various reasons (such as urban systematization), it is not allowed to build an underground construction.

III. FUZZY LOGIC

Fuzzy logic is a fascinating field of research because it makes a very good connection between meaning and accuracy.

The advantages of using fuzzy logic over other methods are:

a. is easy to understand, because it uses simple mathematical concepts;
b. it is flexible because it starts from information with a greater or lesser degree of inaccuracy;
c. can model nonlinear functions with arbitrary complexity; a fuzzy system can be created, starting from any set of input-output data;
d. is based on natural language, ie the language of human communication;

e. can be combined with conventional control techniques.

Fuzzy sets start from the fundamental idea that if X is the “total” set, any subset A, in the classical sense, of X, can be identified with its characteristic function [4]:

$$f_A : X \rightarrow \{0,1\} \tag{1}$$

where $\begin{cases} f_A(x) = 0, \ x \neq A \\ f_A(x) = 1, \ x = A \end{cases}$

The fuzzy subset A of X is defined by a membership function:

$$f_A : X \rightarrow [0,1] \tag{2}$$

A membership function is a curve that defines how each point in the definition domain is assigned a membership value (degree) between 0 and 1.

The usual operations of classical set theory (reunion, intersection, complement, etc.) can be repeated in the case of fuzzy sets, in terms of the function of membership.

IV. PROPOSED MODEL

The analyzed MV/LV substation feeds both single-phase and three-phase household and non-household consumers.

Prosumers are also connected to the transformer station, ie consumers who can store and sell electricity produced from renewable sources [3, 5].

To determine the power consumed in a transformer station, we will use the graphical user interface (GUI) in the Fuzzy Logic Toolbox module of the Matlab application.

In the Fuzzy Logic Toolbox module there are 5 graphical interfaces to use for building, editing and observing a problem: Fuzzy Interface System, Fuzzy Editor (FIS Editor), Membership Function Editor, Rule Editor and Rule Viewer.

The proposed fuzzy system has four inputs (period, type of source, consumer category and installed power) and one output (power consumed).

In the first stage, the functions of the membership are established for the inputs and outputs of the fuzzy system.

The membership functions will be trapezoidal functions, with 4 value ranges each, covering the entire range of installed power values.

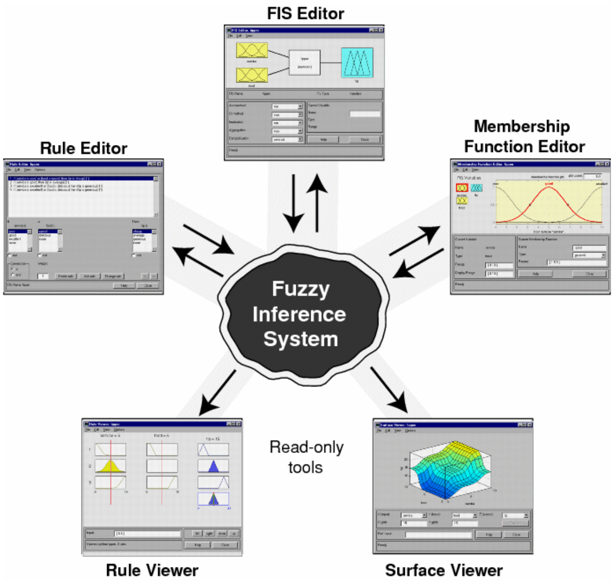

Fig. 1. Fuzzy simulator interfaces.

The membership functions for the system inputs and outputs are shown in Figures 2÷6.

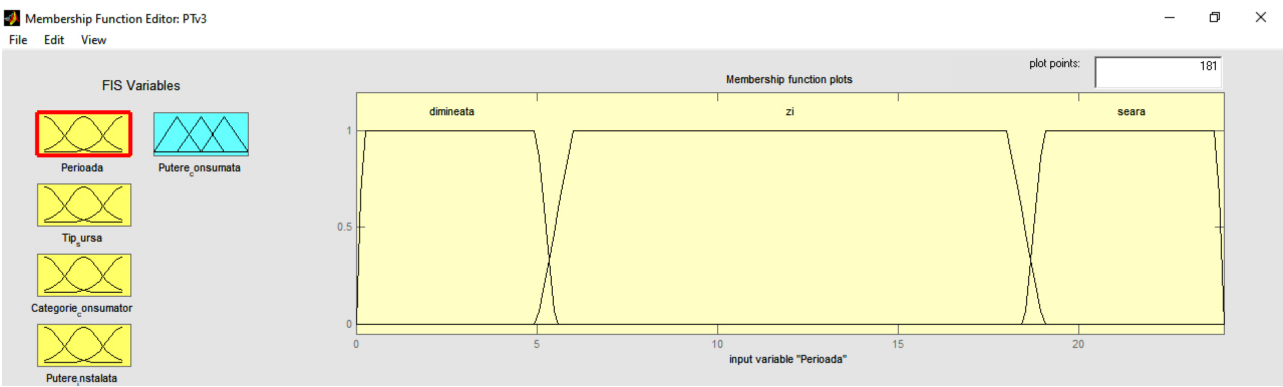

Fig. 2. Membership functions for the the time period: morning (0 0,2 5 5,5), day (5 6 18 19), evening (18.5 19 23.8 24).

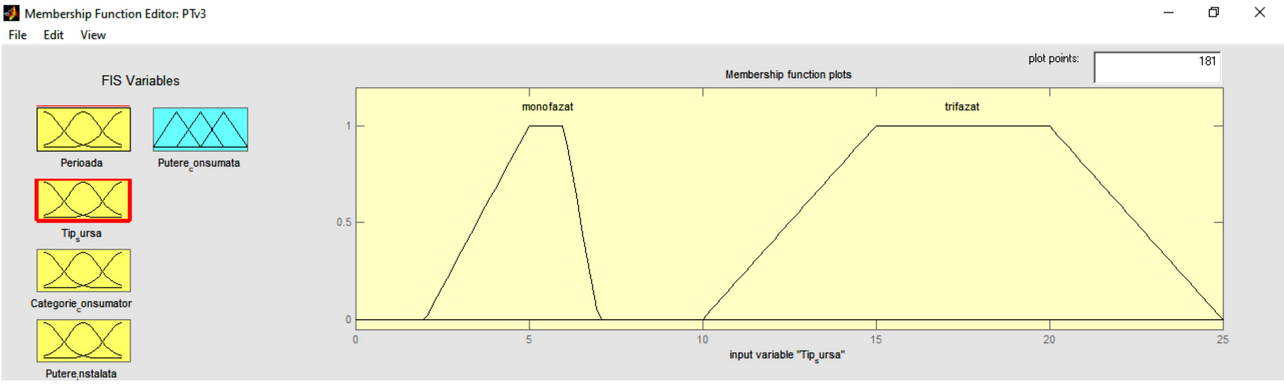

Fig. 3. Source type membership functions: single phase (2 5 6 7) and three-phase (10 15 20 25).

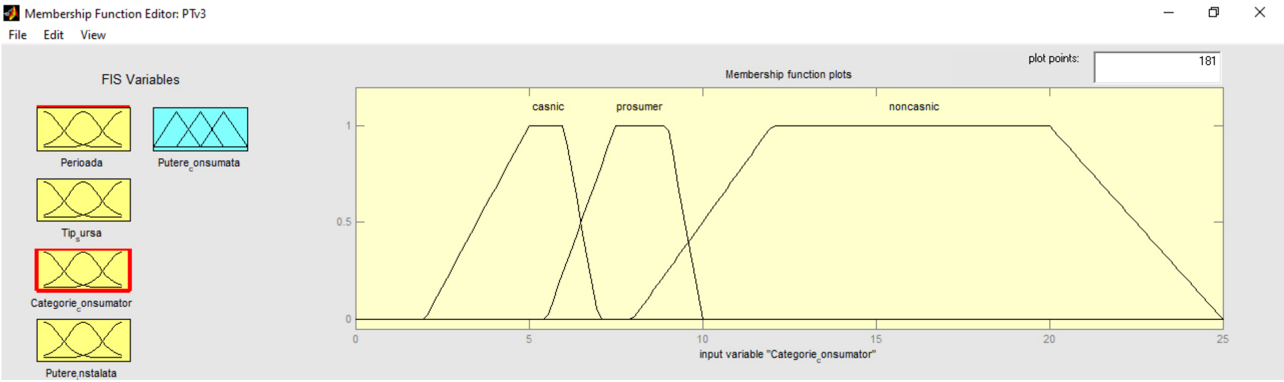

Fig. 4. Consumer functions: household (2 5 6 7), prosumer (5.5 7.5 9 10) – only applicable for day time and non-household (8 12 20 25).

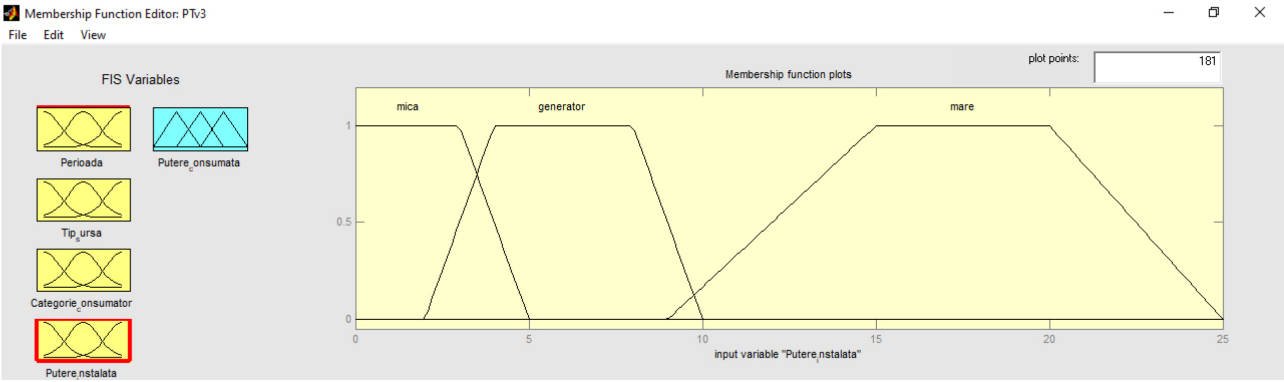

Fig. 5. Belonging functions for installed power: small (0 0 3 5), large (9 15 20 25), generator (2 4 8 10) – was considered for consumers who only generate in the network, without having individual consumption.

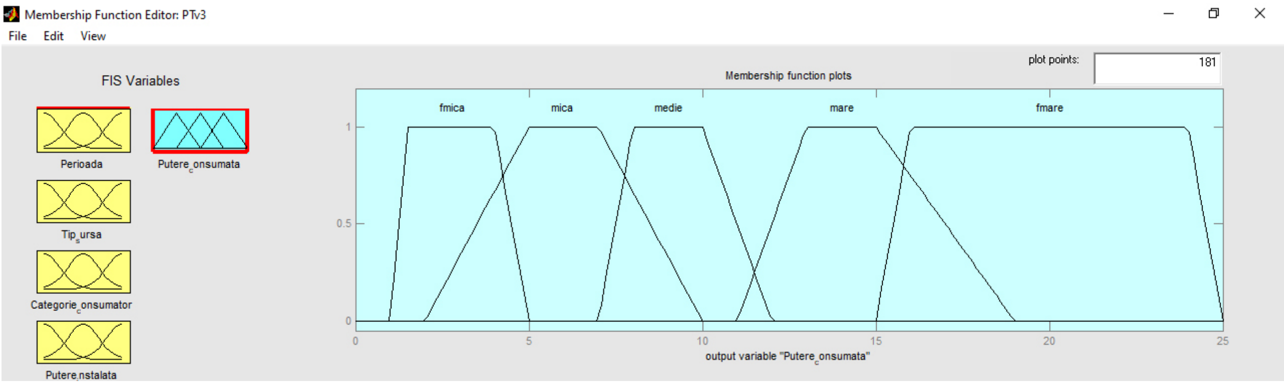

Fig. 6. Membership functions for power consumption: very low (1 1.5 4 5), low (2 5 7 10), medium (7 8 10 12), high (11 13 15 19) very high (15 16 24 25).

In the second stage, the rules used to create the fuzzy diagram will be established and implemented, depending on the time period:

a. night:

* three-phase consumer – household – low installed power =>low consumption

* three-phase consumer – household – high installed power =>medium consumption

*single phase consumer – household – low installed power => very low consumption

* single phase consumer – household – high installed power => low consumption

* three-phase consumer – non-household – low installed power => medium consumption

* three-phase consumer – non-household – high installed power =>very high consumption

* single phase consumer – non-household – low installed power => low consumption

* single phase consumer – non-household – high installed power =>high consumption

b. day:

* three-phase consumer – household – low installed power => low consumption

* three-phase consumer – household – high installed power => medium consumption

* single phase consumer – household – low installed power => very low consumption

* single phase consumer – household – high installed power => low consumption

* three-phase consumer – non-household – low installed power => medium consumption

* three-phase consumer – non-household – high installed power =>very high consumption

* single phase consumer – non-household – low installed power => low consumption

* single phase consumer – non-household – high installed power =>high consumption

*prosumers – three-phase – low installed power => low consumption

* prosumers – three-phase – high installed power =>medium consumption

* prosumers – single phase – low installed power => very low consumption

* prosumers –single phase – high installed power => low consumption

* prosumers – three-phase – generator => low consumption

* prosumers – single phase – generator => very low consumption

c. evening:

* three-phase consumer – household – low installed power => low consumption

* three-phase consumer – household – high installed power => medium consumption

* single phase consumer – household – low installed power => low consumption

* single phase consumer – household – high installed power => medium consumption

* three-phase consumer – non-household – low installed power => medium consumption

* three-phase consumer – non-household – high installed power => very high consumption

* single phase consumer – non-household – low installed power => low consumption

* single phase consumer – non-household – high installed power => high consumption

In the third stage, the output values are obtained, the inputs in the fuzzy system and the activated rules are shown in Figure 7 and 8. Depending on the values set for the 4 inputs, an answer will be established which represents the power consumed.

The fuzzy simulator from the Matlab application also allows the generation of results in the form of three-dimensional surfaces (Figures 9÷11).

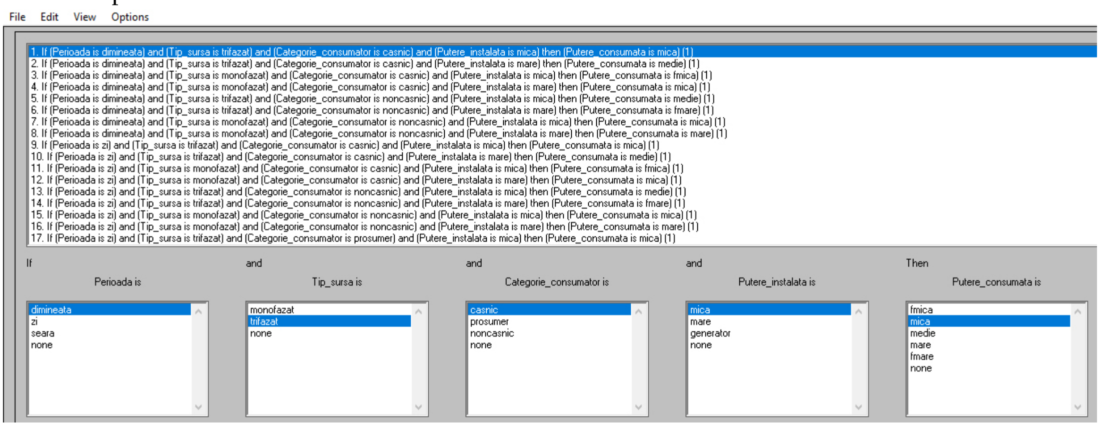

Fig. 7. The rules used to create the fuzzy diagram

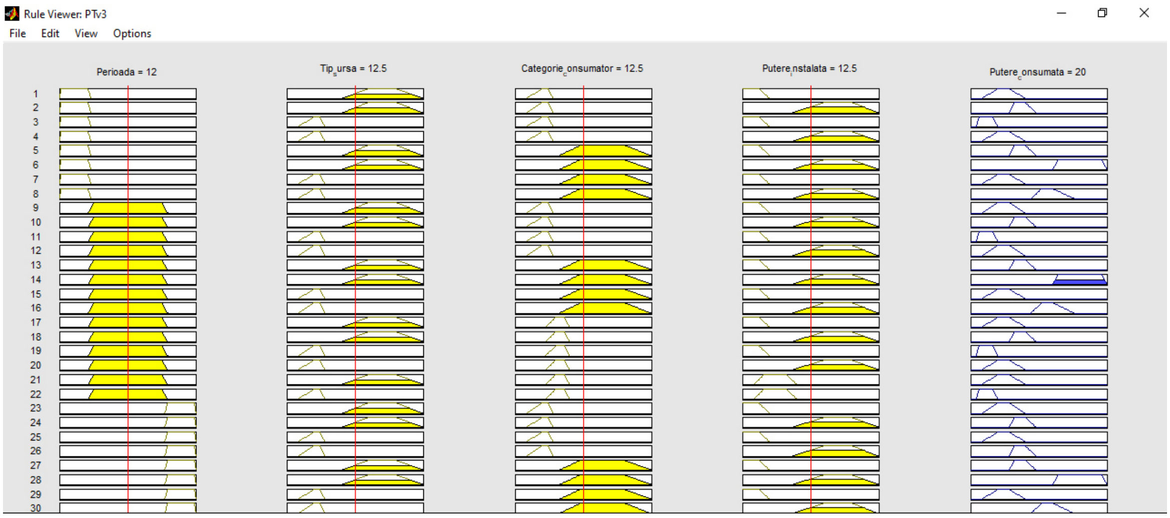

Fig. 8. For non-household, three-phase consumers who have a high installed power, variations are observed for three periods of time (morning, day, night) of the energy consumed due to the compensation of the prosumers during the day.

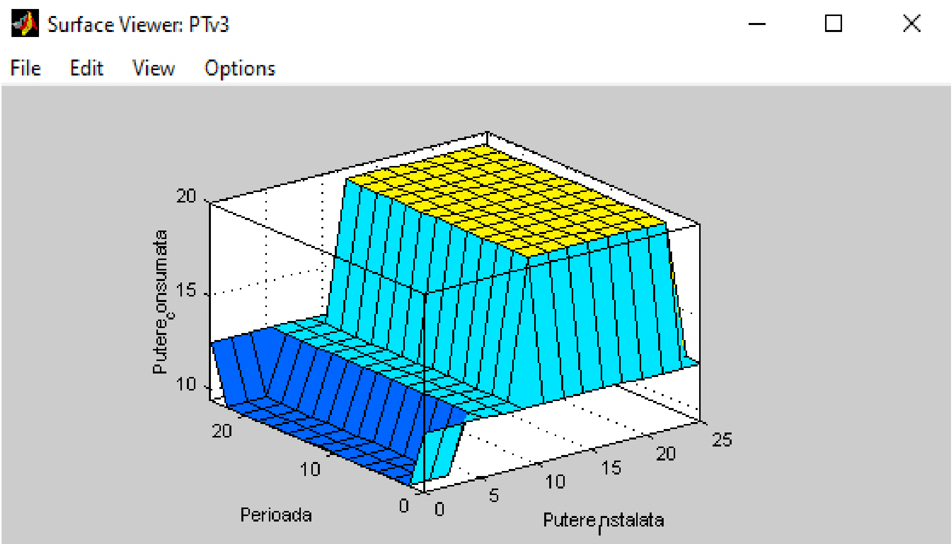

Fig. 9. View as "surface" for consumed power taking into account the time period and installed power.

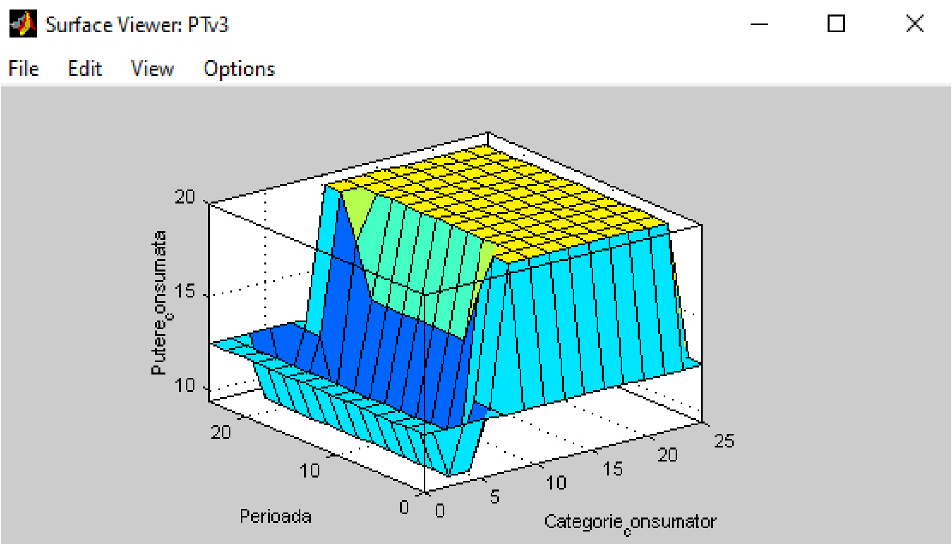

Fig. 10. View as "surface" for consumed power taking into account the time period and the category of consumers.

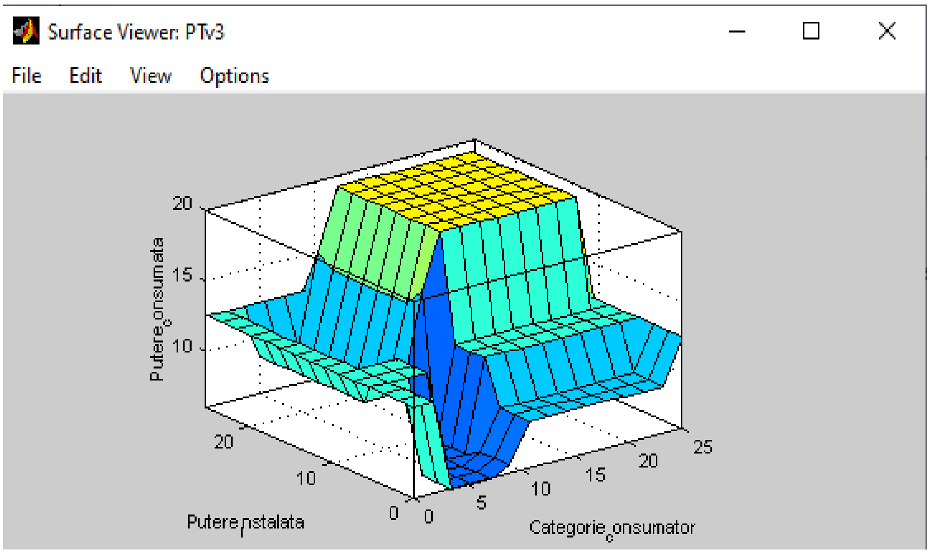

Fig. 11. View as "surface" for consumed power taking into account the installed power and the category of consumers.

Of course, variations in these indices can be greatly customized and the level of accuracy can increase with a more accurate approach to input data, Also, with the optimization for the area of interest of the operation regime of the prosumers, more realistic data can be obtained in accordance with the topographic, meteorological, atmospheric data etc.

V. Conclusions

Although it seems a difficult and complicated process to create correct diagrams, it must be borne in mind that the network administrator interacts only with the graphical interface, which is much easier to use and interpret.

The advantage of using artificial intelligence in electrical networks through the use of a graphical interface, has a clear advantage due to easy use but also the possibilities of network efficiency thus reducing losses and at the same time ensuring continuity in power supply to consumers.

As perspectives of the applications of computational intelligence in energy, a bridge is currently being created between the pool of producers and that of electricity consumers beyond the electricity transmission and distribution network: the electricity storage facilities.

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First coauthor – 30%
Second coauthor – 20%.

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